THE CURRENT ROLE OF PALM SPECIES *HYPHAENE CORIACEA* AND *PHOENIX RECLINATA* IN LOCAL LIVELIHOODS IN THE ZITUNDO AREA, SOUTHERN MOZAMBIQUE

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ABSTRACT

The majority of rural households in developing countries are heavily dependent on non-timber forest products (NTFPs) to fulfill much of their basic daily needs. In Mozambique more than 64% of the population lives in rural areas and depends heavily in the extraction of NTFPs to complement agricultural production. One substantial source of NTFPs are palm species. Palms are sources of food, building materials, cloth, ornaments, medicines, and are also used for cultural purposes. In southern Mozambique two important palms species used as NTFPs are *Hyphaene coriacea* and *Phoenix reclinata*. These two species provide an array of subsistence and commercial products. The sap, leaves and stems of these two palms are harvested by local people as sources of traditional beverages, weaving, roofing, fencing and furniture material as well as other household utensils. The effects (if any) of harvesting of these palm products on palm distribution, population structure, dynamics and viability have never been examined, and thus the sustainability of the practices and benefits flows to local livelihoods are unknow-n. Any effects harvesting effects may also be exacerbated by predicted climate change for the area. The present study aims to investigate the role of the palm species *Hyphaene coriacea* and *Phoenix reclinata* in the livelihoods of households in the Zitundo area, Matutuine district, southern Mozambique and under future climate scenarios. Specifically, this study: i) evaluates the abundance, population structure and harvesting selection of these species; ii) characterizes the ethnobotanical knowledge and use of the two species; iii) examines the local production and trade of palm wine in the area; iv) examines the contribution of palm income to livelihoods and income diversification in area; v) describes the local management practices and perceptions on palm productivity and abundance; and vi) models the current and future distribution of the these palm species in the area.

To evaluate the abundance, population structure and stability of these two palm species a population census was carried out, and the size class distribution, Simpson index of dominance, permutation index and the quotient between successive size classes were calculated. I further calculated the preference ratio for specific size classes. Additionally a questionnaire survey was conducted with 179 randomly selected households from the 16 villages in the study area to characterize the ethnobotanical knowledge and use of these two species, as well as to examine the contribution of palm income to livelihoods and diversification. Standard ethnobotanical indices were used as

measures of each palm species use and knowledge while principal component analysis and cluster analysis were applied to highlight the livelihood patterns and the role of diversification and of palm income in local livelihoods. Structured interviews with 37 palm tappers were additionally used to examine the local production and trade of palm wine in the area, while both the household survey and palm tappers interviews, were employed to investigate the local management practices and perceptions on palms productivity and abundance. Maxent Software was used to model the current and future under climate change distribution of the two palm species.

Hyphaene coriacea was more abundant than *Phoenix reclinata*. Both species exhibited steep negative slopes in the regression analyses of size class distribution, indicating the presence of more individuals in shorter size classes. Although there was a dominance of shorter over taller size classes, limited recruitment was observed through low stem densities of seedlings and juveniles compared to the 1-50 cm size class The Simpson index of dominance, the permutation index, and the fluctuating quotients between the consecutive size classes showed a level of instability in both populations. *Hyphaene coriacea* appeared to be more resilient to tapping than *Phoenix reclinata* as showed by the higher rate of stem survival after tapping. *Hyphaene coriacea* was favored for tapping compared to *Phoenix reclinata.* The most preferred size class to tap for both species was between 101cm and 150 cm.

Currently the distribution of *Hyphaene coriacea* and *Phoenix reclinata* was mostly confined to the eastern side of the study area. Most of the area was predicted as unsuitable for both palm species, with less than six percent predicted to be suitable or higher. The occurrence of both species appeared to be influenced mostly by water related variables, such as precipitation, and distance to rivers and distance to water bodies. The habitat suitability for *Hyphaene coriacea* was predicted to increase under future climate conditions scenarios, while little variation was predicted for *Phoenix reclinata* distribution.

The knowledge about the uses of these two palm species was widespread in the area, although only 32% of respondents were engaged in palm exploitation. Thirteen palm products were exploited, with palm wine production from the sap of both palms being the dominant activity, followed by broom production from *Phoenix reclinata* stems and basket production from *Hyphaene coriacea* leaves. The cultural importance of these species included the production of anklets and skirts used during traditional dances and the use of palm wine in the traditional ritual of libation. Palm tapping was practiced year round in five of the sixteen villages in the area. Palm tapping was an important livelihood activity, contributing over 80% of tappers' total annual income, and tappers earned up to three times more than the national minimum wage for the agricultural and forestry sector. Palm wine was also a highly commercial commodity in Zitundo area, with an average commercialization index above 60%. The income from palm wine sales showed an important role in mitigating the level of poverty in the area. Palm income accounted for over 60% reduction on poverty incidence among palm tappers. Households in Zitundo further engaged in some level of livelihood diversification. The majority of households adopted a wage-based strategy, although this strategy was among the less remunerative in terms of per capita cash income. A palm-based livelihood strategy, although adopted only by 11% of households, was one of the most remunerative strategies. Palm income played a vital role in enhancing household livelihoods and mitigating poverty in the area as shown by the lower poverty incidences among households engaged in the palm-based livelihood strategy than alternatives strategies. The village of household residency, along with household demographic and socio-economic characteristics appeared to determine the knowledge and exploitation level of palms as well as a households' choice of livelihood strategy, level of palm wine returns, commercialization index and palm income dependency.

The importance of palms in local livelihoods and poverty alleviation needs greater acknowledgement by government and development agencies in the area. Palm wine, broom and basket production have a high potential for income generation, and therefore should be included in future local development policies and poverty reduction strategies. Although palms are an open access resource in Zitundo area, the perception is that they are abundant and that tapping does not have many detrimental effects. However, this study found some negative impacts of tapping on the recruitment of both palms species. The inclusion of palm products in future development programs and poverty reduction strategies will require the design of participatory conservation and management strategies that involve all palm users groups and others stakeholders and include long-term participatory monitoring of the effect of palm use on the populations.

DECLARATION

I, Angelina Rosa de Oliveira Martins, hereby declare that the work contained in this thesis is my original work, has not been submitted for any degree or examination at any other university, and that the sources used have been fully acknowledged by complete references. This thesis is submitted in fulfilment of a PhD in Environmental Science in the Faculty of Science at Rhodes University, South Africa.

Signature: ______________________________ Date: ________________________

DEDICATION

This thesis is dedicated:

To My husband, Emilio for his endless love, restless support and encouragement. Hub, I am finally done with my “Noble Prize”.

To my son Emilson and daughter Rihanna for their understanding and patience during my long periods of absence. May this work be a source of inspiration and motivation for you.

In memory of my mother, who taught me the value of education and my dad who was taken from me way too soon.

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Last but not least, I wish to express my special thanks to my family. My husband Emílio, for his mentorship, encouragement, support, and love. You were my strength in this PhD journey. My son Emilson and daughter Rihanna for their love and patience coping with my long absences from home. You were my source of inspiration.

LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
ANOVA	Analysis of Variance
AR5	Fifth Assessment Report
AUC	Area Under Receiver-Operating Characteristic Curve
BP	Before Present
CENACARTA	Centro Nacional de Cartografia e Teledetecção
CI	Commercialization Index
CIESIN	Center for International Earth Science Information Network
CIFOR	Center for International Forestry Research
CMIP5	Coupled Model Inter-Comparison Project - Fifth Phase
CREED	Collaborative Research in the Economics of Environment and Development
DEM	Digital Elevation Model
DFID	Department for International Development
FAO	Food and Agricultural Organization
GAM	Generalized Additive model
GCM	Global Circulation Model
GLM	Generalized Linear Model
GPS	Global Positioning System
GPW	Gridded Population of the World
HADGEM2-CC	Hadley Centre Global Environment Model, version 2–Carbon Cycle
HCI	Household Commercialization Index
HII	Human Influence Index
HIV	Human Immunodeficiency Virus
IEK	Indigenous Ecological Knowledge
IESE	Instituto de Estudos Sociais e Económicos
IFAD	International Fund for Agricultural Development

IIAM	Instituto de Investigação Agrária de Moçambique
INE	Instituto National de Estatística
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LEK	Local Ecological Knowledge
LS	Livelihood Strategy
LWP-2	Last of the Wild Project, Version 2
MAE	Ministério da Administração Estatal
MEA	Millennium Ecosystem Assessment
MEF	Ministério de Economia e Finanças
MODIS	Moderate Resolution Imaging Spectroradiometer
MSU	Michigan State University
MZM	Mozambican Meticais
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NTFP	Non-Timber Forest Product
PCA	Principal Component Analysis
RCP	Representative Concentration Pathway
SANBI	South African National Biodiversity Institute
SCD	Size Class Distribution
SD	Standard Deviation
SDI	Simpson Diversification Index
SDM	Species Distribution Model
SEDAC	Socioeconomic Data and Applications Center
SRTM	Shuttle Radar Topography Mission
TEK	Traditional Ecological Knowledge
TLU	Tropical Livestock Units
UNEP-WCMC	United Nations Environment Programme-World Conservation Monitoring Centre

WCS	Wildlife Conservation Society
WRC	Water Research Commission
WWF	World Wildlife Fund

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CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background

1.1.1 Contribution of NTFPs to rural livelihoods

Most rural households rely on several livelihood strategies to achieve food and nutrition security and meet all other needs (Scoones, 1998; Ellis, 2000). One important strategy is the harvesting of non-timber forest products (NTFPs). Several definitions of what are NTFPs can be found in the literature, however this study adopted the one by Shackleton (2004a) as "NTFP is any biological resource (animal or plant) harvested from forested lands by rural households for domestic consumption or small-scale trade, with no, or limited capital investment". The majority of rural households in developing countries are heavily dependent on NTFPs to fulfill their basic daily needs. The FAO (1997) estimated that 80% of the rural population in developing countries use NTFPs to meet their health, shelter and nutritional needs. More recent estimates reveled that globally, about 1.4 - 1.6 billion people use or trade NTFPs (FAO, 2001; Shanley *et al*., 2016). These products are used for household subsistence as well as for income generation, and they act as important buffers during times of hardship (Shackleton *et al.*, 2007a; Angelsen *et al*., 2014), as well as playing keystone roles in ecological and cultural communities (Shackleton *et al*., 2018). Therefore, they have a role in household food security, reduction of poverty, rural development as well as biodiversity conservation.

According to Shackleton (2015), NTFPs play six roles in livelihoods: i) household provisioning, where NTFPs support direct household consumption needs for food, medicines, energy and shelter. Studies have shown that these products contribute considerably more to poorer and female-headed households, and that rural households and the ones located relatively closer to NTFP abundant environments gather greater quantities than otherwise (Angelsen *et al*., 2014; Shackleton, 2015). ii) Cash saving, where the free nature of NTFPs provisioning allows scarce cash to be saved or directed to other household needs such as agricultural supplies, school fees and materials and medical costs (Delang, 2006). iii) Cash generation through casual or full-time trading to complement other sources or as the main source of income. While some NTFPs are traded internationally, most are sold at local and regional markets (Shackleton *et al*., 2007b; Shanley *et al*., 2016). The local trade of NTFPs is particularly important for marginal groups who usually lack formal education and skills, therefore have limited formal sector job opportunities (Shackleton *et al*. 2008). iv) Safety nets, as a mean to cope with social and environmental shocks, such as death or sickness of the household income provider and crop and livestock failure due to droughts, floods, pests and diseases (Paumgarten, 2005; Wunder *et al*., 2014). Three mechanisms for safety nets been recognized, i.e. intensification of the use of an already utilized NTFP; adoption of a new NTFP for daily provisioning, and engagement in a short-term trade of NTFPs (Shackleton, 2015). v) local culture, where many NTFPs or sites with NTFPs play an important role in folklore, traditions and rituals (Cocks *et al*., 2012); and vi) providing supporting and regulating services as habitat, food and nesting grounds for other important NTFP species (Shackleton *et al*., 2018). In many instances these roles overlap.

There is much literature on the role of NTFPs in rural livelihoods in developing countries and the determinants of NTFP use and dependency. In general, rural households depend on a wide variety of NTFPs. The degree of reliance on NTFPs varies across countries and regions, varying from less than 10% to over 50% of the total household cash and non-cash income (Vedeld *et al*., 2007; Angelsen *et al*., 2014; Shackleton, 2015). Vedeld *et al*. (2007), Stanley *et al*. (2012) and Angelsen *et al.* (2014) presented comprehensive global analyses of the level of household dependency on NTFPs. Vedeld *et al*. (2007) noted that, on average, 22% of the total income of rural households from developing countries comes from NTFPs. Stanley *et al*. (2012) showed that, on average, in African and Latin American countries, NTFP income accounts for 25% of the total household income, only slightly higher than the share of 23% in Asian countries. More recently, Angelsen *et al.* (2014) reported an average NTFP contribution of 30% of the total household income for Africa and 32% for Latin America.

Household characteristics such as age of household head, household size, education, assets, other income opportunities, residency time in a given location and ethnicity are among the most important factors that shape use and level of dependency on NTFPs (Gavin and Anderson, 2007; Dovie *et al*., 2005; Heubach *et al.*, 2011; Angelsen *et al*., 2014; Khosravi *et al*., 2016). Gavin and

Anderson (2007), working in Peru, found that the longer a household lives in a given area the higher is the value of the products extracted from the wild. In Benin Heubach *et al.* (2011) found that increasing land holding was negative correlated with NTFP dependency, while the number of women in the household and age of the head of household had a positive effect on the NTFP dependency. Angelsen *et al.* (2014) revealed that environmental income is more important to households with a young head of household, to large households and to less educated households. They also found that livestock and agricultural land ownership are positively correlated with NTFP income. Khosravi *et al*. (2016) noted that in Iran, other income opportunities and higher education level increased NTFPs dependency, while having a larger household size had the opposite effect. Beside household characteristics, other factors also influence NTFP use and dependency, including abundance and diversity of habitats and resources (Coomes *et al*., 2004; Dovie *et al*., 2005; Mugido and Shackleton, 2017), seasonality of resource exploited (Shackleton, 2004b), population structure of sought after NTFPs (Coomes *et al*., 2004; Adam *et al.*, 2013) and access to markets (Barbier, 2010; Adam *et al.*, 2013; Mugido and Shackleton, 2017). From the studies mentioned above, it is clear that the level of household dependency on NTFPs and the factors influencing it must be understood within the specific social-ecological context of the households and communities.

1.1.2 Local ecological knowledge in the use and management of NTFPs

The diversity of NTFP types and uses underpin diverse, dynamic and place specific knowledge systems about these resources (Cámara-Leret *et al*., 2014). Local ecological knowledge (LEK) is a core component of such knowledge systems. There are several definitions of LEK and the kind of knowledge it incorporates (Cook *et al*., 2014). For the present study, LEK was taken as a body of knowledge held by a given human community, which includes the perceptions, beliefs and practices gained through interactions with their natural environment, and accumulated over time (Aswani *et al.*, 2018), including the traditional ecological knowledge (TEK) and indigenous ecological knowledge (IEK) (Brook and McLachlan, 2008; Aswani *et al.*, 2018). The LEK and the factors that influence the level of LEK that an individual holds are important factors in shaping the use and consequently the dependency on NTFPs (Gaoue and Ticktin, 2009; Cámara-Leret *et al*., 2014). According to Davis (2005) high levels of LEK may, at times, allow a heavy but sustained exploitation of NTFP, and gives resilience and adaptive capacity in the event of socio-ecological changes (Araújo and Lopes, 2012; Blanco and Carrière, 2016). It may also provide the basis for engagement in trade in particular NTFP species (Weyer and Shackleton, in press). This knowledge is an essential part of local or traditional use, as well as highly sophisticated management and conservation systems of NTFPs that maintain the provision of this resource for local people (Ticktin, 2015; Paniagua-Zambrana, *et al*. 2017; Constant and Tshisikhawe, 2018). LEK may provide relevant biological and management information and can help minimize costs by providing the useful and tested information and insights in a less costly manner (Anadón *et al*., 2009; Polfus, 2010; Lima *et al*., 2017). Therefore, LEK can be a useful and important contribution to formal resource management strategies designed by state and conservations authorities (Hill *et al*., 2010; Cámara-Leret *et al*., 2014; Ticktin, 2015).

Local ecological knowledge is heterogeneous because it is not evenly distributed among all members of a given community (Blanco and Carrière, 2016). Additionally, it is dynamic and place specific since it can change with changing in socio-economic and ecological contexts (Hill *et al*., 2010; Paniagua-Zambrana, *et al*., 2017; Aswani *et al*, 2018). Therefore, the LEK about NTFPs in a given area, and who holds such knowledge, is influenced by various factors such as: i) the floristic composition of a given area (de la Torre *et al*., 2009); ii) characteristics of the exploited species, including its uses, abundance, seasonality and morphology (Hoffman and Gallaher, 2007; de la Torre *et al*., 2009; Macía *et al*., 2011; Blanco and Carrière, 2016); iii) socio-economic characteristics such as, age, gender, formal education, occupation, household size, assets and ethnicity (Byg and Balslev 2001; Gaoue and Ticktin, 2009; Blanco and Carrière, 2016; Paniagua-Zambrana *et al*., 2017); and iv) cultural and traditional values (Hoffman and Gallaher, 2007; de la Torre *et al*., 2009). These factors give a valuable information to better understand the socio-ecological context framing the LEK and thus NTFP use. They are further mediated through formal and informal customary institutions and knowledge holders, such as traditional healers, elders or 'headmen' who promote or enforce traditional customs, practices and taboos around use (Constant and Tshisikhawe, 2018). Therefore, it is important to understand and integrate knowledge and use patterns of NTFPs and the factors that affect them in a specific cultural, social and economic context. This is also useful in setting conservation and management priorities aligned with the local culture and needs (Araújo and Lopes, 2012; Cámara-Leret *et al*., 2014).

1.1.3 Palm species as sources of NTFPs

Palm species are significant sources of NTFPs in most tropical and subtropical regions, and are among the most abundant and highly harvested plant species in these regions (Martínez-Balleste´ *et al.*, 2008; Balslev, 2011; Macía *et al.*, 2011). Palms provide multiple products, such as food, building and weaving materials, ornaments, medicines and beverages. These products are exploited for subsistence and commercial purposes (Byg and Balslev, 2001; de la Torre *et al.*, 2009). Most palm species are also important in the culture, folklore and indigenous knowledge systems of local people and are frequently considered as cultural keystone species (Cámara-Leret *et al*., 2014). In some instances the extent of cultural integration and use is influenced by the physical attributes of the species, such as frond and fruit size or tree height (Cámara-Leret *et al*., 2014).

Balick and Beck (1990) recorded over 390 products obtained from 200 genera of palms. Many palm products come from the harvesting of fruits, seeds, leaves, sap, stems and roots (O'Brien and Kinnaird, 1996; McKean, 2003, Paniagua-Zambrana *et al*., 2015). Exploited palm products belong to all ethnobotanical use categories as decribed by Macía *et al*. (2011) such as: human food (Cunningham, 1990a; b; O'Brien and Kinnaird, 1996; Sambou *et al*., 2002; Pizo and Vieira, 2004, Sola *et al.*, 2006; Chowdhury *et al*., 2008; Manzi and Coomes, 2009; Babitseng and Teketay, 2013; Kumagai and Hanazaki, 2013), tools and utensils (O'Brien and Kinnaird, 1996; McKean, 2003; Martínez-Ballesté *et al.*, 2008; Calvo-Irabién *et al.*, 2009; Isaza *et al.*, 2013), construction (O'Brien and Kinnaird, 1996; Calvo-Irabién *et al.*, 2009), cultural uses (Gruca *et al*, 2014; Johnson, 2016), animal food (O'Brien and Kinnaird, 1996), medicinal and veterinary (Gruca *et al*, 2015; Paniagua-Zambrana *et al*, 2015), environmental uses (de la Torre *et al*, 2009) and fuel (de la Torre *et al*, 2009).

Among tropical and subtropical areas, continental Africa is characterized as a region of relatively low palm diversity, with approximately 65 to 68 species (Blach-Overgaard *et al*., 2015; Stauffer *et al*., 2017; Cosiaux *et al*., 2018). The low palm diversity does not prevent them from being one of the most economically important groups, playing a significant role in the daily lives of people throughout Africa (Okereke, 1982; Cunningham, 1985; 1990a; b; McKean, 2003; Amwatta, 2004).

Rattan, palm wine, basketry and hand brushes are regarded as the most important commodities exploited from palms (Cunningham, 1985; McKean, 2003; Amwatta, 2004; Sola, 2004; Sunderland *et al*., 2004).

In southern Zimbabwe income from *Hyphaene petersiana* wine and basketry was critical during droughts and in between planting and harvesting seasons (Foote *et al*., 2003). In agro-pastoral areas of northern and eastern Kenya income from *Hyphaene compressa* thatch, basketry and mats was one of the most important livelihood strategies (Amwatta, 2004). Income from *Phoenix reclinata* hand brush sales was the second-most important source of cash for households in the Eastern Cape, South Africa (Mjoli and Shackleton, 2015). Sunderland *et al*. (2008) reported that in west and central Africa, over 50% of households were engaged in rattan harvesting. Okereke (1982), Okon and Okorji (2014) and Asa and Eyo (2015) all reported the notable profitability of palm wine production and sales in Nigeria. Similarly Lebbie and Guries, (2002) affirmed that palm wine income in Sierra Leone is several times higher than the national minimum wage. Cunningham (1985; 1990a; b) and McKean (2003) have emphasized the economic importance of palm wine and palm fronds from *Hyphaene coriacea* and *Phoenix reclinata* in the Maputaland coastal plains of northeastern Kwazulu-Natal, South Africa. These two palms are sources of fruits, palm wine, fibres and weaving and building material used for subsistence and commerce.

The exploitation of these resources, in some instances, has resulted in the depletion of the population of sought after palm species due to overharvesting. According to IUCN Red Data List (2019), 37 out of 124 species of palms from the African mainland and islands, classified as endangered and critically endangered, are threatened by unsustainable harvesting of palm parts, such as *Lodoicea maldivica* in Seychelles (Rist *et al*., 2010); the rattan species *Eremospatha dransfieldii* in Ghana, Ivory Coast and Sierra Leone (Cosiaux *et al*., 2017); *Livistona carinensis* and *Phoenix atlantica* in Djibuti and Cape Verde, respectively (IUCN Red Data List, 2019) and several species of *Dypsis* and *Ravenea* in Madagascar (IUCN Red Data List, 2019).

1.1.4 The palms *Hyphaene coriacea* and *Phoenix reclinata*

Hyphaene coriacea (Figure 1.1A) belongs to the family Arecaceae and is one of the two species of the genus *Hyphaene* that grows in southern Africa (SANBI, 2016a). It is a dioecious species, up to 5 m tall, occurring individually or in clusters (McKean, 2004). Stems are upright or slightly reclined. The shape of the leaves resembles a fan and are situated at the apex of the stem (Hyde *et al*., 2016a). The flowers appear between November and February (Hyde *et al*., 2016a). The fruits are pear-shaped, and female trees can bear up to 2 000 fruits. The fruits normally take about four years to mature and drop (McKean, 2004). High rates of seed germination probably require fire or animal consumption (Palgrave, 2002). *H. coriacea* occurs mainly in coastal lowland regions, from Somalia to South Africa and in Madagascar (Hyde *et al*., 2016a), on nutrient-poor, sandy soils (McKean, 2004). This species seldom extends to inland areas (Hyde *et al*., 2016a).

Phoenix reclinata (Figure 1.1B) belongs to the family Arecaceae, and is a dioecious palm, usually being 3 m to 6 m tall, but, occasionally up to 12 m (SANBI, 2016b). It is multi-stemmed, forming clusters or sometimes extensive thickets (SANBI, 2016b). The shape of the frond resembles a feather and is located at the apex of the stem (Hyde *et al*., 2016b). The flowers appear between August and October and fruits from February to April (Hyde *et al*., 2016b). The fruits are small, in a range of colors from yellow to orange-brown (SANBI, 2016b). It is distributed throughout Sub-Saharan Africa from Egypt to South Africa (Hyde *et al*., 2016b). It occurs from sea level to up to 3 000 m altitude, in a range of habitats such as inundated areas, riverine forest, coastal savanna, open grassland and rain forests (Hyde *et al*., 2016b; SANBI, 2016b).

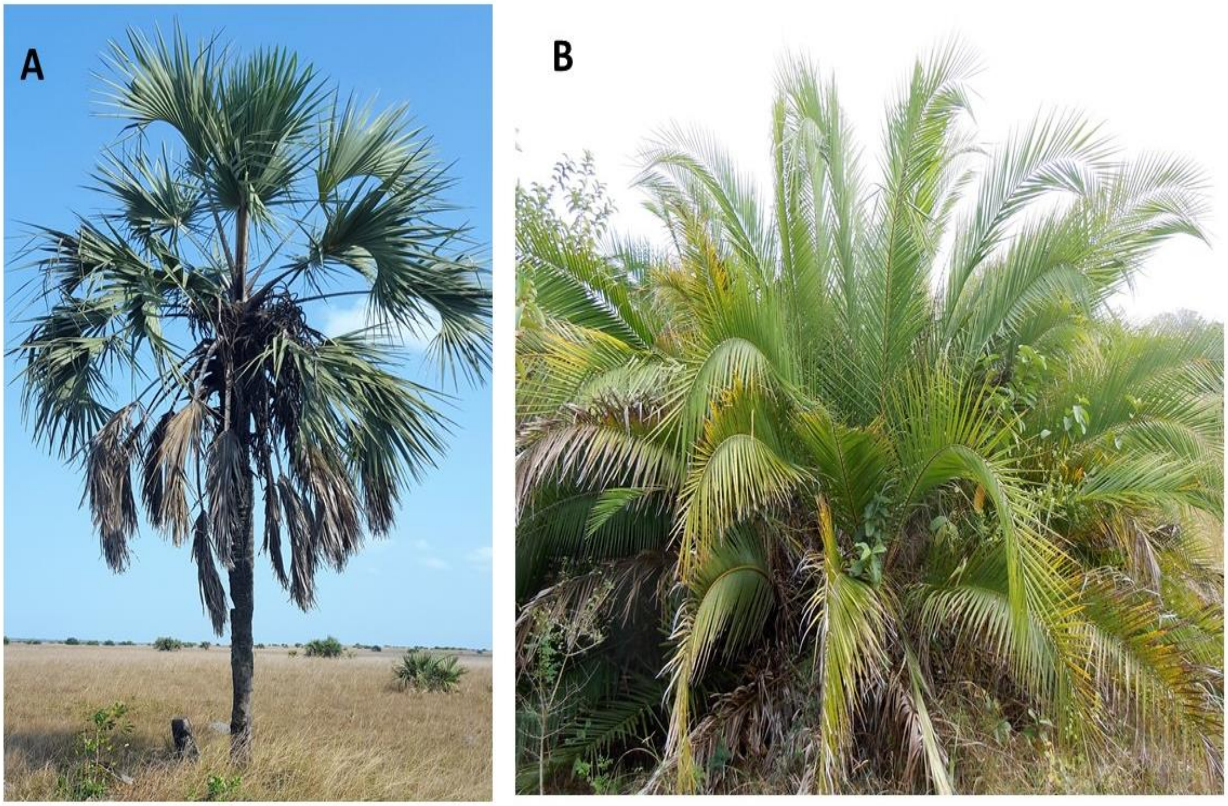

Figure 1.1: Study species. (A) *Hyphaene coriacea*. (B) *Phoenix reclinata*.

1.1.5 *Hyphaene coriacea* and *Phoenix reclinata* in the Maputaland palm savanna

Hyphaene coriacea and *Phoenix reclinata* are the two dominant species in the palm savannas of the Maputaland coastal plain (Figure 1.2) which covers the southeastern parts of Maputo province in southern Mozambique and northeastern parts of Kwazulu-Natal in South Africa. These two palm species are a source of weaving materials used to make baskets, sieves and other tools and utensils; fronds are used for roofing houses and a traditional palm wine, locally called *ntchemane*, is produced from the sap. Campbell (1969) reported that the sap is rich in riboflavin, vitamin B and nicotinic acid, and is a vital part of the diet of local people. Additionally, the fruits of *Phoenix reclinata* are edible and its stem is used to make brooms, while the fronds of *Hyphaene coriacea* are also used to make brooms (Figure 1.3). The differentiated uses of the two species are presented in Table 1.1.

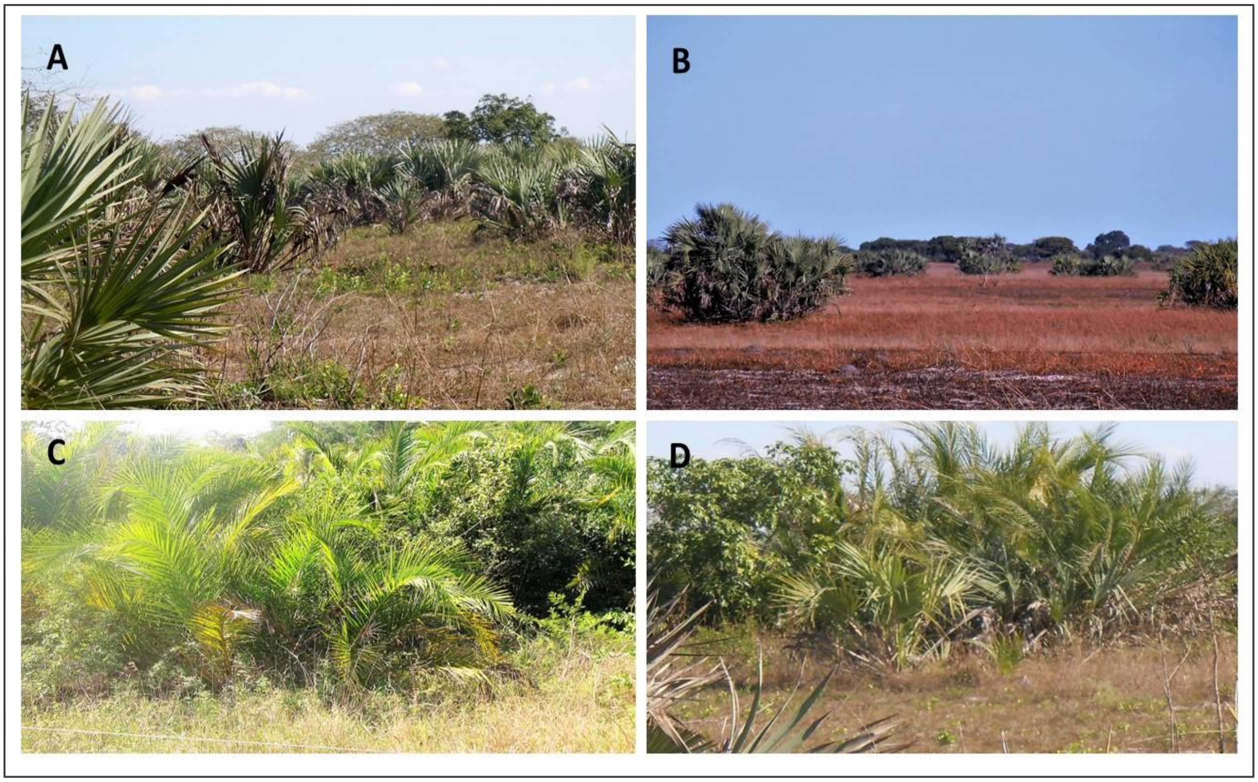

Figure 1.2: Palm savanna in Zitundo. (A) Palm savanna with high density of *Hyphaene coriacea*. (B) Palm savanna with low density of *Hyphaene coriacea*. (C) Palm savanna with high density of *Phoenix reclinata*. (D) *Hyphaene coriacea* and *Phoenix reclinata* mixed palm savanna.

Table 1.1: Differentiated uses of *Hyphaene coriacea* and *Phoenix reclinata*. √ denotes that the species is used and x denotes that the species is not used.

Uses	Species	
	H. coriacea	*P. reclinata*
Baskets	√	x
Brooms	√	√
Edible fruits	x	√
Fish traps	√	x
Furniture	√	x
Hats	√	x
Mats	√	x
Palm wine	√	√
Poles for fencing	√	√
Ropes	√	x
Sieves	√	x
Roofing	x	√
Wallets	x	√

Cunningham (1985; 1990a; b) and McKean (2003; 2004) have examined the role of these palms in the economy of the South African part of Maputaland coastal plain, and also looked at the effects of harvesting on the species. According to Cunningham (1985; 1990a; b) while individual returns from palm wine sale were small, the regional impact of this sale was large, providing income for nearly 500 people in the palm wine trading chain, through sale, resale and transportation. Cunningham (1985; 1990a; b) also inferred that palm wine production from *H. coriacea* was reaching its maximum capacity in the area, while the harvesting of *H. coriacea* leaves for basketry was suboptimal (Cunningham, 1988). McKean (2003) found that *H. coriacea* leaf harvesting in KwaZulu-Natal (South Africa) had negligible impact on leaf production, while heavy harvesting of the species for palm wine production had resulted in population declines (McKean, 2004).

Figure 1.3: *Hyphaene coriacea* and *Phoenix reclinata* uses. (A) *P. reclinata* tree with edible fruits. (B) Riped *P. reclinata* fruits. (C) Shelter roofed with *P. reclinata* fronds. (D) A sieve made using *H. coriacea* fronds. (E) A broom made using *H. coriacea* fronds. (F) Furniture set made using *H. coriacea* fronds. (G) *H. coriacea* fronds bench. (H) Shelves made with *H. coriacea* fronds. (I) Brooms made using *P. reclinata* stems. (J) Baskets (handbags) from *H. coriacea* fronds (K) Wallets made using *H. coriacea* fronds. (L) A hat made with *H. coriacea* fronds. (M) Palm wine from both species being sold at a local market. (N) *H. coriacea* being tapped.

These two species are also widely used in southern Mozambique. Palm wine is likewise an important resource for households in the Matutuine district of southern Mozambique (Mander and Pollet, 1994). However, the level of palm use, its role in local livelihoods and impacts on the species population are unknown. These kind of information is important to assess the conservation status of these highly used species and in designing conservation and development plans if required (Ticktin, 2015). Although these two palm species are abundant in southern and coastal Mozambique, some anecdotal reports have suggested that there excessive pressure on the species, presumably from the palm wine trade (Gaugris, 2008; MAE, 2012). However, this has not been verified and consequently this PhD study sought to investigate this further with the intention of supporting both livelihood benefits from the palms, but proving the information and insight necessary to guide any conservation actions if necessary.

1.1.6 The impacts of harvesting on palm populations

Harvesting of plant parts may have various positive or negative effects on individuals and populations of exploited species. Specific responses stem from a complex interplay of social and ecological factors, such that the response may vary according to plant part removed, harvest method, time of year, harvest intensity and frequency, vitality of the plant at the time of harvest, and synergistic or antagonistic effects from other pressures (such as fire, browsers, pests, drought, etc.) (Ticktin and Shackleton, 2011). Harvest may change the vital rates of individuals as well as the demographic and genetic composition of populations (Ticktin, 2004; 2015). Ticktin (2004; 2015) noted that changes in the survival, growth and reproduction rates can affect the structure and dynamic of the population. Ticktin's (2004; 2015) assessment of the effects of NTFP harvesting found that responses to and tolerance of harvest, on both individuals and populations, are extremely diverse and are dependent on the plant life form, the plant part and amount harvested, the environmental conditions and the human management practices such as harvest techniques, seasonal timing of harvest, timing of harvest in the plant life cycle, frequency of harvest, size of individuals harvested and intensity of harvest. Therefore, palm responses to harvesting will be context specific and differ according to the above mentioned factors, ranging from tolerance and capability to recover through compensatory mechanisms (Strauss and Agrawal, 1999) to negative effects such as reductions in growth, reproduction, density and even mortality (O'Brien and

Kinnaird, 1996; Sambou *et al*., 2002; Sola *et al*., 2006; Calvo-Irabién *et al*., 2009; Zuidema *et al*., 2007; Babitseng and Teketay; 2013).

The high marketability of some palm products have been linked to excessive harvesting and destructive methods in various regions. Vasquez and Gentry (1989) and Gilmore *et al*. (2013) stated that populations of *Mauritia flexuosa* and *Oenocarpus bataua* have been depleted in Peru and Ecuador, respectively, due to destructive methods and over-harvesting linked to commercialization. According to Johnson (1998) palm wine production from *Jubaea chilensis*, a palm from Chile, may have played a role in endangering the species. In Colombia and Ecuador the natural stocks of *Wettinia kalbreyeri* have been decreasing due to decades of unsustainable harvesting (Vásquez *et al*., 2012). In Africa, some destructive techniques of tapping were responsible for the disappearance of palm species in areas of Ivory Coast (Portères, 1964). Rist *et al*. (2010) used population models for *Lodoicea maldivica* and reported that the current levels of nut harvest will probably result in populations declining by up to 50 % in the next 200 years.

Examples of sustainable harvesting of palm products have also been reported. Martínez-Ballesté *et al.* (2005) reported that traditional harvesting of *Sabal yapa* leaves for thatch in Mexico is sustainable. Fiber extraction from *Aphandra natalia* for commercial and subsistence purpose in Ecuador have been reported to be sustainable (Kronborg *et al*, 2008). Sustainable harvest of fiber from *Astrocaryum standleyanum* for handicraft production was also observed in Colombia (Garcia *et al*., 2013). In Peru sustainable alternatives for commercial harvesting of *Mauritia flexuosa* have been developed, putting an end to decades of destructive harvesting of this species (Gilmore *et al*. 2013). Sampaio and Santos (2015) also reported that the traditional harvesting technique for buriti palm (*Mauritia flexuosa*) fruits in central Brazil appear to be sustainable, whist also in Brazil, Kumagai and Hanzaki (2013) concluded that the current use of *Butia catarinensis* to produce rum was sustainable. However, sustainability assessments are context and time specific (Ticktin and Shackleton, 2011) and thus conclusions will change in time if the yields decline for one or more reasons or harvest pressures increase. Additionally, very few sustainability assessments consider synergistic pressures or sustainability at scales above or below that of the individual plant or population scale (Ruwanza and Shackleton, 2017).

As shown by the above mentioned studies, the effects of harvesting of palm products on the population of the exploited species are variable across species and locations, depending on the part harvested, the amount and method of harvest and the local context; making it difficult to generate general recommendations. Therefore, each species and context must be investigated individually before guidelines or conclusions can be developed.

1.1.7 Climate change as a threat to NTFP provision

The distribution, abundance and viability of NTFPs can also be influenced by other pressures such as fire, browsing, and invasive species. A particular novel and pervasive one is climate change. According to Heubes *et al.* (2012) climate change is among the drivers that can influence the provision of NTFPs as well as food production from subsistence agriculture and therefore, the very livelihoods of rural communities. According to Boko *et al*. (2007) Africa is one of the most susceptible to projected future climate changes because of above average temperature increases relative to the expected global mean and a lack of adaptive capability.

While there is no doubt of the importance of climate change as a driver of changes in the distribution, abundance and vitality of NTFP populations, only a few studies have investigated the impact of future climate changes on the distribution of NTFP species. The majority of these have focused on the effects of climate change on biodiversity in general, and show different effects of climate change on species distributions. Iverson *et al*. (1999) investigated the potential future distributions of tree-species in the United States under climate change scenarios, and observed a large decrease in habitat suitability for Virginia pine. Similarly, a decrease in habitat suitability for *Lantana camara* due to climate change was also found by Taylor and Kumar (2013) in Australia, whereas the same species is anticipated to increase its range in southern India due to climate change (Kannan *et al*., 2013). Vieilledent *et al.* (2013) estimated the vulnerability of three endangered baobab species to climate change in Madagascar, and found an increase in habitat suitability for one, *Adansonia grandidieri*, and a decrease in habitat suitability for the other two, *Adansonia perrieri* and *Adansonia suarezensis*. These authors concluded that these latter two species are threatened by climate change in Madagascar. Heubes *et al.* (2012) studied the impact of future climate and land use change on NTFPs provision in Benin using niche-based modeling with ecosystem service values**.** They found that economic value derived from the use of three species, *Adansonia digitata*, *Parkia biglobosa*, and *Vitellaria paradoxa* will be reduced by 50 % by 2050 due to predicted decreases in habitat suitability of the three species. Chitale *et al*. (2018) reported mixed responses to climate change effects for ten NTFP species from Nepal, with a potential increase in distribution for seven and a decrease for three by 2050. This mix within and between studies once again emphasizes the need for local and context specific studies and understanding.

The same applies with respect to modelled responses of palm species to future climate change scenarios. Blach-Overgaard *et al.* (2009) assessed the role of climatic and non-climatic factors on the distribution of *Hyphaene petersiana* in Africa via Maxent modelling and reported that the current distribution is controlled by climate and non-climate variables. Water related variables such as annual precipitation and precipitation during the driest quarter were highly important for the distribution of *Hyphaene petersiana,* while the role of temperature was less obvious (Blach-Overgaard *et al.*, 2009). Shabani *et al.* (2012) studied the climate change effects on the future worldwide distribution of date palm (*Phoenix dactylifera*) using CLIMEX, and found that climate suitability for date palm cultivation in North Africa, North and South America and the Middle East will change. They found decreases in habitat suitability of date palm in Algeria and Saudi Arabia, and increases in habitat suitability of date palm in Benin, Ghana, Cameroon, Nigeria, Venezuela and China. In Africa specifically, Blach-Overgaard *et al*. (2015) forecasted over 70% reductions in the climate suitability of economically important African palm species by 2080. However, Idohou *et al*. (2017) found increases in highly suitable habitat for seven out of eight economically important palms species from west Africa.

1.2 Problem statement and justification

Supportive and effective resource management programs require a range of information pertaining to the species and landscapes in question and the current and possible future uses of the target species and landscapes in which it occurs and the livelihoods in which it may be embedded (Schmidt and Skidmore, 2003). It must also acknowledge the information is only valid for a certain period as conditions and local livelihoods undergo constant changes, and therefore the program needs to be updated, adaptive and flexible. Yet, a starting point is the collection and assessment of detailed ecological, environmental and socioeconomic information regarding NTFPs used by rural people and recognition of the needs of different resource users (Sieben, 2011; Shackleton and Pandey, 2014). In many regions, the sustainable management of some NTFPs is of crucial importance for sustaining the livelihoods of the rural poor and the maintenance of local cultures and knowledge.

However, despite their important role in securing and improving the quality of life of the rural and urban poor, NTFPs, are in most countries, not included in national statistics and consequently in national policy and development strategies (Shackleton and Pandey, 2014). The various reasons for their omission from the development agenda have been explored by Shackleton and Pandey (2014). The same authors have also proposed several steps to facilitate the integration of NTFPs into the development agenda, two of them being the "proper inventory of NTFPs" and "research on NTFP ecology and sustainable harvest levels" (Shackleton and Pandey, 2014).

There is a growing body of literature on NTFPs. However, according to Sills *et al*. (2011), most NTFPs research and political action over the past decades was carried out in South America and Southeast Asia, and has focused on products with the potential to enter international markets (Sills *et al*., 2011, Shackleton and Pandey, 2014). So there is still insufficient information on the spatial distribution, stocks, harvesting rates and socioeconomic and cultural roles of many NTFPs in many countries, especially in Sub-Saharan Africa. Mozambique is no exception regarding the lack of detailed information on NTFPs. Although NTFPs play a role in the rural livelihood strategies of Mozambican people, their contribution to rural livelihoods has been hardly explored or enumerated. With few exceptions (Falcão *et al.*, 2007; Hegde and Bull, 2008; Walelign and Øystein, 2013; Jones *et al*., 2016; Vollmer, *et al*., 2017) most previous studies carried out in Mozambique have focused on ethnobotanical listing and describing the plants and animals used by people (Bandeira *et al*., 1999; Matavele and Habib, 2000; Bandeira *et al*., 2001; Ribeiro *et al*., 2010; Bruschi *et al*., 2011; Bruschi *et al*., 2014) with little focus on their roles in rural livelihoods or the sustainability of current use patterns and demand.

Mozambique is one of the poorest countries in the world. About 45% of the population live in poverty (MEF, 2016). Poverty is predominantly a rural phenomenon in Mozambique, with more than 70% of the poor living in rural areas (IFAD, 2013) and a rural poverty incidence of about 50% (MEF, 2016). The majority of the rural people live on less than US$1.25 a day (INE, 2009) and rely heavily on the extraction of NTFPs to complement rain-fed agricultural production for daily subsistence. The dependency on NTFPs is especially high in areas where crop yields are relatively low, as in southern Mozambique (Governo do Distrito de Matutuine, 2008). Key NTFPs in Mozambique due to their marketability and versatile uses include honey, bush meat, fuelwood, wild fruit and medicinal plants (Crafter *et al*., 1997; Walter, 2001; Nhancale *et al*., 2009). Additionally, palm products are also an important NTFP in the areas of the country where palm savannas predominate, such is the case of the coastal plains of southern Mozambique (Governo do Distrito de Matutuine, 2008). Although the use of NTFPs improves household food security and welfare of households, policies regarding use, management and conservation of these products, as well as their integration into poverty reduction and development strategies, are still lacking in the country. One potential explanation is the limited information on the availability and the role of NTFPs used by rural people. Therefore, knowledge about the available stocks of NTFPs and their role in livelihoods is important in the design effective and sustainable development strategies. This information can be included in national and sectoral policies, as well as in development strategies that can help to alleviate or mitigate the effects of poverty (Shackleton and Pandey, 2014).

This study adds value to the field of NTFPs use and trade in Mozambique. Four key contributions are expected as a result of conducting this research: 1) a better understanding of the distribution, abundance, harvesting rates and expected potential distribution of the palm species *Hyphaene coriacea* and *Phoenix reclinata* under different climate change scenarios, 2) a more comprehensive analysis of the role of NTFPs in rural livelihoods, especially the role of palm species, than has been done for the Zitundo area, 3) practical results to assist in developing policies and strategies to alleviate poverty or mitigate the effects of poverty as well as to promote conservation, since this is the first study on the contribution of palm species to household well-being in Mozambique, and 4) provide fresh results to the literature that complement the now dated work of Cunningham (1999a; b) and McKean (2003) in the Maputaland Region of South Africa, which borders southern Mozambique.

1.3 Aims of study

The aim of this study was to investigate the role of the palm species *Hyphaene coriacea* and *Phoenix reclinata* in the livelihoods of households in the Zitundo area, Matutuine district, southern Mozambique and under future climate scenarios. Specifically, this study sought to:

Evaluate the abundance, population structure and harvesting selection of these species;
Characterize the ethnobotanical knowledge and use of the two species;
Examine the local production and trade of palm wine in the area;
Examine the contribution of palm income to livelihoods, income diversification and poverty mitigation in area;
Describe the local management practices and perceptions on palm productivity and abundance; and
Model the current and future distribution of these palm species in the area.

1.4 Conceptual and theoretical framework

This study drew from five theoretical and conceptual approaches to fulfill its objectives. To evaluate the population structure of the studied species, I used the continuous approach to size class distribution developed by Condit *et al*. (1998), combined with three measures of population stability. Two ethnobotanical hypothesis (Gaoue *et al*., 2017), the plant use value hypothesis and the age, gender, and dynamics of knowledge hypothesis were used to examine the ethnobotanical knowledge and use of the two species. The sustainable livelihoods framework (Scoones, 1998; DFID, 1999; Ellis, 2000) was used to guide the examination of the production and trade of palm wine and the contribution of palm income to livelihoods and income diversification. Additionally, the ecological niche theory (Hutchinson, 1957) guided the species distribution modelling.

1.4.1 The continuous theoretical approach to size class distribution

The size class distribution continuous theoretical approach developed by Condit *et al*. (1998), combined with three measures of population stability: the Simpson index of dominance, the permutation index and the quotients between successive size classes, was used in this study to analyze the population structure of the two palms. The continuous approach to size class distribution (SCD) describes the distribution of abundance per size classes in a given population, as a function of time or size of the class, using a partial differential equation (Condit *et al*., 1998). From the partial differential equation Condit *et al*. (1998) derivated the following equation Ln (N_i) = Ln (N_i +1). This is a regression equation between the midpoint of size class *i* as the independent variable (N*i*+1) and the abundance of individuals in the size class *i* as the dependent variable (N*i*). According to Condit *et al*. (1998), the slope of this equation describes the shape of the size class distribution and the relative level of the recruitment on a given population. Negative slopes are linked to a reverse-J SCD curve (Figure 1.4A), implying good recruitment levels. Positive slopes are related to a unimodal SCD curve (Figure 1.4B), denoting limited or sporadic recruitment. Slopes of zero or approaching zero indicate a flat SCD curve (Figure 1.4C) with similar proportions of individuals in smaller and larger size classes (Condit *et al*., 1998). For populations with flat SCD curve, the probability of juveniles becoming adults is high, however it is also a suggestive of low recruitment (Midgley *et al*., 1990; Lykke, 1998). Healthy, growing populations are characterized by steep negative slopes (Condit *et al*., 1998).

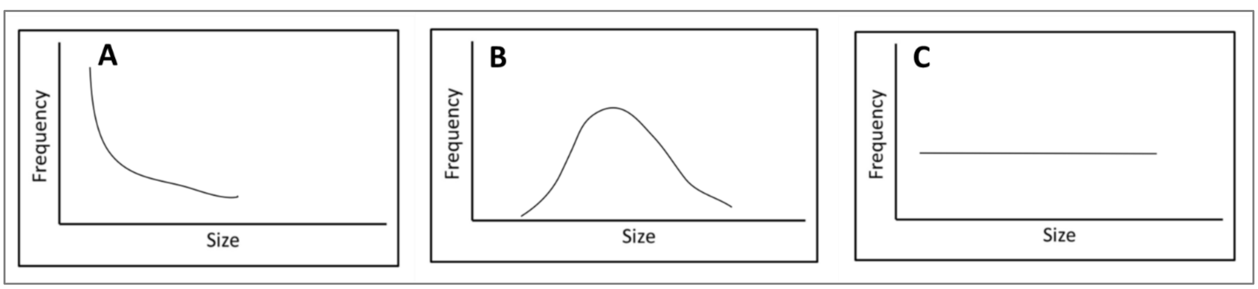

Figure 1.4: Size Class Distribution (SCD) curve shapes according to Condit *et al*. (1998). (A) reverse-J SCD curve, (B) unimodal SCD curve, (C) flat SCD curve.

This study combined the size class distribution continuous approach described above with three SCD indices: the Simpson index of dominance and the permutation index used by Wiegand *et al*. (2000), and the quotients between successive size classes (Meyer, 1952; Leak, 1964; Botha *et al*., 2002). Each of these SCD indices measure a different dimension of population stability (Wiegand *et al*., 2000). The Simpson index of dominance determines if the size classes of a given population are evenly distributed (Wiegand *et al*., 2000). Values of the Simpson index below 0.1 suggest that the size classes are evenly distributed and that the population is stable (Wiegand *et al*., 2000). The permutation index measures the departure from a uniform decline in the SCD of a given population. A population that does not decline uniformly is considered unstable (Wiegand *et al*., 2000). Quotients between consecutive size classes also give insights on the stability of population. Stable populations exhibit steady quotients while unstable populations are characterized by oscillating quotients (Botha *et al*., 2002).

1.4.2 The plant use value hypothesis and the age, gender, and dynamics of knowledge hypothesis

To fulfill the objective on the local use and knowledge of these species, this study considered two ethnobotanical hypothesis (Gaoue *et al*., 2017): the plant use value hypothesis and the age, gender, and dynamics of knowledge hypothesis. The plant use value hypothesis is based on the use value index developed by Phillips and Gentry (1993a, b), and suggests that the usefulness of a plant is related to the traits of the plant species such as life form, local abundance and size (Phillips and Gentry 1993a, b). This hypothesis was further improved to include the demographic and socio-cultural characteristics of the user such as gender, ethnicity, age, and proximity to markets as determinants of a plant usefulness (Gaoue *et al*., 2017). The age, gender, and dynamics of knowledge hypothesis also advocates that the individual socio-cultural and demographic characteristics, as well as education determines the level of an individual's knowledge (Gaoue *et al*., 2017). This hypothesis suggested an accumulation of knowledge about plants and ecology and uses as the individual ages, is differentiated according to gender roles, typical of a given society, determine the individual level of knowledge (Gaoue *et al*., 2017). This hypothesis also implies that higher formal levels of education are negatively linked to plant knowledge (Voeks and Leony, 2004; Voeks, 2007). According to Gaoue *et al*. (2017) the hypotheses are not mutually exclusive and assume that humans are rational and efficient in their choices. This study uses the demographic and so cio-cultural characteristics of the users as well as a proxy for local abundance (village) to examine the level of palm use and palm use knowledge.

1.4.3 The sustainable livelihoods framework

The sustainable livelihoods framework (Scoones, 1998; DFID, 1999; Ellis, 2000) was used in this study to analyze the household livelihood strategy selections, the factors underlining these selections and the resulting outcomes in relation to NTFP use and poverty. Additionally, the production and trade of palm wine was also analyzed based on this framework. Five components are recognized in this framework: i) the assets or capitals (human, physical, financial, natural and social), ii) the vulnerability context, iii) the transforming structures and processes (policy and institutional context); iv) the livelihood strategies and v) the outcomes (Figure 1.4) (Scoones, 1998; Ellis, 2000; Ellis and Allison, 2004). In the framework, a household's diverse assets or capitals are used in the specific vulnerability, policy and institutional contexts thereby shaping possible livelihood strategies and associated outcomes (Ellis, 2000; Ellis and Allison, 2004). Outcomes accomplished by a household through pursuing one or more specific strategies can include better, or worse, incomes and well-being, food security, sustainable use of natural resources, etc. (Soltani *et al*., 2012; Khatiwada *et al*., 2017). This framework is holistic, integrative and multidimensional, recognizing the complexities imbedded in rural livelihoods (Fisher *et al*., 2013). It can be applied in different socioeconomic, biophysical and geographical contexts to identifying the multiple and diverse types of livelihoods, the social and economic nature of the livelihood strategies adopted, the role of formal and informal institutions that support or hinder livelihoods strategy, the factors influencing vulnerability, and the connections between livelihoods and policies (Ellis and Allison, 2004). Due to its characteristics the sustainable livelihoods framework has been widely applied in a variety of research areas that focus on the links between people, land and resources, such as rural development, vulnerability analyses and poverty reduction; natural resources use, conservation and sustainability (Khatiwada *et al*., 2017).

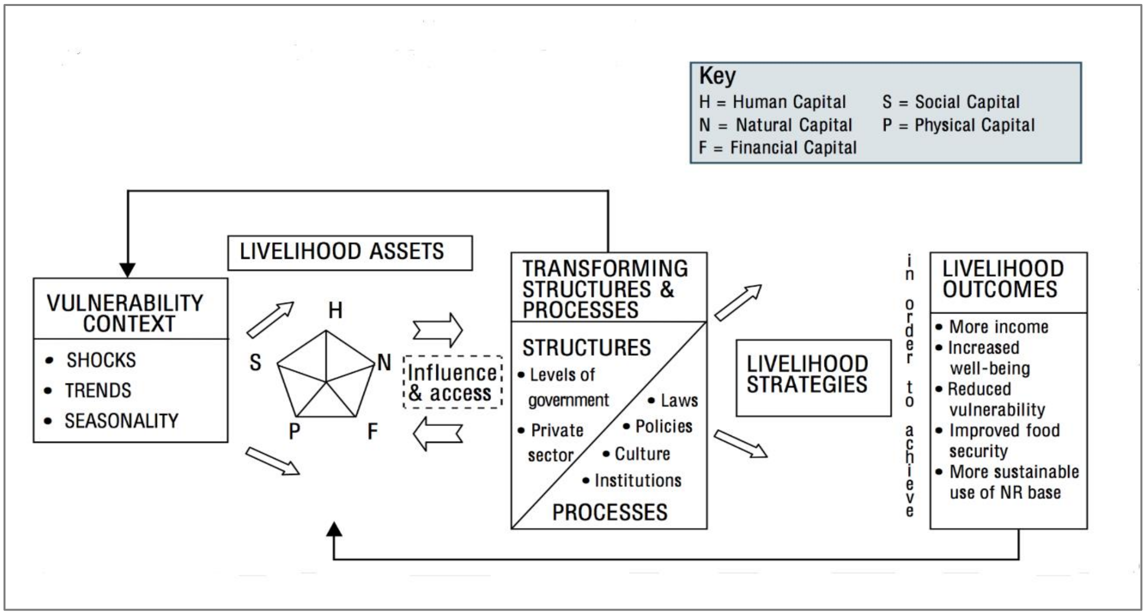

Figure 1.5: The Sustainable Livelihoods Framework (Source: DFID, 1999)

Following Soltani *et al*. (2012) and Khatiwada *et al*. (2017) this study centered on three components of the framework, i.e. livelihood assets, strategies, and outcomes, although the general context (vulnerability and other) is provided to aid understanding. A livelihood strategy is considered in this study as the set of income (cash and non-cash) earning activities that a household does for a living (Ellis, 2000). The strategy adopted by a household is determined by the various assets or capitals owned by, or available to, the household. Assets included in this study try to capture the five types of capital recognized in the framework: natural, human, social, physical and financial. Ellis and Allison (2004) recognized that not all resources that households use to pursuit their households can match exactly these asset categories and that some can play multiple roles. For example, household land can be categorized as both natural and physical capital, while livestock as financial and physical. Soltani *et al*. (2012) used village as location capital to account to environmental state and infrastructure. In this study, I designated a village as natural capital to account for the biophysical characteristics of a village that influence the availability of natural resources. The measures of outcomes resulting from a chosen strategy considered in this study are: total income, income per capita, poverty incidence, palm wine sales profit, palm wine commercialization index and dependency.

1.4.4 The ecological niche theory

The ecological niche theory was used to guide the modelling of the current and future distribution of the two studied species. According to Soberon and Peterson (2005) and Soberon (2007) the geographical distribution of a given species is determined by: i) the local abiotic environment, which allows the species population to grow; ii) the species biotic interactions with other species, such as: predation, competition, mutualism, which permit the species to persist and iii) the dispersal abilities of the species which regulate the capability of the species to colonize other areas. These determinants of species distribution comprised the different concepts of the ecological niche that have been discussed in the ecological literature. Hutchinson (1957) defined two concepts of a species ecological niche: the fundamental niche and the realized niche. The species fundamental niche is composed by all environmental conditions that permit the long-term persistence of the species. However, this full environmental potential for the species occurrence (fundamental niche) can be reduced by factors such as: human influence, biotic interactions and geographic barriers (that can obstructed the species dispersal and the colonization of new ecological suitable areas) (Phillips *et al*., 2006) creating what Hutchinson (1957) called the realized niche, which is the sub-section of the fundamental niche actually occupied by the species.

Species distribution models (SDMs) rely on the ecological niche theory assumption that the observed geographical occurrence of a given species is a function of its ecological requirements (Hirzel and Le lay, 2008) and, in most cases assume that observed occurrences have already been constricted by biotic interactions and limiting resources (Phillips *et al*., 2006). Elith and Leathwick (2009) defined SDMs as models that predict the distribution of the species in a defined geographical area, using correlations between the data on the species occurrence locations and the environmental features of those locations. Currently there are many SDM methods available including: DOMAIN, BIOCLIM, GAM, GLM and Maxent (Elith *et al*., 2006; Elith *et al*., 2011). These methods differ in their input requirements (Rana *et al*., 2017). Maxent, developed by Phillips *et al*. (2006), has shown a stable and consistent predictive capability, and was reported to perform better than most SDM methods. This method makes predictions or inferences with incomplete information (Jaynes, 1957; Phillips *et al*., 2006), and has the following advantages: i) only requires presence data; ii) can be used with small sample sizes; iii) can use continuous and categorical data, iv) uses interactions between different variables; and v) has some robustness against geo-referencing errors (Elith *et al*., 2006; Phillips *et al*., 2006; Graham *et al*., 2008; Phillips and Dudík, 2008).

In this study I used the Maxent method to model the current and future distribution of the studied species. Bioclimatic variables, distance to rivers and water bodies, slope, soils, NDVI and land cover were chosen to reflect the environmental conditions that potentially regulate the species occurrence, while distance to villages, Human Influence Index (HII) and population density tried to capture anthropogenic factors that can constrain the distribution of the species.

1.5 Structure of thesis

This thesis is presented in seven chapters. Chapters two, three, four, five and six are written as independent scientific journal articles, therefore there is cross-referencing between them. Chapter 1 is the current introductory chapter, it gives background on the importance of NTFPs and palms (as a NTFP) to livelihoods. It also provides information on the impacts of palm harvesting on the palms population, as well as the impact of climate change on the provision of NTFPs. It provides the rationale and background to the study, which lead into the objectives of study as well as theories, approaches, hypotheses and framework supporting the study. It ends with a short description of the study area.

Chapter 2 assesses the abundance and population structure of the two palm species using a SCD approach combined with three measures of population stability. It also includes results on the influence of anthropogenic factors on palm density and population structure. Furthermore the preference to harvest a specific size class is considered. This chapter has already been published on 15 August 2017, in Forest Ecology and Management, volume 398, pages 64-74.

Chapter 3 deals with the level of general household use and knowledge about palms. In this chapter ethnobotanical indices are used to determine the use and knowledge about palm uses in the area, and the factors that determine them. It determines the most preferred palm uses, and the cultural importance of these species in the area. The perceptions on palm management and abundance are also presented and contrasted with the views of palm tappers described in Chapter 4 (published chapter).

Chapter 4 examines the local production and trade of palm wine, using interviews with palm wine tappers. The chapter characterizes the local tapping activities, palm market and palm management practices as well as perceptions on palm productivity, abundance and fluctuations. The income derived from palm wine sales, the level of palm income commercialization, the level of dependency on palm income as well as the factors determining the above mentioned parameters are also assessed in this chapter. This chapter has also already been published on May 2018, in the South African Journal of Botany, volume 116, pages 6-15.

Chapter 5 elaborates on the contribution of palm income to livelihoods and diversification in the area. The chapter assesses the different livelihood strategies adopted by households in the area and the factors determining the choice of livelihood strategies. It further evaluates how the chosen strategy, as well as palm income, influence household total income, income per capita and the level of poverty.

Chapter 6 assesses the current and future distribution of the two palm species, using a participatory mapping exercise and species distribution modelling taking climate change scenarios into account. Local people perceptions on palm occurrence areas, abundance, as well as factors determining the occurrence are presented. The current and future habitat suitability for the two species, and the main factors influencing the distribution of the species are also described.

Lastly, Chapter 7 is the synthesis chapter and it summarizes the key finds of thesis and draws conclusions and recommendations based on the results of this thesis. It reconsiders the original aims and draws from each chapter to provide an integrated picture of the status, use and importance of the two palm species in the Zitundo area.

1.6 Study area

The study was carried out at the 16 villages that composed the Zitundo Administrative Post namely: Ponta de Ouro, Malongane, Momole, Zitundo-sede, Gala, Ndovo, Mabucuti, Phuza, Mussongue, Massale, Huco, Xibaluine, Gueveza, Mugovene, Vumidava, and Tchovane (Figure 1.6). Zitundo, is located in southern Mozambique, with an area of 864 km^2 (INE, 2009), is the southernmost administrative post of Mozambique. It is bordered by South Africa to the south, Bela Vista Administrative Post to the north, the Indian Ocean to the east, and in the west the Maputo River separates Zitundo from Catuane Administrative Post. The climate of the area is tropical to sub-tropical, with the average annual temperature around 22.6^o C and annual rainfall varies between 600 mm to 888 mm (Mander and Pollet, 1994). Two seasons can be discerned, one hot and rainy, which lasts from October to April, and another cool and dry which runs from May to September (Shaffer, 2010). The average daily maximum temperatures varies from 28^o C to 30^{o}C, and occurs between December and February (Schulze 1997), while the average daily minimum temperature is less than 10^o C, and occurs between June and August (Schulze 1997). The climate varies from the coast to inland. Along the coast, the climate is tropical and humid, with an annual precipitation of over 1 000 mm and average annual temperatures of about 22^o (Kirkwood, 2014). Inland, the climate is sub-tropical, with the annual rainfall of less than 600 mm and average annual temperatures is about 23^{o}C (Kirkwood, 2014). Humidity and evaporation are high throughout the year ranging from around 50% in winter to over 80% in summer (Morley, 2005). The topography is characterized by a flat or slightly undulating, low coastal plain alongside the Indian Ocean (Mucina and Rutherford, 2006), with average elevations around 50 m (McKean, 2003) and no more than 150 m (Kirkwood, 2014). Young, steep-sided vegetated dunes occur along the coastline (Kirkwood, 2014), and behind the dunes, coastal lakes, marshes and temporary rain-fed ponds can be found (Kirkwood, 2014). The soils in Zitundo area are mainly sandy, yellow and gray, with low organic content, high drainage rates and infertile, therefore with low agricultural potential (McKean, 2003; Morley, 2005). On the floodplains of rivers and the fringe of lakes and wetlands the soils are alluvial, red, clay rich and more fertile (Morley, 2005).

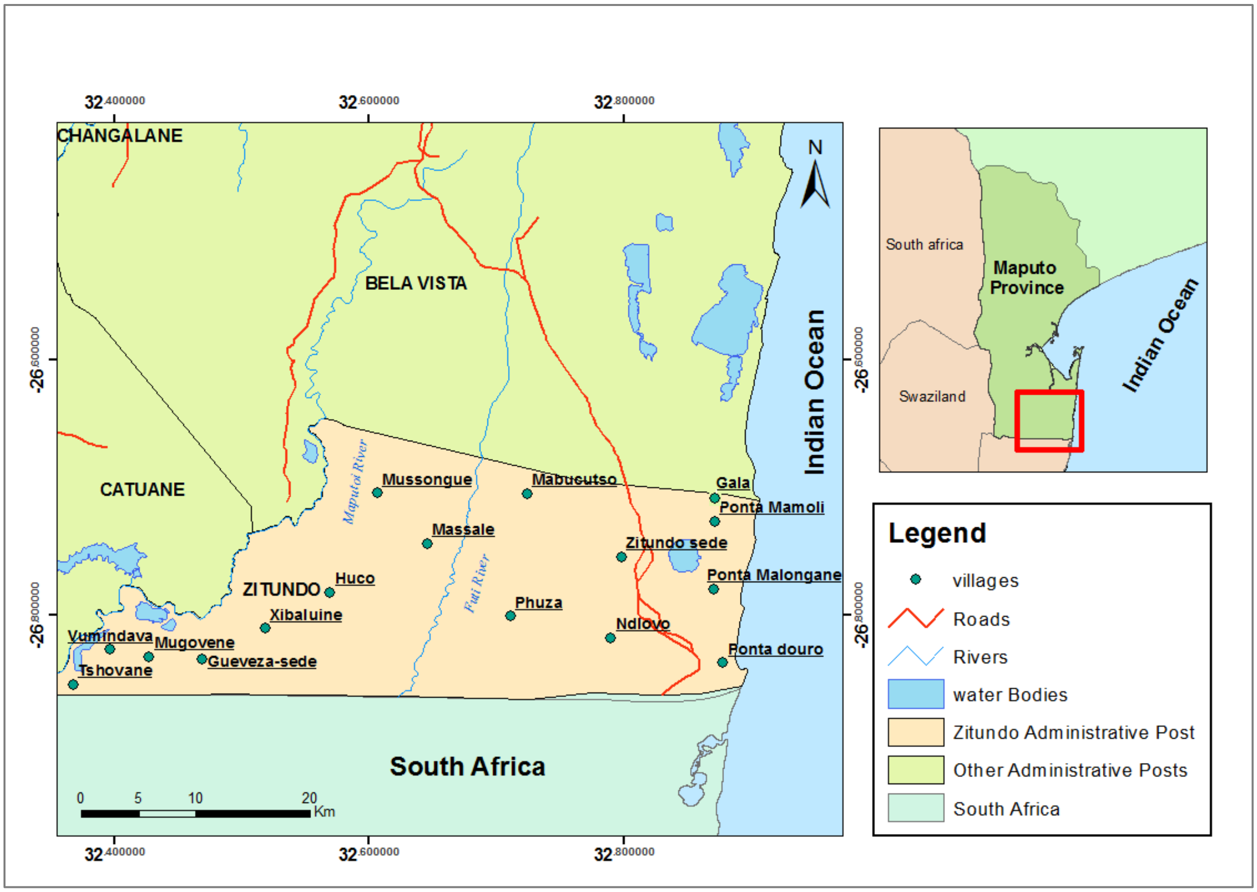

Figure 1.6: location of Zitundo Administrative Post, southern Mozambique

Biogeographically Zitundo lies in the Maputaland Centre of Endemism, within the Maputaland-Pondoland-Albany biodiversity hotspot (Van Wik and Smith, 2001). The area is characterized by diverse vegetation types, including forests, savannas, woodlands, grasslands, wetlands, estuarine and riverine vegetation (Kirkwood, 2014). According to Kirkwood (2014) the windward side of the vegetated dunes along the coast is characterized by a short dune forest or thicket. This forest grades to a more diverse and tall forest on the leeward side. Moving further to the interior, the landscape is dominated by an open grassland, where grasses and short woody species are prevalent. In this vegetation formation, some trees species such as *Syzygium cordatum* and *Trichilia emetica* and the palm species *Hyphaene coriacea* and *Phoenix reclinata* can also be found sparsely scattered (Kirkwood, 2014). Patches of woodlands and swamp forests are embedded in the open grassland. Vast areas of palm savanna lie mainly between the open grassland and the Futi River. In these areas *Hyphaene coriacea* and *Phoenix reclinata* are the dominant tree species. Other common tree species in palm savanna are: *Dichrostachys cinerea, Strychnos madagascariensis*, *Syzygium cordatum* and *Schotia brachypetala* (McKean, 2004; Kirkwood, 2014). The grass layer of the palm savanna is dominated by the genera *Themeda*, *Aristida*, *Perotis* and *Eragrostis* (McKean, 2004; Kirkwood, 2014). Further inland, a sand forest and a woodland with patches of open savanna can be found (Kirkwood, 2014). In the floodplains of the Maputo and Futi rivers and the fringes of the lakes, riverine species such as *Phragmites australis*, *Typha latifolius*, *Cyperus papyrus* (Morley, 2005) and the tree species *Vachellia xanthophloea* (previously *Acacia xanthophloea) and Phoenix reclinata* are common.

According to MAE (2012) there are 6 674 people living in Zitundo in 1 777 households, resulting in a low population density of approximately 7.7 people/km^2. The average household size in the area is four (INE, 2009), the illiteracy rate and poverty incidence are high, and estimated in 2005 at 62% and 78%, respectively (MAE, 2012). About 39% of population is below 15 years, and the dependency ratio is 1:1.2. Nearly 52% of population in the Zitundo area is male (MAE, 2012; INE, 2009). The majority of the population belong to the Ronga ethnic group, a sub-group of Thonga tribe (Junod, 1962), which have occupied the area for more than 500 years (Shaffer, 2010). The Rongas are mostly found in the Maputo province in Mozambique and in the Northern KwaZulu Natal in South Africa (Kloppers, 2003). Junod (1962) referred that the word Ronga means dawn in Zulu, and was used by the Zulu people (a neighboring ethnic group from Kwazulu Natal, in South Africa) to refer to all people inhabiting north and east of their kingdom.

Historically the people of Maputaland are called the Tembe or the Tembe-Thonga, and are named after Chief Mthembu who settled in the area south of Maputo Bay around 1554 (Kloppers, 2003), forming the Tembe chiefdom. This chiefdom occupied the area spreading from Maputo Bay in Mozambique, in the north to the present day Ubombo District in KwaZulu-Natal in South Africa, in the south and the Maputo River in the west (Felgate 1982). With the recognition and formalization of the traditional leadership system in 2000 (Decree 15/2000), the local traditional authorities are now part of the administration system of Zitundo Administrative Post. In Zitundo, the traditional leadership system is composed by the “Regulo”, who is the head of traditional leadership system, and is supposedly a close relative of the first Tembe chief, and the village’s traditional leaders (each village has its own traditional leader) (Zitundo Regulo, pers. comm.). Activities under the umbrella of the traditional authorities include participation in village conflict resolution and in the decision process of land allocation and access rights to natural resources within the village (Zitundo Regulo, pers. comm.).

The early inhabitants of the study area were agriculturalists, who used the slash-and-burn or shifting agriculture technique (Kloppers, 2003), and were also highly dependent on natural resources from the land and from along the seashore (Kloppers, 2003; Gaugris, 2008). Presently, the lifestyle of people from the Zitundo area are still based on intense use of natural resources. The main livelihood activities in the area are deemed to be rain fed-subsistence agriculture using mixed cropping, goat and cattle husbandry, wild fruits and wild plant collection, beekeeping for honey production, fishing, hunting, charcoal production, craft and mat production and palm wine tapping (Governo do Distrito de Matutuine, 2008; Shaffer, 2010). The average field size for subsistence agriculture in the area is 0.9 ha/household and the main crops cultivated are cassava, sweet potatoes, collards, garlic, lettuce, corn, onions, tomatoes, beans, peanuts and rice. Common livestock includes chickens, ducks, cattle and pigs (MAE, 2012; Governo do Distrito de Matutuine, 2008).

According to the Mozambican land law (Law nº19/97 of 1997), land is legally owned by state, with power to transfer the use rights to individuals, communities and companies through deeds (Republica de Moçambique, 1997). This law also recognizes the customary rights and the equal access rights to women and men. In Zitundo area, the majority of the local people do not have official deeds for the land they live on and use (MAE, 2012). The access to land is mostly governed by local customary systems, where land is inherited from fathers by sons, and women get use rights through their husband's family's rights (Waterhouse, 1997; MAE, 2012). The local traditional authorities have also the power to allocated land use rights upon request regardless of gender, as underlined under the land law. Most households are allocated by the local traditional leadership an area of land for building a house and for cultivating crops. Unallocated land is regarded as communal land, which local residents can use for grazing livestock and collection of NTFPs.

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CHAPTER TWO: ABUNDANCE, POPULATION STRUCTURE AND HARVESTING SELECTION OF TWO PALM SPECIES (*HYPHAENE CORIACEA* AND *PHOENIX RECLINATA*) IN ZITUNDO AREA, SOUTHERN MOZAMBIQUE[1]

2.1 Abstract

In southern Mozambique, the sap and leaves of the palms *Hyphaene coriacea* and *Phoenix reclinata* are harvested by local people as sources of traditional beverages, weaving, roofing, fencing and furniture material. The harvesting of these palm products may affect palm populations structure, dynamics and viability. This work evaluates the abundance, population structure and harvesting selection of these two heavily harvested palm species. *Hyphaene coriacea* was more abundant, with a mean density of 601.5 ± 455.9 stems ha-1 against the 251.9 ± 527.3 stems ha-1 of *Phoenix reclinata*. Both species exhibited steeper negative slopes in the regression analyses of SCD, indicating the presence of more individuals in shorter size classes. Although there was a dominance of shorter over taller size classes, limited recruitment was noted observed through lower stems densities of seedlings and juveniles size classes comparing to the size class 1-50 cm. The Simpson index of dominance, the permutation index, and the fluctuating quotients between the consecutive size classes showed a certain level of instability in both populations. *Hyphaene coriacea* appears to be more resilient to tapping than *Phoenix reclinata* as showed by the higher rate of stem survival after tapping. *Hyphaene coriace*a is favored for tapping compared to *Phoenix reclinata*. Tappers exhibited positive selection for five out of the six *Hyphaene coriacea* size classes, against only one *Phoenix reclinata* size class. The most preferred size class to tap for both species was between 101cm and 150 cm. The instability detected by the indices of population stability, the coincidence between the size classes with high numbers of dead stems and the most preferred and the low level of the sexual reproduction encountered in both population emphasizes

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the need for long-term monitoring as well as management measures that integrate the resource users, to ensure the long-term sustainability of these populations.

Keywords: cluster density; preference ratio; size distribution; stability indices, stem density; tapping

2.2 Introduction

Palm species are substantial sources of non-timber forest products (NTFPs) and therefore, are frequently heavily harvested, especially in the tropics, where they are often abundant (McCurrach, 1960; Martínez-Ballesté *et al.*, 2008). Balick and Beck (1990) recorded more than 390 goods obtained from palms. Palms are a source of food; beverages; syrup; sugar; fibres; construction materials for houses, boats, and furniture; ornaments; medicines, and are also used for traditional purposes (Cunningham, 1990; Johnson, 1992; Kinnaird, 1992; O'Brien and Kinnaird, 1996; Dalibard, 1999; Sambou *et al*., 2002; McKean, 2003; Pizo and Vieira, 2004; Sola *et al.*, 2006; Chowdhury *et al*., 2008; Martínez-Ballesté *et al.*, 2008; Calvo-Irabién *et al.*, 2009; Manzi and Coomes, 2009; Duarte and Montúfar, 2012; Babitseng and Teketay, 2013; Isaza *et al.*, 2013). These goods are exploited for subsistence and commercial purposes (Johnson, 1992), thus playing a significant role in the lives of many people in South America, Asia, and Africa (Kinnaird, 1992).

The impacts of palm products harvest on the population of the exploited species are variable across species and locations (Moll, 1972; Kovoor, 1983; Cunningham, 1990; O’Brien and Kinnaird, 1996; Sambou *et al*., 2002; Endress *et al.*, 2006; Sola *et al.*, 2006; Zuidema *et al.*, 2007; Martínez-Ballesté *et al.*, 2008; Calvo-Irabién *et al*., 2009; Lopez-Toledo *et al*., 2011; Babitseng and Teketay, 2013) depending on the part harvested, the amount and method of harvest and the local context; making difficult to generate general recommendations. Therefore, each species and context must be investigated individually before guidelines or conclusions can be developed.

In southern Mozambique, *Hyphaene coriacea* and *Phoenix reclinata* are important palm species used by local people as sources of weaving material employed to make furniture, baskets, sieves, and other utensils. Fronds are used as roofing material, and the petioles are used as poles to build cattle sheds and fences. A traditional palm wine, locally called *sura* or *ntchemane*, is produced from the sap and contributes significantly to the household income in Zitundo area. Furthermore, the fruits of *Phoenix reclinata* are edible and its stem is used to make brooms. Despite the importance of these palms species for the rural people in southern Mozambique no previous studies have assessed their population status. In neighbouring South Africa, McKean (2004) showed that heavy harvesting of *Hyphaene coriacea* has resulted in population declines.

The distribution, abundance, population structure and dynamics of plant species are influenced by environmental and anthropogenic factors (Boll *et al*., 2005; Herrero-Jáuregui *et al.,* 2012). This is especially so for NTFPs species. The rate and nature of resource exploration is one of these anthropogenic factors (Herrero-Jáuregui *et al.*, 2012). Harvesting NTFPs may influence the survival, growth, and reproduction of an exploited species, having impacts on the population structure and dynamics (Ticktin, 2004).

Sound management plans and policies for NTFP species need knowledge about the ecology, abundance, population structure and dynamics of the exploited species (Herrero-Jáuregui *et al.*, 2012), as well as the long-term impacts of the species exploitation on such parameters (Venter and Witkowski, 2010). This knowledge is not only important for the species conservation but also for the people depending on that resource for a living (Shackleton *et al*., 2015).

According to Ticktin (2015), the harvesting of NTFPs is only sustainable if it has no or limited immediate or future negative effects on the population and in the ecosystems in which the species is found. To investigate these effects, medium to long-term studies of population dynamics are required (Obiri *et al*., 2002; Ticktin, 2015). Life tables, survival curves, and time-series data evaluate the dynamics of populations over time, therefore, are appropriate measures to study population structures and dynamics (Kai *et al*., 2013; Ticktin, 2015). However, these are costly in terms of time and resources needed (Obiri *et al*., 2002; Ticktin, 2015).

Although long-term data are preferable to study population dynamics, static data obtained from a snapshot survey can still be used to gain insight into the population trends (Obiri *et al*., 2002). Static approaches such as determination of the size class distribution of the exploited species can reflect the level of recruitment, growth and mortality that a given species has undergone over several years or decades (Wiegand *et al*., 2000). Wiegand *et al*. (2000) found that rare recruitment events over many years was a major determinate of o size class distribution of *Acacia raddiana* in Negev de Desert in Israel. Size class distribution have been successfully used by several authors to gain insight on NTFP species population trends and stability (Botha *et al*., 2002; Obiri *et al*., 2002; Shackleton *et al.*, 2005; Venter and Witkowski, 2010; Traoré *et al*., 2012).

According to Condit *et al*. (1998), frequently ecologists postulate that a growing, stable population will have a high number of seedlings and juveniles what would be reflected in a reverse-J population curve shape. While a unimodal or even flat population distribution shows a lack of recruitment, which in the long run could jeopardize the existence of that population (Obiri *et al*., 2002). Exceptions are made for long-lived species which normally present a unimodal curve due to the sporadic recruitment events typical of this kind of species, especially in arid and semi-arid environments (Venter and Witkowski, 2010).

While the size class distribution of a species population is not the best approach to assess population dynamics and sustainability, several measures such as the slope of the relationship between the size classes and the frequency of individuals in each class, the Simpson index of dominance, the permutation index, as well as the quotients between successive size classes, are useful in adding interpretive insights into the dynamics and stability of the exploited population (Wiegand *et al*., 2000; Botha *et al*., 2002; Shackleton *et al*., 2005; Venter and Witkowski, 2010; Traoré *et al*., 2012; Shen *et al*., 2013). The slope of the relationship between the size classes and the frequency of individuals in each class describes the shape of the size class distribution and the relative level of the recruitment on a given population. Healthy, growing populations exhibit steep negative slopes (Condit *et al*., 1998). The Simpson index of dominance assesses the stability of a given population, through determining if the size classes of that population are evenly distributed or not (Wiegand *et al*., 2000). Values of the Simpson index below 0.1 suggest that the size classes are evenly distributed and that the population is stable (Wiegand *et al*., 2000). The permutation index was first introduced by Wiegand *et al*. (2000) to also assess the stability of a given population. This index measures the departure from a uniform decline in the size classes' distribution of a given population. A population that does not decline uniformly is considered unstable (Wiegand *et al*., 2000). Although the Simpson index of dominance and permutation index both assess the stability of population, each measures a different dimension of that stability (Wiegand *et al*., 2000). The present study assesses the abundance, population structure and harvesting selection of palm species *Hyphaene coriacea* and *Phoenix reclinata* in the Zitundo area, Matutuine district, southern Mozambique. We used the indices of size frequency distribution to characterize the population structure of the two palm species.

2.3 Methods

2.3.1 Study area

Zitundo Administrative Post with an area of 864 km^2 (INE, 2009), is located in southern Mozambique and lies in what Van Wyk and Smith (2001) called the Maputaland Centre of Endemism, within the Maputaland-Pondoland biodiversity hotspot. It borders South Africa to the south, the Indian Ocean on the east, Maputo River on the west, and Bela Vista Administrative Post on the north (Figure 2.1).

The climate of the area is tropical to sub-tropical, with the average annual temperature around 22.6^{o} C and annual rainfall varies between 750 mm to 888 mm (Mander and Pollet, 1994). The topography is characterized by a low coastal plain alongside the Indian Ocean (Momade and Achimo, unpublished), with elevations around 50 m (McKean, 2003). The soils are sandy, gray and infertile in many areas (McKean, 2003).

Palm savannas alongside dry forests, swamp forests, grasslands, wetlands, estuarine vegetation, are the common vegetation types in the area (Kirkwood, 2014). Common tree species include *Hyphaene coriacea*, *Phoenix reclinata*, *Dichrostachys cinerea, Strychnos madagascariensis*, *Syzigium cordatum* and *Schotia brachypetala* (McKean, 2004; Kirkwood, 2014). The grass layer is dominated by the genera *Themeda*, *Aristida*, *Perotis* and *Eragrostis* (McKean, 2004).

The main livelihood activities of the residents in the area include rain-fed, subsistence agriculture, wild fruits and wild plant collection, honey production, fishing, hunting, charcoal production, craft production and palm wine production (Governo do Distrito de Matutuine, 2008). Common crops are cassava, sweet potatoes, peanuts, corn, collards, garlic, lettuce, onions, tomatoes and beans. Common livestock includes chickens, cattle, goats and ducks (Governo do Distrito de Matutuine, 2008).

The study was carried out in the palm savanna, where *Hyphaene coriacea* and *Phoenix reclinata* are the dominant species. At Zitundo Administrative Post, palm savanna is mainly located to the east of the Futi River and west of the coastal dune forest and includes the villages of Phuza, Mabucutso, Ndovo and Zitundo-Sede and their surroundings (Figure 2.1).

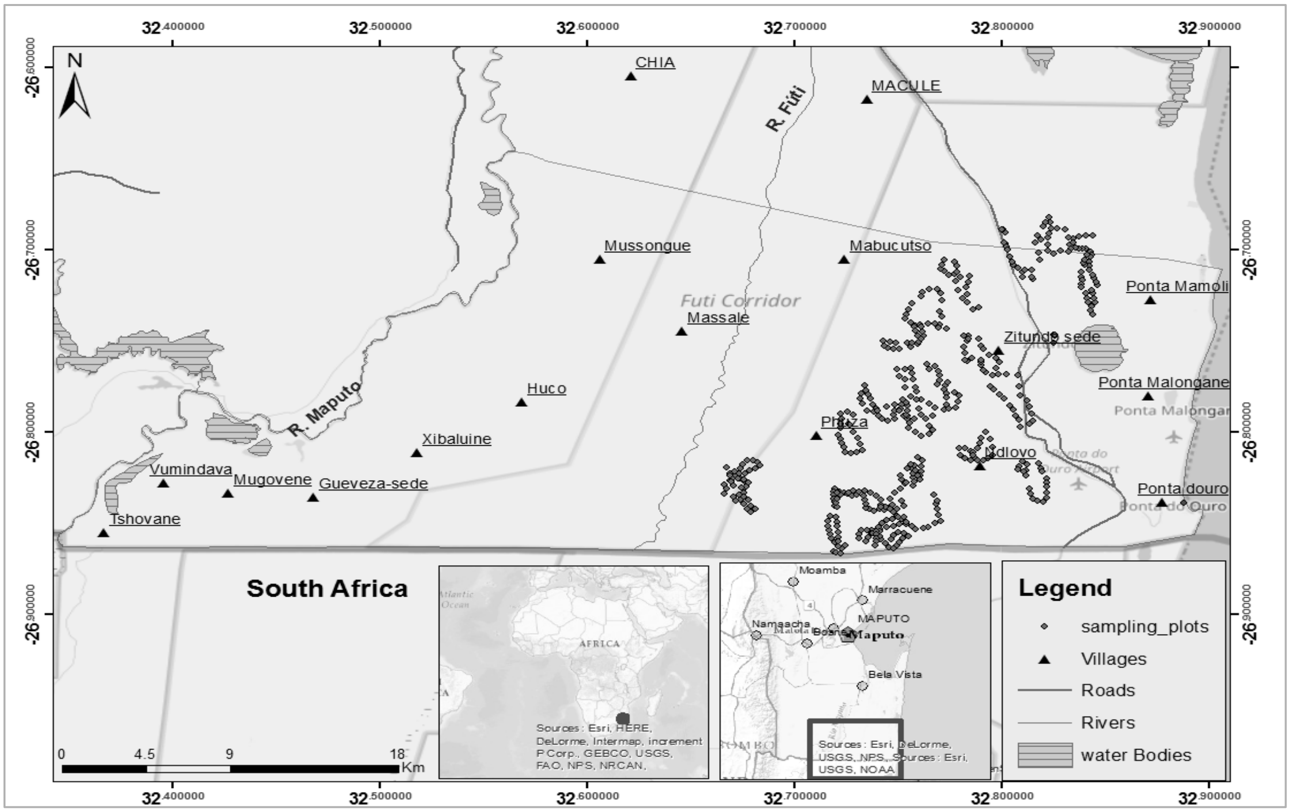

Figure 2.1: Study area indicating the location of sampling plots

2.3.2 Study species

Hyphaene coriacea is a dioecious palm and is one of the two species of the genus *Hyphaene* that grows in southern Africa (SANBI, 2016a). It occurs individually or in clusters (McKean, 2004), mainly in coastal lowland regions, from Somalia to South Africa and in Madagascar (Hyde *et al*., 2016a), on nutrient-poor, sandy soils (McKean, 2004). This species seldom extends to inland areas (Hyde *et al*., 2016a). *Phoenix reclinata* is a multi-stemmed dioecious palm, forming clusters or sometimes extensive thickets (SANBI, 2016b). It is distributed throughout Sub-Saharan Africa from Egypt to South Africa (Hyde *et al*., 2016b). It occurs from sea level to up to 3 000 m altitude, in a range of habitats such as inundated areas, riverine forest, coastal savanna, open grassland and rain forests (Segu, 2011; Hyde *et al*., 2016b; SANBI, 2016b).

2.3.3 Description of the palm sap tapping process in Zitundo

After choosing the palms clusters to be tapped, the tappers burn them to reduce the dead biomass, clear the area and dispel possible animals that have been hiding in them (Figure 2.2A). After that the remaining leaves are removed and the stems are debarked and cut, until the sap start flowing (Figure 2.2B). The sap of each tapped stem drips into a bottle and is collected twice or three times a day (Figure 2.2C). Each time the sap is collected the tapper cuts a small piece of the tip of the stem to promote sap flow. After the above ground portion of the stem finishes the tapper digs around the stem continuing to tap the below ground portion of the stem (Figure 2.2D). The tapping process ends when the stem stops producing sap and dries up.

2.3.4 Field data collection

A palm population census was carried out from October 2015 to August 2016.The study used a randomized cluster sampling approach since it is an effective option in large areas where the vegetation occurs in clusters as in this case. A grid of 1 km X 1 km was overlaid on the distribution map of the two species, each block was numbered, and 25 blocks were randomly selected using ArcGIS. In each block, 20 plots of 30 m X 30 m size were randomly situated resulting in a total of 500 plots.

In the field, the location of each plot was determined using a Global Positioning System (GPS). Measurements in each plot for each species included: i) the number of clusters, ii) the number of live stems, iii) the number of seedlings, iv) the number of dead stems (stumps), v) the height of each stem, measured from the ground to where the youngest leaf starts, vi) the number of stems with evidence of being tapped (denoted cut stems), vii) the number of stems with evidence of being tapped that were still alive (denoted cut and alive stems), vii) the number of stems with reproductive organs (flowers, fruits or old raceme) and viii) the number of stems with fire scars (denoted burnt stems).

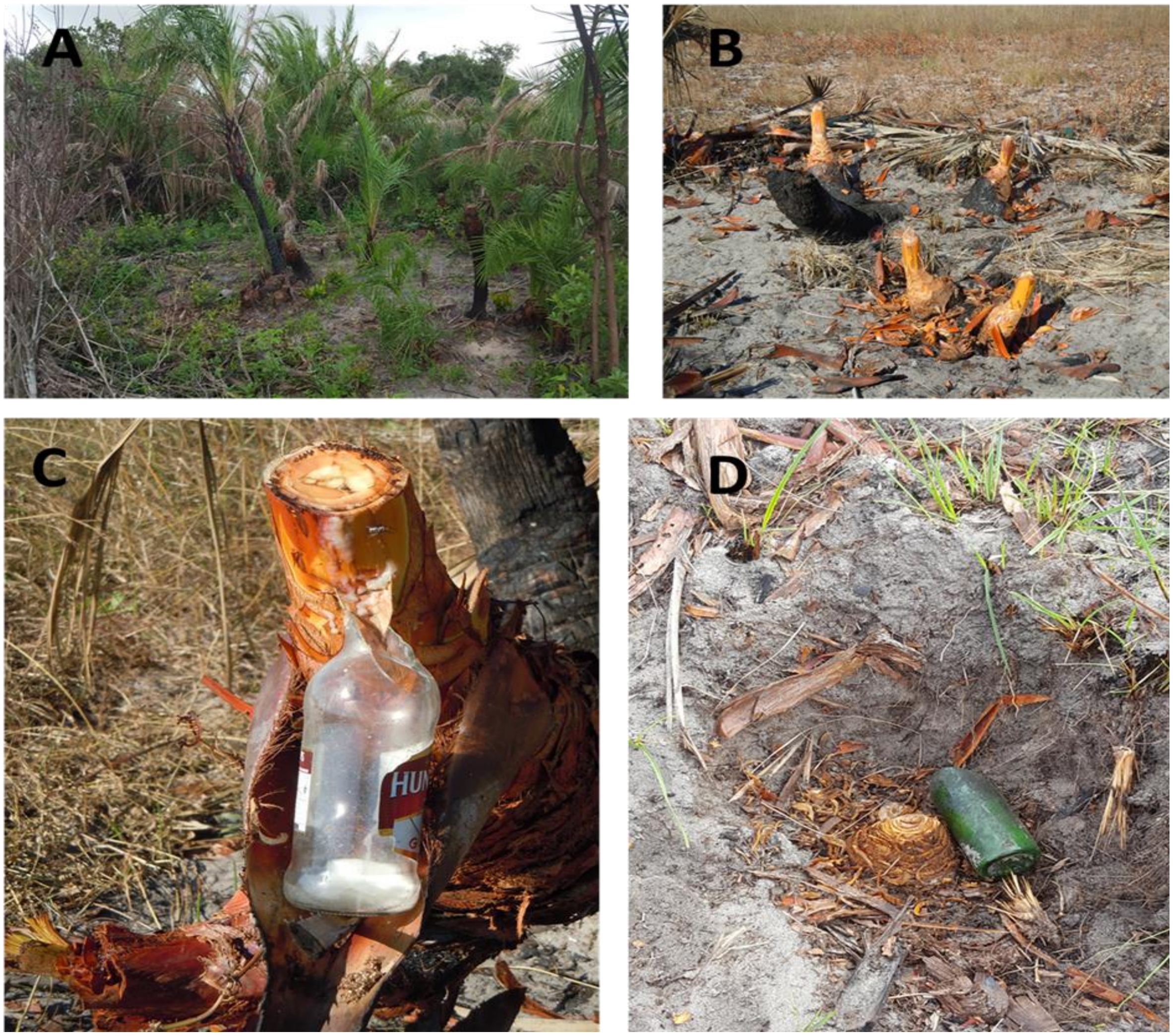

Figure 2.2: the sap tapping process to produce palm wine in Zitundo. (A) Burnt site with *Phoenix reclinata* palm stems to be tapped. (B) Debarked and cut *Hyphaene coriacea* stems ready to be tapped. (C) *Hyphaene coriacea* stem being tapped, with a container to collect the sap. (D) Below ground portion of tapped stems.

2.3.5 Data and statistical analyses

Palm species abundance was expressed in terms of frequency and density. Frequency was calculated as the proportion of plots in which a species is present, ranging from 0% to 100%. Frequency indicates the species abundance and its distribution range in the community. The mean density for all the population parameters for each species was calculated and expressed as the number of stems per hectare. Population parameters investigated per species were: density of clusters, established stems, seedlings, dead stumps, reproductive stems, cut stems, cut and alive stems and burnt stems.

In palms, the size class distribution is better investigated using the stem height since the diameter does not vary much (Cunningham, 2001). Therefore, to analyze the population structure, the palms were divided in eight size classes, based on height of palm stem and leaf development (Joyal, 1994; Lopez-Toledo *et al.,* 2011) as follows: Seedlings (individuals originated from seed germination with only one undeveloped leaf); juveniles (individuals without stems, but with developed leaves); individuals with stems with a height of between one cm and 50 cm (1-50 cm); then, four classes of 50 cm increments (i.e. 51-100 cm, 101-150 cm,151-200 cm, 201-250 cm) and lastly those taller than 250 cm. The mean density of established stems, reproductive stems, cut and alive stems and dead stumps were computed for each size class and expressed as number of stems per hectare.

To investigate the *Hyphaene coriacea* and *Phoenix reclinata* size class distribution (SCD) shape and population stability, the size classes for seedlings and juveniles were pooled, since the stem height of both were zero and the size class seedlings did not include stems derived from vegetative reproduction. Size class distribution analysis was performed following the method described by Condit *et al*. (1998), Obiri *et al*. (2002), Venter and Witkowski (2010) and Traoré *et al*. (2012). A least square linear regression analysis was conducted between the midpoint of each size class as the independent variable and the mean density of established stems as the dependent variable. Both the independent and dependent variables were transformed by Ln (midpoint +1) and Ln (mean density of stems +1), respectively, as explained by Condit *et al*. (1998).

The shape of the SCD and the level of recruitment were inferred using the slopes obtained from the regression analysis as described by Obiri *et al*. (2002), Venter and Witkowski, (2010) and Traoré *et al*. (2012). Negative slopes suggest that the population has a reverse-J SCD curve, implying good recruitment with more individuals in smaller size classes and fewer individuals in larger size classes. Populations with a unimodal SCD curve have positive slopes and more individuals in larger size classes and fewer individuals in smaller size classes, denoting limited or sporadic recruitment. Populations with a flat SCD curve have similar proportions of individuals in smaller and larger size classes and slopes of zero or approaching zero. The relative degree of the recruitment can also be deduced from the steepness of the slope. Steep, negative slopes imply a higher recruitment level relative to superficial negative slopes (Venter and Witkowski, 2010).

Hyphaene coriacea and *Phoenix reclinata* population stability was investigated using the Simpson index of dominance (S), permutation index (P) and the quotient between successive size classes (Wiegand *et al*., 2000; Botha *et al*., 2002; Shackleton *et al*., 2005; Venter and Witkowski, 2010; Traoré *et al*., 2012; Shen *et al*., 2013). According to Shackleton *et al.* (2005), it is worthwhile to use multiple indices to describe population structures because each has distinctive weightings and sensibility.

The Simpson index of dominance was employed to assess the size class evenness as described in Wiegand *et al*. (2000), Botha *et al*. (2002) and Shackleton *et al*. (2005). It indicates if the size class distribution is even, regardless of the order in which the size classes are positioned (Wiegand *et al*., 2000 and Botha *et al*., 2002). According to Wiegand *et al*. (2000), this index expresses the likelihood that two stems drawn at random from the same population are from the same size class. Values below 0.1 indicate that the size classes are more evenly distributed while values above 0.1 indicate that the size class frequency is steeper than what would have been expected from a stable population (Botha *et al*., 2002). The Simpson index of dominance equation is (Wiegand *et al*., 2000):

$$S = 1/\mathrm{N}(\mathrm{N}-1)\sum_{i=1}^{7} Ni\ (Ni - 1) \qquad (1)$$

Where N is the total number of stems and N*i* the number of stems in class *i*.

According to Wiegand *et al*. (2000) the permutation index is the aggregation of the absolute distances between the predicted and the actual ranking of all size classes and assesses the departure from a uniform decline that is characteristic of an undisturbed population. For this to occur, the ranking of the size classes should correspond to the enumeration of the size classes from the smallest (most frequent) to the largest (least frequent) (Wiegand *et al*., 2000). For populations with a discontinuous distribution, the ranking diverges from the enumeration (Wiegand *et al*., 2000). An undisturbed population will have a permutation index approaching zero, while a population with discontinuous distribution will have a permutation index above zero (Wiegand *et al*., 2000; Botha *et al*., 2002). The higher the permutation index the more disturbed is the population. The permutation index equation is (Wiegand *et al*., 2000):

$$P = \sum_{i=1}^{7} |Ji - i| \quad Ji = 1, \dots, 7 \qquad (2)$$

Where Ji is the rank of size class *i* (*i*=1 for the smallest trees), with the top rank (*Ji*= 1) given to the most frequent size class.

To further investigate the stability of both species population, quotients between consecutive size classes were computed and presented graphically. Stable populations exhibit steady quotients between consecutive size classes while oscillating quotients are characteristic of the unstable populations (Botha *et al*., 2002; Venter and Witkowski, 2010; Traoré *et al*., 2012; Shen *et al*., 2013). The quotients were calculated as the ratio of the mean number of stems in successive size classes following equation (3) (Meyer, 1952; Leak, 1964).

$$Q = N(i-1)/\mathrm{N}i \qquad (3)$$

Where N*i* is the number of stems in class i and N (*i*-1) is the number of stems in the *i* previous class.

A generalized linear mixed model was used to evaluate the influence of diverse anthropogenic factors on each species population density and size classes densities. Explanatory variables used in the model are: distance to market (measured as the nearest distance from the plots to the market where palm wine is sold), distance to roads (measured as the distance from plots to the nearest road), distance to villages (measured as the distance from plots to the nearest village); the number of stems with fire scars and the number of stems with evidence of being tapped.

The preference to harvest a specific size class was evaluated using the preference ratio, which contrasts demand and availability, as presented in equation (4) (Dzerefos *et al*., 2003; Shackleton *et al*., 2003; Pote *et al*., 2006). Demand was expressed as the percentage of cut stems in a specific size class and availability was expressed as the percentage of available stems in that size class (alive stems and dead stumps). Since the seedling and juveniles have no stem, they are not cut and therefore were excluded from this analysis. Preference ratios vary from zero to infinite. Preference ratios above one denote active selection, below one, suggests avoidance and approaching one denotes a random selection (Dzerefos *et al*., 2003; Shackleton *et al*., 2003).

$$PRi = \mathrm{PD}i/\mathrm{PA}i \qquad (4)$$

Where, PR*i* is the preference ratio for class *i*, PD*i* is the percentage of cut stems in a size class *i* (demand), PA*i* is the percentage of available stems in size class *i* (availability).

All statistical analyses were performed on statistical package SAS 9.4. A Kolmogorov-Smirnov test was used to check for data normality. Since the data were not normally disturbed, a Mann-Whitney U-test was used to compare the mean density of the population parameters between the two species and Kruskal-Wallis test was used to compare the mean density of the population parameters among the height size classes for each species. Following a significant Kruskal-Wallis test results, we further investigated differences between size classes performing a Dunn's post hoc multiple comparison test, using SAS based macro protocol developed by Elliott and Hynan (2011). We selected the generalized linear mixed model approach to account for the non-normal data distribution and the spatial dependence of plots which generated the block random effect. The model was fitted using a Poisson distribution, a Log link function and the block as random effect.

2.4 Results

2.4.1 *Hyphaene coriacea* and *Phoenix reclinata* Population Parameters

Within the 500 plots sampled *Hyphaene coriacea* was relatively more widespread, occurring in 93% (465 plots) of the plots while *Phoenix reclinata* occurred in 53.8% (269 plots). For *Hyphaene coriacea* we found 31 008 stems within 4 847 clusters; eighty-seven percent of stems (27 068 stems) were alive and established, eight percent (2 568 stems) were dead and four percent (1 372 stems) were seedlings. For *Phoenix reclinata* we found 12 389 stems within 1 216 clusters; Ninety-two percent of them (11 337 stems) were alive and established, two percent (245 stems) were dead and seven percent (807 stems) were seedlings. *Hyphaene coriacea* had significantly higher mean densities of clusters, live established stems, seedlings and dead stumps than *Phoenix reclinata* (Table 2.1). The opposite applied for reproductive stems. The prevalence of reproductive structures (flowers/fruits/old racemes) was low for both species, being on only two percent of live stems of *Hyphaene coriacea* and four percentage of live *Phoenix reclinata* stems.

Twelve percent (3 579 stems) of all *Hyphaene coriacea* stems showed evidence of being tapped (denoted cut stems), with the corresponding figure for *Phoenix reclinata* being two percent (276 stems). The rate of stem survival after being tapped was low for both species. From all *Hyphaene coriacea* and *Phoenix reclinata* with evidence of being tapped only 28% (1 011 stems) and 11% (31 stems) survived, respectively. The frequency of burnt stems in the *Hyphaene coriacea* population was 29% (9 065 stems) against the 12% of *Phoenix reclinata* population. *Hyphaene coriacea* showed significantly higher mean densities of cut stems, burnt stems, as well as cut and alive stems while *Phoenix reclinata* had higher mean densities of reproductive stems.

Table 2.1: Population density (mean ± standard deviation) of *Hyphaene coriacea* and *Phoenix reclinata* in the study area

Stem type	*Hyphaene coriacea*	*Phoenix reclinata*	*P* value <0.0001
Clusters (clusters ha^{-1})	107.7 ± 115.8	27.0 ± 52.6	χ^2 = 291.0
Established stems (stems ha^{-1})	601.5 ± 455.9	251.9 ± 527.3	χ^2 = 261.6
Seedlings (stems ha^{-1})	30.5 ± 87.0	17.9 ± 65.8	χ^2 = 32.1
Dead stumps (stems ha^{-1})	57.1 ± 58.8	5.4 ± 27.6	χ^2 = 449.1
Reproductive stems (stems ha^{-1})	9.8 ± 17.9	11.8 ± 40.9	χ^2 = 43.6
Cut stems (stems ha^{-1})	79.5 ± 73.8	6.1 ± 28.5	χ^2 = 520.5
Cut and alive stems (stems ha^{-1})	22.5 ± 29.4	0.8 ± 4.5	χ^2 = 352.1
Burnt stems (stems ha^{-1})	201.4 ± 283.6	85 ± 276.6	χ^2 = 150.3

2.4.2 Size class distribution

The mean density of stems was statistically different among the size classes. Both populations followed the same trend with the smaller size classes being the most common (Table 2.2). In *Hyphaene coriacea* population the size class with stems between one centimeter and 50 cm, was the most frequent, representing 56.4% of their population. The size class juveniles presented the second highest density (Table 2.2). In *Phoenix reclinata* population the size class with stems between one centimeter and 50 cm jointly with juveniles were the most frequent, representing 53.6% and 33.6% of their population, respectively (Table 2.2). Thus, approximately 95% of all stems encountered for both species were less than one meter tall.

The results of regression analyses of SCD curves revealed that the slopes for both species were negative and steep (Table 2.3). The slope of *Hyphaene coriacea* population was - 0.88, while the slope of *Phoenix reclinata* was - 0.84, indicating the presence of more individuals in shorter size classes. Moreover the Simpson index of dominance (S) of the two species was above 0.1 showing that the size classes of both populations are not evenly distributed (Table 2.3). The permutation index (P) of the both species was different from zero (Table 2.3). The *Hyphaene coriacea* population had a permutation index of six and *Phoenix reclinata* of two, indicating that *Hyphaene coriacea* has a more discontinuous size class distribution than *Phoenix reclinata*. The quotients for *Hyphaene coriacea* and *Phoenix reclinata* were not constant, fluctuating between consecutive size classes (Figure 2.3). This can be an indication of a certain level of instability in population through growth between successive size classes.

Table 2.2: Population density (mean ± standard deviation) among the eight height size classes. Unlike letters denote significant differences ($p < 0.05$) between the size classes within a species

Size Class	*Hyphaene coriacea*		*Phoenix reclinata*	
	$\chi^2 = 2322.9$		$\chi^2 = 795.6$	
	Density (stems ha^{-1})	%	Density (stems ha^{-1})	%
Seedlings	30.5 ± 87 [a]	4.8	17.9 ± 65.8 [a]	6.6
Juveniles	206.2 ± 231.8 [b]	32.6	90.8 ± 202.4 [b]	33.6
1 – 50 cm	356.2 ± 270.6 [c]	56.4	144.9 ± 325.9 [b]	53.6
51 – 100 cm	26.8 ± 33.7 [d]	4.2	11.5 ± 35.2 [a]	4.3
101 – 150 cm	5.1 ± 11.2 [e]	0.8	2.8 ± 1.3 [c]	1.0
151 – 200 cm	2.8 ± 7.6 [e, f]	0.4	1.4 ± 7.3 [c]	0.5
201 – 250 cm	1.2 ± 5.1 [f]	0.2	0.6 ± 4.0 [c]	0.2
> 250 cm	3.2 ± 9.5 [e, f]	0.5	0.4 ± 3.9 [c]	0.2

Table 2.3: Size class distribution slopes, Simpson index of dominance and permutation index for *Hyphaene coriacea* and *Phoenix reclinata* populations

	Hyphaene coriacea	*Phoenix reclinata*
Slope	-0.88	-0.84
P (level of significance)	0.02	0.02
R^2 (%)	69	72
Simpson index of dominance (S)	0.46	0.45
Permutation Index (P)	6	2

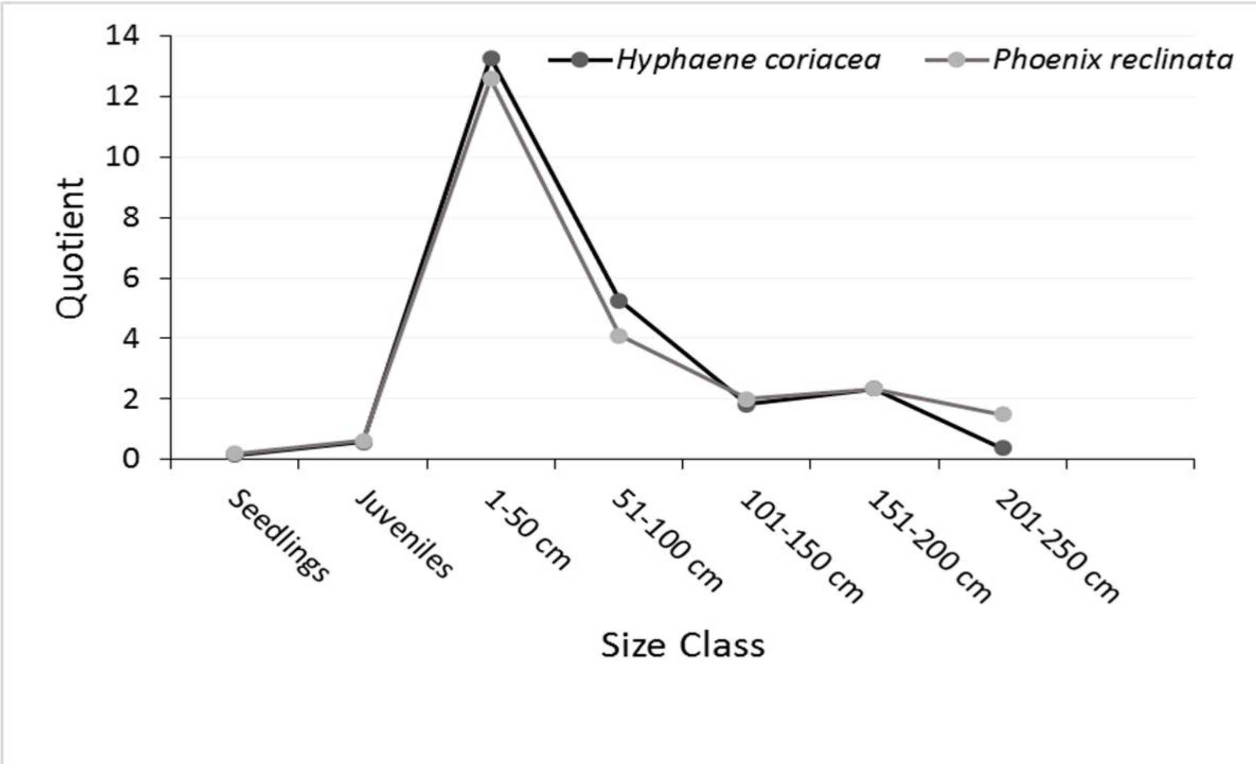

Figure 2.3: Quotients between each successive size class for *Hyphaene coriacea* and *Phoenix reclinata* populations

There are significant differences in the average density of population parameters between the size classes. For *Hyphaene coriacea* population, the size class with stems between one and 50 cm had the higher proportions of cut stems, cut and alive stems and dead stumps. The size class with stems above 250 cm had the higher proportion of reproductive stems however, this was not statistically different from the size classes with stems between 51cm and 100 cm, 101 cm and 150 cm as well as 151 and 200 cm. For the *Phoenix reclinata* population, the size class with stems between one and 50 cm had higher proportions of cut stems and dead stumps. This same size class conjointly with size class 51 cm – 100 cm had higher proportions of cut and alive stems and reproductive stems.

Table 2.4: *Hyphaene coriacea* and *Phoenix reclinata* populations parameters density (mean ± standard deviation) among the size classes. Unlike letters denote significant differences ($p < 0.05$) between the size classes within a species

Size Class	Species	Reproductive Stems (stems ha^{-1})	Cut Stems (stems ha^{-1})	Cut and Alive Stems (stems ha^{-1})	Dead Stumps (stems ha^{-1})
Seedlings	*Hyphaene coriacea*	0 ± 0 (0%)[a]	0 ± 0 (0%)[a]	0 ± 0 (0%)[a]	0 ± 0 (0%)[a]
	Phoenix reclinata	0 ± 0 (0%)[c]	0 ± 0 (0%)[f]	0 ± 0 (0%)[e]	0 ± 0 (0%)[e]
Juveniles	*Hyphaene coriacea*	0 ± 0 (0%)[a]	0 ± 0 (0%)[a]	0 ± 0 (0%)[a]	0 ± 0 (0%)[a]
	Phoenix reclinata	0 ± 0 (0%)[c]	0 ± 0 (0%)[f]	0 ± 0 (0%)[e]	0 ± 0 (0%)[e]
1 – 50 cm	*Hyphaene coriacea*	0.5 ± 3.1 (5.3%)[a]	59.0 ± 66.9 (74.4%)[b]	13.0 ± 22.9 (57.8%)[b]	46.1 ± 53.8 (80.3%)[b]
	Phoenix reclinata	6.7 ± 25.1 (56.4%)[d]	4.5 ± 19.8 (71.7%)[g]	0.3 ± 2.1 (42.9%)[f]	4.2 ± 19.4 (77.3%)[f]
51 – 100 cm	*Hyphaene coriacea*	2.1 ± 6.3 (20.9%)[b]	13.0 ± 19.7 (16.4%)[c]	5.6 ± 12.7 (24.9%)[c]	7.4 ± 13.4 (13.1%)[c]
	Phoenix reclinata	2.8 ± 12.7 (23.9%)[d]	1.2 ± 8.0 (19.1%)[h]	0.3 ± 2.4 (42.9%)[f]	0.9 ± 7.3 (16.5%)[g]
101 – 150 cm	*Hyphaene coriacea*	1.9 ± 6.2 (19.4%)[b]	3.7 ± 7.9 (4.7%)[d]	1.5 ± 5.0 (6.7%)[d]	2.2 ± 5.6 (3.7%)[d]
	Phoenix reclinata	1.1 ± 5.9 (9.4%)[e]	0.5 ± 3.3 (8.0%)[f, h]	0.1 ± 1.6 (14.3%)[e, f]	0.3 ± 2.7 (6.7%)[e, g]
151 – 200 cm	*Hyphaene coriacea*	1.7 ± 5.8 (17.4%)[b]	2.0 ± 4.9 (2.5%)[e]	1.0 ± 4.4 (4.4%)[a]	1.0 ± 3.9 (1.8%)[a]
	Phoenix reclinata	0.7 ± 4.6 (6.2%)[c, e]	0.04 ± 0.7 (0.6%)[f]	0.02 ± 0.5 (0%)[e]	0.02 ± 0.5 (0%)[e]
201 – 250 cm	*Hyphaene coriacea*	0.8 ± 4.1 (7.7%)[a]	0.6 ± 4.1 (0.8%)[a]	0.5 ± 2.9 (2.2%)[a]	0.2 ± 2.2 (0.2%)[a]
	Phoenix reclinata	0.2 ± 2.3 (1.9%)[c, e]	0.02 ± 0.5 (0.3%)[f]	0.02 ± 0.5 (0%)[e]	0 ± 0 (0%)[e]
> 250 cm	*Hyphaene coriacea*	2.9 ± 8.7 (29.3%)[b]	1.0 ± 3.8 (1.3%)[a, e]	0.9 ± 3.7 (4.0%)[a, d]	0.1 ± 0.9 (0.9%)[a]
	Phoenix reclinata	0.3 ± 3.2 (2.3%)[c]	0.02 ± 0.5 (0.3%)[f]	0 ± 0 (0%)[e]	0.02 ± 0.5 (0%)[e]

2.4.3 Anthropogenic influence on the palms density and population structure

The results of the generalized linear mixed model indicated that the density and population structure of the two palm species were significantly influenced by most of the explanatory variables (Table 2.5 and 2.6). According to the sign of the regression estimates, distance to market and distance to villages were negatively related to the density of established stems of both populations, while distance to roads and the number of stems with fire scars had a positive relationship. The variable "number of stems with evidence of being tapped" had opposite effects on each population density, being positive for *Hyphaene coriacea* and negative for *Phoenix reclinata*.

The influence of the explanatory variables on the size classes distribution of each species was variable. For *Hyphaene coriacea* population, the distance to market was positively related to the density of seedling and stems on the height classes above 50 cm; while the distance to roads had a positive relationship on seedlings and juveniles densities. Furthermore, distance to villages was only positively related to the number of stems of juveniles, and of size class between 151cm and 200 cm. The number of stems with evidence of being tapped negatively influenced the density of seedlings and stems of the size classes above 100 cm. Inversely, the number of stems with fire scars was positively related to all size classes. For *Phoenix reclinata* population, distance to market was positively related to all size classes with the exception of juveniles, while distance to roads had a positive influence on the density of seedlings, of stems on size classes between one centimeter and 150 cm and size class with stems above 250 cm. Distance to villages had no significant influence on the density of seedlings and a positive influence on juveniles and the size class 151 – 200 cm. The number of stems with fire scars and the number of stems with evidence of being tapped had a similar influence on the size classes of this species population, both had a negative influence only on the density of stems of the size class 151 – 200 cm.

Table 2.5: Generalized linear mixed models parameters estimates for *Hyphaene coriacea* population density and structure

Dependent Variable	Independent Variable	Estimates	P-value
Established stems	Distance to market	-0.0001	<0.0001
	Distance to roads	0.0001	<0.0001
	Distance to villages	-0.000003	0.007
	Burnt stems	0.0005	<0.0001
	Cut stems	0.0022	<0.0001
Seedlings	Distance to market	0.00004	<0.0001
	Distance to roads	0.0003	<0.0001
	Distance to villages	-0.0001	<0.0001
	Burnt stems	0.0014	<0.0001
	Cut stems	-0.0024	<0.0001
Juveniles	Distance to market	-0.0001	<0.0001
	Distance to roads	0.0002	<0.0001
	Distance to villages	0.0001	<0.0001
	Burnt stems	0.0005	<0.0001
	Cut stems	0.0016	<0.0001
1 – 50 cm	Distance to market	-0.0001	<0.0001
	Distance to roads	-0.00003	<0.0001
	Distance to villages	-0.00004	<0.0001
	Burnt stems	0.0004	<0.0001
	Cut stems	0.0030	<0.0001
51 – 100 cm	Distance to market	0.00002	<0.0001
	Distance to roads	-0.0001	<0.0001
	Distance to villages	-0.0001	<0.0001
	Burnt stems	0.0005	<0.0001
	Cut stems	0.0026	<0.0001
101 – 150 cm	Distance to market	0.0001	<0.0001
	Distance to roads	-0.00004	0.1353
	Distance to villages	-0.0002	<0.0001
	Burnt stems	0.0011	<0.0001
	Cut stems	-0.00002	0.96
151 – 200 cm	Distance to market	0.0002	<0.0001
	Distance to roads	-0.0004	<0.0001
	Distance to villages	0.0001	0.0061
	Burnt stems	0.0018	<0.0001
	Cut stems	-0.0037	<0.0001
201 – 250 cm	Distance to market	0.0002	<0.0001
	Distance to roads	-0.0004	<0.0001
	Distance to villages	-0.0002	<0.0001
	Burnt stems	0.0016	<0.0001
	Cut stems	-0.0036	<0.0001
> 250 cm	Distance to market	0.0002	<0.0001
	Distance to Roads	-0.0003	<0.0001
	Distance to villages	-0.0002	<0.0001
	Burnt stems	0.0017	<0.0001
	Cut stems	-0.0084	<0.0001

Table 2.6: Generalized linear mixed models parameters estimates for *Phoenix reclinata* population density and structure

Dependent Variable	Independent Variable	Estimates	P-value
Established stems	Distance to market	-0.00003	<0.0001
	Distance to roads	0.0003	<0.0001
	Distance to villages	-0.0001	<0.0001
	Burnt stems	0.0016	<0.0001
	Cut stems	-0.0030	<0.0001
Seedlings	Distance to market	0.0001	<0.0001
	Distance to roads	0.0001	0.0004
	Distance to villages	-0.00001	0.5149
	Burnt stems	0.0019	<0.0001
	Cut stems	0.0044	<0.0001
Juveniles	Distance to market	-0.000003	<0.0001
	Distance to roads	-0.00001	0.1056
	Distance to villages	0.0001	<0.0001
	Burnt stems	0.0015	<0.0001
	Cut stems	0.0072	<0.0001
1 – 50 cm	Distance to market	0.00003	<0.0001
	Distance to roads	0.0002	<0.0001
	Distance to villages	-0.0002	<0.0001
	Burnt stems	0.0015	<0.0001
	Cut stems	0.0064	<0.0001
51 – 100 cm	Distance to market	0.0001	<0.0001
	Distance to roads	0.0003	<0.0001
	Distance to villages	-0.0003	<0.0001
	Burnt stems	0.0021	<0.0001
	Cut stems	0.0061	<0.0001
101 – 150 cm	Distance to market	0.0002	<0.0001
	Distance to roads	0.0003	<0.0001
	Distance to villages	-0.0004	<0.0001
	Burnt stems	0.0029	<0.0001
	Cut stems	0.0049	<0.0001
151 – 200 cm	Distance to market	0.0002	<0.0001
	Distance to roads	-0.0004	<0.0001
	Distance to villages	0.00004	<0.0001
	Burnt stems	-0.0061	<0.0001
	Cut stems	-0.0070	<0.0001
201 – 250 cm	Distance to market	0.0003	<0.0001
	Distance to roads	-0.0001	0.4543
	Distance to villages	-0.0003	<0.0001
	Burnt stems	0.0026	<0.0001
	Cut stems	0.0063	<0.0001
> 250 cm	Distance to market	0.0002	<0.0001
	Distance to Roads	0.0003	0.0027
	Distance to villages	-0.0003	<0.0001
	Burnt stems	0.0011	0.010
	cut stems	0.0058	<0.0001

2.4.4 Size class selection for cutting

Stems between one and 50 cm was the only size class avoided for *Hyphaene coriacea*. All the other size classes had the preference ratios above one, indicating a positive selection to harvest these size classes. The most preferred size class to harvest was 151cm - 200 cm (Table 2.7). On the other hand, for *Phoenix reclinata*, the only size class with a positive selection was the one with stems between 101cm and 150 cm, with a preference ratio of 4.2. The size class with stems above 250 cm had a preference ratio of one, signifying that the cutting on this size class was random. All other size classes were avoided (Table 2.7). Analyzing both species combined, the most preferred size class was between 101cm and 150 cm.

Table 2.7: Preference ratio of to harvest *Hypahene coriacea* and *Phoenix reclinata* populations

Size Class	Species	Demand (% cut stems)	Availability (% of total stems)	Preference ratio	Selection
1 – 50 cm	*Hyphaene coriacea*	74.4	88.9	0.8	Avoided
	Phoenix reclinata	71.7	92.3	0.8	Avoided
51 – 100 cm	*Hyphaene coriacea*	16.4	7.6	2.2	Preferred
	Phoenix reclinata	19.1	76.7	0.3	Avoided
101 – 150 cm	*Hyphaene coriacea*	4.7	1.6	2.9	Preferred
	Phoenix reclinata	8	1.9	4.2	Preferred
151 – 200 cm	*Hyphaene coriacea*	2.5	0.8	3.0	Preferred
	Phoenix reclinata	0.6	0.9	0.7	Avoided
201 – 250 cm	*Hyphaene coriacea*	0.8	0.3	2.7	Preferred
	Phoenix reclinata	0.3	0.4	0.8	Avoided
> 250 cm	*Hyphaene coriacea*	1.3	0.7	1.9	Preferred
	Phoenix reclinata	0.3	0.3	1	Random

2.5 Discussion

The results indicate that *Hyphaene coriacea* is more widespread than *Phoenix reclinata* in Zitundo area. This is in concordance with Cunningham (1985) who observed that, in the neighbouring South African Maputaland palm savanna, *Hyphaene coriacea* was more abundant than *Phoenix reclinata*. The density of *Hyphaene coriacea* measured in this study was higher than those found by Moll (1972) for the same species in Kwazulu-Natal, South Africa. Moll (1972) found an average of 489.4 stems ha^{-1} while this study found an average of 601.5 stems ha^{-1}. Inversely, Babitseng and Teketay (2013) in a study in Botswana found over a 1 000 established stems (excluding seedlings) ha^{-1} for *Hyphaene petersiana*, a closely related species to *Hyphaene coriacea*. On the other hand, the number of established stems of *Phoenix reclinata* encountered in the study area was higher than those obtained by Kinnaird (1992) in Kenya, and Mjoli and Shackleton (2015) in the Eastern Cape, South Africa. Differences in the stem densities of these species across the studies are likely to be related to differences in soils, climate and disturbance specific of each local. Anthropogenic causes such as harvesting of different palms products, different harvesting techniques as well as different fire regimes are also likely to result in differences in densities across studies. Results from the generalized linear mixed model obtained in this study showed that anthropogenic factors indeed had a statistically significant impact on the density of established stems of the two palm species.

About 57 dead stumps ha^{-1} of *Hyphaene coriacea* were found in the study area. This result is within the range obtained by Babitseng and Teketay (2013) in Botswana for *Hyphaene petersiana* and lower than the rate found by Sullivan *et al*. (1995) also for *Hyphaene petersiana* in Namibia. Sullivan *et al*. (1995) observed that *Hyphaene petersiana* dead stumps comprised up to 63% of the adult population of that species, while in this study dead stumps correspond to only eight percent of *Hyphaene coriacea* population.

The results illustrated that 12% of *Hyphaene coriacea* stems showed evidence of being tapped against two percent of *Phoenix reclinata* stems. Higher rates of tapped stems of *Hyphaene coriacea* than *Phoenix reclinata* were also obtained by Cunningham (1985). In the South African Maputaland palm savanna, 69% of all tapped stems were *Hyphaene coriacea* against 31% of *Phoenix reclinata* (Cunningham, 1985). The low rate of stem survival after being tapped obtained in this study for both species was also found by Cunningham (1985). We found that 28% and 11% of *Hyphaene coriacea* and *Phoenix reclinata* stems, respectively, survived after being tapped, while Cunningham (1985) found that about 14% and zero percent of *Hyphaene coriacea* and *Phoenix reclinata*, respectively, survived after being tapped. According to Cunningham (1990), Sola *et al.* (2006) and Chowdhury *et al*. (2008) the probability of stem survival after being tapped many times is determined by the harvesting technique used for sap extraction and the skill and experience of the tapper. Furthermore, palm weevil infestation on tapped stems may negatively influence the probability of survival of tapped stems (tappers, pers. comm.). Given the results of this study as well as by Cunningham (1985), we can imply that *Hyphaene coriacea* is more resilient to tapping than *Phoenix reclinata*.

The population structures of *Hyphaene coriacea* and *Phoenix reclinata* in Zitundo are similar. Both species exhibited steeper negative slopes in the regression analyses of SCD, indicating the presence of more individuals in shorter size classes. Nearly 95% of all stems encountered for both species were less than one meter tall. Although there was a dominance of shorter over taller size classes, both seedlings and juveniles size classes presented lower stems density comparing to the size class 1-50 cm. The size class seedling corresponded to only five and seven percent of *Hyphaene coriacea* and *Phoenix reclinata* populations. This can indicate some sort of limitation in the recruitment levels of these two populations. Recruitment levels can be influenced by seed production, seed germination, seedling survivorship, and seedling growth. Our results showed a low prevalence of stems with reproductive structures; only two percent of *Hyphaene coriacea* and four percent of *Phoenix reclinata* had reproductive structures or evidence of reproductive structures. This low prevalence of stems with reproductive structure can hamper the seed production and therefore the recruitment in the palm populations. The low prevalence of reproductive structures obtained in the study area could be linked to the fact that stems are commonly tapped before reaching the reproductive stage. This was particularly evident on *Hyphaene coriacea*, where about 74% of all reproductive stems were taller than 50 cm and preferred for tapping as indicated by the preference ratio. Additional reasons that could be limiting the level of recruitment include: i) the trampling of seedlings during tapping activities contributing to seedling mortality. ii) The use of fire to clear the area for tapping can also kill seedlings. iii) The harvesting of the edible fruit of *Phoenix reclinata* may contribute to reducing the number of seedlings. iv) The extended period that *Hyphaene coriacea* fruits take from its production until its fall from the tree. *Hyphaene coriacea* fruits take about four years from its production until its fall from the tree (SANBI, 2016a). v) Demanding seed germination requirements for *Hyphaene coriacea* because of the needing scarification by heat or passing through the digestive tract of an animal (Palgrave, 2002), can reduce the level of recruits produced by the germination process. The results from generalized linear mixed model indicated that anthropogenic factors such as proximity to the market and to roads had a diminishing effect on the density of seedling of *Hyphaene coriacea* and *Phoenix reclinata*. Additionally increasing tapping also contributed to the reduction of *Hyphaene coriacea* seedling.

Steeper negative slopes are commonly associated to inverse-J shaped size class distribution curves. This kind of pattern is a typical attribute of long-lived species (Chhetri *et al*., 2016) and ecologists believe that is a common demographic feature of healthy, growing populations (Condit *et al*., 1998).We anticipated that the size class distribution of these two heavily utilized species would deviate from this ideal size class distribution profile. However, Sampaio *et al*. (2008) also found an inverse-J shaped size class distribution curve, in a heavily harvested population of *Mauritia flexuosa* palm in Brazil. Inversely, the size class distribution profile of a similarly exploited population of *Hyphaene petersiana* in Botswana did not show an inverse-J shaped curve (Babitseng and Teketay, 2013). A unimodal size class distribution curve was also found by Mjoli and Shackleton (2015) in an Eastern Cape *Phoenix reclinata* population, of which the leaves were being harvested. The shape of a plant population size class distribution reflects the interaction between several intrinsic and extrinsic factors such as: i) the rate of seed production, ii) size specific growth rates, iii) death rates, iv) intra and inter competition and v) size specific attacks by natural enemies (Hutchings, 1997). *Hyphaene coriacea* and *Phoenix reclinata* size class distribution appeared to also be influenced by some of these above mentioned factors. The rate of seed production seem to be negatively affected by tapping having therefore impacts on the seedling density, and the observed dominance of shorter size classes exhibited by both species populations appear to be linked to their strong ability to undergo vegetative reproduction, through root coppicing (Cunningham, 1985). Vegetative reproduction is a successful recruitment option that allows burdened species to thrive in a harsh environment (Traoré *et al*., 2012). On the other hand, the intermediate size classes of these species population are the ones that exhibited high proportions of dead stumps. We found that 97% and 100% of all dead stumps of *Hyphaene coriacea* and *Phoenix reclinata* populations were recorded for the intermediate size classes between 1 cm and 150 cm, being some of these size classes among the preferred size classes to harvest. Thus, a significant share of stems from intermediate size classes are not able to grow to higher size classes. The generalized linear mixed model results substantiated the impact of anthropogenic factors in shapping the size class distribution of these species. It indicated that palm wine harvesting indeed had a negative impact on the density of larger size classes. The density of *Hyphaene coriacea* stems higher than 100 cm as well as the density of *Phoenix reclinata* stems between 151–200 cm decreased when the number of stems with evidence of being tapped increased. In addition, the density of *Hyphaene coriacea* stems above 50 cm decreased with increasing proximity to the market. Proximity to market is associated with lower transportation costs promoting, therefore, higher levels of resource exploration.

The preference ratios for *Hyphaene coriacea* and *Phoenix reclinata* populations showed that there was a positive selection to tap certain size classes. The most preferred size class to tap for both species was between 101cm and 150 cm. Evidence of selective cutting for *Hyphaene petersiana* in Botswana and *Phoenix reclinata* in Kenya were also implied by Babitseng and Teketay (2013) and Kinnaird (1992), respectively. Intermediate size classes were probably preferred to tap because they yield more sap than smaller size classes, and require less effort than taller size classes. Furthermore tappers exhibited positive selection for five out of the six *Hyphaene coriacea* size classes analyzed, while it was positive for only one of *Phoenix reclinata* size class. This may be an indication that *Hyphaene coriacea* is favored for tapping compared to *Phoenix reclinata*. Preference for tapping *Hyphaene coriacea* in Kwazulu-Natal was also implied by Cunningham (1985) who suggested that this preference was due to the high relative abundance of this species. *Hyphaene coriacea* preference over *Phoenix reclinata* can also be due to the stem hardiness. Tappers report that *Phoenix reclinata* has a harder, more difficult to tap stem than *Hyphaene coriacea* (tappers, pers. comm.).

The three indices of population structures calculated in the study describes different proprieties of size frequency distribution that is expected in “ideal “population, and each has distinctive weightings and sensitivity. Permutation index reflects the ranking of size classes regardless of the number of stems in the size class, therefore is insensitive to small changes in the number of stems. Quotients can easily detect size classes with disproportionally high or low numbers of stems and Simpson index of dominance measure an occurrence of dominant size classes. The Simpson index of dominance above 0.1, the permutation index above zero and the fluctuating quotients between the consecutive size classes obtained for both species are an indication that the size structures of these species population deviate from a stable population. *Hyphaene coriacea* and *Phoenix reclinata* populations are probably undergoing a certain level of instability in terms of through put between size classes. Tapping may well play a role because: i) the biggest decline between size classes is also for the most preferred size; ii) for *Hyphaene coriacea* the only avoided size class for tapping (1 – 50 cm) was the one with the highest density and iii) relatively low levels of seedlings that appear to be linked to the low reproductive stems density. According to Botha *et al*. (2002), instable populations is a recurrent feature in savanna species, considering that they are exposed to high levels of environmental and anthropogenic disturbances. Cunningham (1985) suggested that the current physiognomy of the palm savanna structure in Maputaland area, characterized by short, multi-stemmed palm plants, is the result of long-term anthropogenic pressure in the form of excessive fire frequency regimes, and the damaging palm tapping methods, that have been taking place since the establishment in the area of the agrarian and pastoral society around 1500 before Present.

2.6 Conclusion and management recommendations

Actually the exploitation of palm species in Zitundo area is being done under open access resource use system, and no management plans have been designed to regulate the use of this resource. This study was the first evaluation of the status of the two palms population structure in the area. Our results show that the population structures of *Hyphaene coriacea* and *Phoenix reclinata* exhibited steeper negative slopes, indicating the presence of more individuals in shorter over taller size classes. Although there was dominance of shorter size classes, some degree of recruitment hindrance was noted by lower stems densities of seedlings and juveniles size classes comparing to the size class 1-50 cm. Human induced factors in the form of tapping appeared to contribute to shape the structure and abundance of these palm species population through active selection for taller size classes. This active selection hindered the ability of stems to achieve sexually reproductive size classes therefore negatively impacting the seedling production. Therefore reduction on sexually produced individuals can potentially reduce the genetic variability within the species, and chances of species survival in case of fluctuating environments. Additionally, the highest number of dead stumps were also encountered for the most preferred size class. These factors could probably contributed to population structure instability detected by the Simpson index of dominance, the permutation index and the fluctuating quotients between the consecutive size classes obtained in this study.

The finds obtained in this study could function as an important starting point for future demographic studies and management plans designing. Since the SCD profile is not the best indicator of the dynamics and sustainability of a given population, more long-term demographic studies that include controlled experiments, population dynamics such as: i) growth rates, ii) fruit and seed production, iii) survivorship curves, iv) factors that influence the demographic rates, including the impact of anthropogenic factors, are required in order to provide sound sustainable harvesting and management plans for these two palm species. Until long - term demographic data is available, we recommend precautionary practices to avoid depletion of these resources. We recommend that i) palm tappers should avoid harvesting stems with reproductive structures to secure a continuo flow of seed that will enhance the seed bank and the seedling recruitment. ii) Palm tappers should leave part of apical meristem during the tapping process to allow for recovery through regrowth and vegetative reproduction. The actual harvesting technique appear to be destructive as indicate by the low rate of stem survived after being tapped. iii) Rotation of the harvesting sites to allow for stems recovering and regrowth and avoid site specific overexploitation. iv) Development of community resource conservation and management systems with the participation of all stakeholders such as local government authorities, traditional leaders and palm tappers.

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CHAPTER THREE: LOCAL USE AND KNOWLEDGE OF *HYPHAENE CORIACEA* AND *PHOENIX RECLINATA* IN ZITUNDO AREA, SOUTHERN MOZAMBIQUE

3.1 Abstract

Hyphaene coriacea and *Phoenix reclinata* are two abundant palm species in the Maputaland coastal plains of southern Mozambique. They provide an array of subsistence and commercial NTFPs. This research characterizes the ethnobotanical knowledge and use of these species. Using structured interviews we assessed the knowledge, past and current use, cultural importance, perceptions on abundance, local management practices and the determinants of the knowledge and current use of these species. The knowledge about the uses of these two palms is widespread however only 32% of respondents are engaged in palm exploitation. Thirteen palm products are actually exploited in the area, palm wine production from the sap of both palms is the dominant activity, followed by broom production from *Phoenix reclinata* stems and basket production from *Hyphaene coriacea* leaves. The cultural importance of these species includes the production of anklets and skirts used during traditional dances and the use of palm wine in the traditional ritual of libation. Village of residency, gender and migration status appear to determine knowledge and exploitation of these palms. The perception among people are that palms are abundant and an open access resource with no local or formal management systems. Palm wine, broom and basket production can play an important role for income generation therefore, should be consider in future local development initiatives.

Keywords: Ethnobotanical knowledge, use value index, palms cultural importance, palm use, local people perceptions.

3.2 Introduction

In most tropical and subtropical regions palm species have distinctive morphological and physiological features that make them a major source of non-timber forest products (NTFPs) (Balslev, 2011; Macía *et al*., 2011). Over 390 palm derived products, used for subsistence and commerce, were listed by Balick and Beck (1990) including: food, beverages, syrup, sugar, oil, medicines, woodfuel, fibres and construction and weaving materials (Johnson, 1992; Byg and Balslev, 2001a; de la Torre *et al*., 2009). Cámara-Leret *et al*. (2014) suggested that in several cultures around the world, many palms are cultural keystone species since they i) are intensely used, ii) have a diversity of uses, iii) have names and expressions in local idioms, iv) have roles in narratives, rituals, and dances, v) have uses and recollection of uses preserved throughout cultural changes, vi) are hard to substitute with other native species, and vii) provide opportunities for trade.

Continental Africa, with about 65 to 68 species (Blach-Overgaard *et al*., 2015; Stauffer *et al.*, 2017; Cosiaux *et al*., 2018) is considered an area of lower palm diversity when compared with Asia and Central and South America (Stauffer *et al.*, 2017; Cosiaux *et al*., 2018). Despite the low diversity, palms are one of the most economically important plant groups, playing a significant role in the daily lives of people throughout Africa, as a source of NTFPs used for subsistence and income generation (Okereke, 1982; Amwatta, 2004; Martins and Shackleton, 2018). *Hyphaene coriacea* and *Phoenix reclinata*, locally known as “minala” and “inkindsu”, respectively, are two very abundant palm species in the Maputaland coastal plains of southern Mozambique and northeastern Kwazulu-Natal, South Africa. They provide an array of subsistence and commercial NTFPs such as fruits, palm wine, fibres and weaving and building material. These palms products conjointly with honey, fuelwood, wild fruits and medicinal plants are important NTFPs exploited by people from the Maputaland coastal plains of southern Mozambique (Governo do Distrito de Matutuine, 2008). Cunningham (1985; 1990a; b), McKean (2003) and Martins and Shackleton (2018) have highlighted the importance of these two palms as a source of income for the people from the Maputaland coastal plains. Cunningham (1985; 1990a; b) found a large regional income from *H. coriacea* and *P. reclinata* palm wine sales in the South African region of the Maputaland palm savanna, while McKean (2003) reported an annual regional income of R27 600 from *H. coriacea* fronds trade. Martins and Shackleton (2018) emphasized the significant role of palm wine income to livelihoods and poverty mitigation for people from the Zitundo area, southern Mozambique. Revenues from palm wine sales contributed to over 80% of the tappers' total income and were up to three times above the national minimum wage for the agricultural and forestry sector (Martins and Shackleton, 2018).

The versatility and intensity of palm uses suggest a diverse, dynamic and place specific knowledge about these species, often related to the needs of the people where the species occur (Monteiro *et al*., 2006; Cámara-Leret *et al*., 2014; Martins de Andrade *et al*., 2015). The knowledge and use of palms is subject to the influence of the same factors that affect knowledge and use of other plant resources namely: i) the floristic diversity of a given area (de la Torre *et al*., 2009); ii) characteristics of the exploited species, for instance, abundance, seasonality and morphology (Hoffman and Gallaher, 2007; de la Torre *et al*., 2009; Macía *et al*., 2011); iii) socio-economic characteristics such as, age, gender, formal education, occupation, household size, assets and ethnicity (Byg and Balslev 2001a; Paniagua-Zambrana *et al*., 2017; Martins de Andrade *et al*., 2015); iv) cultural and traditional values (Hoffman and Gallaher, 2007; de la Torre *et al*., 2009; Martins de Andrade *et al*., 2015) and v) accessibility of markets as well as infrastructure and services such as roads, commerce and health (Paniagua-Zambrana *et al*., 2007; de la Torre *et al*., 2009; Martins de Andrade *et al*., 2015). The literature on the influence of these factors on knowledge and use of plant resources show conflicting results, indicating that these factors are not fully understood (Campos *et al*., 2015). Therefore, it is important to document the knowledge and use of plants resources and the factors that affect them in a specific cultural, social and economic context. This is also useful in setting conservation and management priorities aligned with the culture and needs of the local people (Araújo and Lopes, 2012; Cámara-Leret *et al*., 2014).

The knowledge and use of plant resources can be analyzed and summarized using quantitative ethnobotanical measures (Byg and Balslev, 2001a; Paniagua-Zambrana *et al*., 2007; Cámara-Leret *et al*., 2014). One such widely used measure is the use value index (UVs), developed by Phillips and Gentry (1993a; b). This index is based on informant consensus and reports the average number of uses for a given taxon cited by informants. Phillips *et al*. (1994) believed this index to be objective in measuring uses and knowledge since investigator bias is excluded. Although the original and adapted version of the UVs index has been widely used in ethnobotanical literature, Albuquerque *et al*. (2006) mentioned some limitations of this index, namely: i) the selection of respondents must be random, since this index is highly influenced by respondents themselves; ii) the index does not differentiate between knowledge, past use, and actual use (real use), therefore is best suited to measure knowledge related to a given species uses not the actual use of that species; iii) places more emphasis on species that have many uses even if these uses are only known by few people; iv) in order for the index to be used to evaluate the distribution of knowledge among different groups of people, it will require respondents to be interviewed separately, therefore being time consuming. To overcome most of the limitations on the use of the UVs, in this study the selection of the respondents was done randomly, the respondents were interviewed individualy and the questionnaire used during the interviews had questions that distinguished between past use, current use and knowledge. The present study characterizes the ethnobotanical knowledge and use of the palm species *H. coriacea* and *P. reclinata* in the Zitundo area, southern Mozambique. Specifically, the study i) assesses the knowledge, past and current use as well as the cultural importance of these species; ii) determines the factors that influence the knowledge and current use; and iii) describes the perceptions on palm abundance and local management practices.

3.3 Methods

3.3.1 Study area

Zitundo, with an area of 864 km^2 (INE, 2009), is located in the Matutuine district, and is the southernmost administrative post of Mozambique (Figure 3.1). According to MAE (2012) there are approximately 6 674 people living in Zitundo in 1 777 households (however the local leaders records showed only 1 412 households in the area). The average household size is four people (INE, 2009), the illiteracy and poverty incidence are high and in 2005 were estimated in 62% and 78%, respectively (MAE, 2012). Zitundo economy is mainly based in subsistence agriculture, household small informal trade and tourism (Jury *et al*., 2011; Come, 2014; World Bank, 2016), just as most rural coastal areas of Mozambique. Additionally, due to its location of bordering South Africa, migration to work in South Africa is also very common in the area (Jury *et al*., 2011). Wage employment in the area is rare and is mainly found in the coastal villages of Zitundo.

The majority of the population belong to the Ronga ethnic group, a sub-group of the Thonga tribe (Junod, 1962). The Ronga have occupied the area for more than 500 years (Shaffer, 2010), and have been historically called the Tembe or the Tembe-Thonga, after chief Mthembu, who around 1554, created a chiefdom spreading from Maputo Bay in Mozambique to north KwaZulu-Natal in South Africa (Kloppers, 2003). Currently, the traditional leadership system of Zitundo is composed by the "Regulo", who is the head of this system, and the village's traditional leaders (each village has its own traditional leader) (Zitundo Regulo, pers. comm.). The earlier inhabitants of the area were agriculturalists that used slash-and-burn or shifting agricultural techniques (Kloppers, 2003) and were highly dependent on locally harvested natural resources (Kloppers, 2003; Gaugris, 2008), and much of this lifestyle remains nowadays. Presently, the main livelihood strategies include, subsistence agriculture, goat and cattle herding, wild fruits and wild plant collection, fishing and hunting, as well as honey, charcoal, craft, mat and palm wine production (Governo do Distrito de Matutuine, 2008; Shaffer, 2010).

Biogeographically Zitundo lies in the Maputaland Centre of Endemism, within the Maputaland-Pondoland-Albany biodiversity hotspot (Van Wyk and Smith, 2001). This is one of the most plant diverse areas of the country and is characterized by varied vegetation types, each with its specific species composition (Kirkwood, 2014). Dune, swamp and sand forests, in addition to savannas, woodlands, grasslands, wetlands, estuarine and riverine vegetation are found in the area (Kirkwood, 2014) (Figure 3.1). The climate is tropical to subtropical, with two distinctive seasons, one hot and rainy, which runs from October to April and another cool and dry between May and September (Shaffer, 2009). The average annual temperature is around 22.6º C and annual rainfall varies between 750 mm to 888 mm (Mander and Pollet, 1994). Humidity is high throughout the year ranging from 50% to over 80% (Morley, 2005). The topography is flat or slightly undulating, typical of the low coastal plain alongside the Indian Ocean (Mucina and Rutherford, 2006). Average elevations are around 50 m (McKean, 2003), never exceeding 150-200 m (kirkiwood, 2014). The soils are infertile, mainly sandy, yellow and gray, with low organic content and high drainage rates (McKean, 2003; Morley, 2005). On the flood plains of rivers and the fringe of lakes and wetlands the soils are alluvial, red, clay rich and more fertile (Morley, 2005).

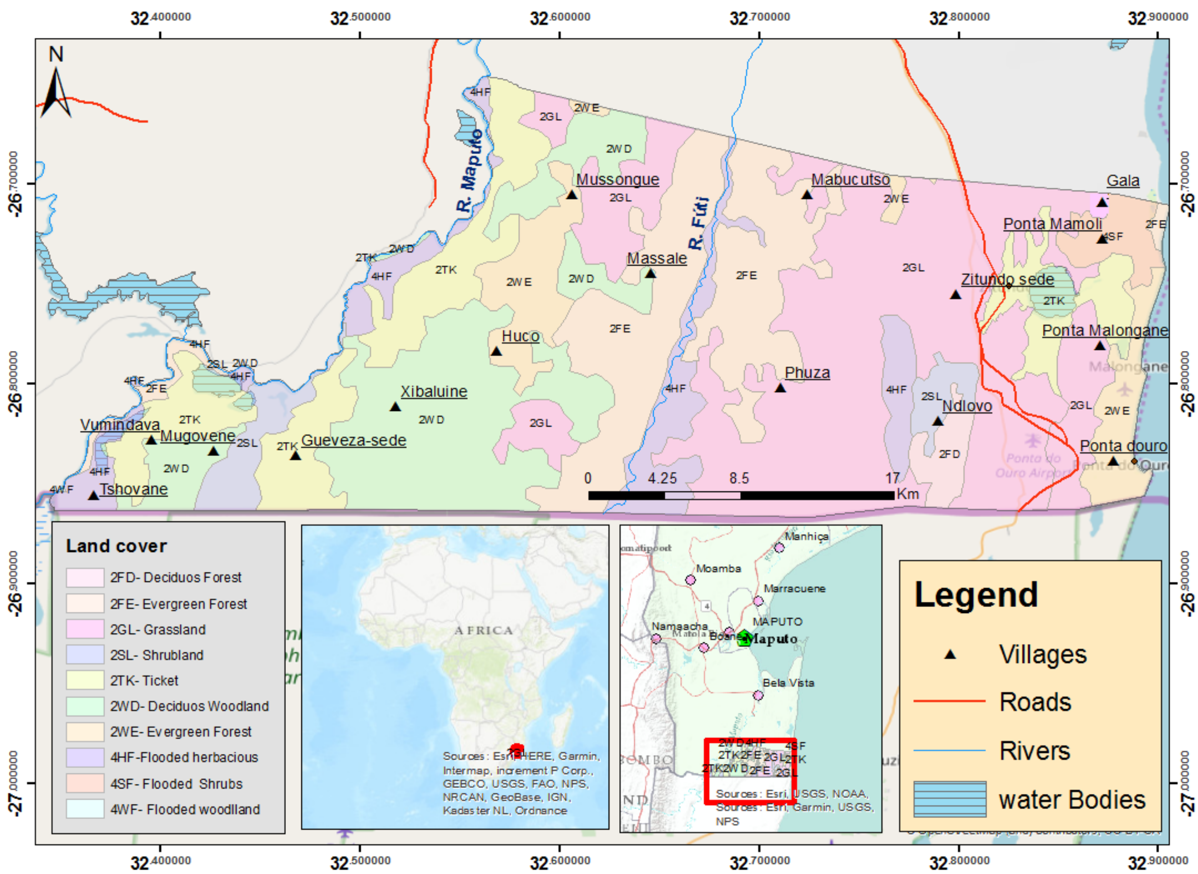

Figure 3.1: Map of the study area, with the villages and vegetation types

The study was carried out in the all 16 villages of the Zitundo Administrative Post namely, Ponta de Ouro, Malongane, Momole, Zitundo-sede, Gala, Ndovo, Mabucuti, Phuza, Mussongue, Massale, Huco, Xibaluine, Gueveza, Mugovene, Vumidava and Tchovane. Ponta de Ouro, Malongane and Momole are located alongside the coast and have been experiencing fast tourism growth. Tourism has generated many employment opportunities, attracting many migrants to the area. Zitundo-sede and Gala are located further inland in the open coastal grassland, where lakes, marshes and temporary rain-fed ponds are abundant. These features support fishing and farming as the main livelihood activities in these two villages. Ndovo, Mabucuti, and Phuza are located in the vast palm savanna, which lies mainly between the open coastal grassland and the Futi River, in these areas *H. coriacea* and *P. reclinata* palms are the dominant species, with approximately 602 and 252 stems per hectare, respectively (Martins and Shackleton, 2017). Palm wine tapping plays an important role on the livelihood of people from these villages. Mussongue, Massale and

Huco are located between the Futi river and Maputo river where the sand forest and woodland mixes with patches of open savanna, where *H. coriacea* and *P. reclinata* can be found. In these villages farming and in limited fishing are the main livelihood activities. Xibaluine, Gueveza, Mugovene, Vumidava and Tchovane are located in the sand forest, adjacent to Maputo River and its floodplains and are highly dependent on farming and fishing.

3.3.2 Data collection

A questionnaire survey was conducted between August 2015 and April 2016 to 179 randomly selected households from the 16 villages that compose the study area (Table 3.1). This sampling effort corresponds to 13% of the total households of the study area. A numbered list of households of each village was produced with the help of community leaders, and households were randomly selected. One of the selected households did not agree to participate. Prior to starting the survey, ethical clearance was acquired from Rhodes University and authorization was secured from the Zitundo traditional leader (Zitundo Régulo) and the villages community leaders. All participants were informed about the purpose of the research and that participation was voluntary.

Semi-structured interviews with the head of household, or any other responsible adult were carried out. The majority of respondents preferred to be interviewed in their native language Ronga, with the rest of the interviews in Portuguese. The interviews took place in the respondent's home and sought the following information: i) household demographics and socio-economic characteristics; ii) land ownership and holding; iii) present and past exploitation of the two palm species, palm parts collected and purposes; iv) knowledge about the two species uses; v) preferred species for each use; vi) cultural importance of the two species (use of these species or products at traditional ceremonies or celebrations; proverbs and sayings about the species and their use as well as traditional games, songs and stories about the species) and vii) perceptions on palm management practices and changes in palm abundance and users over the past five years.

Table 3.1: Total and sampled number of households in each village (* Massale currently only have one household. Other households decided to move out, since the area is prone to elephant incursions that destroy the agricultural fields)

Village	Nº of households	Nº of sampled households
Tchovane	77	6
Vumindava	73	7
Mugovene	34	5
Gueveza	100	10
Xibaluine	34	5
Momole	53	12
Malongane	181	20
Ponta do Ouro	538	50
Phuza	41	7
Mussongue	49	5
Massale*	1	1
Mabucuti	22	3
Gala	33	8
Huco	20	3
Ndovo	20	8
Zitundo - Sede	136	26
Total	1 412	179

3.3.3 Data and statistical analyses

Descriptive statistics (mean, standard deviation and frequencies) were used to summarize the data. Frequencies were expressed as number and percentage of households. Palm uses currently practiced by respondents as well as respondent's knowledge of palm uses for each species were grouped into categories adapted from Macía *et al.* (2011). The following ethnobotanical indexes were used as measures of each palm species use and knowledge: i) current use value, ii) knowledge use value, iii) current palm savanna use value, iv) potential palm savanna use value and v) importance value of each species for the three mostly mentioned palm uses (palm wine, broom and basket production).

Current use value and knowledge use value indices for each species were calculated using Phillips and Gentry (1993a; b) use value index following equation (1).

$$UV = \Sigma UVi/N \qquad (1)$$

Where *UVi* is the sum of all uses practiced (for the case of current use value)/known (for the case of knowledge use value) by the respondent *i* and *N* is the total number of respondents.

Current palm savanna use value and potential palm savanna use value for each species was estimated following the method described by Cámara-Leret *et al*. (2014). I calculated the current and potential palm savanna use value by multiplying respectively the current and knowledge use value by the average stem density of useful size classes of each species as presented in equation (2). The average stem density of useful size classes used in this study were obtained from Martins and Shackleton (2017). I excluded from this analysis stems in seedling and juvenile size classes because they are not exploited. The average density of useful *H. coriacea* and *P. reclinata* stems were respectively 395 and 162 stems per hectare.

$$UVps = \Sigma UVs * Ds \qquad (2)$$

Where *UVps* is the use value of the palm savanna, *UVs* is the current use value of each species (for current palm savanna use value) or knowledge use value (for potential palm savanna use value), *Ds* is the average density of stems of the species *s* in the useful size classes.

The importance value of each species for the three most mentioned palm uses was adapted from Byg and Balslev (2001a) and calculated as the proportion of respondents who reported a given species as the most preferable for a given use (equation 3).

$$IVsu = Nisu/N \qquad (3)$$

Where *IVsu* is the importance value of species *s* for use *u*, *Nisu* is number of respondents who consider species *s* most preferable for use *u* and *N* is the total number of respondents

A Kolmogorov-Smirnov test was used to check for data normality. The correlation between the number of known and currently practiced uses was tested using the Spearman's correlation test. A Mann-Whitney U-test was used to compare the current and knowledge use value as well as the current and potential palm savanna use value between the two palm species. A Mann-Whitney U-test was also used to compare the above mentioned indices between gender and age within each species. Following Hanazaki *et al*. (2000), Begossi *et al*. (2002), Monteiro *et al*. (2006) and Sogbohossou *et al*. (2015), the age comparison was done between respondents that were 40 or below years old (≤ 40) and the ones that were over 40 years (> 40). A Chi-square test for equality of proportions was used to compare the importance value for a given use between the two species. Inferential statistics were used to evaluate the influence of socio-economics factors on household participation in palm exploitation activities as well as current and knowledge use values. Binomial Logistic Regression was used to determine the factors that influence the household participation on palm exploitation activities while Negative Binomial Regression and Generalized Poisson Regression were used to analyze the factors that affect the current use value and knowledge use value, respectively. The independent variables used in the regression models are presented in Table 3.2.

Table 3.2: Variables used in the regression analysis (a are the explanatory variables used in the models, b are variables dropped from the models)

Variables		**Description**
Residency	Tchovane[a]	One if lives in Tchovane, zero otherwise
	Vumindava [a]	One if lives in Vumidava, zero otherwise
	Mugovene [a]	One if lives in Mugovene, zero otherwise
	Gueveza [a]	One if lives in Gueveza, zero otherwise
	Xibaluine [a]	One if lives in Xibaluine, zero otherwise
	Momole [a]	One if lives in Momole, zero otherwise
	Malongane [a]	One if lives in Malongane, zero otherwise
	Ponta do Ouro [a]	One if lives in Ponta do Ouro, zero otherwise
	Phuza [a]	One if lives in Phuza, zero otherwise
	Mussongue [a]	One if lives in Mussongue, zero otherwise
	Massale [a]	One if lives in Massale, zero otherwise
	Mabucuti [a]	One if lives in Mabucuti, zero otherwise
	Gala [a]	One if lives in Gala, zero otherwise
	Huco [a]	One if lives in Huco, zero otherwise
	Ndovo [a]	One if lives in Ndovo, zero otherwise
	Zitundo - Sede [a]	One if lives in Zitundo, zero otherwise; this was the dropped dummy for residency to avoid perfect multicollinearity and therefore was used as the reference
Demographic	Gender[a]	One for female, zero otherwise
	Age[a]	Age of the head of household (years)
	Ethnicity[a]	One if Ronga, zero otherwise
	Born in village[a]	One if born in the village of residency, zero otherwise
	Place of birth[b]	One if was born in Zitundo administrative post, zero otherwise
	Size of household[a]	Number of people living in the house
	Years living in the village[a]	Number of years living in the village
Formal education	Education[a]	Number of years of schooling
	Literacy[b]	One if knowns how to read and write, zero otherwise
Socio-economics	Leadership position[a]	One if is leader (traditional, community, political, religious), zero otherwise
	Existence of formal jobs in the household[b]	One if at least one member has a formal job, zero otherwise
	Number of formal jobs in household[a]	Number of people in the household with formal job
	Land ownership[a]	One if has land, zero otherwise
	Size of the land[a]	Amount of land owned by the household (m^2)

Statistical analyses were performed using SAS 9.4 and Stata 13.1. A variance inflation factor was used to check for multicollinearity. Since multicollinearity was present I dropped the variables that were causing it (place of birth, literacy and existence of formal jobs in the household, since these variables were highly correlated to born in village, education and number of formal jobs in the household respectively). The variables selected to continue in the models were believed to be more relevant and could better explain the dependent variables. I selected the Negative Binomial Regression to model the current use value since the data were discrete counts with over dispersion, while the Generalized Poisson Regression was better suited to analyze the knowledge use value because it exhibited under dispersion. The estimation procedures utilized robust standard errors in case residuals were heteroscedastic.

3.4 Results

3.4.1 Household characteristics

The majority of the respondents were male (76%), and belonged to the Ronga ethnic group (64%) (Table 3.3). The most common age group ranged between 31 and 40 years old, with 45 ± 14 years old being the average age of the respondents. Although the average number of years of schooling was low (4 ± 3 years), the majority of the respondents (56%) affirmed that they know how to read and write. Forty-three percent of all respondents were born in Zitundo administrative post, and 34% are still living in the village where they were born. The average years the respondents had been living in their village was 26 ± 20 years. Most of the respondents did not hold any leadership position in the village (83%) while 12% stated that they were traditional or community leaders and five percent declared they were religious leaders. The average household size was 5 ± 3 people, and most of the households did not have any member with a formal job (59%). Most (79%) stated that they own land, with an average of 4 605 ± 7 387 m^2 (Table 3.3).

Table 3.3: Respondent characteristics in Zitundo area

Characteristic	Categories	Nº	%
Gender	Male	136	76
	Female	43	24
Age (years)	≤ 20	2	1
	21 – 30	25	14
	31 – 40	53	30
	41 – 50	32	18
	51 – 60	34	19
	> 60	33	18
	Mean ± SD	45 ± 14	
Education	Can read and write	101	56
	Years of school (mean ± SD)	4 ± 3	
Ethnicity	Ronga	114	64
	Changana	29	16
	Matsua	14	8
	Bitonga	6	3
	Sena	5	3
	Other	11	6
Place of birth	Born in village of residency	61	34
	Zitundo area	76	43
Years living in the village	Mean ± SD	26 ± 20	
Household size (Nº persons)		5 ± 3	
Leadership position in the community	No position	148	83
	Traditional/community leader	22	12
	Religious leader	9	5
Formal jobs in the household	No formal Jobs	106	59
	Formal Jobs	73	41
Land ownership	Own land	140	79
	No land	38	21
Size of land (m^2)	Mean ± SD	4 605 ± 7 387	

3.4.2 Palm Use

Fifty-seven households (32%) are currently engaged in palm exploitation activities, while 25 (14%) used to collect palms in the past and 97 (54%) have never been involved in palm exploitation activities. Thirty-nine (22%) households currently involved in palm exploitation stated that they collect *Hyphaene coriacea* parts compared to 33 (18%) for *Phoenix reclinata*. However, few households (8%) declared to exploit both palm species. Thirteen palm products in six categories are currently exploited (Table 3.4). Palm wine production from the sap of both palms is the dominant activity among the palm collectors (40% of *H. coriacea* and 21% of *P. reclinata*) followed by broom production from *P. reclinata* stems (37%) and basket production from *H. coriacea* leaves (21%) (Table 3.4). *H. coriacea* is the species with more uses, ten products relative to six products from *P. reclinata*. *H. coriacea* leaves were the most collected part due to their diversity of applications (Table 3.4).

The main reasons that some households do not currently exploit palms included: i) not knowing how to (44% for *H. coriacea* and 39% for *P. reclinata*) and ii) being involved in other livelihood activities (18% for *H. coriacea* and 17% for *P. reclinata*) (Table 3.5). Regarding the past collection some stated that they used to produce palm wine from the sap of the two palms (6%), followed by basket production from *H. coriacea* leaves (3%) and broom production from *P. reclinata* stems (3%) (Table 3.5). Getting a job at the tourism enterprises was the main reason stated by respondents who had stopped exploiting palms.

Table 3.4: Current uses of palm species in Zitundo area

Category	Product	Part collected	*Hyphaene coriacea*			*Phoenix reclinata*		
			Nº of users	% Palm users	% Households	Nº of users	% Palm users	% Households
Beverages	Palm wine	Sap	23	40	13	12	21	7
Tools and utensils	Baskets	Leaves	12	21	7	0	0	0
	Wallets	Leaves	0	0	0	1	2	1
	Brooms	Leaves	4	7	2	0	0	0
	Brooms	Stems	0	0	0	21	37	12
	Ropes	Leaves	1	2	1	0	0	0
	Hats	Leaves	1	2	1	0	0	0
	Mats	Leaves	2	4	1	0	0	0
	Fish traps	Petiole	2	4	1	0	0	0
Furniture	Furniture	Leaves	3	5	2	0	0	0
Food	Edible fruits	Fruits	0	0	0	3	5	2
Construction (animal shed)	Poles	Petiole	1	2	1	1	2	1
	Roofing	Leaves	0	0	0	1	2	1
Other	Leaves for sale	Leaves	1	2	1	0	0	0

Table 3.5: Past palm collection and reasons for not exploiting palm species

Characteristic	Categories	*H. coriacea*		*P. reclinata*	
		Nº	%	Nº	%
Past palms exploitation	Sap for palm wine	10	6	11	6
	Leaves for basket	5	3	0	0
	Stems for broom	0	0	5	3
	Leaves for mat	3	2	1	1
	Leaves for hat	3	2	0	0
	Leaves to make traditional dancing skirts	1	1	0	0
Reasons for not exploiting palm	Do not know how to work with it	78	44	69	39
	Other livelihood activities	33	18	30	17
	Limited local supply	17	10	13	7
	No need	7	4	17	10
	Too physically demanding	5	3	4	2
	Other	0	0	12	7

3.4.3 Knowledge regarding palm uses

Although the majority of households reported not currently exploiting palms, they have knowledge about their uses. Ninety-nine percent of all respondent cited at least one use of the palms while 2% and 3% reported not knowing any uses for *H. coriacea* and *P. reclinata*, respectively. The Spearman's correlation test showed that there was no significant correlation between the number of *H. coriacea* known and practiced uses ($r = -0.08$, $p = 0.3$), while *P. reclinata* showed a very weak correlation ($r = 0.16$, $p = 0.03$). Seventeen palm uses arranged in six categories were reported for the two species (Table 3.6). Thirteen uses were reported for each species, with much overlap between the two species. More than 90% of the respondents mentioned palm wine production as one of the uses of both palms, while above 70% and 87% mentioned broom production from both species and basket production from *H. coriacea*, respectively (Table 3.6). *H. coriacea* was preferred by 31% and 68% of the respondents for palm wine and basket manufacture, respectively, while *P. reclinata* was preferred for broom production (48%). Reasons for *H. coriacea* preference for palm wine production include, the wine being tastier (10%), greater sap production (9%) and lower alcohol content (5%). Preference for this species for basket production was due to its long unopened leaf (34%) and its perceived strength and durability (39%). *P. reclinata* was preferred for broom production due to: i) its high number of fibres in the stem and more flexible fibres that make the brooms better for sweeping (12%), ii) *P. reclinata* brooms last longer (11%) and iii) it is easier to work (10%).

Table 3.6: Knowledge of palm uses among households in Zitundo area

Categories	Uses	*Hyphaene coriacea*		*Phoenix reclinata*	
		Nº households	% households	Nº households	% households
Beverages	Palm wine	173	97	171	96
Tools and utensils	Baskets	155	87	6	3
	Wallets	0	0	5	3
	Brooms	140	78	138	77
	Ropes	7	4	0	0
	Hats	8	5	2	1
	Mats	6	3	0	0
	Fish traps	2	1	0	0
Furniture	Furniture	95	53	0	0
Food	Fruits	0	0	21	12
	Palm heart	1	1	1	1
Construction (animal shed)	Poles	4	2	3	2
	Roofing	0	0	1	1
Cultural	Anklet for traditional dances	36	20	5	3
	Skirts for traditional dances	36	20	9	5
	Decoration and protection of the grooms and brides house during weddings	0	0	10	6
	Use in traditional medicine/beliefs	3	1.7	3	1.7

3.4.4 Quantitative measures of use, knowledge and importance of palms

There were no statistically significant differences in the overall current use value and palm savanna use value between the two species. However, overall knowledge use value (3.74 ± 1.38) and overall potential palm savanna use value (1 479 ± 545) of *H. coriacea* was higher than *P. reclinata* (Table 3.7). Male respondents exhibited a higher current use value (0.35 ± 0.67) and current palm savanna use value (136.5 ± 265) for *H. coriacea* than females, while there were no significant age differences on the current use value and current palm savanna use value for this species. There were also no significant gender and age differences in the current use value and current palm savanna use value of *P. reclinata* as well as knowledge use value and potential palm savanna use value of both species (Table 3.7). There were no significant differences on the importance value for palm wine production between the two species but, *H. coriacea* was significantly more important for basket production (0.68) while, *P. reclinata* was more important for broom manufacture (Table 3.7).

Table 3.7: Quantitative measures of use, knowledge (mean ± standard deviation) and importance value (proportion) of *Hyphaene coriacea* and *Phoenix reclinata* in Zitundo area. (* denotes significant differences between the species, while unlike letters denote significant differences between gender and age groups within a species)

Index	Category	Species	
		H. coriacea	*P. reclinata*
Current use value	Overall	0.3 ± 0.6	0.2 ± 0.5
	Male	0.4 ± 0.7[a]	0.2 ± 0.6
	Female	0.1 ± 0.3[b]	0.1 ± 0.4
	≤ 40 years	0.3 ± 0.6	0.2 ± 0.5
	> 40 years	0.3 ± 0.6	0.3 ± 0.5
Knowledge use value	Overall	3.7 ± 1.4*	2.1 ± 0.9*
	Male	3.7 ± 1.4	2.1 ± 0.8
	Female	3.8 ± 1.5	2.1 ± 1.0
	≤ 40 years	3.9 ± 1.2	2.0 ± 1.0
	> 40 years	3.6 ± 1.5	2.2 ± 0.8
Current palm savanna use value	Overall	110.3 ± 240.6	35.3 ± 82.8
	Male	136.5 ± 265.0[c]	39.3 ± 89.3
	Female	27.6 ±101.8[d]	22.6 ± 56.8
	≤ 40 years	98.8 ± 239.3	28.4 ± 80.6
	> 40 years	119.7 ± 242.4	40.9 ± 84.5
Potential palm savanna use value	Overall	1478.5 ± 544.5*	339.4 ± 142.3*
	Male	1475.4 ± 527.2	337.1 ± 136.7
	Female	1488.1 ± 602.4	346.6 ± 160.4
	≤ 40 years	1545.4 ± 471.1	326.0 ± 153.6
	> 40 years	1424.4 ± 594.0	350.2 ± 132.2
Importance Value	Palm wine	0.3	0.3
	Brooms	0.2*	0.5*
	Baskets	0.7*	0.0*

3.4.5 Factors affecting palm use, current use value and knowledge use value

The regression analysis indicated that the independent variables have good explanatory power regarding household participation in palm exploitation and the current use value of both species. McFadden pseudo r-square for palm exploitation and *H. coriacea* and *P. reclinata* current use value were respectively 0.36, 0.39 and 0.24 (Table 3.8 and 3.9). However, McFadden pseudo r-square of 0.05 and 0.01 obtained for the knowledge use value of respectively *H. coriacea* and *P. reclinata*, suggested a poor explanatory power of independent variables determining the level of knowledge of palm uses among households (Table 3.9). The village where the household resides was the only independent variable that significantly influenced household participation in palm exploitation. Living in Phuza, Massale, Huco and Ndovo had a positive influence on palm exploitation, while living in Malongane negatively affected participation (Table 3.8). Living in Ponta de Ouro and Malongane and being a female head of household had a negative effect on the current use value of *H. coriacea* while, living in Ponta de Ouro negatively influenced the current use value of *P. reclinata*. Households that are headed by a person who still lives in the village where they were born had a higher *H. coriacea* current use value (Table 3.9). The village where the household resides also influenced the knowledge use value of *H. coriacea*. Living in Ponta de Ouro and in Mussongue positively influenced the level of knowledge about this species' uses (Table 3.9). In contrast none of the variables had a significant influence on the knowledge use value of *P. reclinata*.

Table 3.8: Binomial Logistic Regression estimates for household participation in palm use (significant variables are indicated in bold)

Independent variable	Palm use	
	Estimates	P-value
Tchovane	-1.76	0.16
Vumindava	-1.78	0.20
Mugovene	0.53	0.66
Gueveza	0.40	0.62
Xibaluine	-0.41	0.75
Momole	-0.51	0.53
Malongane	-2.48	**0.03**
Ponta do Ouro	-1.05	0.13
Phuza	17.70	<**0.0001**
Mussongue	-0.86	0.42
Massale	16.28	<**0.0001**
Mabucuti	1.54	0.36
Gala	-1.22	0.34
Huco	16.40	<**0.0001**
Ndovo	16.91	<**0.0001**
Gender (female)	0.80	0.19
Age	-0.02	0.48
Ethnicity (Ronga)	-0.54	0.33
Born in village	0.73	0.40
Size of household	0.04	0.57
Years living in the area	-0.02	0.40
Education	-0.10	0.19
Leadership position	0.82	0.09
Number of formal jobs in household	-0.04	0.86
Land ownership	0.60	0.50
Size of the land	0.00	0.86
McFadden Pseudo R-Square		0.36

Table 3.9: Generalized Linear Regression estimates for current use and knowledge use value (significant variables are indicated in bold)

Variable	Current use value				Knowledge use value			
	Hyphaene coriacea		*Phoenix reclinata*		*Hyphaene coriacea*		*Phoenix reclinata*	
	Estimates	P-value	Estimates	P-value	Estimates	P-value	Estimates	P-value
Tchovane	-14.65	0.98	-1.06	0.35	0.11	0.66	-0.17	0.62
Vumindava	-14.58	0.98	-1.48	0.17	0.26	0.24	-0.001	0.99
Mugovene	-14.39	0.99	-0.03	0.97	0.25	0.34	-0.10	0.78
Gueveza	-0.28	0.66	-0.23	0.75	0.26	0.20	0.09	0.74
Xibaluine	-14.40	0.99	-0.57	0.64	0.06	0.84	0.19	0.57
Momole	-14.81	0.98	-0.16	0.80	0.08	0.68	-0.004	0.99
Malongane	-2.41	**0.02**	-14.42	0.98	-0.23	0.22	-0.13	0.56
Ponta do Ouro	-1.88	**0.002**	-1.55	**0.04**	0.38	**0.01**	0.13	0.48
Phuza	0.58	0.36	-1.13	0.37	-0.19	0.51	-0.06	0.86
Mussongue	-0.84	0.43	-14.71	0.99	0.46	**0.05**	0.24	0.44
Massale	0.39	0.73	-14.89	0.99	0.17	0.74	-0.17	0.82
Mabucuti	-0.56	0.57	-0.10	0.94	-0.18	0.68	0.24	0.59
Gala	-13.98	0.98	-0.98	0.36	0.10	0.66	-0.01	0.97
Huco	0.76	0.19	0.89	0.13	0.36	0.23	0.07	0.87
Ndovo	0.35	0.59	0.33	0.70	-0.04	0.89	-0.15	0.66
Gender (female)	-1.40	**0.03**	-0.02	0.97	-0.01	0.95	0.01	0.96
Age	0.01	0.51	-0.02	0.48	0.001	0.77	0.002	0.76
Ethnicity (Ronga)	-0.89	0.06	0.20	0.72	-0.03	0.79	-0.01	0.93
Born in village	1.62	**0.05**	0.68	0.39	0.02	0.90	0.05	0.83
Size of household	-0.01	0.90	0.03	0.57	0.01	0.42	0.02	0.42
Years in the area	-0.04	0.08	-0.01	0.74	-0.0003	0.95	-0.002	0.77
Education	-0.12	0.09	-0.05	0.49	0.01	0.39	-0.01	0.57
Leadership	0.05	0.89	0.08	0.84	0.02	0.88	0.05	0.71
Nº formal jobs	0.08	0.75	-0.23	0.39	-0.02	0.63	-0.001	0.99
Land ownership	-0.24	0.70	-0.25	0.77	0.12	0.39	0.07	0.71
Size of the land	0.00	0.62	0.00	0.41	0.00	0.40	0.00	0.55
McFadden Pseudo R-Square		0.39		0.24		0.05		0.01

3.4.6 Cultural importance of palms

Beside the cultural uses mentioned (Table 3.6), such as the manufacture of anklets and skirts used during traditional dances, the products of *H. coriacea* and *P. reclinata* play a substantial role in the culture and traditional belief systems of people in the area. Thirty-five percent of the respondents stated that palm wine is used in the traditional ritual of libation to invoke, remember and worship ancestors (Table 3.10). Some respondents (10%) declared that *P. reclinata* leaves are placed at the entrance of the groom and bride's house during weddings, for protection and decorative purposes. A derogatory popular saying, that compares people's attitudes and character with *P. reclinata* physiognomy, was known by 49% of the respondents. The saying is as: "*Don't be as inkindsu (P. reclinata) that cleans far away while nearby is dirt*". This is in reference to the arching appearance of the leaves, with the tip touching the ground far from the stem and, when the wind blows its movements mimic the movement of sweeping the ground. Many interpretations of the above saying were reported by the respondents, however, the most common was that it refers to people who like to get involved in other people lives instead of taking care of their own (Table 3.10).

Table 3.10: Palms in the culture and traditional/beliefs system

Characteristic	Categories	Nº	%
Palms in the traditional belief/ritual system	Palm wine used in the traditional ritual of libation	63	25
	P. reclinata leaves are placed on the entry door of the groom's and bride's house during weddings for protection and decoration	10	6
	Palm wine used as offering for the bride family during traditional weddings	6	3
	Palm leaves used around the neck to treat neck pain	2	1
	H. coriacea used inside the house to protect against thunderstorms	2	1
Proverbs/popular saying	Don't be as "inkindsu" (*P. reclinata*) that cleans faraway while nearby is dirt	87	49
Meaning of proverbs/popular saying	Someone who likes to get involved in other people's lives instead of taking care of their own	13	7
	Someone who likes to appear to be a good person while inside they a bad person	9	5
	Someone who treats outsiders well and mistreats their family	8	5
	A liar	7	4
	Someone who spends the money outside the house and does not contribute to the family expenses	4	2
	Other	11	6
	Don't know	35	20

3.4.7 Perceptions on management and palm abundance and users trends

The majority of the respondents (59% of all respondents) stated that there is no control over exploitation of palms, while 11% and 2%, respectively, said that the traditional leaders and tappers in the area are the ones controlling palm exploitation. Most of the respondents (40%) affirmed that nothing is done in the area to conserve palms, while 22% said that they practice some palm conservation activities. Activities that help conserve the palms mentioned by the respondents include: not cutting small stems (8%), not cutting the entire stem (5%), collecting only one unopened leaf (5%), not burning the area (3%) and not cutting *P. reclinata* when it is flowering or fruiting. Very few respondents grow either species (1%) or had seen somebody growing them (8%). All the cultivation mentioned was for gardening (decorative) purposes (Table 3.11). The above described trends were also observed among palm users, with the majority of palm users also reporting that there is no control over palm exploitation (72%) and that they do nothing to conserve palms (60%) (Table 3.11)

Thirty-two percent of the respondents believe that palm abundance in the area has increased over the past five years while, 22% and 25% believed that had decreased or stayed constant, respectively. The remaining 21% of all respondents stated not knowing if palm abundance has changed. High vegetative growth was the main reason (25%) underlying the increase, while those saying it had decreased attributed it to excessive use (11%). It is also believed that the number of people who collect palms has increased in the last five years (21%) against 16% and 15% who stated that it decreased and stayed constant respectively. The remaining respondents (48%) did not known if the number of palm users have changed. A shortage of job opportunities was mentioned has a core reason for the increase on the number of people involved in palm exploitation. Paradoxically, an increase in the number of jobs offered by tourism companies, which are booming in the coastal section of the study area, was the main reason mentioned by respondents who believe that the number of people involved in palm exploitation decreased in the last five years (Table 3.11). Again the same perceptions of trends were also verified among the palm users, who mostly believe that palm abundance in the area has increased (51%) and the number of people who collect palms has also increased in the last five years (37%) (Table 3.11).

Table 3.11: Perceptions on palm management and trends on palms abundance and number of people involved in palms exploitation over the last five years

Characteristic	Categories	Overall households	% overall households	Palm users	% Palm users
Control over palms exploitation	No control	105	59	41	72
	From the local traditional leaders	19	11	8	14
	Tappers in the area	4	2	4	7
	Don't know	51	29	4	7
Activities to conserve palms	Don't cut small stems	15	8	7	12
	Don't cut the entire stem	8	5	2	4
	Collect only unopened leaves	9	5	2	4
	Do not burn the area	5	3	3	5
	Don't cut *P. reclinata* when it is flowering or fruiting	1	1	1	2
	Nothing	72	40	34	60
	Don't know	71	40	8	14
Palm cultivation	Grow palms	2	1	0	0
	Have seen someone growing palms	15	8	3	5
Change in palm abundance over last five years	Increased	57	32	29	51
	Decreased	39	22	12	21
	Same	45	25	13	23
	Don't know	38	21	3	5
Change in number of palm users over last five years	Increased	38	21	21	37
	Decreased	28	16	9	16
	Same	27	15	7	12
	Don't know	86	48	20	35

3.5 Discussion

The results revealed that palm use is currently not a prevalent activity amongst households in the Zitundo area, with only 32% currently involved in palm exploitation. This low prevalence can be related to two factors: firstly, to the increase in local job opportunities associated the growing tourism sector and secondly, to substitution of some palm products by industrially manufactured ones (e.g. plastic brooms and baskets and alcoholic beverages). De la Torre *et al*. (2009) believed that the low incidence of palm uses founded in the Yucatan peninsula, a touristic destination area, compared to Amazonian Ecuador was related to the Yucatecan preference for paid employment related to an expanding tourism industry. In the Yucatan peninsula palm resources had also being replaced by industrial products (de la Torre *et al*., 2009). A shift from palm thatch roofing to corrugated tin was also observed in Madagascar by Byg and Balslev (2001b).

Thirteen palm products in six categories are used in Zitundo area. This number of uses is within the range reported by Byg and Balslev (2001b) and de la Torre *et al*. (2009). Byg and Balslev (2001b) found 12 different uses for the palm *Dypsis fibrosa* in Madagascar, while de la Torre *et al*. (2009) reported an average of 10 and 12 uses in Ecuadorian Amazon and Yucatan peninsula, respectively. Tools and utensils was the category with the most uses, seven out of the 13. This concords with findings from Araújo *et al*. (2016) for babassu palm (*Attalea speciosa*) in eastern Amazon, and Macía *et al*. (2011) in a review on palm uses in northwestern South America reported tools and utensils as the second largest category. In contrast Paniagua-Zambrana *et al*. (2007) and Cámara-Leret *et al*. (2014) found that food and construction were the two dominant uses categories in western Amazon and northwestern South America, respectively. The different results obtained by these two last authors and this study may be related the fact that their results are based in many more species than this study (Paniagua-Zambrana *et al*., 2007 results are based in 38 species and Cámara-Leret *et al*., 2014 results are based in 120 species). Leaves, particularly from *H. coriacea*, were the organ with most utilities. This corroborates findings from Amwatta (2004), Macía *et al*. (2011), Campos *et al*. (2015) and Araújo *et al*. (2016). Amwatta (2004) and Araújo *et al*. (2016) observed that in Kenya and eastern Amazon, leaves were the most commonly used part of *Hyphaene compressa* and *Attalea speciose*, respectively. Additionally, Macía *et al*. (2011) reported that in northwestern South America fruits, stems and leaves were the most useful parts of the Arecaceae family, while Campos *et al*. (2015) mentioned that in northeastern Brazil, leaves and fruits of *Attalea speciosa* are the main parts used. The long unopened leaf and the strength and durability of *H. coriacea* fibre make them versatile for a diversity of weaving work (Cunningham, 1985). Byg and Balslev (2001a) argued that palm species attributes determine the uses of a given species.

Although *H. coriacea* was the species with more current uses than *P. reclinata*, there were no statistical differences on the number of uses between them, as indicated by the current use value index. The current use value index of *H. coriacea* was 0.28 while *P. reclinata* was 0.22. These are lower than the ones reported by Phillips and Gentry (1993a), Phillips *et al.* (1994) and Milanesi *et al*. (2013). Phillips and Gentry (1993a) in a study in Peru found an average use value index of 3.0 for the Arecaceae family. In the southeastern Peruvian Amazon the palm use value index ranged between 3.0 and 4.4, while the use value index of *Euterpe edulis* in southern Brazil was 0.68

(Milanesi *et al*., 2013). The differences in the use value index between different studies and different taxa must be analyzed with caution, since as mentioned in introduction the use of this index has some limitations. For instance, the differences in the use value index between this study and the above mentioned ones could be related to the latter studies not differentiating between practiced uses and known uses while this study did.

Palm wine, broom and basket production were the dominant uses of palms in the Zitundo area. Palm wine and basket production were the two most common uses of *H. coriacea* while *P. reclinata* was mostly used to produce brooms and palm wine. Forty percent and 21% of palm collectors reported producing palm wine from *H. coriacea* and of *P. reclinata*, respectively. The rate of palm wine exploitation is likely related to its commercial value in the area. According to Martins and Shackleton (2018), palm wine is a highly marketable commodity in Zitundo area, with an average commercialization index of 63%. Campos *et al*. (2015) also observed a preference for uses of *Attalea speciosa* that provide high monetary returns in northeastern Brazil. Although palm wine tappers in the Zitundo area preferred *H. coriacea* over *P. reclinata* for palm wine production (Martins and Shackleton, 2018), this study found no statistical differences in the importance value index for palm wine production between the two species. These results are likely due to the importance value index being estimated based on a respondent's knowledge and perceptions of the best species to produce palm wine and not in the actual species used as in Martins and Shackleton (2018).

Phoenix reclinata was more important for broom production and *H. coriacea* for basket production. Preference of *H. coriacea* for basketry was due to its strength and long unopened leaf as stated by 73% of respondents. According to Cunningham (1985) the leaves of palms from the genus *Hyphaene* are highly suitable for weaving due to their strength and length of fibre and have been used in several parts of Africa for basketry. *H. coriacea* has been widely used in South Africa (Moll, 1972; Cunningham, 1985; McKean, 2003); *H. petersiana* in Botswana, Namibia and Zimbabwe (Cunningham and Milton, 1987; Konstant *et al*., 1995; Sola *et al*., 2006); *H. thebaica* in Sudan (Cunningham, 1985) and *H. compressa* in Kenya (Amwatta, 2004). The majority of respondents believed that *P. reclinata* is more important for broom production than *H. coriacea* since the stem has many flexible fibres which facilitates development of a suitable broom. Manufacture of brooms and brushes from the stem of *P*. *reclinata* was also reported by Orwa *et al*. (2009), while Kinnaird (1992) reported broom production from the leaf rachis in Kenya and Gyan and Shackleton (2005) and Mjoli and Shackleton (2015) reported production of hand brushes from the leaves in Eastern Cape, South Africa.

Although current palm exploitation was low, the majority of villagers have knowledge of its uses. Ninety-nine percent of all respondents knew at least one use of palms compared to 32% who reported using palms. The discrepancies between known uses and practiced uses were also reflected in the knowledge and the current use value indices of both species. For *H. coriacea* the knowledge use value was 3.7 against the 0.3 of current use value while, for *P. reclinata* was 2.1 versus 0.2. *H. coriacea* showed no significant correlation between the number of known and practiced uses while *P. reclinata* showed a very weak association. The absence of association between known and practiced palm uses were also observed by Campos *et al*. (2015) in Brazil, where just 14% to 17% of known *Attalea speciosa* uses were being practiced. Additionally, Byg and Balslev (2001b) and Martins de Andrade *et al*. (2015) also found discrepancies between palm use knowledge and use in Madagascar and Brazil, respectively. Byg and Balslev (2001b) reported that although all the informants in their study cited thatching as one of the uses of *Dypsis fibrosa*, it was used by less than half for this purpose. From the 537 leaf uses of the palm *Syagrus coronata* recorded by Martins de Andrade *et al*. (2015) only 151 were practiced by artisans in Bahia state, Brazil. Byg and Balslev (2001b) argued that the disparities between known and practiced uses may suggest an ongoing change on the use of a given resource due to factors such as declining in resource abundance and higher availability of manufactured substitutes, which could be occurring in Zitundo.

Respondents reported 17 uses organized in six categories. Most of the known uses and categories overlapped with the ones currently being practiced, with the exception of the cultural uses, which were not practiced by any of the respondents. This lack of engangement on cultural uses of the two species could be an indication of ongoing changes on the socio-cultural and socio-economical values in the study area. According to Vandebroek and Balick (2012) cultural homogenization and desire for modernization are some of the factors linked to the disappearance of traditional practices involving plant use. Likewise, Kala (2007) recorded a decline in the traditional and ceremonial use of wild edible species in Indian Himalaya due to socio-economic changes in the area.

Respondents in the area knew significantly more uses of *H. coriacea* than *P. reclinata*, as shown by the knowledge use value index. *H. coriacea* had a knowledge use value of 4.0 against 2.0 of *P. reclinata.* These results are within the range of those obtained by Byg and Balslev (2001b) and Cámara-Leret *et al*. (2016). Byg and Balslev (2001b) found that in Madagascar the average number of *Dypsis fibrosa* known uses was 2.3, while Cámara-Leret *et al*. (2016) reported a range between 2.0 and 7.0 in Mesoamerica and northwestern South America. The known palm uses in the study area followed the currently practiced uses trend, with palm wine production from both species being again the most known use, followed by basket production from *H. coriacea* leaves and brooms from both species. Furniture fabrication using *H. coriacea* leaves was also cited by over 50% of the informants. Broom and furniture making from *H. coriacea* leaves apparently are not customary uses of palms in the area and appear to have been recently introduced by migrants from other parts of country.

The two palm species are also important in the culture and traditional belief systems of residents in Zitundo. The use of palm wine in the traditional ceremony of libation to invoke, remember and worship ancestors, was cited by 25% of respondents. Gruca *et al*. (2014), in a review of the ritualistic uses of palms in sub-Saharan Africa, found that palm wine was also used in Kenya and South Africa as offerings and sacrifices to the ancestors. Libation is one of the most common and important rituals in African culture, being used to ask for blessings and protection from the ancestors and can be performed at the familiar or community level (Agyarko, 2005). These two palms are also used to produce skirts and anklets used during traditional dances, as reported by 20% of respondents, and for decoration and protection during weddings. The use of palm frond skirts by Liberian and Zambian dancers during traditional festivities was likewise reported by Gruca *et al*. (2014). This author also cited the use of *Dypsis fibrosa* fronds to decorate houses during religious festivities in Madagascar and of *Raphia vinifera* leaves suspended at village entrances in Cameroon to protect against evil. The importance of the palms in Zitundo folklore was also revealed by the high number of respondents who cited knowing the proverb that compares people's behavior to *P. reclinata* physiognomy and by the diversity of meanings reported.

The regression analysis results showed that the village of residency influences participation in palms exploitation. Residents from Phuza, Massale, Huco and Ndovo are more likely to engage in palm exploitation while residents from Malongane are less so. The positive influence of living in Phuza, Huco, Ndovo and Massale in palm exploitation can be related to the comparatively high palm availability in these villages while the negative influence of living in Malongane to the greater job opportunities there. Phuza and Ndovo are located within the palm savanna, where palm abundance is high (Martins and Shackleton, 2018) additionally, the surroundings of Huco and Massale are characterized by a mosaic of forests interrupted by patches of palm savanna. On the other hand, Malongane is a coastal village where coastal vegetation, with very low palm abundance dominates. Malongane has been experiencing in expansion on tourism facilities and activities that increase job opportunities. This result is in line with Martins and Shackleton (2018) who found that in Zitundo area most of palm tapping activities occur in Phuza and Ndovo. According to Paniagua-Zambrana *et al*. (2017) unmeasured factors such as the village's level of marginalization or integration in markets, surrounding vegetation composition as well as ethnic makeup of its residents can have unexpressed contributions to the village influence.

The influence of village was also evident in the palms current use value index and in a lesser extent on the knowledge use value. People who live in Malongane practiced fewer *H. coriacea* uses as did people who lived in Ponta de Ouro, also a coastal village, for both species. However, living in Ponta de Ouro positively influenced the number of *H. coriacea* known uses. As previously stated, Ponta de Ouro has received a lot of migrants from other ethnic groups looking for job opportunities in the growing tourism sector. These migrants bring with them new knowledge and skills enriching the body of palm uses knowledge. Jury *et al*. (2011) stated that Ponta de Ouro is a multi-ethnic community, where about 90% of people are informally employed in tourism services. Byg and Balslev (2001b) and Paniagua-Zambrana *et al*. (2017) also found that the village of residency influences the palm use knowledge in Madagascar, and Bolivia and Peru, respectively.

Regression analysis suggests that men in Zitundo practice more uses of *H. coriacea* than women. This was also corroborated by comparing the average current use value index for this species by gender using a Mann-Whitney test. Sunderland *et al.* (2014), in a global assessment of gender differentiation of forest product exploitation, also found that men collect a higher diversity of forest goods than women. The physical strength required for the collection of certain products, the place specific customary patterns of natural resource use and ownership and the cultural obstacles in accessing markets and infrastructure, were some of the factors underlining gender differentiation in natural resources exploitation (Sunderland *et al*., 2014). For the case of palm exploitation in Zitundo, gender differentiation is possibly linked to three main reasons, namely: i) the physical strength required for the collection of some palm products (for example palm sap for palm wine production), indeed there is a general perception in the study area that tapping palms is a physically strenuous activity (Martins and Shackleton, 2018); ii) the fact that the majority of palm products are harvested for sale. Cavendish (2000) and Shackleton *et al*., (2001) found that men are often involved in the harvesting of high-value forest products for sale, while women are frequently engaged on the harvesting of NTFPs for household consumption, especially those that directly contribute to the household food security (Cavendish, 2000) and iii) the relatively large amount of time away from home needed for the collection of some palm products. For example, palm wine production is only done in palm savanna, and tappers spend an average of 25 hours per week on tapping activities which include collecting sap three times a day (Martins and Shackleton, 2018). According to Sunderland *et al*. (2014) women generally prefer collecting activities that allow them to be closer to home since in many cultures they are responsible to care for the younger children and for other household chores such as meals preparation.

It has been highlighted in the literature that the gender differentiation in natural resources exploitation is the main factor shaping the differences in knowledge of resource uses between men and women (Voeks, 2007; Martins *et al*., 2014, Araújo *et al*., 2016). In this study, however, gender did not have any significant influence on palm uses knowledge. Paniagua-Zambrana *et al*. (2017) also found no gender differences in the use knowledge of two acaí species (*Euterpe precatoria* and *E. oleracea*) in Bolivia and Peru. However, gender differences in palm uses knowledge were found by Byg and Balslev (2001b), Paniagua-Zambrana *et al*. (2014) and Araújo *et al*. (2016). Byg and

Balslev (2001b) and Paniagua-Zambrana *et al*. (2014) found that in Madagascar and northwestern South America, respectively men know more palm uses while Araújo *et al*. (2016) found that women from eastern Amazon know more babassu (*Attalea speciosa*) uses. However, caution is needed in extrapolating the results of gender influence in palm use and knowledge to the entire population of Zitundo, since in this study I interviewed more men than women. Therefore, further research on the influence of gender on palm use and knowledge might be needed in the area."

Being born in the same village of residency increased the number of *H. coriacea* practiced uses. This is probably linked to the long tradition of palm use in the area and that the majority of migrant's households move to the area to work in tourism facilities or construction. The literature shows conflicting results on the effect of migration status in the exploitation of plant resources. Coulibaly-Lingani *et al*. (2009) found no effect of migration status on the access of forest products in Burkina Faso. In the same way, Kar (2010) reported that in Bangladesh income derived from NTFP was not influenced by migration status of the head of household. In contrast, Malleson *et al*. (2014) stated that in Cameroon, Ghana and Nigeria native households were more likely to report NTFP based income than migrants.

In this study the age of the respondents had no influence on the number of practiced and known uses of both palm species. No age differentiation in the palm use and knowledge was reported by Martins *et al*. (2014) in central western Brazil, Campos *et al*. (2015) in northeastern Brazil and Paniagua-Zambrana *et al*. (2017) in Peru. However, Araújo *et al.* (2016) and Paniagua-Zambrana *et al*. (2017) found that older people in eastern Amazon and Bolivia respectively, know more uses of babassu and asaí palms. The lack of age differentiation in palm use knowledge can be an indication that no knowledge erosion has been occurring in Zitundo area (Phillips and Gentry 1993b) or that the assimilation of this kind of knowledge occurs early in life (Byg and Balslev, 2001b). Phillips and Gentry (1993b) argued that erosion of plant use knowledge is one of the possible reasons for relatively high plant use knowledge among old people.

Comparison of the perceptions on management and palm abundance changes over the years between all respondents and the palm users shows the same trend. More than 50% of all the respondents believe that there is no control over palm exploitation in Zitundo. This belief was also common among palm users (Table 3.11). This is contrary to Martins and Shackleton (2018) findings that 68% of palm wine tappers in the area reported needing permission to start tapping. However, the perception of the respondents on changes in palm abundance and activities to conserve palms agree with Martins and Shackleton's (2018) findings. Thirty-two percent of all the respondents and 51% of palm users in this study believe that palm abundance is increasing against the 22% and 21% of all respondents and palm users, respectively, who believe that is decreasing. Martins and Shackleton (2018) reported over 60% of palm tappers perceived increases in palm abundance. Forty percent of the study respondents stated that nothing is done to conserve palms. This percentage was even higher among the palm users (60% of palm users). This echoes the results from Martins and Shackleton (2018) who reported 62% of palm tappers not doing anything to conserve palms. On the other hand 22% of all respondents stated that palm conservation activities exist in the area. Among palm users 27% declared practicing some type of activity to conserve palms (Table 3.11)

3.6 Conclusion

This study highlights the knowledge and uses of the palm species *H. coriacea* and *P. reclinata* in the Zitundo area, southern Mozambique. Thirteen palm products are actually exploited in the area. Despite this diversity of palm uses, there is a tendency to exploit products with more commercial value such as palm wine, brooms and baskets. Palm wine is produced from the sap of both species, however there is a preference for *H. coriacea* for basketry and for *P. reclinata* for brooms. These two palms also play a significant role in the culture and traditional beliefs system of people from Zitundo, being used in traditional ceremonies and are part of local folklore. The knowledge about the uses of these two palms is widespread among Zitundo residents, however few people are currently engaged in palm exploitation. The increase in job opportunities in the coastal section of Zitundo in conjunction with the great availability of substitute products appears to have diluted palm exploitation in the area. Village of residency and some household demographic characteristics appear to determine knowledge and exploitation of palms in the area. The village influence factor appear to be linked to palm availability, ethnic diversity, job opportunities and market marginalization or integration among the villages. The three palm products with potential commercial value can play an important role for income generation, especially in the areas with limited employment opportunities. Coincidentally these are areas with higher palm abundance and therefore deserve to be included in future local development initiatives by the government and development agencies. The perceptions among people of Zitundo are that palms are abundant and an open access resource with no local or formal management systems. This suggests a role for management strategies and harvesting guidelines for each species based on scientific and traditional approaches to promote resource conservation and livelihood contributions.

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CHAPTER FOUR: THE PRODUCTION AND COMMERCIALIZATION OF PALM WINE FROM *HYPHAENE CORIACEA* AND *PHOENIX RECLINATA* IN ZITUNDO AREA, SOUTHERN MOZAMBIQUE[2]

4.1 Abstract

In southern Mozambique a traditional wine is produced using the sap from two palm species, *Hyphaene coriacea* and *Phoenix reclinata*. Production of palm wine is one of the main livelihood activities in the Zitundo area. We examined the local production and trade of palm wine in the area. Using structured interviews we investigated the tapping activity, local management practices and the palm wine market, and assessed the incomes derived from palm wine sales and the tappers' perceptions on productivity, abundance and sales fluctuation. Tapping palms was practiced year round in five of the sixteen villages in the area and the mean number of palms tapped per day was 102 ± 52 per tapper. Tappers spent an average of 25 ± 18 hours per week on tapping activities resulting in an average return to labour of R39 (+ US$3) per hour. The mean, annual, net income from palm wine sales was R24 981 ± R12 094 (US$1 878 + 909) per tapper, which accounted for 85% ± 22% of the tappers' annual household income. Palm wine is a highly commercial commodity in Zitundo area, with an average commercialization index of 63% ± 23%, and is likely to help alleviate poverty in the area. Hyphaene coriacea was tapped more than Phoenix reclinata, although most tappers regard the wine from the latter to be of a better quality. The importance of palm tapping in local livelihoods and poverty alleviation needs greater acknowledgement by government and development agencies in the area, towards inclusion in sectoral development policies and conservation programmes.

Keywords: Non-timber forest products, local trade, income, dependency, commercialization index, perceptions.

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[2] Martins, A.R.O., Shackleton, C.M., 2018. The production and commercialization of palm wine from *Hyphaene coriacea* and *Phoenix reclinata* in Zitundo area, southern Mozambique. South African Journal of Botany 116, 6-15.

4.2 Introduction

Harvesting and trading non-timber forest products (NTFPs) is an important source of income to many rural households, particularly in areas where other economic opportunities are scarce (Dovie *et al*., 2005; Angelsen *et al*., 2014). According to Shanley *et al*. (2016) about 1.5 billion people globally utilize or sell NTFPs. Although some NTFPs can enter international markets, most are traded at local and regional level (Shackleton *et al*., 2007a; Shanley *et al*., 2016), which, according to Shackleton *et al.* (2007a), are growing via the entry of new products and the expansion of the existing trade. These local markets are especially important for marginal groups who, due to their lack of formal education, skills and isolation, have limited formal sector income-earning opportunities (Shackleton *et al.* 2008).

Shackleton *et al.* (2011) listed four main reasons for individuals or households to participate in NTFP trade, including i) as a short-term safety-net to smooth household shocks, fill income gaps, and cope with special needs when facing emergencies or tribulations; ii) diversifying livelihood strategies by using NTFP income to complement other sources of income; iii) as the main source of income, when some level of specialization in a given NTFP generally occurs; and iv) as a last resort strategy due to the lack of other income earning or livelihoods opportunities. In southern Africa, there are multiple examples and case studies of each, but as yet the relative magnitude of each of these has not been ascertained.

Frequently the economic returns derived from local NTFP sales are considered to be modest (Emery and Zasada, 2001; Pearce and Pearce, 2001; Shackleton *et al.*, 2007a), and are often insufficient to fully support a household (Wilkie *et al*., 2001). However, most studies do not disaggregate part-time or casual traders from full-time ones, which serves to underestimate mean incomes for full-time traders. For example, Shackleton *et al*. (2007b) demonstrated that returns per unit time worked are frequently higher for NTFP trade than other unskilled wage opportunities, were such opportunities available. Both absolute income from NTFPs as well as dependency on this source of income varies across countries and regions (Heubach *et al.*, 2011; Saha and Sundriyal, 2012; Stanley *et al*., 2012; Adam *et al.*, 2013; Angelsen *et al.*, 2014). The meta-analysis of Stanley *et al*. (2012) on ecological and economic sustainability of NTFPs, found that, on average, in African and Latin American countries, NTFP income accounts for 25% of the total household income, only slightly higher than the share of 23% in Asian countries. Additionally Angelsen *et al.* (2014) conducted a global comparative analysis of environmental income across 24 developing countries, and found that both absolute environmental income and dependency were higher in Latin America ($US 1 473 per annum and 32% for absolute income and dependency, respectively), with Africa ranking third in absolute income ($US 304 per annum) and second in dependency (30%). Income from NTFPs, as well as dependency, can be influenced by several factors, such as i) ecological conditions (Coomes *et al*., 2004; Mugido and Shackleton, 2017); ii) seasonality of resource exploited (Shackleton, 2004); iii) trader's socio-economic characteristics including age, household size, education, assets, income opportunities, residency time and ethnicity (Gavin and Anderson, 2007; Heubach *et al.*, 2011; Angelsen *et al*., 2014; Khosravi *et al*., 2016; Mjoli and Shackleton, 2015); and iv) market accessibility (Barbier, 2010; Adam *et al*, 2013; Mugido and Shackleton, 2017). From the studies mentioned above, it is clear that the effect of NTFP trading on livelihoods must be understood within the specific social-ecological context of individuals and households.

An important NTFP produced and traded by households in many countries is palm wine. Palm wine is a fermented beverage produced from the sap of various species of palms (Mbuagbaw and Noorduyn, 2012), and is common in areas of Asia, Africa and Latin America with high palm abundance (Johnson, 1992; Tapsoba *et al*, 2014). In these areas, palm wine has a nutritional, sociocultural and economic importance (Lasekan *et al*., 2007; Mbuagbaw and Noorduyn, 2012). According to Campbell (1969) palm sap is rich in riboflavin, vitamin B and nicotinic acid, thereby contributing to the diet of people who use it. Palm wine is also a mandatory beverage for many traditional ceremonies in many African societies (Okon and Okorji, 2014), and has been used in Nigerian traditional medicine to treat malaria, measles, and jaundice and to promote breast milk production in nursing women (Bassir, 1968; Okon and Okorji, 2014). The trade in palm wine is also an important economic activity in many areas, providing income, not only to the palm tappers, but also to a variety of other market chain participants (Okereke, 1982; Cunningham, 1990a; b; Naidu and Misra, 1998; Dalibard, 1999; McKean, 2003; Mbuagbaw and Noorduyn, 2012; Babitseng and Teketay, 2013; Okon and Okorji, 2014).

Hyphaene coriacea and *Phoenix reclinata* are the two dominant species in the palm savanna of the Maputaland coastal plain which covers the southeastern parts of Maputo province in southern Mozambique and northeastern parts of Kwazulu-Natal in South Africa. These species are a source of edible fruits, weaving materials and palm wine. Cunningham (1985; 1990a; b) and McKean (2003) investigated the role of these species in the local economy and the effects of harvesting on the species in the same ecoregion in neighbouring South Africa. According to Cunningham (1985; 1990a; b) although individual profits from palm wine sales are small (R30 - R70), the regional income from palm wine sales, transportation and resale is large (about R158,000 or R410,000 p.a. in current terms), providing income for nearly 500 people in the area. Furthermore Cunningham (1985; 1990a; b) suggested that the exploitation of *H. coriacea* for palm wine at the time of his study was close to maximum capacity in the area, while the level of domestic and commercial harvesting of *H. coriacea* leaves for basketry was low and below the optimal capacity (Cunningham, 1988). McKean (2003) found that *H. coriacea* leaf harvesting in KwaZulu-Natal (South Africa) had negligible impact on leaf production.

Palm wine production from *H. coriacea* and *P. reclinata* is an ancient activity in southern Mozambique. According to Cunningham (1990a), palm wine tapping has been practiced in this area since the early iron age around 1500 BP. Presently, production and trade of palm wine is regarded as one of the main livelihood activities in the Zitundo area, southern Mozambique. However, the level of production and trade is unknown, as are local practices and management. Local data on harvesting, trading and management practices, along with biological data such as the ecology, abundance, population structure, and dynamics of the exploited species, are important to assess the conservation status of traded species and in designing conservation and development plans (Svarrer and Olsen, 2005; te Velde *et al*., 2006; Ticktin, 2015). Therefore, this study examined the local production and trade of palm wine in the Zitundo area of southern Mozambique. Specifically we i) describe the tapping activities, local management practices, local trade and the perceptions on productivity, abundance and sales fluctuations; ii) determine the incomes derived from palm wine sales, the level of dependency on palm wine income and the palm wine commercialization index; and iii) identify the factors that influence the income earned, the level of dependency and palm wine commercialization index.

4.3 Methods

4.3.1 Study area

The study was conducted in five of 16 villages that compose the Zitundo Administrative Post in Matutuine district, southern Mozambique, namely Phuza, Ndovo, Mabucuti, Zitundo-sede and Huco. They were selected because they are the sites where palm wine tapping activities occur. With the exception of Huco, these villages are within the palm savanna, where *H. coriacea* and *P. reclinata* are the dominant tree species, with approximately 602 and 252 stems per hectare, respectively (Martins and Shackleton, 2017). Beside palm savannas, dry forests, swamp forests, grasslands, wetlands, and estuarine vegetation are found in the Zitundo area (Kirkwood, 2014). The climate is tropical to sub-tropical with mean annual temperatures of approximately 23˚C, and precipitation between 750 mm to 888 mm p.a. (Mander and Pollet, 1994). Physiographically the area is a low coastal plain with elevations around 50 m (McKean, 2003). The soils are sandy and gray with low agricultural potential (McKean, 2003).

The Zitundo Administrative Post covers an area of 864 km^2 (INE, 2009), with a population of 6 674 people (MAE, 2012) in 1 777 households, and an average of four people per household (INE, 2009). Fifty-two percent of the Zitundo population is male, the illiteracy rate is 27% and the poverty incidence was 78% in 2005 (MAE, 2012).The majority of the population are of the Ronga ethnic group, which have occupied the area for more than 500 years (Shaffer, 2010). The main livelihood activities in the area include subsistence agriculture, goat and cattle herding, wild fruits and wild plant collection, beekeeping, fishing, hunting, charcoal production, craft and mat production as well as palm wine production (Governo do Distrito de Matutuine, 2008; Shaffer, 2010).

4.3.2 Data collection

Thirty-seven tappers were interviewed between February and August 2016. Preceding the commencement of the survey permission was obtained from the Zitundo traditional leader (Zitundo Régulo) and the local community leaders, and ethical clearance was obtained from Rhodes University. All participants were briefed about the purpose of the research and informed that participation was voluntary. We obtained the consent from the interviewees and the confidentiality of the information received was assured. We identified and selected the first tappers with the help of local leaders, and interviewed all other tappers as identified by their fellow tappers working in these areas. We were not able to interview all the tappers in the area (around 50 tappers work in the area) because some were out of the country (in South Africa) in the days the interviews took place and a few declined to participate. The interviews were conducted in the tappers native language Ronga and took place in the locations where they harvest the species on a regular basis as well as in Phuza market. A questionnaire survey was conducted to gather information on: i) tapper demographics and socioeconomic characteristics; ii) sources of income and assets; iii) amounts harvested, activity timing, and techniques used; iv) quantities traded, selling prices, costs involved and income derived; v) management practices and potential constraints; vi) perceptions on resource abundance, rate of regrowth, changes over time, drivers of change and sustainability of the activity.

4.3.3 Data and statistical analyses

Descriptive statistics (mean, standard deviation, and frequencies) were used to summarize the data. Frequencies were expressed as number and percentage of tappers. Hierarchical cluster analysis was used to group tappers according to different characteristics and tapping strategies. Parameters used in the analysis are presented in Table 4.1. After the different clusters were identified, ANOVA was used to test for differences among the different clusters.

To assess the contribution of palm wine sales to household income, palm wine weekly returns were calculated based on the quantity of palm wine sold, multiplied by the selling price. The weekly amounts were converted to annual figures conservatively assuming 40 weeks of trade per year. Annual profit was calculated by subtracting from the gross annual returns all costs associated with the palm wine extraction and transport to the market. Returns to tapping-labour were calculated by dividing the palm wine profit by the time spent in tapping activities (Eaton and Sarch, 1997; Avocèvou-Ayisso *et al.*, 2009). Total household income was calculated as the sum of all income generated from all activities reported by the tappers. The level of dependency on palm wine income was subsequently calculated as the share of income from palm wine trade to total income (Vedeld *et al.*, 2004; Tugume *et al.*, 2015; Moe and Liu, 2016). The dependency level was adjudged high when the contribution of palm wine sales to the total income was above 60%; moderate (40% - 60%) and low if it was below 40% (Singh *et al.*, 2010). To assess the contribution of palm wine income to poverty alleviation we estimated the proportion of tappers with incomes below the national (MEF, 2016) and international poverty line (World Bank, 2015) for the different types of income (total income, palm wine income, other than palm wine income). The national poverty line is 26.7 Meticais/day (MEF, 2016) equivalent to 5.3 Rands and US$1.90 /day (World Bank, 2015), and the international one US$1.90 per day, equivalent to 25.3 Rands (exchanged rate used: 1 Rand = 5 Meticais and 1 USD = 13.3 Rands as of August 2016). Values were expressed in Rands because this is the currency used by the tappers in the region.

A palm wine Commercialization Index (CI) was adapted from the Household Commercialization Index (HCI) proposed by Govereh *et al*. (1999) and Strasberg *et al*. (1999) and modified to estimate the level of commercialization of palm wine following Abu (2015) and Baiyegunhi and Oppong (2016). The palm wine Commercialization Index was calculated by dividing the quantity of palm wine traded by the quantity of palm wine produced. The quantity of palm wine produced per tapper per day was obtained by multiplying the number of palms tapped per day by the average sap production per stem per day. Daily sap production was then converted to weekly sap production by multiplying by five days. We used five days instead of seven for conservative purposes since two days a week the tappers participate in the palm wine market which reduces tapping time and consequently sap production. The palm wine Commercialization Index was categorized in high when the index was above 50%; moderate (25% and 50%) or low when 25% (Abu, 2015).

Inferential statistics were used to determine the factors affecting sales profit, the level of dependency on palm wine income, the palm wine Commercialization Index, and the adoption of conservation practices. Ordinary Least Square multiple regression was used to determine the factors that influence the sales profit, and Fractional Logistic Regression (Papke and Wooldridge, 1996) was used to analyze the factors that influence the tappers' dependency and Commercialization Index. Since regression estimates from a logistic model are difficult to interpret because the model is nonlinear in parameters, marginal effects were calculated to assess the magnitude of change in the dependent variable due the explanatory variable. Furthermore binominal logistic regression was used to analyze the effects of tappers' characteristics on adoption of conservation practices. The explanatory variables used in the models are presented in Table 4.1.

Statistical analyses were performed using SAS 9.4 and Stata 13.1. A variance inflation factor, and the Breusch Pagan test were used to check for multicollinearity and heteroscedasticity in the data, respectively, used for the multiple regression analyses. Because both multicollinearity and heteroscedasticity were detected, the tests on the regression coefficients used heteroscedasticity consistent standard errors. The multicollinearity was resolved by dropping the variables that were causing it (tappers age, years living in the area, tapping as main source of income, and years of schooling, since these variables were highly correlated to respectively number of years tapping, move to Zitundo to tap palms, other activities while tapping, and know how to read and write). The variables chosen to remain in the model were believed to be more relevant and could better explain the dependent variable. We selected the Fractional Logistic Regression to model dependency and Commercialization Index since both variables are fractions bounded between zero and one (Papke and Wooldridge, 1996). The estimation procedure utilizes robust standard errors in case residuals are heteroscedastic.

Table 4.1: Description of variables used in the statistical analysis (a are variables used in the cluster analysis, b are explanatory variables used in the regression analysis and c are variables dropped from the regression analysis)

Variables		**Description**
Demographic	Gender[a, b]	One for male, zero otherwise
	Age[c]	Age of the tapper (years)
	Age group[a]	≤ 20, 21 – 30, 31 – 40, 41 – 50, 51 – 60 and > 60 (years)
	Ethnicity[a, b]	One if was Ronga, zero otherwise
	Place of birth[a ,b]	One if was born in Zitundo administrative post, zero otherwise
	Years living in the area[a, c]	Number of years the tapper is being living in Zitundo administrative post
	Household size[a, b]	Number of people living in the tappers house
Formal education	Education[a, c]	Number of years of schooling
	Literacy[a, b]	One if knowns how to read and write, zero otherwise
Socio-economics	Reason for moving to Zitundo[a, b]	One if moved to area to tap palms, zero otherwise
	Main source of income[a, c]	One if tapping is the main source of income, zero otherwise
	Other sources of income[a, b]	One if tapper has, zero otherwise
	Palm wine sales profit[a]	Annual tappers net profit from palm wine sales
	Total annual tappers income[a]	Annual tappers net total income
Tapping site	Tapping in Phuza area[a, b]	One if tapper taps in Phuza area, zero otherwise; this was the dropped dummy for tapping site to avoid perfect multicollinearity and therefore was used as the reference
	Tapping in Ndovo area[a, b]	One if tapper taps in Ndovo area, zero otherwise
	Tapping in Mabucuti area[a, b]	One if tapper taps in Mabucuti area, zero otherwise
	Tapping in Zitundo-Sede area[a, b]	One if tapper taps in Zitundo-Sede area, zero otherwise
	Tapping in Huco area[a, b]	One if tapper taps in Huco area, zero otherwise
	Tapping only *Hyphaene coriacea*[a, b]	One if tapper taps only *Hyphaene coriacea*, zero otherwise
Tapping characteristics	Years tapping[a, b]	Number of years each tapper have been tapping
	Tap entire year[a, b]	One if tapper taps the entire year, zero otherwise
	Palms tapped per day[a, b]	Number of palms each tapper taps per day
	Time spending in tapping activities[a, b]	Number of hours each tapper spend in tapping activities
	Distance to market[a, b]	distance from the tapping site to the market (km)

4.4 Results

4.4.1 Profile of tappers

The palm wine tapping activity was dominated by males (92%) between 21 and 40 years old (Table 4.2). The mean age was 37 ± 12 years old. With an average of only four years of schooling, the level of literacy among the tappers was low, with only 41% of tappers knowing how to read and write. The majority of tappers (68%) belonged to the Ronga ethnic group. Job-seeking emigration is widespread, since only 35% of tappers were born in the Zitundo area, and 27% were born in South Africa. Twenty-seven percent of the tappers live in South Africa and cross the border to Mozambique almost every day to tap. Thirty-two percent of tappers affirmed that they moved to Zitundo to tap. A lack of other job opportunities was the main reason (stated by 73% of tappers) to enter the palm wine trade, while 22% said that they entered this activity to increase their household income. On average, tappers have been in the trade for 12 ± 12 years, and many of the tappers had learnt to tap from their parents (32%) or friends (27%). The mean size household size was 5 ± 3 persons. Tapping palms was the main source of household income for 78% of the tappers. Other household cash income sources included: working as a shepherd (22%), other activities (palm wine transportation to the market, selling baskets, and cleaning work) (8%), cattle trade (8%), old-age pension (5%) and child pension (3%).

Table 4.2: Profile of palm wine tappers in Zitundo area

Characteristic	Categories	No.	%
Gender	Male	34	92
	Female	3	8
Age (years)	≤ 20	2	5
	21 – 30	11	30
	31 – 40	14	38
	41 – 50	4	11
	51 – 60	5	14
	> 60	1	3
	Mean ± SD	37 ± 12	
Education	Can read and write	15	41
	Years of school (mean ± SD)	4 ± 4	
Ethnicity	Ronga	25	68
	Matsua	5	14
	Changana	3	8
	Other	4	11
Place of birth	Zitundo area	13	35
	South Africa	10	27
	Inhambane Province	6	16
	Other	8	22
Reason for moving to Zitundo area	Already lived in Zitundo	11	30
	Tapping	12	32
	Work	11	30
	Harvest *H. coriacea* leaves	1	3
	Make furniture using *H. coriacea*	1	3
Reason for entering tapping activity	Increase household income	8	22
	Lack of job opportunities	27	73
	Good business	1	3
	Opportunity to work for oneself	1	3
Years tapping	Mean ± SD	12 ± 12	
Household size (Nº persons)	Mean ± SD	5 ± 3	
Main source of income	Tapping	29	78
	Work as a shepherd	8	22
Other cash income sources	Yes	9	38
	None	23	62

4.4.2 Tapping palm sap for wine production

Tapping activities for commercial purposes occurred in five of out of the sixteen villages in Zitundo Administrative Post. The majority of tappers carried out their activities in Ndlovo area (46%) followed by Phuza area (43%) (Table 4.3), Huco (5%) and three percent each for Mabucuti and Zitundo-Sede. *Hyphaene coriacea* was the main species tapped, with 60% of tappers saying that they only used this species, against the three percent that used solely *P. reclinata*, and 38% that used both species. The main reasons for favoring *H. coriacea* was its softer stem than that of *P. reclinata*, which made tapping easier, and its higher abundance in the area.

Tappers tapped an average of 102 ± 52 palms per day and they spent an average of 25 ± 18 hours per week on tapping activities, which includes walking to and from the tapping site, site and stem preparation, as well as tapping. The tapping process starts with the selection of clonal palm clusters which contain most stems of a desirable size. A tapper then fills the cluster with dry leaves and grass and burns it to clear the area. The remaining leaves are then cut off and the stems are debarked and sliced until the sap start flowing. The sap that flows in the first day is disposed, because they believe that it causes stomach ache and diarrhea. After that, the sap is collected two to three times a day until the stems dries up. Each time the sap is collected the stems are sliced to stimulate sap flow. If the sap continues flowing even after the above-ground section of the stem is cut down to ground level, they dig around it to uncover the below-ground section and tap it. Palm wine production is a year-round activity for most tappers (89%). The other 12% tap at different periods of the year and invoked reasons such as: i) the need for rest because tapping is a hard activity (5%), ii) having other activities to do (3%), and iii) tapping only in periods when sales are high (3%). The main challenges faced by tappers include (i) palm weevil infestations that destroy the tapped stems (51%), (ii) bees sucking the sap from tapped stems, which reduces the amount of sap collected (43%), and (iii) elephants that eat and destroy the tapped stems (22%).

Table 4.3: Characteristics of tapping activity in Zitundo area

Characteristic	Categories	No.	%
Species tapped	*Hyphaene coriacea*	22	60
	Phoenix reclinata	1	3
	Both	14	38
No. of palms tapped per day	Mean ± SD	102 ± 52	
Nº of hours per week spent tapping	Mean ± SD	25 ± 18	
Tapping season	All year	33	89
	Several months	4	11
Problems faced	Palm weevil infestation	19	51
	Bees suck the sap	16	43
	Elephants eat and trample tapped stems	8	22
	Birds destroy the tapped stem	3	8
	Other	5	13
Who taught them how to tap	Parents	12	32
	Grandfather	4	11
	Other family	6	16
	Friend	10	27
	Seeing others tapping	4	11

The cluster analysis separated the tappers into three clusters and a single outlier (Table 4.4). The largest cluster comprised of 73% of the tappers and other two clusters 14% and 11%, respectively. The variables responsible for the significant differences between the clusters were (i) whether or not the tapper was born in Zitundo Administrative Post, (ii) if they could read and write, (iii) years living in the tapping area, (iv) tapping palms at Ndovo and Huco sites, (v) the number of palms tapped per day, and (vi) the total annual tappers income.

Table 4.4: Characteristics of palm wine tappers per cluster

Parameters	Clusters				P-value
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	
No. of tappers (% of total tappers)	27 (73)	4 (11)	5 (14)	1 (3)	
Place of birth (% of clusters tappers)	4 (15)	4 (100)	4 (80)	1 (100)	< 0.0001
Years living in the area (Mean ± SD)	8 ± 12	44 ± 11	32 ± 17	38 ± 0	0.004
Literacy (% of clusters tappers)	14 (52)	0 (0)	0 (0)	1 (100)	0.020
Total net annual tappers income (Mean Rands ± SD)	30 275 ± 13 824	19 754 ± 9 148	67 144 ± 42 681	78 256±0	0.040
Tapping in Ndovo area (% of clusters tappers)	16 (59)	0 (0)	0 (0)	0 (0)	0.001
Tapping in Huco area (% of clusters tappers)	0 (0)	0 (0)	1 (20)	1 (100)	0.010
No. of palms stems tapped per day (Mean ± SD)	91 ± 37	75 ± 36	174 ± 75	150 ± 0	0.010

4.4.3 Palm wine trade

The tappers sell their product on local markets, averaging about 173 l per week per tapper (Table 4.5). The average price in 2016 was R4.1 ± 0.4 per litre. The mean weekly return per tapper was R716 ± 334 while the mean annual return was R28 649 ± 13 352. The mean annual fixed costs were R180 ± 99, mostly for containers, while the mean annual transport cost was R3 489 ± 2 387, summing to a mean annual total cost of R3 668 ± 2 465 per tapper. Consequently, the mean annual profit from palm wine sales was R24 981 ± 12 094 per tapper, while the hourly return to labour from tapping was R39 ± 41 (Table 4.5).

4.4.4 Palm wine income dependency, commercialization index and role in poverty alleviation

On average, income from palm wine sales accounted for 85% ± 22% of a tapper's annual income, with the dependency level ranging from 35% to 100%. Most (78%) tappers had dependency levels above 60% being therefore, highly dependent on palm wine sales income, against the only three percent that showed low dependency (less than 40%). Palm wine is a highly commercial commodity in the Zitundo area, as demonstrated by the commercialization index, and appears to have a positive impact on alleviating poverty (Figure 4.1). The palm wine commercialization index ranged from 23% to100%, with an average of 63% ± 23%. The majority of tappers (65%) sell more than 50% of the palm wine they produce, whilst only five percent sell less than 25%. When palm wine income is not included accounted about 73% and 65% of tappers fall under the World

Bank international poverty line and the national poverty lines, respectively. When palm wine income is included only 5 % fall below the national poverty line, and none below the international poverty line.

Table 4.5: Average annual costs and income from palm wine production and sales

Parameter		Mean ± SD
Income	Palm wine sales per week (l)	173 ± 79
	Weekly returns (R)	716 ± 334
	Annual returns (R)	28 649 ± 13 352
Costs	Containers (R/yr)	180 ± 99
	Transportation (R/yr)	3 489 ± 2 387
	Total costs (R/yr)	3 668 ± 2 465
Profit	Palm wine sales profit (R/yr)	24 981 ± 12 094
Labour	Time spending in tapping activities (hours/yr)	1 013 ± 720
	Returns for labour (R/hour)	39 ± 41

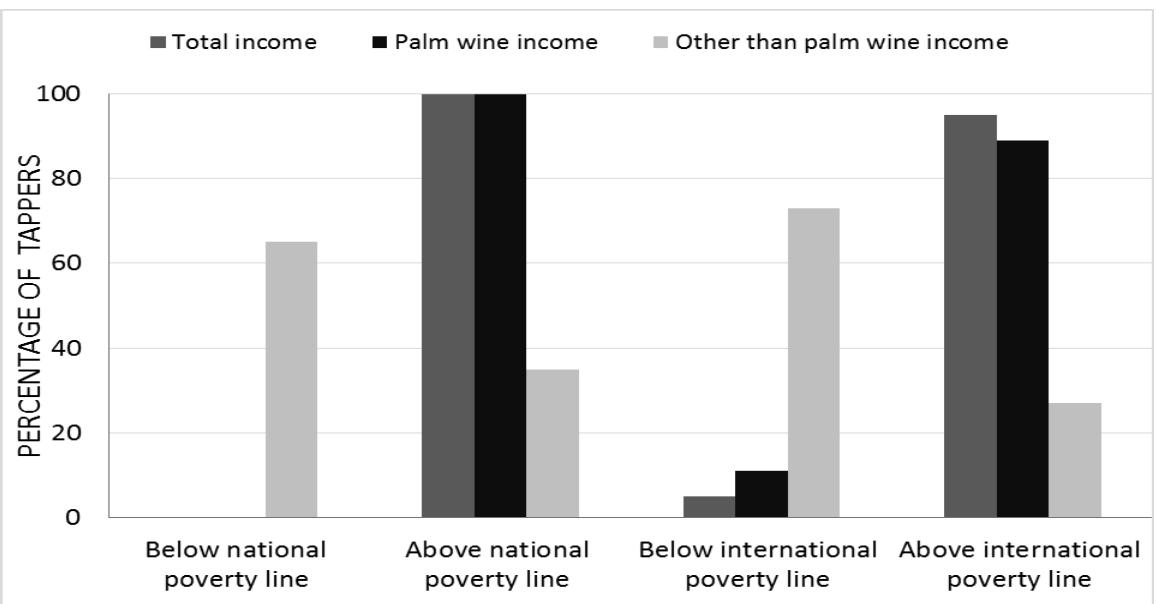

Figure 4. 1: Proportion of tappers under national and international poverty lines for different kinds of income

4.4.5 Factors affecting palm wine profit, dependency level and commercialization index.

The results of the regression analysis indicated that 70% of the variation in sales profit is accounted by the explanatory variables included in the regression model (Table 4.6). Additionally, these variables explained 34% of variation in palm wine income dependency, but only 14% of variation in the commercialization index (Table 4.7). Five variables had a significant influence on palm wine profit; place of birth, tapping only *H. coriacea*, and the number of palms tapped per day had a positive influence on profits, while tapping in Zitundo-sede area, and the number of years tapping palms had a negative influence (Table 4.6).Tapping in Mabucuti and Zitundo-sede, as well as the number of years tapping palms, increased the level of dependency on palm wine income, whereas tapping in Ndovo site and having other sources of income decreased the level of dependency (Table 4.7). On the other hand, bigger households and tapping in Huco site increased the Commercialization Index while tapping more palms per day and tapping in Zitundo-sede site decreased the index (Table 4.7).

Table 4.6: Ordinary Least Square regression estimates for palm wine sales profit

Independent Variable	Estimates	P-value
Gender	4210.22	0.48
Ethnicity	- 6785.60	0.1344
Place of birth	15114	0.01
Size of household	584.79	0.20
Literacy	3655.79	0.32
Reason to move to Zitundo	3372.91	0.34
Other sources of income	-2452.34	0.36
Tapping in Ndovo area	-1174.60	0.70
Tapping in Mabucuti area	-572.20	0.93
Tapping in Zitundo-Sede area	-15346	0.001
Tapping in Huco area	-7361.20	0.56
Tapping only *Hyphaene coriacea*	5962.80	0.03
Years tapping	-391.99	0.02
Tap entire year	5189.47	0.36
Palms tapped per day	167.12	<0.0001
Time spending in tapping activities	-56.92	0.38
Distance to market	-364.46	0.93
R-Square		0.70

Table 4.7: Fractional Logistic Regression estimates and marginal effects for level of dependency on palm wine income and commercialization index

	Dependency Level			Commercialization Index		
Independent Variable	Estimates	Marginal effects	P-value	Estimates	Marginal effects	P-value
Gender	1.93	0.17	0.08	0.33	0.11	0.14
Ethnicity	1.13	0.10	0.19	014	0.05	0.70
Place of birth	0.10	0.01	0.94	- 0.07	- 0.02	0.86
Size of household	- 0.16	- 0.01	0.20	0.07	0.02	0.01
Literacy	1.85	0.16	0.12	0.25	0.08	0.31
Reason for moving to Zitundo	2.88	0.25	0.03	0.18	0.06	0.43
Other sources of income	- 1.72	- 0.15	0.03	- 0.22	- 0.07	0.29
Tapping in Ndovo area	- 2.51	- 0.22	0.01	- 0.03	- 0.01	0.91
Tapping in Mabucuti area	15.40	1.35	<0.0001	- 0.15	- 0.05	0.59
Tapping in Zitundo-Sede area	15.75	1.38	<0.0001	- 0.49	- 0.16	0.02
Tapping in Huco area	- 1.46	- 0.13	0.56	1.01	0.33	0.03
Tapping only *Hyphaene coriacea*	0.73	0.06	0.25	0.69	0.22	<0.000
Years tapping	0.07	0.01	0.02	- 0.01	- 0.003	0.17
Tap entire year	- 1.76	- 0.15	0.18	0.60	0.19	0.05
Palms tapped per day	0.02	0.001	0.19	- 0.01	- 0.002	0.002
Time spending in tapping activities	- 0.06	- 0.05	0.11	0.01	0.003	0.05
Distance to market	1.06	0.09	0.25	0.50	0.16	0.09
R-Square			0.34			0.14

Palm wine is an export commodity. The majority of the tappers sold the palm wine at Phuza market (87%) which is close to the international border with South Africa and where most buyers come from South Africa and purchase the wine for resale (Table 4.8). Forty-six percent of the tappers stated that the palm wine sales were higher during Christmas and Easter holiday seasons, while 22% of tappers believed that the sales did not vary through the year. Ninety-two percent of tappers affirmed that the price is adjusted annually and the new price is set by the tappers at a tappers meeting (Table 4.8).

Table 4.8: Palm wine markets in Zitundo area

Characteristic	Categories	No.	%
Markets	Phuza	32	87
	Pontinha bridge	2	5
	Huco	2	5
	Phuza and S. Africa	1	5
Main buyers	South African women	14	38
	South African men and women	19	51
	Migrant workers from S. Africa	2	5
	Neighbours	2	5
Price decision	Annual tappers meeting	25	68
	Traditional leader decides	5	14
	Other	5	14
	Don't know	2	5
Season with higher sales	Christmas and Easter holiday	17	46
	Same throughout the year;	8	22
	Summer	7	19
	Other	3	9
	Don't know	2	5

4.4.6 Perceptions on productivity, abundance and sales fluctuation

The tappers estimated that each tapped stem produces an average of 0.6 ± 0.3 l of sap per day, and lasts for about 56 ± 24 days before the sap flow ceases. Sixty-two percent of tappers believed that sap production is highest during winter (Table 4.9). This is because the cool temperatures during winter do not dry out the tapped stem as is the case during summer. Ninety-seven percent of tappers said that *H. coriacea* produces more sap than *P. reclinata*, mainly because the stem of *H. coriacea* is thicker than the *P. reclinata* (35%) and lasts longer before drying out (35%). However, 38% of the tappers felt that *P. reclinata* sap produces a better wine against the 27% who believed that *H. coriacea* does so. The higher alcohol content (22%) and sugar (16%) present in *P. reclinata* wine were the main reasons it was considered better.

Sixty-eight percent of tappers believed that the palm abundance in the area had increased in the past five years, against only 19% that believed that it had decreased. The high rate of lateral shoot production after being tapped was mentioned by 60% of tappers as the main reason for the increase in palm abundance. Tappers that considered palm abundance to have decreased mentioned several reasons for the decrease: i) increase in the number of tappers (8%), ii) the removal of the stem meristem (3%), iii) increase in trade (3%) and iv) that tapped stems take a long time to recover (3%). Seventy percent of respondents said that the number of tappers in the area had increased, and that the increase was mainly due to the lack of job opportunities in the area (27%) and because sales of palm wine provide a high profit (14%). Fifty-seven percent of tappers considered that the number of palm wine buyers had increased, attributed to higher profitability of palm wine resale in South Africa (32%), while five percent believed that the increase was due to a rise in the number of consumers.

4.4.7 Local management of palms for palm wine production

Tappers in Zitundo stated that they follow some local conservation practices. All respondents said that they do not tap all palm stems within a cluster. Ninety-six percent mentioned leaving the smaller stems to grow to be used in future. The mean stem height targeted for tapping was 57 ± 42 cm. Forty-three percent of tappers affirmed that the minimum stem height used was between 10 and 30 cm while 35% believed that it should be between 31 and 50 cm. Twenty-two percent of tappers believed that it takes one to two years growth to reach the minimum stem size for tapping. Seventy percent of tappers believed that tapping activities do not affect the growth and reproduction of the palms while 11% believed that it does. The results show that although the reasons for doing so may vary, there are local management practices followed by tappers with regard to number of stems left uncut and leaving smaller steams to grow.

Sixty-eight percent of tappers stated that permission is required to start tapping in the area either from tappers already in the area (43%), by the traditional leaders (22%) or the site owner (3%) and that there is no need to pay for that permission. Regarding the distribution of tapping sites among tappers 76% stated that is made through agreement between the tappers already in the area and the new tapper and 14% said that the traditional leader is the one who assigns tapping sites for the new tapper. Sixty-two percent of tappers stated that they don't do anything to conserve the palms while 38% said that they conserve the palms. Practices used by the tappers to conserve the resource include: i) not tapping small stems (22%), ii) not finish the entire tapped stem (11%), iii) use insecticide to protect tapped stems from palm weevil attack (3%), iv) not tap *P. reclinata* because it bears edible fruits and v) a traditional ceremony made in Phuza by traditional leaders to protect palms from dying (3%). None of the tappers said that they cultivate the palms and never saw anyone cultivate them. The binomial logistic regression (Likelihood ratio = 6.73, P-value = 0.45) could not explain the factors that influence the adoption of palm conservation practices by the tappers.

Table 4.9: Perceptions on productivity, abundance and sales changes

Characteristic	Categories	No.	%
Daily sap production (l/stem)	Mean ± SD	0.6 ± 0.3	
No. of days the stem lasts	Mean ± SD	56 ± 24	
Season with highest sap production	Winter	23	62
	Summer	5	14
	Same	6	16
	Don't know	3	8
Species with highest sap production	*Hyphaene coriacea*	22	60
	Phoenix reclinata	8	22
	No difference	2	5
	Don't know	5	14
Species that produces the best wine	*Phoenix reclinata*	14	38
	Hyphaene coriacea	10	27
	No difference	5	14
	Don't know	8	22
Change in palm abundance over last five years	Increased	25	68
	Decreased	7	19
	Same	3	8
	Don't know	2	5
Change in number of tappers over last five years	Increased	26	70
	Decreased	4	11
	Same	4	11
	Don't know	3	8
Change in the number of buyers over last five years	Increased	21	57
	Decreased	1	3
	Same	12	32
	Don't know	3	8

Table 4.10: Local management practices of palms in Zitundo area

Characteristic	Categories	No.	%
Minimum stem height target for tapping (cm)	10 – 30	16	43
	31 – 50	13	35
	51 - 100	6	16
	> 100	2	5
	Mean ± SD	57 ± 42	
Years required to reach minimum size	Don't know	16	43
	1 – 2	8	22
	3 – 4	5	14
	5 – 6	5	14
	> 6	3	8
Permission to tap	Don't need	12	32
	From the tappers already in the area	16	43
	From the area traditional leaders	8	22
	Site owner	1	3
Effects of tapping on plants	Doesn't affect	26	70
	Reduces stem growth	4	11
	Reduces sexual reproduction	4	11
	Only if over tapped	5	14
	Don't know	2	5
Activities used to conserve palms	Don't cut small stems	8	22
	Don't cut the entire stem	4	11
	Use insecticide against palm weevil	1	3
	Don't cut *P. reclinata* because it bears edible fruits	1	3
	Traditional ceremony to protect the palms	1	3
	Nothing	23	62

4.5 Discussion

The results revealed that palm wine tapping and trading in southern Mozambique was dominated by young males, aged between 21 and 40 years. This accords with other studies showing that palm wine tapping and trading is mainly a man`s activity (Okereke, 1982; Lebbie and Guries, 2002; Babitseng and Teketay, 2013; Okon and Okorji, 2014; Asa and Eyo, 2015). The dominance of young men in this activity can be related to the perception that tapping palms is a physically strenuous activity. Blockhus *et al*. (2002) also found gender differentiation in NTFP collection in Sri Lanka, where women were typically exempted from more physically demanding tasks. The majority of tappers had limited formal education, with an average of four years of schooling, and only 41% could read and write, thereby limiting their ability to compete in the formal employment sector. The level of illiteracy among tappers is higher than those reported for Zitundo Administrative Post region at 27% MAE (2012). Low levels of formal education and high illiteracy levels were also found by Makhado and Kepe (2006) among mat and basket crafters in Eastern Cape, South Africa; Gyan and Shackleton (2005) and Mjoli and Shackleton (2015) among *P. reclinata* hand brush traders in the Eastern Cape, South Africa; Shackleton *et al.* (2008) among NTFP sellers in a South African semi-arid savanna; Adam and Pretzsch (2010) among fruit vendors in Sudan and Okon and Okorji (2014) among palm wine tappers in Nigeria.

Palm tapping is an important livelihood activity in the area, being the main source of household income for 78% of the tappers. On average, tappers have been in the palm wine trade for 12 years. Lack of other job opportunities was the main reason stated by the tappers to enter the palm wine trade, probably being the reason for the relatively long period tappers stayed in the palm wine business. This is in the line with Shackleton *et al.* (2011) who mentioned that individuals and households frequently enter the trade of NTFPs due to lack of other livelihood or cash earning alternatives and this becomes a long-term source of income. Tapping palms yielded an average return to labour of R39 per hour, well above the local wage rate of R6 per hour working as a shepherd. Taking into account that other cash earning activities are scarce in the study area, these returns to labour can provide an important incentive to the people to enter and remain in the palm wine trade.

The majority of tappers carried out their activities at Ndlovo and Phuza areas, probably due to the comparatively high palm abundance in these two areas (Martins and Shackleton, 2017). *H. coriacea* was the main species used to produce palm wine. This confirms the findings of Cunningham (1985) in Kwazulu-Natal to the south and Martins and Shackleton (2017) in the same study area. Cunningham (1985) reported that 69% of all stems being tapped were *H. coriacea*.

The average number of stems tapped per day was higher than reported by other studies. We found that a tapper taps on average 102 stems daily against the 71 stems found by Cunningham (1985) for the same species in neighbouring Kwazulu-Natal, South Africa. This result can be related to differences in abundance between the two sites. According to Martins and Shackleton (2017), the density of *H. coriacea*, the preferred species for tapping, was higher in the study area than in Kwazulu-Natal, which means that distances between palms are shorter. Additionally, Cunningham (1985) estimated the number of tappers in Kwazulu-Natal to be around 200 against the around 50 tappers involved in tapping in Zitundo area (tappers, pers. comm.) suggesting that there is potentially more competition in the former. The lower number of stems tapped per day than the ones obtained in this study were also obtained for other palm species by Okereke (1982) and Lebbie and Guries (2002) for oil palm, *Elaeis guineensis*, in Nigeria and Sierra Leone, respectively; by Babitseng and Teketay (2013) for *H. petersiana* in Botswana and Okon and Okorji (2014) for *Raphia* palm, *Raphia* spp, in Nigeria. This can be an indication that tappers in southern Mozambique are trying to maximize their returns by increasing the number of palms tapped per day, since the palms in the study area are small, with lower sap yields, compared to the higher yields of the above mentioned studies (Cunningham, 1985).

The tappers sell their product on local markets. Phuza market, located adjacent to the South African border, was the main market, and major buyers came from South Africa and purchase the wine for resale. This echoes the findings of Kloppers (2005), who stated that undiluted palm wine is one of main products sold in Phuza market, which is then transported for resale in Manguzi and other areas outside of the palm savanna in South Africa. This consumption and trading of a given product among related ethnic groups living on both sides of a border is a common practice due to their shared cultural background (Ruiz Pérez *et al.*, 2000), as well as a disparity in incomes and purchasing power across the border.

Several authors have highlighted the low economic returns derived from local NTFP sales (Neumann and Hirsch, 2000; Emery and Zasada, 2001; Pearce and Pearce, 2001; Shackleton *et al.*, 2007a). Yet, the palm wine trade appears to be a profitable business is southern Mozambique as demonstrated by relatively good returns to labour. The results indicated that tappers earn average of R24 981 per annum, which is about three times higher than the Mozambican minimum wage for the agricultural and forestry sector. These results are within the range obtained by Lebbie and Guries (2002) for palm wine trade in Freetown, Sierra Leone, where sales income ranged between USD 2.18 and USD 10.63 (corresponding to USD 2.9 and USD 14.2 currently; R39 to R189) per tapper per day. However, the results obtained in this study are higher than those obtained by Cunningham (1985), Naidu and Misra (1998), Ndoye and Awono (2005) for palm wine sales income in South Africa, India and Democratic Republic of Congo, respectively, as well as Angelsen *et al.* (2014) for NTFPs in general at a global scale. Cunningham (1985) and Naidu and Misra (1998) reported that tappers annual income in South Africa and India were R390 (corresponding to about R4 578 in 2016 values) and 103 Indian Rupee (corresponding to about 319 today value, equivalent to R70), respectively, whereas Ndoye and Awono (2005) found that annual income per household from palm wine ranged between USD 13.2 and USD 228 (corresponding to USD 16.2 and USD 280.2, equivalent to R216 and R3 727).

Several factors may underlie the relatively high incomes encountered in this study. For instance, the daily number of stems tapped per tapper as well as the price of palm wine encountered by Cunningham (1985) was lower than those of this study. The price per litre of palm wine in Cunningham's (1985) study was 20 cents (equivalent to R2.4 now), compared to R4 of this study. Furthermore, market proximity as well as the costs involved during the product collection, processing and transportation such as: labour, technology, advertisement and transportation costs can also have a role in the profitability of NTFPs (Avocèvou-Ayisso *et al.*, 2009). For the Zitundo area, the palm wine market is close to the majority of tapping sites and most of the above-mentioned costs were not encountered; 95 % of the costs were for transport to the market. The results of the regression analysis indicated that the number of palms tapped per day increased the palm wine sales income, while tapping in Zitundo-sede area, the village located farthest away from the Phuza market, decreased the palm wine income. Neumann and Hirsch (2000) acknowledged that proximity between NTFP production and sales sites may contribute to high returns from some NTFPs sales.

The importance of palm tapping in the area was substantiated by the level of dependency on palm wine income. On average, income from palm wine sales accounted for 85% of the tappers' annual cash income and 78% of all tappers had dependency levels above 60%. These results are well above those found by Stanley *et al*. (2012), Angelsen *et al.* (2014), Melaku *et al.* (2014) and Tugume *et al.* (2015) for NTFPs in other African countries. Stanley *et al*. (2012) and Angelsen *et al.* (2014), in their respective studies, found that in African countries the dependency levels were 25% to 30%, while Melaku *et al.* (2014) and Tugume *et al.* (2015) found dependency levels in Ethiopia and Uganda were 47% and 40%, respectively. Factors such as, ecological conditions of the area (Coomes *et al*., 2004), seasonality of the resource (Shackleton, 2004), socio-economic characteristics of the traders (Gavin and Anderson, 2007; Heubach *et al.*, 2011; Angelsen *et al*., 2014; Khosravi *et al*., 2016) and market accessibility (Barbier, 2010; Adam *et al*, 2013) can influence the level of dependency on NTFP income and, therefore, account for the differences in the above-mentioned studies. High palm abundance, year-round resource availability, existence of a reliable market, low skills needed and lack of other income earning opportunities are likely to underlie the high dependency on palm wine income in the Zitundo area.

The results from regression analysis showed that the level of dependency is higher for tappers who moved to the area to tap. This may indicate that these tappers lack skills to compete in the formal labour market and therefore turn to tapping as an alternative, therefore increasing their reliance in the exploitation of NTFPs for their livelihoods. According to Shackleton *et al.* (2007a) some characteristics of local NTFP trade, such as low barriers of entry, minimal startup capital needed and low-intensity operational costs, make them appealing for those with limited formal education skills or with few other cash earning opportunities. Being engaged in this activity for long periods also increased the level of dependency. Shackleton *et al.* (2011) mentioned that when individuals enter the NTFP trade due to the lack of other livelihood opportunities and cash earning alternatives, the trade can become a long-term livelihood or cash earning choice, if the circumstance that propelled them into it persist. This appears to be the case of the palm wine trade in Zitundo. As expected, the results show that having other sources of income decreased the level of dependency on palm wine income, which is in line with results obtained by Illukpitiya and Yanagida (2008) in Sri Lanka and Tugume *et al.* (2015) in Uganda.

Palm wine is a cash oriented commodity in the Zitundo area, as demonstrated by the average commercialization index of 63%. Tappers with large households had a higher commercialization index. Baiyegunhi and Oppong (2015) also found that having more people in a household increased levels of commercialization of mopane worm in South Africa. Baiyegunhi and Oppong (2015) believed that households with high dependency ratios (i.e. more consumers than workers within the household) propels them to increase their income, and thus increasing the level of commercialization. Tapping site also had an influence in the level of palm wine commercialization; tapping at Huco increased it while tapping in Zitundo-sede site decreased it. This is probably related to the transportation costs. At Huco tappers sell palm wine from their houses, and therefore do not incur any transportation costs, while the Zitundo-sede site is located the farthest away from the Phuza market, therefore requiring high transport costs. Baiyegunhi and Oppong (2015) observed a similar result within South Africa where there was a decrease in the level of mopane worm trade with increasing distance to the market.

Palm tapping is clearly an important poverty reducing activity in Zitundo. The inclusion of palm wine income in total income resulted in a reduction in the proportion of tappers falling under the international and national poverty line from 73% to only 5% and from 65% to zero, respectively, a 65% to 68% reduction in poverty incidence. This is stark in the context of the high poverty incidence in Matutuine district, with Zitundo administrative at 78% (MAE, 2012). A high reduction in poverty among gum and resin traders were similarly noted by Abtew *et al*. (2014) in eastern Africa. Stanley *et al*.'s (2012) meta-analysis found that the income from NTFPs were above the international poverty line or the local wage rate in the majority of the cases studies for Africa and Latin America, suggesting therefore that NTFP exploitation can represent an appealing alternative to lift some relatively unskilled people above the poverty line. However, one must consider the amount of effort or time spent and report incomes accordingly, as those seeking to simply earn supplementary income by working a few hours per week will clearly earn less than those for whom NTFP trade is their primary livelihood activity in which they spend many hours per week (Shackleton *et al*., 2007a; 2008).

The tappers estimated that each tapped stem produces approximately 0.6 ± 0.3 liters of sap per day, and lasts for about 56 ± 24 days. The majority of tappers believed that *Hyphaene coriacea* is more productive than *Phoenix reclinata*, although the latter species yields a better wine. The daily sap yields mentioned by the tappers are above the 0.06 – 0.45 liters range recorded by Cunningham (1985) for the same species in South Africa. These differences are likely to be related to specific climate and soils conditions. Samsudeen *et al*. (2013) found that higher temperatures, cloudiness and wind velocity had a negative impact on sap production from *Cocos nucifera*, while higher precipitation increased the production of sap. The period tapped stems last before drying out mentioned by the tappers is within the ranges found by other authors (Cunningham, 1985; Naidu and Misra, 1998; Babitseng and Teketay, 2013) and are in line with findings of Cunningham (1985) during field observations of a selected tapper in Kwazulu-Natal, where he observed that *Hyphaene coriacea* and *Phoenix reclinata* sap production decreased around the 44^{th} day of tapping.

The majority of tappers believed that both the number of tappers and buyers in the study area had increased over the past five years. A shortage of other cash earning opportunities in the area, alongside the attractive profitability of palm wine sales, were perceived by the tappers to be the reasons driving the increase in the number of participants. Expansion in the number of people engaging in NTFPs trade was similarly reported by Shackleton *et al.* (2008) and Weyer *et al*. (2017). Shackleton *et al.* (2008) observed an increase in the number of traders of marula beer and brooms and mats, and Weyer *et al*. (2017) in the number of sellers and producers of several NTFP products. Both authors revealed that scarcity of other cash earning options were among the main reasons stated for the expansion of market participation. The expansion in palm wine trade does not appear to be currently driving a decline in palm abundance. The majority of tappers believed that palm abundance had increased in the past five years. The high rate of lateral shoot production after being tapped was mentioned by 60% of tappers as the main reason for this. This is supported by Martins and Shackleton (2017) who observed that the population structures of *H. coriacea* and *P. reclinata* in the study area are dominated by individuals in shorter size classes due to high vegetative reproduction via root coppicing. Many of the tappers consider that tapping does not affect the growth and reproduction of palms. However, Martins and Shackleton (2017) found a low rate of stem survival after being tapped along with low prevalence of stems with reproductive structures, because palms are normally tapped before reaching reproductive size, thus impacting recruitment through seeds. This may have long-term implications for recruitment and consequently requires monitoring.

Most of the tappers affirmed that the minimum stem height for tapping is between 10 and 50 cm, and it takes one to two years growth to reach this height. These results are below the 101 to 150 preferred size class for tapping for both species found by Martins and Shackleton (2017) in the study area, and 500 to 1 500 cm stated by Botswana tappers for *H. petersiana* (Babitseng and Teketay 2013). This may indicate a level of over exploitation. Furthermore, Cunningham (1985) reported that it takes five to eight years for a new coppice shoot to achieve a suitable size for tapping. Results show that although the reasons for doing so may vary, there are some local management practices followed by tappers in the area. For example, all interviewed tappers said that they do not tap all stems in a cluster, leaving the smaller stems to grow and to be used in future. This accords with results of Cunningham (1985) in South Africa. The palm wine tapping practice is done under a communal resource use system, and some level of permission by tappers already in the area and the traditional leaders is required to start the tapping activity in the area.

4.6 Conclusion

This study has demonstrated that palm wine is currently an abundant and valuable resource for tappers in the Zitundo area, southern Mozambique, being the main source of household income for more than 70% of tappers and contributing with more than 80% of tappers' total annual income. Palm wine tappers earn up to three times more than the national minimum wage for the agricultural and forestry sector. This income is high in comparison to other NTFP trade in local markets in southern Africa and locally it plays a key role in alleviating poverty. Demographic and socio-economic characteristics of the tappers, along with tapping strategies, appeared to determine the level of palm wine sales returns, commercialization index and the dependency on palm wine income. The high and continuous palm availability in the area, in conjunction with market presence and a shortage of other livelihood options appear to have encouraged the palm wine trade and contributed to the high level of dependency on it. The significant contribution of palm wine income to local livelihoods and poverty mitigation should be acknowledged by government and rural development agencies and incorporated into local development plans and agendas.

Hyphaene coriacea was favoured to produce palm wine above *P. reclinata*. The perceptions among the tappers is that palm tapping does not have many detrimental effects on the species abundance, growth and reproduction due to their higher capacity to coppice after being tapped. Yet previous studies have suggested that tapping palms has a negative impact on the recruitment of both palms species, consequently participatory population monitoring of the effect of tapping on palms should be implemented. Palms in Zitundo area are exploited in a communal tenure system, where some level of voluntary local management exists to try to conserve the resource for future use. However, with the expansion of the trade these measures might be tested in the future. Consequently, participatory conservation and management strategies should be designed and implemented by tappers and others stakeholders.

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CHAPTER FIVE: LIVELIHOOD DIVERSIFICATION AND PALM TRADE PROVIDE GREATER INCOMES THAN WAGE-BASED STRATEGY IN ZITUNDO AREA, SOUTHERN MOZAMBIQUE

5.1 Abstract

In most of southern Mozambique, rural households combine a range of economic activities to generate income, achieve food and nutrition security and fulfil all other livelihood objectives. The activities that rural households combine include: small-scale farming, fishing, hunting, livestock and timber production, non-timber forest products gathering as well as off-farm activities such as wage labour and small informal trading. This work surveys the livelihood patterns and the role of diversification and of palm income on the livelihoods of households from Zitundo area, southern Mozambique. Seven livelihood strategies were identified, with every strategy combining cash income from several sources. Most households adopt a wage-based strategy, although this strategy shows low potential for reducing poverty in the area. Households adopting a palm-based strategy show between 23% and 60% lower poverty incidences than those adopting alternatives strategies, but palm-based livelihood strategy was adopted by only 11% of households. Traders of palm products earn approximately a double the annual absolute income and per capita income than non-traders. Village of residency and some household socio economic and demographic characteristics appear to determine the households' choice of livelihood strategy and palm income dependency. The high adherence of households to a less remunerative wage strategy may indicate that other non-economic factors not included in this study also influence the choice of livelihood strategies and that future development plans and interventions to mitigate poverty in the area should go beyond the traditional agriculture sector, recognizing the role of palm and fishing for people's livelihoods.

Keywords: non-timber forest products; palm traders; palm income; income diversification; livelihood strategies.

5.2 Introduction

Most rural households rely on a diverse range of economic activities to generate income, achieve food and nutrition security and fulfill all other livelihood objectives (Scoones, 1998; Ellis, 2000; Tesfaye *et al*., 2011). Common rural livelihood activities in developing countries include: small-scale farming, fishing, hunting, livestock and timber production, non-timber forest products (NTFPs) gathering as well as off-farm activities such as wage labour and small informal trading (Mills *et al.*, 2017; Torres *et al*., 2018). The activities that households combine for a living are termed livelihood strategies (Ellis and Allison, 2004). One important and widely adopted strategy is diversification across several sources of income (Nielsen *et al.*, 2013; Addisu, 2017). Ellis (2000) defined livelihood diversification as "the process by which rural households construct an increasingly diverse portfolio of activities in order to survive and improve their standard of living".

The drivers of and goals for livelihood diversification vary among households. Ellis (2000) categorized them in two broad groups: necessity and choice, also called survival and accumulation, respectively. Necessity, or survival, involves involuntary and despair reasons to diversify, as a way to mitigate unexpected events, such as socio-economic and natural crises, that compromise livelihoods (Ellis, 2000; Tesfaye *et al*., 2011; Gautam and Andersen, 2016). On the other hand, choice, or accumulation, concerns intentional and proactive motivations to diversify, to manage seasonality, labour market prospects, risk, credit market failure, as well as to augment the asset base (Ellis, 2000; Tesfaye *et al*., 2011; Gautam and Andersen, 2016). Gautam and Andersen (2016) argue that since most motives for diversification are risk related it is mostly a risk management strategy, both a priori for mitigation and post for coping. In adopting a diversified livelihood strategy, households seek to optimally allocate labor into different activities, stabilize income and consumption over time, reduce risk susceptibility and accumulate assets, thereby, increasing their resilience and sustainability (Ellis, 2000; Nielsen *et al.*, 2013; Gautam and Andersen, 2016).

As highlighted in the Sustainable Rural Livelihoods framework (Scoones, 1998; Ellis, 2000) the choice of specific livelihood strategies and the kind and level of diversification is influenced by several factors, including: geographical location, biophysical resource base, infrastructure availability, policy and institutional context as well as the five categories of household assets/capitals, namely: natural, physical, human, financial and social. Natural capital includes the natural resources available to the household. Physical capital refers to production assets such as tractors, irrigation systems, boats, cars, etc. Human capital includes among others: education, training, family size, gender and labour. Financial capital comprises savings, access to credit, livestock holdings, etc. and examples of social capital are: membership and positions in social groups and interpersonal relationships (Jiao *et al*., 2017; Khatiwada *et al*., 2017). Due to the variability of rural economies around the world, these determinants and their influences on livelihoods and level of diversification are context specific (Agyeman *et al*., 2014; Nguyen *et al*., 2015) thus hindering generalization.

The use and trade of NTFPs is often a key livelihood option in many rural and urban areas of the developing world. NTFPs are an important source of cash and subsistence income, particularly in poor regions (Shackleton and Shackleton, 2004; Angelsen *et al.*, 2014; Nguyen *et al*., 2015). FAO (1997) estimates that 80% of the population in developing countries use NTFPs to meet some of their shelter, energy, health and nutritional needs. More recently Shanley *et al*. (2016) estimated that globally, 1.5 billion people use or trade NTFPs. According to Shackleton (2015) NTFPs play six roles in livelihoods: i) household provisioning, where NTFPs support direct household consumption needs for food, medicines, energy and shelter; ii) cash saving, where the free nature of NTFPs provisioning allows the limited cash to be saved or directed to other needs; iii) cash generation through casual or full-time trading to complement other sources or as the main source of income; iv) safety nets, as a mean to cope with social and environmental shocks; v) local culture, where NTFPs play an important role in folklore, traditions and rituals; and vi) providing supporting and regulating services as habitat, food and nesting grounds for other important NTFP species. In many instances these roles overlap.

The level of reliance on NTFP income varies across countries and regions as demonstrated by the comprehensive global analyses of Vedeld *et al*. (2007), Stanley *et al*. (2012) and Angelsen *et al.* (2014). Vedeld *et al*. (2007) found that, on average, NTFP income contributed 22% of the total income of rural households from developing countries. Stanley *et al*. (2012) revealed an average dependency on NTFP income of 25% in Africa and Latin America and 23% in Asia. Angelsen *et* *al.* (2014) showed that NTFPs contributes an average of 30% of the total household income from Africa and 32% from Latin America. At the local scale NTFPs contribution is influenced by: household characteristics such as age of the household head, household size, education, assets, and other income opportunities, amongst others (Heubach *et al.*, 2011; Angelsen *et al*., 2014; Khosravi *et al*., 2016). Beside household characteristics, other factors include abundance, seasonality and population structure of sought after NTFPs (Coomes *et al*., 2004; Shackleton, 2004; Mugido and Shackleton, 2017) as well as access to markets (Barbier, 2010; Adam *et al*, 2013; Mugido and Shackleton, 2017). The wide-ranging and sometimes conflicting results of the effects of these factors emphasize the necessity to understand the role of NTFPs on livelihoods in a specific social-ecological context.

An important NTFP source in many tropical and subtropical regions of the world are palm species (Balslev, 2011; Macía *et al*., 2011). Palms are sources of an array of products used for subsistence and commercial purposes (Johnson, 1992; Byg and Balslev, 2001; de la Torre *et al*., 2009). This also holds true for African rural livelihoods (Okereke, 1982; Amwatta, 2004; Martins and Shackleton, 2018). Foote *et al*. (2003) reported that in southern Zimbabwe income from *Hyphaene petersiana* wine and basketry sale is crucial during droughts and in between planting and harvesting seasons. Trade in thatch, basketry and mats from *Hyphaene compressa* is the second most important livelihood option for the nomadic pastoralists and agro-pastoralists groups from northern and eastern Kenya (Amwatta, 2004). Cash income from *Phoenix reclinata* hand brush sales is also the second-most important source in the Eastern Cape (Mjoli and Shackleton, 2015). According to Sunderland *et al*. (2008) about 52% of households in west and central Africa are involved in rattan exploitation for subsistence and income generation. Okereke (1982), Okon and Okorji (2014) and Asa and Eyo (2015) all reported that in Nigeria palm wine production is a profitable activity and helps supplement farm income. Similarly Lebbie and Guries, (2002) affirmed that palm wine income in Sierra Leone is several times higher than the national minimum wage.

In the palm savannas of southern Mozambique and northeastern Kwazulu-Natal, South Africa, the significance of *Hyphaene coriacea* and *Phoenix reclinata*, two common palm species, for the livelihoods of local people has been emphasized by Cunningham (1985; 1990a; b), McKean (2003) and Martins and Shackleton (2018). Cunningham (1985; 1990a; b) estimated over two decades ago, that in northeastern Kwazulu-Natal around 500 people benefit from regional palm income through sale, resale and transportation. The annual regional palm income was R158 000 (R410 000 in current values) (Cunningham 1985; 1990a; b) while regional income from *H. coriacea* frond trade was estimated by McKean (2003) as R27 600. On the Mozambican side, Martins and Shackleton (2018) recently found that palm wine revenue accounts for more than 80% of tappers' total income and is three times higher than the national minimum wage of the agricultural and forestry sector.

Despite these studies, the contribution of NTFPs to rural livelihoods in southern Mozambique has been little explored, especially with regards to palm species and products. Policies regarding use, management and conservation of palm products, and their integration into poverty reduction and development strategies are still lacking. Recognizing and describing the diversity of livelihood strategies, the factors underlining their adoption and the contribution of NTPFs to livelihoods is a vital first step to advocate for and influence rural development initiatives and policies that include NTFPs. Additionally, such information can also be used to help design management plans for NTFPs that are culturally and locally specific thus, more efficient in alleviating poverty whilst sustaining key NTFPs and landscapes. Therefore, this study examined the contribution of palm income to livelihoods and diversification in Zitundo area, southern Mozambique. Specifically I i) determine the sources and amounts of cash income; ii) estimate the level of household income diversification and the level of dependency on palm income; iii) classify the livelihood strategies prevalent in the area; iv) consider the factors that shape the choice of livelihood strategies, level of diversification and of palm income dependency and v) determine the role of income diversification and palm income on poverty levels.

5.3 Methods

5.3.1 Study area

Refer to Chapter 3 for the detailed information on the study area.

5.3.2 Data collection

I used the sustainable livelihoods framework (Scoones, 1998; Ellis, 2000) to describe the household livelihood strategy selection, the factors underlying the selection and the resulting outcomes. This framework is holistic, integrative and multidimensional thus, efficient in recognizing the complexities of livelihoods (Fisher *et al*., 2013). Following Chilongo (2014), Soltani *et al*. (2012) and Khatiwada *et al*. (2017) this study centered on three components of the framework: livelihood assets, livelihood strategies, and outcomes. Livelihood strategies are a set of income earning activities that a household pursues for a living (Ellis, 2000). Strategies adopted by a household are determined by the various assets or capitals owned or accessed by the household. Assets included the five types of capital recognized in the sustainable livelihoods framework. The outcomes resulting from a choice of strategy considered in this study are: total income, income per capita and poverty incidence. I further analyzed how these assets affect the household level of income diversification, measured as Simpson diversification index (SDI), and palm income dependency as well as how involvement in palm products trade affect the above mentioned outcomes.

Semi-structured interviews with household heads, or any other adult, were administrated between August 2015 and April 2016, to 179 randomly selected households from the 16 villages in the Zitundo administrative post. A sampling frame technique for each village was used to randomly select households to be interviewed. The respondents were informed about the objective of the study, the confidentiality of the information received and that participation was voluntary. One of the selected households did not agree to participate. Preceding the survey, ethical clearance was secured from Rhodes University and authorization was provided by the Zitundo traditional leader (Zitundo Régulo) and the village's community leaders. For further details on household sampling approach and strategy refer to Chapter 4.

The interviews took place in the respondent's home and were mainly conducted in Ronga, the language spoken by the majority of people in the area, with the rest of the interviews in Portuguese. The questionnaire accessed household: i) demographics and socio-economic characteristics; ii) palm use and income derived (quantities produced and traded, selling prices, costs involved and returns); iii) other sources of income and amounts; and iv) assets (car, tractor and boat ownership, land and livestock holdings and house size and construction material). Quantities were reported in local units and converted to SI units through weighing several samples. Interviews lasted 1-3 hours depending on the number of livelihood strategies.

5.3.3 Data and statistical analyses

The data was summarized using descriptive statistics, and frequencies were expressed as number and percentage of households. Income sources were classified into eight categories (adapted from Ellis (2000)): i) palm products, ii) other NTFPs, iii) agriculture, iv) fishing, v) livestock, vi) social grants, vii) wage and viii) other.

Although livelihoods include both cash income and subsistence consumption income (Ellis, 2000; Iiyama *et al*., 2008; Khatiwada *et al*., 2017), this study focus on cash income following Iiyama *et al*. (2008) and Khatiwada *et al*. (2017). I used cash income because the majority of households were not able to report the amount of agricultural products used for consumption since they would collect these products on demand. They were also not able to determine the amount of livestock consumed because it was done very rarely. According to Khatiwada *et al*. (2017) cash income is a suitable livelihood parameter especially to identify absolute poverty reduction livelihood strategies. However, it provides an underestimation of total income and the proportional contribution of non-cash livelihood activities. Thus, in this study the contribution of arable and livestock farming to livelihoods is under-estimated.

Income from social grants, wages and "other" were obtained from respondents' self-reported values, while palm products, other NTFPs, agriculture, fishing and livestock annual net incomes were estimated by multiplying the quantity of product sold in each activity by the local selling price, minus the costs associated with all purchased inputs, hired labour and transportation to the market, for each activity. The household own labour costs were not deducted from the gross income of each activity. Product output quantities, market prices and frequency of trade were obtained using household self-reported values. Total household annual income was calculated as the sum of all net income generated from all activities reported by the household.

Income from palm products included revenues from the sale of palm wine, brooms, baskets, furniture, hats and palm leaves. Other NTFPs income was acquired by selling reeds, reed mats, charcoal, thatch grass, medicinal plants and honey, harvested from local landscapes. Agricultural income was obtained from selling a variety of crops. Fishing income was obtained from selling wild caught freshwater fish. Income from livestock included revenues from cattle, goat and poultry sales. Social grants income included old-age pensions and child grants, while wage income included salaries received from permanent employment. "Other" income included income received from seasonal employment (called biscato), small resale commerce, and remittances, as well as transportation of people or goods to the market.

The level of dependency on each type of income was subsequently calculated as the share of income per activity to total income (Vedeld *et al.*, 2007). The level of dependency on palm income among households was analyzed by classifying the dependency level as high when the contribution of palm income to the total income was above 60%; moderate (40% - 60%) and low if it was below 40% (Singh *et al.*, 2010).

Income per capita was calculated by dividing the total household annual income by the household size. Income per capita was used to estimate the proportion of households with incomes below the national (MEF, 2016) and international poverty lines (World Bank, 2015) and to assess the contribution of palm income to poverty alleviation. The national poverty line is 26.7 Meticais/day (MEF, 2016), while the international poverty line is US$1.90/day (World Bank, 2015). These values are equivalent to 5.3 Rands/day and 25.3 Rands/day for the national and international poverty lines, respectively. Exchanged rate used were 1 Rand = 5 Meticais and 1 USD = 13.3 Rands as of August 2016. Values were expressed in South African Rands because it is the currency mostly used in the study area.

Household income diversification was calculated using Simpson diversification index (SDI), adapted from the Simpson index of diversity (Simpson, 1949). This index is widely used due to its robustness and easy calculation (Khatun and Roy, 2012). SDI considers the number of income sources as well as the distribution of income shares (Addisu, 2017). The index varies between zero and one; households with no income diversification will have a SDI value of zero while, values approaching one represent high levels of income diversification (Khatun and Roy, 2012; Addisu, 2017). Following Addisu (2017) the level of household income diversification was further adjudged high when the SDI was above 0.63, medium (0.39 - 0.63), and low if it was below 0.39. The SDI equation is (Khatun and Roy, 2012; Addisu, 2017):

$$SDI = 1 - \sum_{i=1}^{N} Pi^2 \qquad (1)$$

where *Pi* is the proportion of household income coming from the source *i* and *N* is the number of income sources.

A principal component analysis (PCA) based on the shares of income obtained from the eight different sources, followed by a two-step cluster analysis were used to group households into distinctive livelihood diversification strategies following Davenport *et al*. (2012), Soltani *et al*. (2012) and Khatiwada *et al*. (2017). PCA was first performed to reduce the correlation among the income share variables and to produce a new group of uncorrelated variables that are similar within themselves and heterogeneous among each other (Tesfaye *et al*., 2011; Soltani *et al*., 2012; Walelign and Jiao, 2017). The PCA resulted in six principal components, which explained 87% of the variance. The Kaiser criterion (Eigen values > 1) was used to determine the principal components to be retained. The six principal components were then used in hierarchical cluster analysis to determine the optimal number of clusters, which was then used to perform the K-means cluster analysis. This analysis corrects for possible misclassification of observations at the boundaries between clusters (Hair *et al*., 2010). The resulting clusters were considered as primary livelihood strategies. ANOVA followed by the Tukey's post-hoc test was used to assess differences in average absolute and relative incomes, income per capita and SDI among the different diversification strategies. Chi-square was used to test for equality of proportions of poverty incidence and the levels of diversification.

Fractional Logistic Regression (Papke and Wooldridge, 1996) was used to analyze the factors that influence household palm income dependency and SDI, while Multinomial Logistic Regression Model (Greene, 2000) was used to analyze the determinants of household livelihood strategies. The explanatory variables used in the regression models were identified following the household livelihood strategy framework (Nielsen *et al*., 2013) and portray proxies for different categories of household capital (Table 5.1). Ellis and Allison (2004) recognized that some resources play multiple roles, for example land can be categorized as both natural and physical capital, and livestock as financial and physical. Soltani *et al*. (2012) use village as location capital to account to environmental state and infrastructure. In this study I used village as natural capital to account to the villages' biophysical characteristics that influence the availability of natural resources. The index for the house value accounts for the number of rooms and wall, roof and floor material and was calculated using an adaptation of Porro *et al.* (2015) equation:

$$House\ value = 2 * R\ (a + b + c) \qquad (2)$$

where R is the number of rooms and a, b, c are expansion factors for walls, roof and floor materials, respectively. The expansion factors values were adapted from Malleson *et al.* (2008) and Porro *et al.* (2015) and were categorized as: i) wall materials: 0 = palm leaves, 1 = reeds, 2 = poles and mud, 3 = poles and cement, 4 = bricks; ii) roof materials: 0 = grass and palm leaves, 1 = aluminum and fiber-cement sheets, 2 = concrete; iii) floor materials: 0 = sand, 1 = mud, 2 = cement. The quantity of livestock was expressed as tropical livestock units (TLU) following Jahnke (1982) and Chilongo (2014) where cattle = 0.7, goat and sheep = 0.1 and chicken and duck = 0.01.

Statistical analyses were performed using SAS 9.4 and Stata 13.1. A Mann-Whitney U-test was used to assess significant differences for continuous variables of the household characteristics, absolute and relative incomes, SDI and poverty incidence between palm product traders and non-traders, while Chi-square tests for equality of proportions was used to compare categorical variables. A variance inflation factor was used to check for multicollinearity. Any variables causing multicollinearity were dropped (place of birth, literacy and existence of formal jobs in the household, since these variables were highly correlated to born in village, education and number of formal jobs in the household, respectively). The variables selected to continue in the models are more relevant and could better explain the dependent variables. Fractional Logistic Regression was selected to model palm income dependency and SDI since both variables are fractions bounded between zero and one (Papke and Wooldridge, 1996). The Multinomial Logistic Regression was appealing to model the choice of household livelihood strategies since the dependent variables are composed by more than two unordered nominal outcomes (Wooldridge, 2002). The estimation procedures utilized robust standard errors in case residuals were heteroscedastic.

Table 5.1: Variables used in the regression analysis

Capital	Measure	Description
Natural	Village of residency	1 - Tchovane, 2 – Vumindava, 3 – Mugovene, 4 – Gueveza, 5 – Xibaluine, 6 - Momole, 7 - Malongane, 8 - Ponta do Ouro, 9 – Phuza, 10 – Mussongue, 11 – Massale, 12 - Mabucuti, 13 - Gala, 14 – Huco, 15 – Ndovo, 16 - Zitundo – Sede (used as the reference)
	Size of the land	Amount of land owned by the household (ha)
Human	Gender	1 = female, 0 otherwise
	Age	Age of the head of household (years)
	Education	Number of years of schooling of the head of household
	Size of household	Number of people living in the house
Social	Ethnicity	1 = Ronga, 0 otherwise
	Born in village	1 = born in the village of residency, 0 otherwise
	Years living in the village	Number of years living in the village
	Leadership position	1 = leader (traditional, community, political, religious), 0 otherwise
Physical	House value	Index for the house accounting for number of rooms and wall, roof and floor material
	Car ownership	1 = car, 0 otherwise
	Tractor ownership	1 = tractor or mult-cultivator, 0 otherwise
	Boat ownership	1 = boat, 0 otherwise
Financial	TLU	Tropical livestock units
	Number of formal jobs in household	Number of people in the household with formal job

5.4 Results

5.4.1 Household characteristics

Refer to Chapter 3 for the detailed information on household characteristics.

5.4.2 Characteristics of palm products traders and non-traders

Seventeen percent of respondents derived some cash income from palm products. However, there were few differences in the demographics and socio-economic characteristics between palm traders and non-traders (Table 5.2). Both groups were mostly male, middle-aged (30–50 years old), born in and long-term residents of the region. Both groups had low formal education and most did not hold leadership positions. Fewer palm traders owned land (53%) than non-traders (83%). However, the average land size did not differ between the two groups (Table 5.2).

Table 5.2: Characteristics of palm product traders and non-traders (significant statistical differences between palm product traders and non-traders in bold)

Characteristic	Categories	Palm traders N = 30	Non palm traders N = 149	Overall N = 179
Gender	Male	25 (83)	111 (75)	136 (76)
	Female	5 (17)	38 (26)	43 (24)
Age (years)	≤ 20	0 (0)	2 (1)	2 (1)
	21 – 30	**4 (13)**	**2 (1)**	25 (14)
	31 – 40	8 (27)	45 (30)	53 (30)
	41 – 50	8 (27)	24 (16)	32 (18)
	51 – 60	6 (20)	28 (19)	34 (19)
	> 60	4 (13)	29 (20)	33 (18)
	Mean ± SD	45 ± 12	46 ± 15	45 ± 14
Education	Can read and write	13 (43)	88 (59)	101 (56)
	Years of school (mean ± SD)	**2 ± 3**	**4 ± 3**	4 ± 3
Ethnicity	Ronga	18 (60)	96 (64)	114 (64)
	Changana	6 (20)	23 (15)	29 (16)
	Matsua	2 (7)	12 (8)	14 (8)
	Bitonga	2 (7)	4 (3)	6 (3)
	Sena	1 (3)	3 (2)	5 (3)
	Other	1 (3)	11 (7)	11 (6)
Place of birth	Born in village of residency	13 (43)	48 (32)	61 (34)
	Zitundo area	16 (53)	60 (40)	76 (43)
Years living in the village	Mean ± SD	29 ± 18	25 ± 20	26 ± 20
Household size (nº persons)	Mean ± SD	5 ± 4	5 ± 3	5 ± 3
Leadership position	No position	27 (90)	121 (81)	148 (83)
	Traditional/community leader	2 (6)	20 (13)	22 (12)
	Religious leader	1 (3)	8 (5)	9 (5)
Formal jobs in the household	Formal Jobs	11 (37)	62 (42)	73 (41)
Land ownership	Own land	**16 (53)**	**124 (83)**	140 (79)
Size of land (ha)	Mean ± SD	0.5 ± 0.9	0.5 ± 0.7	0.5 ± 0.7

5.4.3 Household cash income sources and income diversification

Households in Zitundo area were dependent mainly on eight cash income sources: i) palms; ii) other NTFPs; iii) agriculture; iv) fishing; v) livestock; vi) social grants; vii) wages and viii) Other (includes small commerce and transportation). The average annual household absolute cash income was R22 598 ± R22 832, with an average annual per capita income of R6 502 ± R9 107. Wages were the major contributor to the total cash income, with an annual average of R9 375 ± R15 266 corresponding to 34% ± 44% of the annual income. Agriculture was the least with R754 ± R4 268 corresponding to 4% ± 15%. Palm income (R3 264 ± R10 738) contributed only approximately 10% ± 26 % for the total annual cash income, at the same level as social grants (Table 5.3), across the entire sample, but 57% for palm traders.

Beside the differences in palm income between palm traders and non-traders, there were also significant differences on other sources of absolute and relative income, such as wages relative income, total income and income per capita between the two groups. Palm traders had a higher average annual total cash income (R37 223 ± R34 007) and income per capita (R12 642 ± R14 440) than non-traders (R19 653 ± R18 663 and R5 266 ± R7 051, respectively), while the latter obtained a higher income from other sources (R2 806 ± 6 669) than the former (R347 ± R1 899). Palm income was the greatest income source for the traders (57% ± 38%), followed by wages (16% ± 26%), while wages (38% ± 46%) and "other" (16% ± 33%) were the highest sources for non-traders (Table 5.3).

Income diversification in the area was low, with an average SDI of 0.17 ± 0.22. Most households (75%) fell in the low income diversification class (Table 5.3). Palm traders showed higher income diversification than non-traders, being 0.31 ± 0.21 for traders against 0.14 ± 0.21 for non-traders (Table 5.3).

Table 5.3: Average absolute and relative cash incomes (Rands) and SDI (significant statistical differences between palm traders and non-traders in bold)

Income sources	Absolute cash income			Relative cash income		
	Palm traders (Mean ± SD)	Non palm traders (Mean ± SD)	Combined (Mean ± SD)	Palm Traders (%)	Non palm traders (%)	Combined (%)
Agriculture	2 514 ± 9 493	400 ± 1 871	754 ± 4 268	4 ± 11	4 ± 16	4 ± 15
Fishing	2 581 ± 7 130	3 126 ± 11 189	3 035 ± 10 603	10 ± 23	9 ± 24	9 ± 24
Livestock	4 995 ± 22 036	458 ± 2 427	1 218 ± 9 322	5 ± 17	5 ± 18	5 ± 18
Other	**347 ± 1 899**	**2 806 ± 6 669**	2 393 ± 6 198	**1 ± 3**	**16 ± 33**	14 ± 31
Other NTFPs	919 ± 2 405	1 024 ± 3 674	1 007 ± 3 488	5 ± 13	7 ± 20	7 ± 19
Palm products	**19 474 ± 19 525**	**0 ± 0**	3 264 ± 10 738	**57 ± 38**	**0 ± 0**	10 ± 26
Social grants	1 114 ± 3 518	1 640 ± 5 114	1 552 ± 4 879	3 ± 9	12 ± 29	10 ± 27
Wages	5 280 ± 11 699	10 199 ± 15 792	9 375 ± 15 266	**16 ± 26**	**38 ± 46**	34 ± 44
Total	**37 223 ± 34 007**	**19 653 ± 18 663**	22 598 ± 22 832			
Income per capita	**12 642 ± 14 440**	**5 266 ± 7 051**	6 502 ± 9 107			
SDI	**0.31 ± 0.21**	**0.14 ± 0.21**	0.17 ± 0.22			
Low diversification				**57**	**79**	75
Medium diversification				37	21	24
High diversification				**7**	**0**	1

The per capita incomes, relative incomes and diversification level were calculated for each household and averaged for each group.

R1 = USD 0.08 as of August 2016

5.4.4 Palm cash income, dependency and role in poverty alleviation

Among the palm traders, cash income from palm wine sales was the dominant source of income (R16 716 ± R19 024), contributing 86% of all palm income and covered 60% of traders (Table 5.4). On the other hand, palm fronds and hats contributed less than 2% of the palm income. Palm frond sales were only reported by one respondent and the sale of hats returned the smallest income (R50 ± R194) (Table 5.4). Although the overall dependency on palm income was low, with 89% of all households showing dependency levels under 40%, palms are a vital source of income for traders. Fifty percent of palm traders were highly dependent on palm income, with dependency levels above 60%, against 17% and 33% that showed moderate and low dependency, respectively (Figure 5.1). Palm income also plays a role in mitigating the level of poverty in Zitundo. There was a 6% increase in poverty incidence when palm income was excluded from the total cash income (Table 5.5). Thirty-one percent and 89% of households fall under the national and international poverty line, respectively, when palm income is excluded, against the 25% and 83%, respectively, when is accounted for. The poverty incidence was lower among traders than non-traders. Seven percent and 53% of traders fall under the national and international poverty line, respectively, when palm income is accounted for, against 29% and 90% of non-traders. However, there were no significant differences among the two groups when palm income is not considered (Table 5.5).

Table 5.4: Sources and net annual values of palm cash income

Product	Household (Nº)	Overall (%)	Traders (%)	Overall (Mean ± SD) (Rands)	Traders (Mean ± SD) (Rands)
Baskets	6	3	20	58 ± 433	343 ± 1 024
Brooms	7	4	23	96 ± 839	575 ± 2 008
Furniture	2	1	7	269 ± 3 384	1 603 ± 8 251
Hats	2	1	7	8 ± 81	50 ± 194
Palm fronds	1	1	3	31 ± 419	187 ± 1 022
Palm wine	18	10	60	2 802 ± 9 908	16 716 ± 19 024
Total				3 264 ± 10 738	19 474 ± 19 525

R1 = USD 0.08 as of August 2016

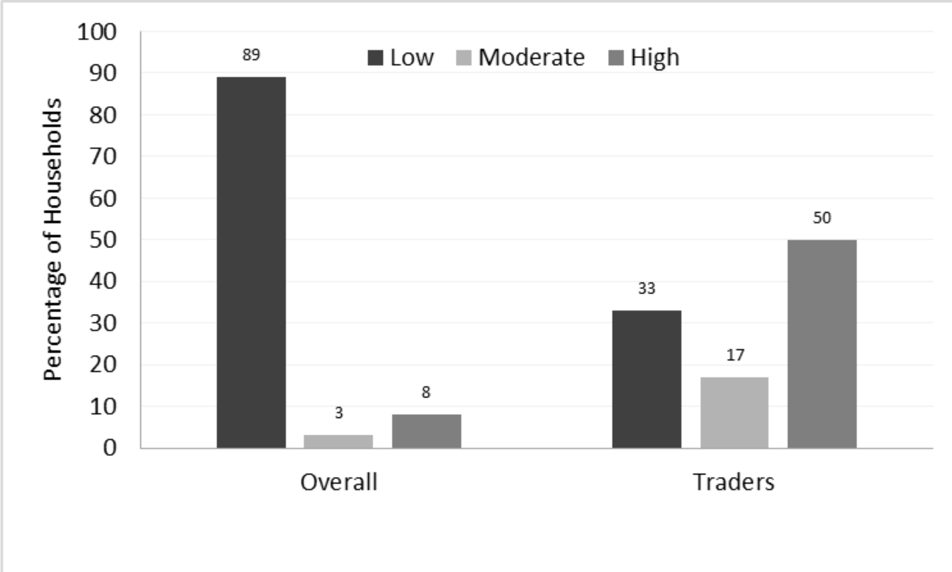

Figure 5.1: Differences in palm income dependency between all respondents and palm traders

Table 5.5: The proportion of households under the national and international poverty lines (significant statistical differences between palm product traders and non-traders in bold)

Palm income	Households	National poverty line		International poverty line	
		Above	Below	Above	Below
Included	Traders	**93**	**7**	**47**	**53**
	Non-traders	**71**	**29**	**10**	**90**
	Combined	75	25	17	83
Excluded	Traders	63	37	10	90
	Non-Traders	71	29	10	90
	Combined	69	31	11	89

The national poverty line is 5.3 Rands/day (MEF, 2016), the international poverty line is 25.3 Rands/day (World Bank, 2015)

R1 = USD 0.08 as of August 2016

5.4.5 Household livelihood strategies

Seven livelihoods strategies (LS) were identified in Zitundo area. Although the strategies usually exhibited a dominant activity, all included participation in several activities, varying between six to eight (Table 5.6). The largest cluster was LS7, which involved 42% of households and included eight activities. The households in this strategy were mostly dependent in wages (75% ± 39%). LS1 was the second largest cluster with 14% of households involved in seven activities and highly dependent on "other" (84% ± 22%). Households from LS3 comprised 11% of households involved in seven income earning activities and were highly dependent in palm income (81% ± 18%). LS2 and LS6 were both composed by 10% of households involved in six and eight activities respectively. LS2 households were highly dependent in social grants (90% ± 16%) while LS6 households derived their income mostly from other NTFPs (50% ± 36%) and agriculture (33% ± 38%). The smallest clusters were LS4 and LS5 which were composed by nine and five percent of households, practicing seven activities. Households in LS4 were highly dependent on fishing (81% ± 18%) while the ones in LS5 were livestock-based (80% ± 17%) (Table 5.6).

The highest total annual cash income and annual per capita income were obtained by palm-based (LS3) and fishing-based (LS4) strategies. An average of R34 097 ± R22 894 for annual total cash income and R16 244 ± R16 491 per capita income were obtained by households in LS3, while the ones in LS4 obtained R37 351 ± R27 255 and R11 748 ± R15 001 for total annual and annual per capita income, respectively (Table 5.6). The palm-based strategy also exhibited a lower poverty incidence, in both national and international terms. Ten percent and 40% of households in this strategy fell below the national and international poverty lines, respectively. The remaining strategies showed high levels of poverty incidence especially in international terms, with over 60% of households being under the international poverty line (Table 5.6).

The wage-based strategy (LS7) displayed the lowest level of income diversification with an average SDI of 0.07 ± 0.16, and over 90% of households placed in the low diversification category. Mixed other NTFP and agriculture-based strategy (LS6) obtained the highest level of diversification with an average SDI of 0.32 ± 0.24, followed by fishing-based (0.27 ± 0.22), livestock-based (0.27 ± 0.22) and palm-based (0.25 ± 0.21) strategies. There were no significant differences on the proportion of households in the high diversification category among the seven livelihood strategies (Table 5.6).

Table 5.6: Absolute and relative cash incomes, poverty incidence and SDI across seven livelihoods strategies (Unlike letters denote significant differences between the livelihood strategies clusters within a parameter)

	Parameter	Livelihoods strategies (LS)						
		LS1 Other-based	LS2 Social grant-based	LS3 Palm-based	LS4 Fishing-based	LS5 Livestock-based	LS6 Mixed other NTFPs and agriculture-based	LS7 Wage-based
Absolute	Agriculture (R)	149 ± 673[a]	234 ± 651[a]	0 ± 0[a]	1 154 ± 2 615[a]	6 571 ± 16 859[b]	2 842 ± 5 007[a, b]	18 ± 108[a]
	Fishing (R)	673 ± 1 922[a]	1 122 ± 4 186[a]	1 304 ± 5 829[a]	28 983 ± 21 598[b]	100 ± 300[a]	424 ± 1 746[a]	125 ± 1 085[a]
	Livestock (R)	11 ± 39[a]	75 ± 268[a]	330 ± 965[a]	1 301 ± 3 326[a]	20 304 ± 38 398[b]	28 ± 116[a]	79 ± 417[a]
	Other (R)	11 588 ± 7 783[b]	1 172 ± 3 386[a]	520 ± 2 326[a]	4 000 ± 10 930[a]	267 ± 800[a]	353 ± 1 455[a]	480 ± 2 920[a]
	Other NTFPs (R)	519 ± 1 335[a]	219 ± 588[a]	607 ± 2 205[a]	360 ± 834[a]	194 ± 487[a]	6 404 ± 8 631[b]	466 ± 1 916[a]
	Palm (R)	0 ± 0[a]	0 ± 0[a]	27 350 ± 19 052[b]	321 ± 1 196[a]	102 ± 215[a]	125 ± 372[a]	387 ± 2 696[a]
	Social grants (R)	961 ± 3 398[a]	11 492 ± 9 660[b]	986 ± 3 159[a]	1 233 ± 3 509[a]	1 685 ± 4 783[a]	131 ± 292[a]	21 ± 129[a]
	Wage (R)	1 728 ± 6 592[a]	0 ± 0[a]	3 000 ± 5 150[a]	0 ± 0[a]	0 ± 0[a]	2 647 ± 5 192[a]	20 399 ± 17 878[b]
	Total abs. (R)	15 629 ± 13 500[a]	14 314 ± 13 092[a]	34 097 ± 22 894[a, b]	37 351 ± 27 255[b]	29 224 ± 55 10[a, b]	12 954 ± 12 342[a]	21 976 ± 19 221[a, b]
	Income per capita (R)	3 690 ± 2 239[a]	2 646 ± 2 170[a]	16 244 ± 16 491[c]	11 748 ± 15 001[b, c]	3 618 ± 3 914[a, b]	4 473 ± 5 646[a, b]	5 402 ± 5 657[a, b]
Relative	Agriculture (%)	1 ± 3[a]	2 ± 5[a]	0 ± 0[a]	3 ± 7[a]	6 ± 12[a]	33 ± 38[b]	0.1 ± 1[a]
	Fishing (%)	3 ± 9[a]	3 ± 10[a.]	2 ± 10[a]	81 ± 18[b]	2 ± 5[a]	2 ± 9[a]	1 ± 4[a]
	Livestock (%)	0.1 ± 0.2[a]	1 ± 2[a]	1 ± 2[a]	3 ± 5[a]	80 ± 17[b]	1 ± 2[a]	0.4 ± 3[a]
	Other (%)	84 ± 22[b]	4 ± 11[a]	1 ± 3[a]	6 ± 16[a]	4 ± 13[c]	2 ± 7[a]	1 ± 7[a]
	Other NTFPs (%)	5 ± 11[a]	1 ± 2[a]	3 ±11[a]	4 ± 9[a]	1 ± 2[a]	50 ±36[b]	2 ± 7[a]
	Palm (%)	0 ± 0[a]	0 ± 0[a]	81 ± 18[b]	1 ± 2[a]	0.3 ± 1[a]	1 ± 2[a]	1 ± 5[a]
	Social grants (%)	4 ± 12[a]	90 ± 16[b]	4 ± 10[a]	3 ± 7[a]	7 ± 13[a]	3 ± 6[a]	0.04 ± 0.3[a]
	Wage (%)	4 ± 13[a]	0 ± 0[a]	10 ± 16[a]	0 ± 0[a]	0 ± 0[a]	9 ± 17[a]	75 ± 39[b]
	Nº households (%)	25 (14)	17 (10)	20 (11)	16 (9)	9 (5)	17 (10)	75 (42)
	Below NPL (%)	20[a, c]	35[a, b]	10[b, c]	0[c]	56[a]	47[a]	25[a, b]
	Below IPL (%)	100[a]	100[a]	40[c]	63[b, c]	88[a, b]	82[a, b]	89[a]
	SDI	0.19 ± 0.25[a, b]	0.14 ± 0.21[a, b]	0.25 ± 0.21[a]	0.27 ± 0.22[a]	0.27 ± 0.22[a, b]	0.32 ± 0.24[a]	0.07 ± 0.16[b]
	Low divers. (%)	72[a]	77[a, c]	65[a, b]	69[a, b]	56[a, b]	41[b]	91[c]
	Medium divers. (%)	28[a]	24[a, b]	35[a]	25[a, b]	44[a]	53[a]	9[b]
	High divers. (%)	0[a]	0[a]	0[a]	6[a]	0[a]	6[a]	0[a]

R1 = USD 0.08 as of August 2016

5.4.6 Determinants of household palm dependency, SDI and livelihood strategy

The regression analysis revealed that 62% of the variation in palm income dependency and 10% in SDI were explained by the regression models (Table 5.7). Furthermore, 76% of the variation on the choice of livelihood strategy is also explained by these independent variables (Table 5.8). The village of residency, education, ethnicity and boat ownership were the variables that significantly impacted palm dependency. Households from Tchovane, Vumidava, Xibaluine, Momole, Malongane, Mussongue, Gala exhibited a lower palm dependency (comparing with the Zitundo-sede the village used as reference), while living in Mugovene, Phuza, Huco and Ndovo increased the level of dependency on palms (Table 5.7). Being of Ronga ethnicity and possessing a boat had a negative influence on palm dependency, while more years of schooling had a positive influence. Only living in Huco had influence on the SDI.

Five variables influenced households' choice of livelihood strategy: village of residency, gender, number of formal jobs in the household, being born in the village of residency and land size. Households from Ponta de Ouro are more likely to adopt a wage-based strategy (LS7) than others. Female-headed households are less prone to engage in wage (LS7) and other-based (LS1) strategies. Furthermore, the number of formal jobs in the household had a positive influence on the choice of palm (LS3) and wage-based (LS7) strategies, while the size of land positively influenced fishing as a primary strategy (Table 5.8).

Table 5.7: Fractional Logistic estimates for palm income dependency and SDI (significant variables are indicated in bold)

Independent variable	Palm dependency		Simpson Diversity Index	
	Estimates	P-value	Estimates	P-value
Tchovane	- 15.52	**< 0.0001**	- 0.84	0.18
Vumindava	- 15.64	**< 0.0001**	- 0.43	0.49
Mugovene	2.70	**0.04**	0.58	0.28
Gueveza	0.74	0.65	0.35	0.51
Xibaluine	-16.49	**0.01**	- 0.67	0.53
Momole	- 17.14	**< 0.0001**	-1.46	0.09
Malongane	- 17.41	**< 0.0001**	- 0.18	0.70
Ponta do Ouro	- 1.40	0.27	- 0.82	0.07
Phuza	6.15	**< 0.0001**	- 0.89	0.24
Mussongue	- 16.29	**< 0.0001**	- 0.90	0.36
Massale	1.70	0.29	0.44	0.27
Mabucuti	1.73	0.27	0.76	0.31
Gala	- 15.12	**< 0.0001**	- 1.07	0.11
Huco	4.64	**< 0.0001**	0.97	**0.01**
Ndovo	4.08	**< 0.0001**	0.15	0.78
Gender (female)	0.84	0.31	- 0.17	0.66
Age	0.003	0.93	- 0.01	0.47
Education	0.21	**0.04**	- 0.05	0.35
Size of household	- 0.03	0.73	0.02	0.69
Number of formal jobs in household	0.14	0.61	- 0.07	0.62
Ethnicity (Ronga)	-1.51	**0.03**	0.01	0.97
Born in village	0.23	0.85	- 0.30	0.51
Years living in the village	0.01	0.87	0.01	0.51
Leadership position	- 0.64	0.38	0.23	0.43
Size of the land	- 0.51	0.20	0.32	0.08
House value	- 0.02	0.49	- 0.01	0.42
Car ownership	- 0.05	0.97	0.60	0.13
Tractor ownership	2.93	0.68	- 2.86	0.15
Boat ownership	-12.70	**< 0.0001**	- 0.85	0.24
TLU	0.03	0.10	0.01	0.12
McFadden Pseudo R-Square		0.62		0.10

Table 5.8: Multinomial Logistic coefficients for the choice of livelihood strategy (significant variables are indicated in bold)

Independent variable	Dependent variable [Livelihoods strategies (LS)]					
	LS1	LS2	LS3	LS4	LS5	LS7
Tchovane	- 2.52	12.89	7.75	- 3.89	11.22	10.40
Vumindava	3.41	8.15	3.89	7.74	- 2.06	6.07
Mugovene	- 6.80	- 4.33	7.09	11.27	- 11.30	- 1.83
Gueveza	- 6.77	1.45	5.38	8.07	- 0.36	- 1.10
Xibaluine	- 8.67	- 5.80	- 4.19	- 5.31	- 8.35	2.80
Momole	- 1.26	4.67	1.73	- 5.59	- 0.10	6.75
Malongane	- 0.38	- 2.19	- 5.46	- 3.61	4.06	- 1.97
Ponta do Ouro	2.09	1.85	1.55	1.45	2.28	**3.45**
Phuza	- 0.95	1.47	15.15	- 9.36	2.47	6.40
Mussongue	3.96	5.40	2.22	4.09	3.93	8.31
Massale	24.38	19.71	5.08	3.83	18.12	9.66
Mabucuti	- 7.03	- 4.55	- 1.73	0.81	- 1.84	- 3.46
Gala	- 0.27	8.41	1.42	8.21	10.49	6.15
Huco	- 4.74	- 1.26	15.17	9.22	- 0.12	2.55
Ndovo	- 2.89	1.32	11.82	1.27	9.69	0.22
Gender (female)	**- 3.20**	0.07	- 0.66	- 3.85	0.04	**-2.89**
Age	0.01	0.02	0.06	- 0.24	0.22	- 0.06
Education	- 0.14	0.25	0.21	0.11	- 1.18	- 0.24
Size of household	0.02	0.06	- 0.74	- 0.78	0.04	- 0.27
Number of formal jobs in household	- 1.03	- 2.46	**4.67**	- 0.90	- 3.84	**4.76**
Ethnicity (Ronga)	0.64	0.73	- 2.83	1.19	- 4.84	0.32
Born in village	3.10	0.37	6.20	- 3.08	**20.74**	2.60
Years living in the village	- 0.08	0.04	- 0.09	0.17	- 0.35	- 0.09
Leadership position	- 0.49	0.58	- 0.05	- 2.18	1.38	0.15
Size of the land	- 0.09	- 1.89	- 1.44	**4.84**	0.63	0.30
House value	- 0.03	- 0.03	0.04	- 0.18	0.07	0.05
Car ownership	4.83	- 0.18	1.70	13.18	- 2.36	5.00
Tractor ownership	- 11.27	- 0.21	- 8.02	- 30.89	- 2.23	- 16. 29
Boat ownership	- 0.26	- 4.39	5.76	16.12	- 6.81	0.61
TLU	- 0.78	- 0.52	- 0.003	0.01	0.02	- 0.20
McFadden Pseudo R-Square						0.76

5.5 Discussion

5.5.1 Household cash income sources

This study revealed that relatively few households (17%) in Zitundo derived cash income from palm products. This is in line with reports from Shackleton (2005) and Shackleton and Shackleton (2004) who referred that on average, 3% to 14% of rural households in savannas of South Africa are engaged in NTFPs trade. Shackleton (2005) found a rate of 2% of household engagement in NTFP trade in the Bushbuckridge area, South Africa, while Mugido and Shackleton (2017) found that 6.4% engaged in NTFP trade in three agro-ecological zones of South Africa. The low involvement of Zitundo households in commercially exploiting palms can be related to two factors, the first is the uneven distribution of palms across the villages, which would make the commercial exploitation of these resources less appealing in areas with low palm abundance due to the possible costs involved. The second is the increased attraction and availability of job opportunities in the coastal zone of the study area due to the growing tourism sector.

Households in Zitundo depended mostly on eight sources of income: palm, other NTFPs, agriculture, fishing, livestock, social grants, wages and other. Although few households were involved in palm products trading this activity generated substantial cash income for those involved. Palm traders earned approximately double the annual absolute cash income of non-traders, being R37 223 against the R19 653 for non-traders. Lower annual income among non-NTFPs trading households were also observed by Mugido and Shackleton (2017) in South Africa. The differential was even greater on a per capita income basis. The annual cash income per capita obtained for all groups (overall, palm traders and non-traders) were well above the ones reported by Mather *et al*. (2008) for rural households in Mozambique in 2005, of approximately 3 344 MZM (Mozambican Meticais), equivalent to R1 940 today. The annual income per adult equivalent for Maputo province, where Zitundo is located, was estimated by Mather *et al*. (2008) in 7 145 MZM (equivalent to R4 144 today), slightly below the non-traders annual income per capita of R5 266 ± R7 051 but considerably inferior to R12 642 of palm traders.

Generally wages were the highest contributor (34%) to annual cash income while agriculture contributed only 4%. Palm income was the third highest contributor (10%), the same as social grants. Mugido and Shackleton (2017) found the same tendency in three agro-ecological zones of South Africa, where social grants, non-cash NTFP and wages were important sources of income contributing 47%, 21% and 13%, respectively, and agriculture contributing with only 4%. Likewise Flores *et al.* (2006), Maldonado *et al.* (2006) and Mugido and Shackleton (2017) reported a 10%, 7%-14% and 12% contribution to annual households cash income from *Chamaedorea* flowers, wild cocoa and NTFP trade, in Mexico, Bolivia and South Africa, respectively. However these results are well below the 90% and 54% contribution obtained by Rodriguez *et al.* (2006) and Adam and Pretzsch (2010) from rubber and *Ziziphus spina-christi* fruits sale in Bolivia and Sudan, respectively.

5.5.2 Palm income, dependency and factors affecting dependency

Although palm income ranked third across the total sample and only contributed with 10% of household income, it was of crucial importance for the households involved in palm trade, most of whom it was the highest cash source. The average return from palm trade was R19 474 per annum, equivalent to 57% of total palm traders' cash income. The returns obtained for selling palm products obtained in this study are higher than those obtained by Cunningham (1985), Naidu and Misra (1998) and Ndoye and Awono (2005) for palm wine sales in South Africa, India and Democratic Republic of Congo, respectively and Mjoli and Shackleton (2015) for palm bruhes sales in South Africa (Table 5.9). However, these results are within the returns range obtained by Lebbie and Guries (2002) for palm wine trade in Freetown, Sierra Leone (Table 5.9).

Table 5.9: Palm products sales returns obtained by other studies

Author	Country	Resource	Return	Annual Returns (Rands)	Annual current day value (Rands)*
Cunningham (1985)	South Africa	Palm wine	R390/year	390	4 578
Naidu and Misra (1998)	India	Palm wine	INR103/year	14.4	36.03
Lebbie and Guries (2002)	Sierra Leone	Palm wine	USD2.2-10.6/day	792-3 816**	8 134-39 190
Ndoye and Awono (2005)	DRC	Palm wine	USD13.2-228/year	87-1 493	180-2 702
Mjoli and Shackleton (2015)	South Africa	Palm brushes	R135/month	1 620***	1 704

* The annual current day value was calculated using the "Inflation Tool" calculator available in https://www.inflationtool.com/south-african-rand from the year when the study was published to the year 2016.
** The annual returns was calculated by multiplying the daily return by 30 days and then by 12 months.
*** The annual returns was calculated by multiplying the monthly return by 12 months.
INR - Indian Rupee, DRC - Democratic Republic of Congo.
INR 1 = R0.14 as August 1998 (https://fxtop.com/en/historical-currency-converter.php)
USD 1 = R10.27 as of August 2002 (https://fxtop.com/en/historical-currency-converter.php)
USD 1 = R6.55 as of August 2005 (https://fxtop.com/en/historical-currency-converter.php)

Palm wine sale was the dominant source of palm income among the palm traders, contributing to over 80% of all palm income and being pursued by 60% of traders. The high palm cash income obtained in this study contradicts the assumed low economic returns from local NTFP sales (Neumann and Hirsch, 2000; Shackleton *et al*., 2007) and corroborates the profitable nature of palms in the study area found by Martins and Shackleton (2018).

Households from Mugovene, Phuza, Huco and Ndovo are more dependent on palm income while living in Tchovane, Vumidava, Xibaluine, Momole, Malongane, Mussongue and Gala decreased the level of dependency. The biophysical features surrounding these villages and the job market availability are the unexpressed factors underlining the influence of villages. Phuza, Huco and Ndovo villages are located in palm savanna characterized by high palm abundance (Martins and Shackleton, 2017) and infertile soils that constrain agriculture (McKean, 2003), which, makes the use of palms to generate income very attractive. Furthermore, Mugovene is located adjacent to the Maputo River floodplains where there is high abundance of *P. reclinata* which promotes its use and commercialization. Villages that exhibited lower levels of dependency (Tchovane, Vumidava, Xibaluine and Mussongue) are located where palms were in very low abundance. Momole and Malongane villages are located alongside the coast, where tourism development creates job opportunities and Gala is located near lakes, marshes and temporary rain-fed ponds that support fishing and farming.

Boat ownership reduced the dependency on palm income. This was expected since a boat is a productive asset for fishing activities that could reduce the reliance on palms. This is in line with results from other studies affirming that asset-poor households have higher dependency in NTFPs (Nguyen *et al*., 2015; Torres *et al*., 2018).

5.5.3 Household livelihood diversification strategies

Despite the significance of palm income to some households, most households in the area diversify their income sources. Seven livelihoods strategies were common in the area, although every strategy obtained income from several sources. This corroborates previous studies showing that rural households in developing countries engage in multiple activities to diversify their livelihoods for survival and accumulation (Tesfaye *et al*., 2011; Jiao *et al*., 2017; Torres *et al*., 2018). In Zitundo a wage-based strategy was the most common (42%), while the least adopted strategy was livestock-based (5%). A palm-based livelihood strategy was adopted by 11% of households. In comparison, Nielsen *et al*. (2013) reported that most households in central Mozambique adopted small-scale agriculture and livestock production, while wages was adopted only by 13%. Others reported a higher adoption of subsistence agriculture than wages in Cambodia (Jiao *et al*., 2017), Nepal (Walelign and Jiao, 2017) and Ecuador (Torres *et al*., 2018). The differences in the number and type of livelihood strategies, as well as adoption rates across studies, reflect the effects of specific local biophysical, socio-economic and cultural contexts across the studies.

Palm and fishing based strategies were the most cash remunerative in terms of total annual and per capita income, while the mixed other NTFPs and crop based, "other" and social grants income based strategies were less remunerative. These latter three strategies together with livestock and wage based also had lower per capita income. However, since this study only considered cash income, and most Zitundo households practice subsistence agriculture, this would have underestimated the returns obtained by the mix of other NTFPs and crop incomes based strategies. Nguyen *et al*. (2015) and Mills *et al*. (2017) also found that in coastal Timor-Leste and northeastern Cambodia fishing was a highly remunerative livelihood strategy. Mills *et al*. (2017) argued that was because fishing is less susceptible to shocks than most of rural livelihoods activities such as farming and livestock production, and is typically available year-round. Similarly, palms are also a year-round resource and palm wine, the most profitable product from palms, has a reliable market in the area, with low entry barriers (Martins and Shackleton, 2018). Furthermore the low income per capita from the wage-based strategy could indicate that most households in this strategy are involved in low returns, unskilled jobs and that the higher adherence of households to this strategy is probably motivated by non-economic factors. Reasons such as status and prestige linked to a formal job and the laboriousness of palm products exploitation (Martins and Shackleton, 2018) may explain the preference for a wage-based strategy over palms despite lower incomes. According to Ghosh (2018) 50 years ago upper caste Hindus and Muslims from India, shifted from fishing which had good returns, to agriculture with lower returns, because fishing was considered an unpretentious job. Furthermore, Schreckenberg *et al*. (2006) found that despite lower returns, Bolivian households prefer rubber exploitation to rice cultivation, because it involves less working under the sun.

The results from the multinomial logistic model showed that a wage-based strategy was more likely to be adopted by households from Ponta de Ouro, probably related to the greater job opportunities there. Ponta de Ouro is a coastal village undergoing tourism development which increases job opportunities. Often these are unskilled jobs related to construction, gardening, security, etc. these occupations are traditionally regarded as male jobs which would explain that female-headed households engaged less in the wage-based strategy. As expected, the number of formal jobs in the household had a positive influence in the adoption of the wage-based strategy, since more formal jobs increase the dependency on it. The number of formal jobs also positively affected the choice of the palm-based strategy. This echoes the findings of Nguyen *et al*. (2015) regarding the positive influence of the number of household workers on decisions to engage in environmental resource exploitation. In Zitundo, wage income only contributed 10% for the total annual income of households using a palm-based strategy. This indicates that households in this strategy specialize in palm products trade and only use the low paying jobs to supplement palm income.

The size of land had a positive influence on the adoption of the fishing-based strategy. Nielsen *et al*. (2013) and Jiao *et al*. (2017) also found a positive influence of land size on more remunerative livelihood strategies in central Mozambique and Cambodia, respectively. In Zitundo area fishing in one of the most remunerative livelihood strategies and its adoption was positively influenced by land size. Furthermore, migration status was also important in the choice of livelihood strategy. Living in the village where the head of household was born had a positive influence on the adoption of the livestock-based strategy. This result could suggest that these native households have higher social capital that gave them advantage in benefiting from the post 1976–1992 civil war cattle restocking programs implemented by the government.

Income diversification in the area was low as demonstrated by the low average SDI and the high proportion of households in the low income diversification category. The average SDI in the area was 0.17 and 75% of households exhibited diversification index below 0.39. This level of diversification was well below the range of 0.34-0.58 SDI obtained for other rural areas in Africa (Agyeman *et al.*, 2014; Chilongo, 2014; Addisu, 2017). Differences on natural and socio-economics contexts across studies are likely to result in differences in the diversification level. Different levels of diversification were also observed between palm traders and non-traders as well as among livelihoods strategies. Palm traders exhibited higher diversification than non-traders and more non-traders households were in the low diversification category than traders. Looking at the different strategies, the wage-based strategy displayed the lowest level of diversification, while the mixed other NTFP and agriculture-based strategy obtained the highest level of diversification. Nielsen *et al*. (2013) found that in central Mozambique higher levels of specialization did not lead to a more profitable strategy. This also appears to be true in Zitundo since the wage-based strategy displayed amongst the lowest per capita income. Although the mixed other NTFP and agriculture-based strategy was the most diversified, it was the least profitable. This corroborates Chilongo (2014) and Walelign and Jiao (2017) regarding higher levels of diversification among less profitable strategies in Malawi and Nepal, respectively. However this does not hold true when comparing palm traders and non-traders. This is an indication that in Zitundo the survival vs accumulation diversification dichotomy is also occurring.

5.5.4 The role of palm income in poverty alleviation

Palm income plays an important role in mitigating the level of poverty in Zitundo. Overall, there was a six percent decrease in poverty incidence when palm income was included. Additionally, poverty incidence was 22% to 37% lower among traders than non-traders. This also holds true when comparing the poverty incidence between palm-based strategy and other strategies. The palm-based strategy exhibited a lower poverty incidence against both national and international measures. These results suggest that in Zitundo area palm exploitation is an attractive option to enhance income and mitigate poverty.

5.6 Conclusion

This study highlights the livelihood patterns and the role of diversification and of palm income on the livelihoods of households from Zitundo area, southern Mozambique. The results showed that all households in Zitundo engage in some level of livelihood diversification. Seven livelihood strategies were identified, with every strategy combining cash income from several sources. The majority of households adopted a wage-based strategy, although this strategy was among the less remunerative in terms of per capita cash income indicating, therefore, that its potential for poverty reduction in the area is low. A Palm-based livelihood strategy was adopted by only 11% of households. However, this strategy, conjointly with fishing, was the most remunerative strategy in terms of total annual and per capita cash income. Palm products traders earned approximately double the annual absolute income and per capita income than non-traders. This income play a vital role in enhancing households and mitigating poverty in the area. A palm-based strategy exhibited between 23% and 60% lower poverty incidences than the alternatives strategies. Village of residency and some household socio economic and demographic characteristics appear to determine the households' choice of livelihood strategy and palm income dependency. The village effect appear to be associated to different biophysical features surrounding the villages and the job market availability that provides access to different natural and human capital. The high adherence of households to a less remunerative wage strategy may indicated that other non-economic factors that this study was not able to captured may also influence the choice of livelihood strategies. These findings suggest that future development plans and interventions to mitigate poverty in the area should acknowledge the heterogeneity and potential of the natural capital and go beyond the traditional agriculture sector, recognizing the role of palm and fishing for people's livelihoods. Since this study only examined the contribution of cash income for people's livelihoods more studies are required specially to understand the contribution of consumptive goods from agriculture and other NTFPs. Given that palms in Zitundo are an open access resource, the inclusion of palm products for future development programs and poverty reduction strategies will require the design of conservation and management plans to sustain the flow of these resources for peoples' livelihoods in the area.

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CHAPTER SIX: ASSESSING THE CURRENT AND FUTURE DISTRIBUTION OF TWO PALM SPECIES (*HYPHAENE CORIACEA* AND *PHOENIX RECLINATA*) IN ZITUNDO AREA, SOUTHERN MOZAMBIQUE

6.1 Abstract

The palms *Hyphaene coriacea* and *Phoenix reclinata*, are two important non timber forest products (NTFPs) species, used in southern Mozambique to produce traditional beverages, weaving, roofing, fencing and furniture material. The present study assesses the current and future distribution of these two species, using a participatory mapping exercise and spatial distribution modelling (SDM) taking climate change scenarios into account. The participatory mapping was implemented through local village workshops to elicit local knowledge about perceptions on these palm occurrence, abundance and factors determining the occurrence. Participatory mapping results were used to build a preliminary palm distribution map used in the field survey to record occurrence locations of the two species. The presence records of the two species and 14 environmental and anthropogenic variables, were imputed in Maxent software to model the current and future habitat suitability for the species, and the factors influencing their distribution. Currently the distribution of both species were mostly confined to the eastern side of the study area, and over 90% of the area was deemed to be unsuitable or barely suitable for either species. The occurrence of both species appeared to be influenced mostly by precipitation, distance to rivers and distance to water bodies. The habitat suitability for *Hyphaene coriacea* was predicted to increase under future climate scenarios, while little variation was predicted for *Phoenix reclinata* distribution. Given the importance of these species in the local livelihoods and apparent resilience to climate change, they should be included in future local development and climate change adaptations strategies.

Keywords: species distribution modelling, climate change, Maxent, habitat suitability, participatory mapping

6.2 Introduction

The Intergovernmental Panel on Climate Change (IPCC) has predicted that by the end of this century, Sub-Saharan Africa will experience average temperature increases of between 1°C-1.5°C for the best (RCP2.6) and 4°C-5°C worst case scenario (RCP8.5). Additionally, the Southern Africa region will likely experience a 10% to 20% decrease in precipitation (IPCC, 2014). Climate change impacts can be seen at the ecosystem level as well as at species and their habitat. Major climate change impacts on plant species include: changes in distribution range and phenology as well as increase in species extinctions and pest and disease outbreaks (Iverson and Prasad, 2001; MEA, 2005; Thompson *et al*., 2009). According to IPCC (2018), with a 1.5°C warming, eight percent of plant species worldwide are predicted to lose half of their climatically delimited geographic range. Blach-Overgaard *et al*. (2009) reported that 5 000 plant species from sub-Saharan Africa are projected to lose their climatically suitable areas by 2085.

An important resource for many communities in most developing countries that could also be impacted by climate change is NTFPs. According to Heubes *et al*. (2012) climate change is one of the factors that can influence the provision of NTFPs and therefore, the livelihoods of rural communities. While there is no doubt of the importance of climate change on the provision of NTFPs, few studies have investigated the impact of future climate change scenarios on the distribution of NTFP species. Aforementioned studies include the ones by Heubes *et al*. (2012), Vieilledent *et al*. (2013) and Chitale *et al*. (2018) for several NTFPs in Benin, Madagascar and Nepal, respectively; Remya *et al*. (2015) and Yi *et al*. (2016) for a medicinal plant in India and China; and Blach-Overgaard *et al*. (2015) and Idohou *et al*. (2017) for economically important African palm species. These studies show variable results on the impact of future climate change scenarios on the distribution of NTFP species.

Palms are major source of NTFPs especially in tropical and subtropical areas (Balslev, 2011; Macía *et al*., 2011). Palms provide an array of products used for nourishment, housing, health and decorations. The palm species *Hyphaene coriacea* and *Phoenix reclinata,* are two important NTFP species in Southern Mozambique. In Zitundo area, local people currently exploit 13 products from these two species (for further details on palm use on the area refer to Chapter 4). Palm wine produced from the sap of the two palms is the most important product, contributing significantly to the livelihood of people in the area and helping alleviate poverty (Martins and Shackleton, 2018). Beside palm wine, people in Zitundo produce baskets, wallets, hats, mats, brooms, ropes, furniture, thatch, poles, and fish traps using parts of these two species. *Phoenix reclinata* fruits are also consumed by people in the area.

The use of these two palm species in Zitundo area presently occurs in an open access resource system, with no management plans to regulate their exploitation. This lack of regulation allows harmful palm exploitation practices in the area, which can jeopardize the populations and consequently the livelihoods of local people. Martins and Shackleton (2017) noted that the palm wine tapping technique in Zitundo appears to be destructive, resulting in a high level of stem mortality after being tapped. Additionally, the tapping had a detrimental effect on seed recruitment, since the tapping normally occurs before the stems attain reproductive size (Martins and Shackleton, 2017). Such negative impacts of tapping on palm populations may be aggravated by climate change (IPCC, 2014; Chakraborty *et al*., 2016; Rana *et al*., 2017). The rapid rate in which climate change is occurring in many regions, makes long-lived tree species, such as these palms, more susceptible (IPCC, 2014; Hansen and Phillips, 2015), since their cannot quickly adapt to new conditions or change their geographical ranges due to their long-life cycle and slow migration rates (Lindner *et al*., 2010, Pearson, 2006, Zhu *et al*., 2012, IPCC, 2014). Therefore, this situation calls for urgent conservation and management plans to foster sustainable use of these resources sustainable harvesting techniques, which will maintain the flow of benefits provided.

Adequate conservation and management plans for these two species require information on the species distribution range, the factors that condition their distribution and how the predicted climate change may influence these. Such information will give estimates of the current and future resource availability (Idohou *et al*., 2017; Rana *et al*., 2017). The distribution of plant species is influenced by environmental, anthropogenic and the species inherent biological attributes. Environmental factors include, among others, climate, soils, geology and topography (Mott, 2010; Kaeslin *et al*., 2012). Anthropogenic factors, in the form of anthropogenic disturbance that affect plant species distribution, include harvesting, habitat loss, pollution, fire, livestock densities, introduction of non-native species and global climate change (Lande, 1998; Mott, 2010). A species inherent biological characteristics, that condition their distribution include, growth rates, reproductive output and dispersal capability, propensity for asexual reproduction, and seed bank longevity, as well as biotic interactions such as competition and predation (Lozada *et al.*, 2008; Mott, 2010). These factors interact to delimit the distribution range of a species and population viability (Mott, 2010).

The assessment of distribution ranges, the factors that affect the distribution and the impacts of climate change is usually investigated using species distribution models (SDMs). Elith and Leathwick (2009) defined SDMs as models that predict the distribution of the species on a defined geographical area, using correlations between the data on the species occurrence locations and the environmental features of those locations. Usually the SDMs assess the species environmental requirements, therefore their results indicate suitable habitats for the species rather than the actual distribution of the species (Elith and Leathwick, 2009; Chakraborty *et al.*, 2016), which as mentioned above, is also conditioned by other non-environmental factors. According to Elith and Leathwick (2009) and Elith *et al*. (2011) SDM methods have been extensively used in conservation biology, ecology and biogeography to, among other uses, assess the potential distribution of species of ecological and socio-economic importance, such as endangered species and NTFPs species; evaluate areas susceptible to potential invasion from invasive species and assess the impacts of climate changes in species distribution (Yi *et al*., 2016; Idohou *et al*., 2017).

SDMs require good data quality and quantity to produce reliable results (Rykiel, 1996). Data are usually obtained through intensive and extensive field surveys. These surveys are usually time and resources expensive (Anadón *et al*., 2009; Polfus, 2010; Bélisle *et al.*, 2018). Local ecological knowledge (LEK) may provide relevant biological information and can help minimize costs by providing the required information in less costly manner (Anadón *et al*., 2009; Polfus, 2010; Lima *et al*., 2017). The use of LEK is especially useful for areas and taxonomic groups poorly surveyed (Polfus, 2010; Lima *et al*., 2017). In addition to data provision, LEK may be used to help develop the conceptual framework underlining the model, define the model assumptions as well as to validate the results of the model (Krueger *et al*., 2012).

Participatory mapping provides an opportunity to visually incorporate LEK into a spatial framework (Sieber, 2006; IFAD, 2009; Smith *et al*., 2012). Participatory mapping is any process where several people contribute in the conception of a map, and is widely used to generate maps that represent local land and resource use patterns, hazards and conflict areas, and community values and perceptions (Raymond *et al*., 2009; McLain *et al*., 2013; Rainforest Foundation UK, 2015). An important motivation for undertaking participatory mapping is to anticipate and identify areas of potential occurrence of species and make inferences about species abundance, and can be used as starting point to build models of species distribution. This study integrates LEK on the distribution and abundance of *H. coriacea* and *P. reclinata* in the Zitundo area with species distribution modelling techniques to assess and map the current and future suitable habitat for these two species. Furthermore, it examines the concordance between the results from LEK and the SDM. Therefore, this study aimed to model the current and future distribution of the palm species *H. coriacea* and *P. reclinata* in the Zitundo area, southern Mozambique. Specifically, the study i) builds a participatory map using LEK; ii) describes local perceptions on the occurrence of *H. coriacea* and *P. reclinata* and their preferred and avoided habitats; iii) models the current distribution of *H. coriacea* and *P. reclinata* using SDM; iv) determines the environmental and anthropogenic factors that conditioned the distribution of these species; and v) models their future distribution, given predicted climate change in the area. In this study, the LEK on the occurrence of the two palm species was used to build a preliminary map of the distribution of these two species. This participatory map was then used to select the locations for a palm occurrence census, which provided the species occurrence data for SDM development. This approach was used to reduce the time and effort needed for the species occurrence data census. For this study, I hypothesized that climate is a key factor on the distribution of these two species, therefore climate changes foreseen for the study area will affect the species habitat suitability and consequently the future distribution of the two species.

6.3 Methods

6.3.1 *Hyphaene coriacea* and *Phoenix reclinata* participatory mapping

A participatory mapping approach was implemented through local village workshops to elicit local knowledge about the occurrence of *H. coriacea* and *P. reclinata* and their preferred and avoided habitats. With the help of local leaders, I identified and selected twenty participants (eighteen men and two women) with an extended knowledge of the area, representing the 16 villages from study area. These participants were selected from different palm users and non-users groups. Additionally two Maputo Special Reserve technicians were also involved in the mapping exercise. In total six village workshops, each lasting about two hours and including four to six participants, were carried out between March and May 2015. The workshops were conducted in the local native language Ronga with the assistance of a local translator. During the workshops, after first orientation of local reference landmarks on a map, participants were asked to locate the sites in the study area where each palm species occurs, marking on tracing paper overlaid on a geo-referenced map. The results were then debated within the group to reach a collective opinion on the distribution of each palm species. Participants were also asked about their perceptions on the level of species abundance in the areas where it occurs, and the characteristics of these areas as well as the ones where the species are usually absent. The level of the species abundance was assessed via a qualitative perception. Prior to starting the village workshops, ethical clearance was acquired from Rhodes University and authorization was secured from the Zitundo traditional leader (Zitundo Régulo) and the villages community leaders. All participants were informed about the purpose of the research and that participation was voluntary.

6.3.2 Species occurrence data

The occurrence areas for the two species obtained through participatory mapping were digitized, and a preliminary palm distribution map was constructed and used to select locations for a palm population census. The field survey to record occurrence locations coordinates of the two palm species was conducted from October 2015 to August 2016. I used a randomized cluster sampling approach since it is an effective option in large areas where the vegetation occurs in clusters as in this case (Martins and Shackleton, 2017). A grid of 1 km X 1 km was overlaid on the preliminary distribution map, each block was numbered, and 25 blocks were randomly selected using ArcGIS. In each block, 20 plots of 30 m X 30 m size were also randomly chosen, totaling 500 checking locations (Martins and Shackleton, 2017). At the selected locations the presence or absence of the species were recorded and geo-referenced using a Global Positioning System (GPS) device. In total, 461 and 272 presence records of *H. coriacea* and *P. reclinata* respectively, were used by Maxent to model their potential distribution.

6.3.3 Predictor variables

To model the predicted current habitat suitability distribution of the two species, 33 predictor variables were first collected from diverse sources (Table 6.1). Nineteen bioclimatic variables were downloaded from WorldClim database (http://www.worldclim.org/) with 30 arc-seconds (approximately 1 km^2) resolution. These variables characterize the current climatic conditions and were obtained by averaging monthly temperature and precipitation of the years between 1970 and 2000, collected from weather stations around the world (Hijmans *et al*., 2005). The bioclimatic variables represent annual trends, seasonality and temperature and precipitation extremes (Hijmans *et al*., 2005).

Besides the bioclimatic variables I also obtained anthropogenic and biophysical variables: Euclidian distances from: villages (INE, 2007), rivers and water bodies (CENACARTA, 2000); Human Influence Index (HII) (WCS and CIESIN, 2005), human population density (CIESIN, 2017), land cover (Marzoli, 2007), soils (IIAM, 1996), slope and Normalized Difference Vegetation Index (NDVI). The Euclidian distance variables as well as land cover and soils data were derived from national geospatial databases, rasterized into 100 m x 100 m resolution grids. The distance variables captured the nearest distance to the specific feature as applied (village, river/stream and water body). The HII and the human population density data have 30 arc-seconds (approximately 1 km^2) of spatial resolution and were downloaded from the Global Human Influence Index database (CIESIN, 2017- http://sedac.ciesin.columbia.edu). The HHI measures direct human influence on terrestrial ecosystems, and was generated using variables of human presence such as, population density, land use and infrastructure (built-up areas, night-time lights, land use and land cover), as well as human access (coastlines, roads, railroads and navigable rivers). HII values range from zero to 64; zero value represents no human influence and 64 represents maximum human influence. The slope data have 90 m x 90 m resolution derived from global digital elevation model (DEM), acquired from the Shuttle Radar Topography Mission (SRTM). The NDVI was derived from National Aeronautics and Space Administration (NASA)

Moderate Resolution Imaging Spectroradiometer (MODIS) satellite, at 250 m x 250 m resolution. I used 10 days NDVI compositions to generate annual and dry and rainy season averages and standard deviations, using a 10 year period from 2007 to 2016. These predictor variables are among the factors mentioned in the literature as influencing the occurrence of species in a given area (Engler *et al*., 2009, Blach-Overgaard *et al*., 2010; Vedel-Sørensen *et al*., 2013), and have been used in several species distribution modelling studies, successfully (Blach-Overgaard *et al*., 2010; Vedel-Sørensen *et al*., 2013; Chitale *et al*., 2014).

Table 6.1: Variables used in the Maxent species distribution models (SDMs)

Variables	Units	Source	Resolution	Description
Isothermality (Bio_3)	-	WorldClim dataset	30 arc-seconds (~ 1 km^2)	Bio2/Bio7
Maximum temperature of the warmest month (Bio_5)	º C	WorldClim dataset	30 arc-seconds (~ 1 km^2)	Average maximum temperature of the warmest month between 1970 - 2000
Mean temperature of the driest quarter (Bio_9)	º C	WorldClim dataset	30 arc-seconds (~ 1 km^2)	Average mean temperature of the driest quarter between 1970 - 2000
Mean temperature of the warmest quarter (Bio_10)	º C	WorldClim dataset	30 arc-seconds (~ 1 km^2)	Average mean temperature of the warmest quarter between 1970 - 2000
Precipitation of the wettest quarter (Bio_16)	mm	WorldClim dataset	30 arc-seconds (~ 1 km^2)	Average precipitation of the wettest quarter between 1970 - 2000
Distance to rivers	m	CENACARTA (2000)	100 m x 100 m	Distance to the nearest river
Distance to villages	m	INE (2007)	100 m x 100 m	Distance to the nearest village
Distance to water bodies	m	CENACARTA (2000)	100 m x 100 m	Distance to the nearest water bodies
Human Influence Index (HII)	-	Global Human Influence Index dataset - Wildlife Conservation Society (WCS) and Center for International Earth Science Information Network (CIESIN), Columbia University	30 arc-seconds (~ 1 km^2)	Global Human Influence Index created from nine global data layers covering human population pressure (population density), human land use and infrastructure (built-up areas, nighttime lights, land use/land cover), and human access (coastlines, roads, railroads, navigable rivers). HII values range from 0 to 64. Zero value represents no human influence and 64 represents maximum human influence
Land cover	-	Marzoli (2007)	100 m x 100 m	1- Regularly flooded woodland; 2 - Ticket; 3 - Deciduous forest; 4 - Grassland; 5 - Shrubland; 6 - Regularly flooded grassland; 7 - Deciduous woodland; 8 - Water bodies; 9 - Evergreen forest; 10 - Evergreen woodland, 11 - Regularly flooded shrubland
Mean annual NDVI	-	NASA MODIS database	250 m x 250 m	Mean annual Normalized Difference Vegetation Index (NDVI) from 2001 to 2016. NDVI values range from -1 to +1
Population density	People/km^2	Global Human Influence Index dataset - Wildlife Conservation Society (WCS) and Center for International Earth Science Information Network (CIESIN), Columbia University	30 arc-seconds (~ 1 km^2)	Number of people per square kilometer, based on counts consistent with national censuses and population registers for the year 2015
Slope	%	Shuttle Radar Topography Mission (SRTM)	90 m x 90 m	Slope derived from SRTM global DEM (Digital Elevation Model) data
Soils	-	IIAM (1996)		1 - Yellow sandy soils; 2 - Coastal dunes; 3 - Lakes, lagoons or rivers; 4 – Red-grey soils; 5 - Hydromorphic sandy soils; 6 - White sandy soils; 7 - Mananga soils with sandy cover; 8 - Yellow sandy soils-dunar phase; 9 - Clay alluvial soils, 10 - Mananga soils

To avoid model over-fitting due to multi-collinearity among the predictor variables (Dormann *et al*., 2013), a Pearson's correlation analysis was conducted, and only one variable from a set of highly correlated variables, with a Pearson's correlation coefficient ≥ 0.85, was kept for modelling (Graham, 2003; Yang *et al*., 2013). The variables chosen to remain in the modelling exercise for both species distribution, were believed to be the more relevant predictors. After the correlation analysis, 14 variables remained for the modelling namely (Table 6.1): isothermality (Bio_3), maximum temperature of the warmest month (Bio_5), mean temperature of the driest quarter (Bio_9), mean temperature of the warmest quarter (Bio_10), precipitation of the wettest quarter (Bio_16), distance to rivers, distance to villages, distance to water bodies, HII, land cover, mean annual NDVI, population density, slope and soils. All the selected variables were resampled (when necessary) to the same spatial resolution (100 m x 100 m) and extended for the modelling exercise.

To characterize the future habitat suitability distribution model, under climate change scenarios, the future projected climate data, for the years 2050 and 2070, of the same group of bioclimatic variables used for the current climatic condition modelling, were also downloaded from WorldClim website. The 2050 data are considered a near-term projection and were generated by averaging the projections for the years 2041-2060, while the 2070 data reflect a long-term projection and correspond to the average of 2061-2080. I derived the future bioclimatic data from the Hadley Centre Global Environment Model, version 2–Carbon Cycle (HADGEM2-CC) Global Circulation Model (GCM). HADGEM2-CC was developed by Met Office Hadley Centre, United Kingdom (Martin *et al*., 2011) and was one of the components for the fifth phase of coupled model inter-comparison project (CMIP5), used by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5). The HADGEM2-CC is one of the GCMs that perform well in the tropics (Martin *et al*., 2011), therefore I used for this study. For its AR5, the IPCC adopted a Representative Concentration Pathway (RCP), developed to explore different combinations of demographic, socioeconomic, land use, and technology scenario backgrounds resulting in a different future climate. Four pathways (scenarios) are recognized: RCP2.6, RCP4.5, RCP6.0, and RCP8.5. This study modeled the two species possible future distribution using the bioclimatic variables under the moderate climate change scenario (RCP4.5), which projects increases in temperature ranging $0.9^{o}C$-$2.0^{o}C$ with a mean of $1.4^{o}C$ and $1.1^{o}C$-$2.6^{o}C$ with an average of $1.8^{o}C$ for the years 2046-2065 and 2081-2100, respectively, as well as the higher emission scenario (RCP8.5), which considers increases in temperature ranging 1.4^{o}C-2.6^{o}C with a mean of 2.0^{o}C and 2.6^{o}C-4.8^{o}C with an average of 3.7^{o}C for the years 2046-2065 and 2081-2100, respectively (IPCC, 2014).

6.3.4 *Hyphaene coriacea* and *Phoenix reclinata* Maxent modelling

The distribution models of the two species were built using the Maxent software (Maxent version 3.3.3; Phillips *et al*., 2006; http://www.cs.princeton.edu/wschapire/maxent/). Maxent aims to assess the probability of a species distribution conditional to environmental constraints (Elith *et al*., 2011).

Data partitioning into 75% of each species occurrence data for the model training and 25% for testing was used in this study (Guisan and Zimmermann, 2000). Additionally the following Maxent settings were applied: The output file format was set for logistic, which gives a 0-1 predicted probability of the species occurrence; the regularization multiplier was fixed to 0.1, to avoid model over-fitting (Phillips *et al*., 2004); the maximum iterations were established at 5000; the convergence threshold was placed at 0.00001 and 10 000 background points were selected. I ran 10 model replicates for each palm species and averaged the results. Since higher occurrence collection effort was within the palm savannas, I generated a bias file, to correct for this geographic sampling bias, using the convex-hull based on spatial distribution of observed species locations. This bias file is used to manipulate the selection of background-points/pseudo-absences to reflect the sampling bias (Syfert *et al*., 2013).

Model performance was evaluated using the Area Under Receiver-Operating Characteristic Curve (AUC). The AUC values range from 0 to 1 (Fielding and Bell, 1997). Swets (1988) categorized model performance as: i) not better than random (AUC = 0.5); ii) failing (0.5<AUC<0.6); iii) poor (0.6<AUC<0.7); iv) fair (0.7<AUC<0.8); v) good (0.8<AUC<0.9) and vi) excellent (0.9<AUC =1). Furthermore, the Jackknife test and the percentage of variable contributions were used to assess the relative importance of the variables included into the two species models. The current and future habitat suitability probability outputs were reclassified into five habitat suitability

classes, following Yang *et al*. (2013) as: unsuitable (0-0.2); barely (0.2-0.4); suitable (0.4-0.6); highly (0.6-0.7); very highly (0.7-1.0). All pre-modelling data preparation as well as the spatial analysis were executed using ArcGIS 10.2 (Environmental Systems Research Institute, USA).

6.4 Results

6.4.1 Participatory mapping and perceptions on *H. coriacea* and *P. reclinata* occurrence and abundance

The participatory mapping identified the eastern side of the Futi River as the main area of occurrence of both palm species in the study area. Additionally, the exercise revealed three main areas with differences in species occurrence and abundance: i) one extensive area ranging from near the coast to the interior where the two species co-occur at low densities; ii) an area enclaved between the above mentioned area and the Futi River, where *H. coriacea* occurs at higher densities and *P. reclinata* is present at low to medium densities; iii) areas close to the Maputo and Futi rivers, where *P. reclinata* occurs at high densities, but with low or no occurrence of *H. coriacea* (Figure 6.1). Regarding the characteristics of areas where these two species are normally found, the participants affirmed that the two species tend to occur in open vegetation with very few trees, and are rarely found inside closed forests or the dune vegetation along the coast. They also believed that both species generally occur together, except close to rivers and lakes, where *P. reclinata* occurs exclusively and at higher densities. This latter species is also perceived to prefer forest edges and depressions. Additionally they perceived that the abundance of both species increased from the coast towards the Futi river.

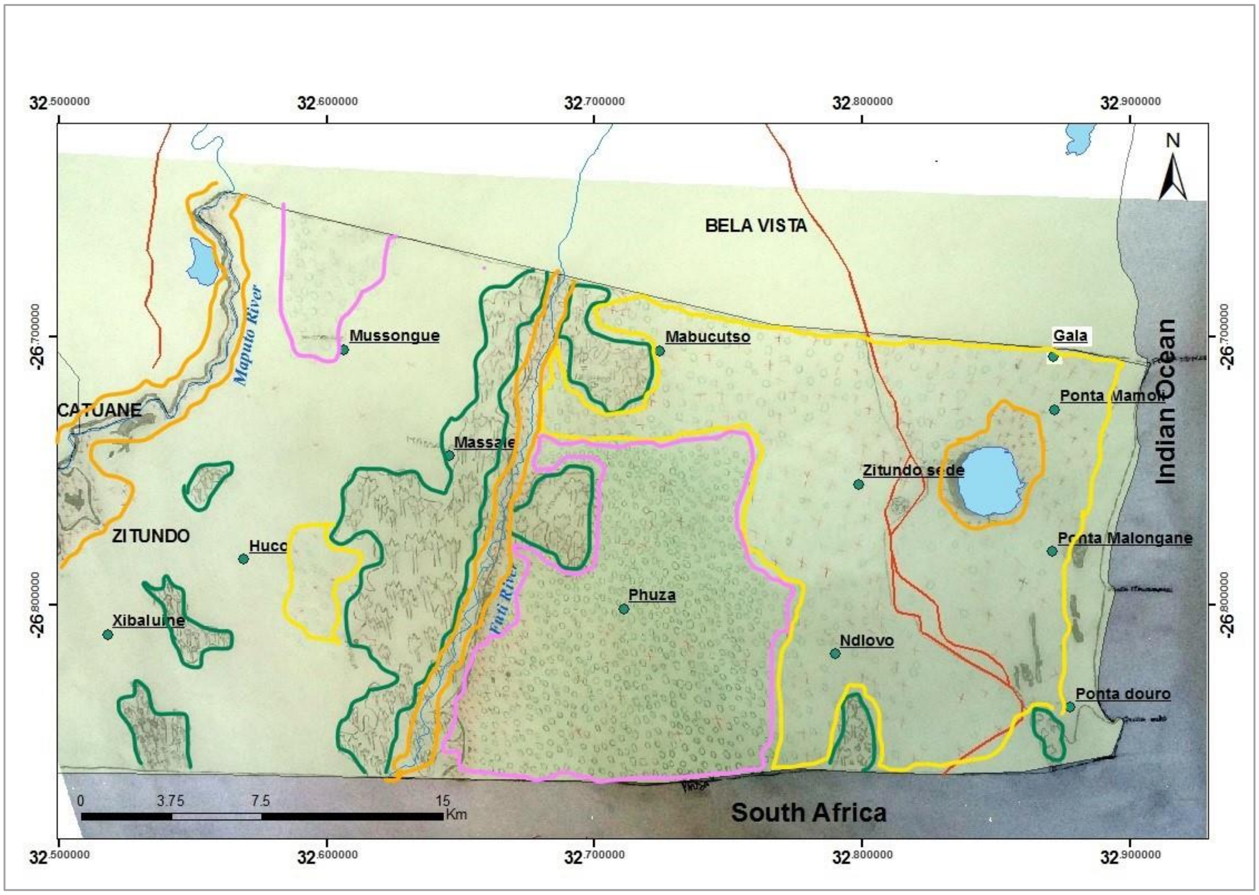

Figure 6.1: Participatory map of the two palm species occurrence and abundance. Small circles denote *H. coriacea* and small "x" *P. reclinata*. Delimited by pink line are areas of higher abundance of *H. coriacea* and some occurrence of *P. reclinata*, by orange line are areas of higher abundance of *P. reclinata* with few or no occurrence of *H. coriacea*, by yellow line are areas with co-occurrence of both species in lower abundance and by green line are closed forests.

6.4.2 Maxent model performance and variables contribution to the *H. coriacea and P. reclinata* model

The distribution model for the two species exhibited satisfactory performances, with average AUC values for the ten replicate runs above 0.8, therefore above the random AUC value of 0.5. The average AUC for *H. coriacea* was 0.82 ± 0.01 and for *P. reclinata* it was 0.81 ± 0.02 (Table 6.2). The Jacknife test results of the variables importance for *H. coriacea* model showed that distance to rivers was the variable with the most useful information by itself followed by precipitation of the wettest quarter (Bio_16) and by annual average of NDVI (Figure 6.2). For *P. reclinata* model, again distance to rivers, followed by distance to water bodies and precipitation of the wettest quarter (Bio_16) were the variables with the most useful information individually (Figure 6.2). However, when analyzing the contribution of all variables to the full models, precipitation of the wettest quarter (Bio_16) had the highest percentage contribution for the distribution models of both species. This variable contributed 23.5% and 21.8% for *H. coriacea* and *P. reclinata* models, respectively (Table 6.2). This variable, along with average annual NDVI, distance to water bodies, distance to villages, distance to rivers and maximum temperature of the warmest month (Bio_5), were the variables that contributed most for both species models, about 92% and 91% for the *H. coriacea* and *P. reclinata* models, respectively (Table 6.2). The average temperature of the driest quarter (Bio_9), type of soils and population density were the variables contributing the least to the *H. coriacea* model while, the latter two variables together with isothermality (Bio_3), contributed less to the *P. reclinata* model (Table 6.2).

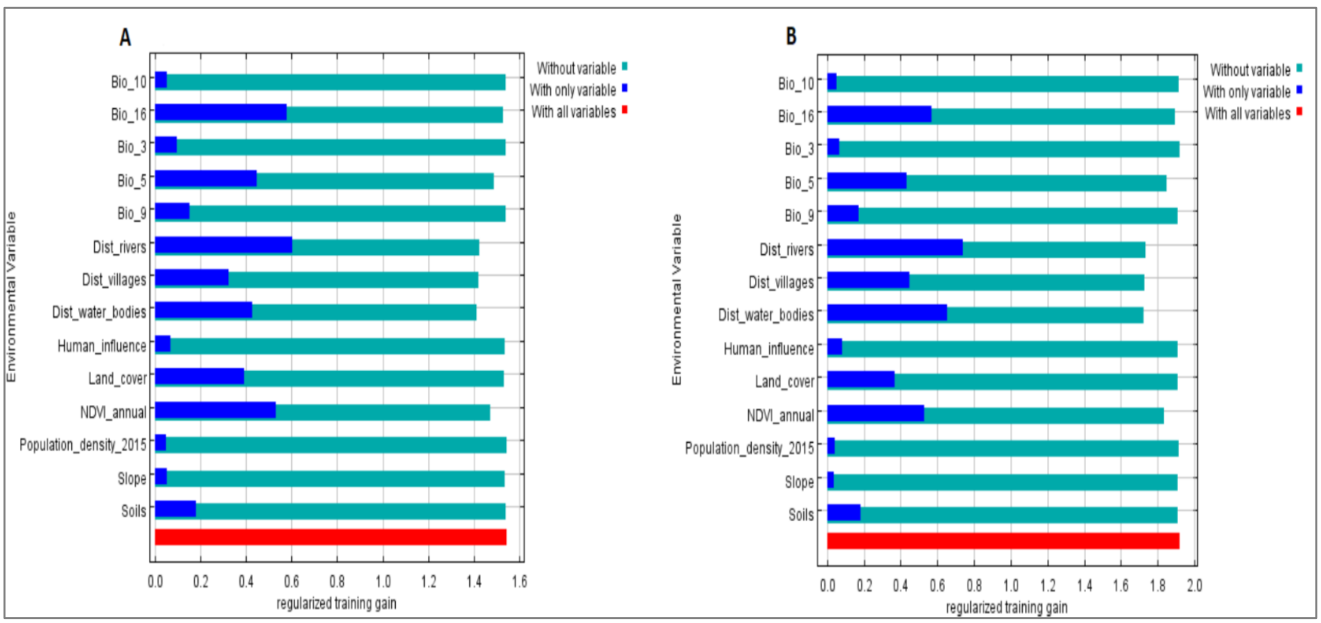

Figure 6.2: Jackknife test of variable importance for *H. coriacea* (A) and *P. reclinata* (B) Maxent models. Dark blue bars denote gains by using the variable uniquely, light blue bars denote lost gain from removing the variable from the full model, while red bars indicate the gain from using all variables.

Table 6.2: Model performance and variable contributions for *H. coriacea* and *P. reclinata* Maxent models. Bold text denotes variables with the highest contribution.

Variables	Species	
	H. coriacea	*P. reclinata*
Isothermality (Bio_3) (%)	0.6	0
Maximum temperature of the warmest month (Bio_5) (%)	**8.1**	**6.6**
Mean temperature of the driest quarter (Bio_9) (%)	0.4	1.1
Mean temperature of the warmest quarter (Bio_10) (%)	1.0	1.4
Precipitation of the wettest quarter (Bio_16) (%)	**23.5**	**21.8**
Distance to rivers (%)	**11.8**	**14.9**
Distance to villages (%)	**13.9**	**15.7**
Distance to water bodies (%)	**14.4**	**15.9**
Human influence index (%)	1.2	3
Land cover (%)	4.2	1.9
Mean annual NDVI (%)	**19.9**	**15.9**
Population density (%)	0.1	0.2
Slope (%)	0.6	1.2
Soils (%)	0.3	0.4
Model performance: AUC (Mean ± SD)	0.82 ± 0.01	0.81 ± 0.02

Response curves for the variables that contributed most to the models showed that higher *H. coriacea* suitability is encountered when the precipitation of the wettest quarter (Bio_16) is approximately 359 mm and 374 mm, while higher *P. reclinata* suitability is found when it is around 358 mm and 367 mm (Figure 6.3 and 6.4). The two species suitability are differently affected by the maximum temperature of the warmest month (Bio_5). *H. coriacea* suitability is high when the maximum temperature of the warmest month (Bio_5) is around 22.5^{o} C, and a decreasing tendency for temperatures between 23^{o} C and 24.5^{o} C, and again to increase over 24.5^{o} C (Figure 6.3). On the other hand, *P. reclinata* suitability is lower when the maximum temperature of the warmest month (Bio_5) is between 22.5^{o} C and 24.5^{o} C and has also a tendency to increase with temperature over 24.5^{o} C (Figure 6.4).

Furthermore, suitability for both species was affected in the same way by average annual NDVI and distance to water bodies. The suitability for both species decreased when average annual NDVI was over 0.33, and increase with increasing distance to water bodies, with the highest suitability found with distances over 20 km from waters bodies (Figure 6.3 and 6.4). The two species showed different responses to distance to rivers. *H. coriacea* suitability showed a small tendency to increase with increasing distance to rivers, however this trend was not noted for *P. reclinata* (Figure 6.3 and 6.4). This species achieved higher habitat suitability around 7-8 km from rivers (Figure 6.3 and 6.4). The influence of distance to villages on the suitability of the two species was not clear, oscillating with increasing distance to villages. Yet, a slight tendency of declining suitability with increasing distance to villages was noted for *H. coriacea*, while *P. reclinata* suitability showed increased as the distance to village increases (Figure 6.3 and 6.4).

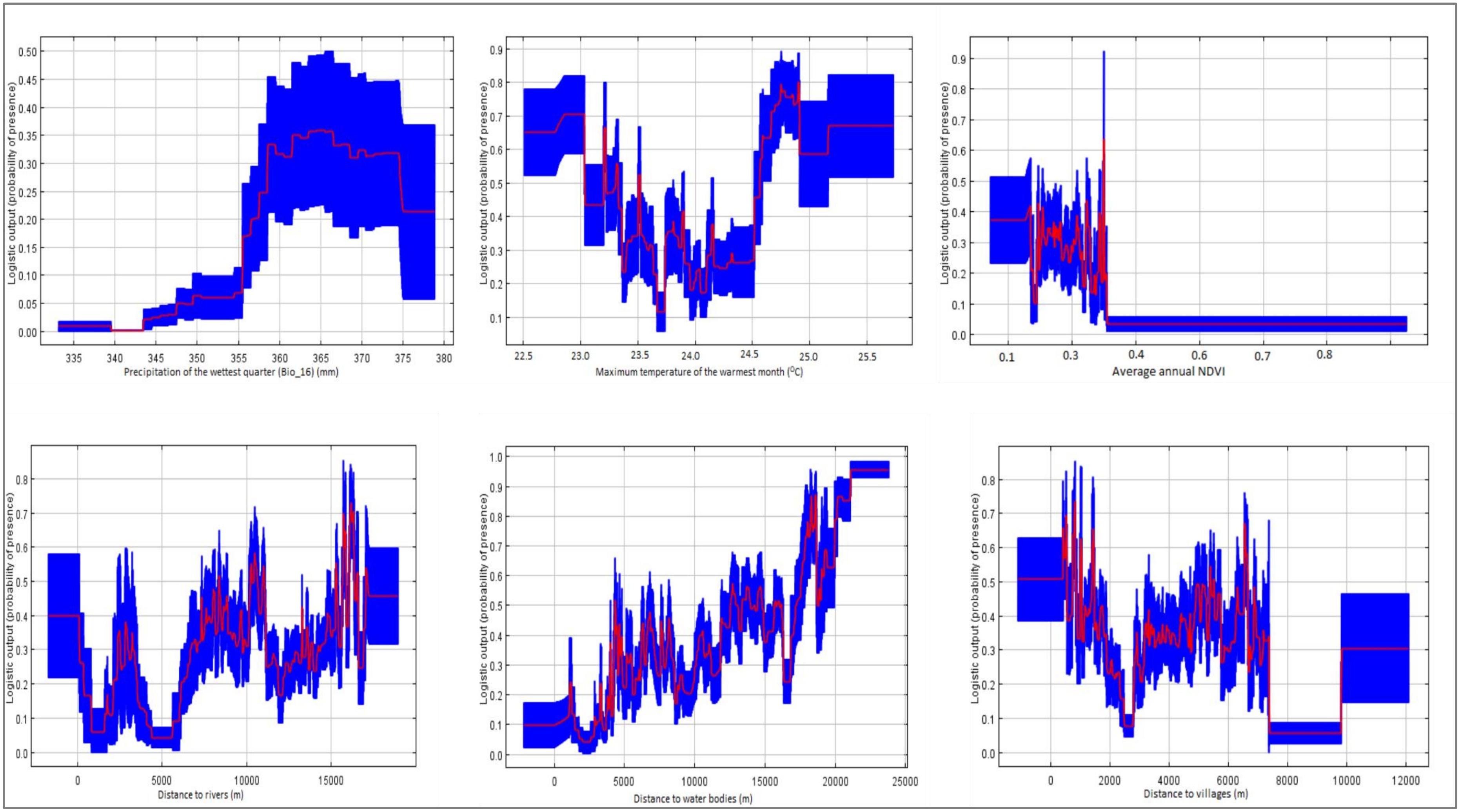

Figure 6.3: Effects of major contributor variables on the suitability for *H. coriacea*. Red lines refer to the average of the ten replicates, while blue displays the standard deviation

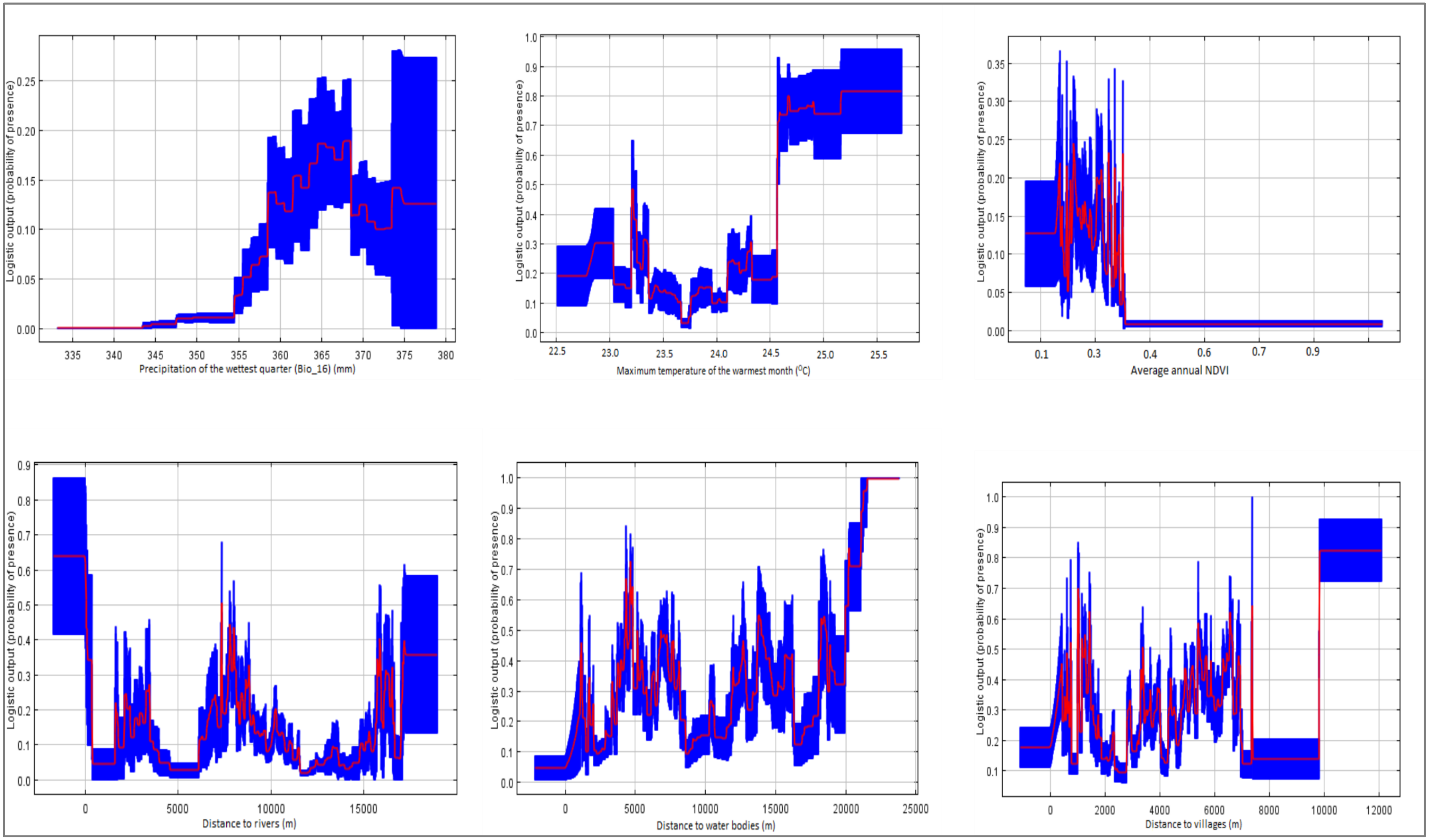

Figure 6.4: Effects of major contributor variables on the suitability of *P.reclinata*. Red lines refer to the average of the ten replicates, while blue displays the standard deviation

6.4.3 Projected current habitat suitability distribution

Potential habitats for both species were modelled to mostly occur in the eastern side of the study area, with a few pockets embeded in the western side (Figure 6.5A and 6.5B). Currently, over 90% of the area was classified as unsuitable or barely suitable habitat for both species, while the three most suitable classes (suitable, highly suitable and very highly suitable) only covered 5.7% and 5.1% for *H. coriacea* and *P. reclinata*, respectively (Figure 6.5A and 6.5B and Table 6.3). Thus, for both species, less than 6% of study area was considered to be suitable to very highly suitable.

Table 6.3: Modelled current coverage of habitat suitability classes for *H. coriacea* and *P. reclinata*

Suitability class	Species			
	H. coriacea		*P. reclinata*	
	Area (ha)	Cover (%)	Area (ha)	Cover (%)
Unsuitable	74 765	85.0	75 799	86.2
Barely suitable	8 218	9.3	7 624	8.7
Suitable	4 003	4.6	3 329	3.8
Highly suitable	652	0.7	729	0.8
Very highly suitable	326	0.4	483	0.5

6.4.4 Projected future habitat suitability distribution

The *H. coriacea* model projection under the two climate change scenarios (RCP4.5 and RCP8.5) for 2050 and 2070, showed an expansion of suitable habitat, and a tendency for the distribution of the species to spread towards the west (Figure 6.5C to 6.5F). For all scenarios and years, the barely suitable class displayed an expansion between 7.1% and 8.5%. The suitable class increased from 11.4% to 12.3%. The highly suitable class had a 6.7% to 8.1% expansion and the very highly suitable expansion range varied between 11.1% and 18.9% (Table 6.4). The maximum expansion was registered for the RCP4.5-2070 and RCP8.5-2050 scenarios, with an 18.9% increase in the likely area covered by the very highly suitable class (Table 6.4). Overall, the area covered by the three most suitable classes (suitable, highly suitable and very highly suitable) increased by 30%, 40.3%, 38.4% and a 30.3% under RCP4.5-2050, RCP4.5-2070, RCP8.5-2050 and RCP8.5-2070 climate change scenarios, respectively (Table 6.4). Therefore, with the climate change scenarios used, the three most suitable habitat for this species are projected to cover between 35% and 45% of study area, against the less than 6% projection for the current situation.

Projections for *P. reclinata* under the two scenarios and two years showed a low variation in this species suitability compared to *H. coriacea*, although a slight westward extension is likely (Figure 6.5G to 6.5J). The very high suitable class was the only one projected to increase under all scenarios and years (Table 6.4). The range of expansion in this class varied from 0.2% to 1.9%, with the highest increase registered for the RCP8.5-2070. Under RCP4.5-2050 the habitat suitability for this species is projected to reduce, with 2.7% and 0.6% declines in the areas of suitable and highly suitable classes, respectively. Overall, the area covered by the three most suitable classes is modelled to diminish by 2.5% under this scenario, while the area covered by unsuitable habitat is projected to increase by 3.8% (Table 6.4). Under the RCP4.5-2070 conditions, the habitat suitability for *P. reclinata* is projected to improve, with increases by 08% and 1.3% in the area covered by suitable and very highly suitable classes, respectively, and a 6% decrease on unsuitable class. This trend continuous for 2050 and 2070 under RCP8.5 scenario. The area covered by the three most suitable classes was expected to increase by 0.7% and 2.6% for RCP8.5-2050 and RCP8.5-2070 respectively, while the unsuitable habitat is anticipated to reduce by 0.8% and 7% for the two scenarios, respectively (Table 6.4).

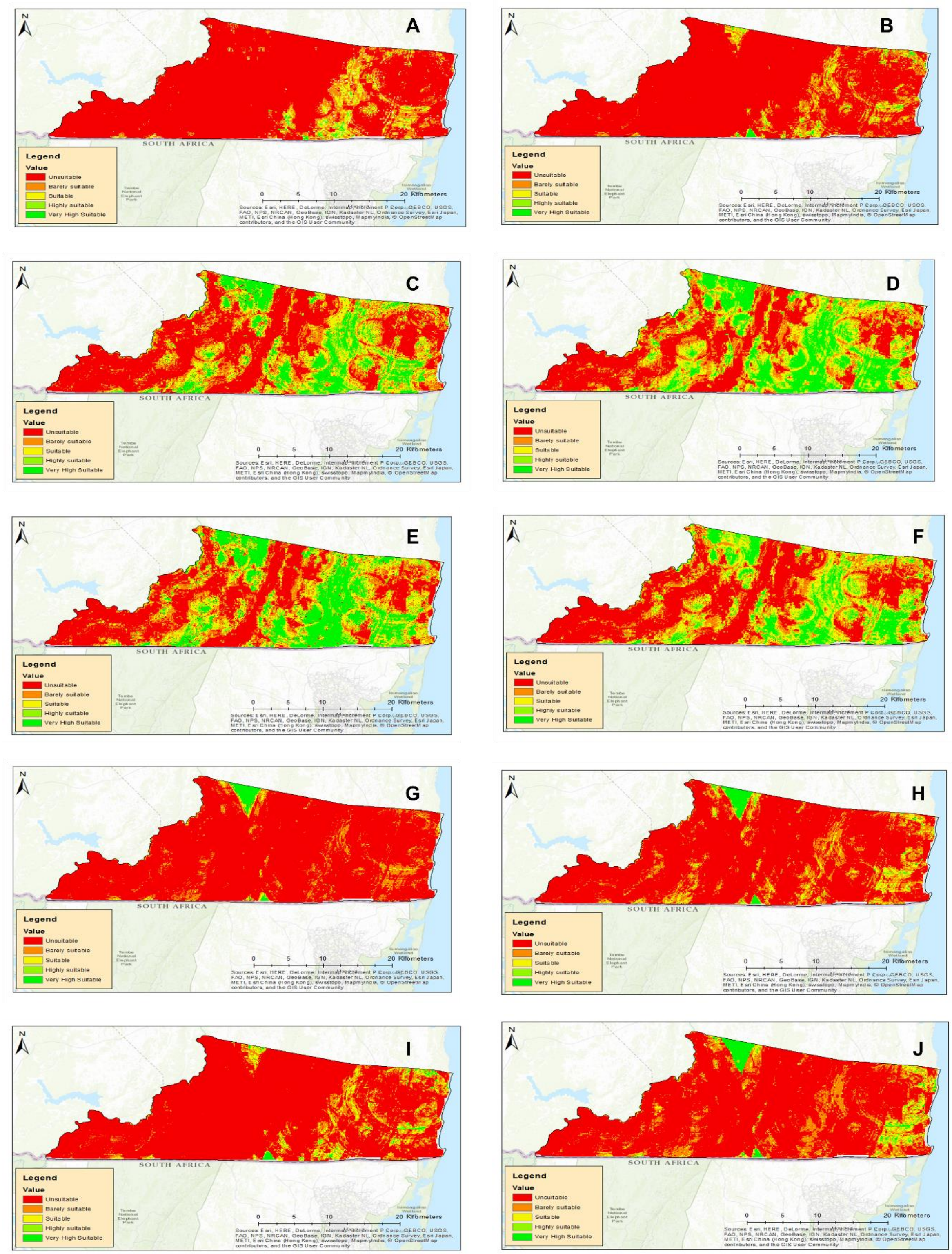

Figure 6.5: Modelled current habitat suitability distribution for *H. coriacea* (A) and *P. reclinata* (B) and projected future habitat suitability distribution. C, D, E and F is for *H. coriacea* distribution under RCP4.5-2050, RCP4.5-2070, RCP8.5-2050 and RCP8.5-2070, respectively and G, H, I and J is for *P. reclinata* under the same scenarios, respectively

Table 6.4: Projected future area of habitat suitability classes for *H. coriacea* and *P. reclinata* under the climate change scenarios RCP4.5 and RCP8.5 for the years 2050 and 2070 and changing trends from the modelled current distribution

Suitability classes	Species	RCP4.5						RCP8.5					
		2050			2070			2050			2070		
		Area (ha)	Cover %	Trend (%)	Area (ha)	Cover (%)	Trend (%)	Area (ha)	Cover (%)	Trend (%)	Area (ha)	Cover (%)	Trend (%)
Unsuitable	*H. coriacea*	41 750	47.5	- 37.5	32 751	37.2	- 47.8	34 711	39.5	- 45.5	40 648	46.2	- 38.8
	P. reclinata	79 173	90.0	+ 3.8	70 584	80.2	- 6	75 105	85.4	- 0.8	69 708	79.2	- 7
Barely suitable	*H. coriacea*	15 121	17.2	+ 7.9	15 661	17.8	+ 8.5	14 457	16.4	+ 7.1	15 613	17.8	+ 8.5
	P. reclinata	6 467	7.4	- 1.3	11 131	12.7	+ 4	7 772	8.8	+ 0.1	11 509	13.1	+ 4.4
Suitable	*H. coriacea*	13 396	15.2	+ 10.6	14 851	16.9	+ 12.3	14 090	16.0	+ 11.4	14 454	16.4	+ 11.8
	P. reclinata	963	1.1	- 2.7	4 008	4.6	+ 0.8	3 664	4.2	+ 0.4	3 750	4.3	+ 0.5
Highly suitable	*H. coriacea*	6 515	7.4	+ 6.7	7 763	8.8	+ 8.1	7 738	8.8	+ 8.1	7 144	8.1	+ 7.4
	P. reclinata	196	0.2	- 0.6	657	0.7	- 0.1	774	0.9	+ 0.1	917	1.0	+ 0.2
Very highly suitable	*H. coriacea*	11 182	12.7	+ 12.3	16 938	19.3	+ 18.9	16 968	19.3	+ 18.9	10 105	11.5	+ 11.1
	P. reclinata	1 165	1.3	+ 0.8	1 584	1.8	+ 1.3	649	0.7	+ 0.2	2 080	2.4	+ 1.9

6.5 Discussion

The Maxent results indicated that the current potential habitat for both species occurred mostly in the eastern side of the study area, and that the majority of the area was currently projected to be unsuitable or barely suitable for both species. Maxent classified over 90% of the study area as unsuitable or barely suitable habitat. The SDM results were consistent with the ones obtained during the participatory mapping. The participatory mapping also identified the eastern side of the Futi River as the main area of occurrence. Participants believed that both species generally occur together, which is comparable to the current habitat suitability distribution for both species produced by Maxent. The overlay between the species habitat suitability prediction given by the SDM and the areas of occurrence of the species as indicated by the participatory mapping could imply that in the study area these two species are presently occupying almost all of their achievable range for occurrence, being therefore in equilibrium with the environment of the area (Guisan and Thuiller, 2005; Blach-Overgaard *et al*., 2009).

Water related variables such as precipitation of the wettest quarter, distance to rivers and distance to water bodies were the variables that most contributed to the models of both species, contributing about 50% and 53% for *H. coriacea* and *P. reclinata* models, respectively. This is in line with findings from Blach-Overgaard *et al*. (2010), reporting that water related variables were the most influential factors on the distribution of 25 out of 29 African palm species. Furthermore, several studies noted that water availability through precipitation and/or high ground water tables is generally the most important determinant of palm distribution (Dransfield *et al*. 2008; Blach-Overgaard *et al*., 2010; Eiserhardt *et al*, 2011). In this study, the higher habitat suitability for both species was encountered when the precipitation of the wettest quarter was around 350 mm and 375 mm, way below the 2 000-3 000 mm optimum obtained by Blach-Overgaard *et al*. (2010) for most African palm species. However, Blach-Overgaard *et al*. (2009) also reported that the habitat suitability for *H. petersiana* in Africa achieved its optimum when precipitation was around 400 mm (Blach-Overgaard *et al*., 2009). Eiserhardt *et al* (2011) indicated that although the majority of palm species exhibit a preference for humid climates, with high levels of precipitation, there are various species that occur under low precipitation. In Africa three species from the genera

Hyphaene (*H. petersiana*, *H. compressa* and *H. coriacea*) revealed preference for low precipitation (Blach-Overgaard *et al*., 2010).

Closeness to water bodies and to rivers had a negative influence on *H. coriacea* suitability. This species suitability increased with greater distance to water bodies and rivers, while *P. reclinata* suitability was optimal at around 7-8 km from rivers. Contrary to this study, Blach-Overgaard *et al*. (2009) found the influence of distance to rivers or other water bodies on the occurrence of *H. petersiana* to be negligible. The authors argued that was because in their study soil variables better described *H. petersiana* habitat than did the distance to rivers and others water bodies, which were calculated from solely larger rivers and water bodies (Blach-Overgaard *et al*., 2009). In the present study the influence of ground water table appeared to be important for *P. reclinata*. Additionally, participatory mapping participants believed that although the two species generally occur together, *P. reclinata* occurs alone and at higher densities in areas close to rivers and lakes. They also stated that *P. reclinata* has preference for depressions, probably due to their shallow water table.

Besides water related variables, average annual NDVI, distance to villages, and in a lesser extent, maximum temperature of the warmest month also contributed to both species models. The average annual NDVI contributed to about 20% and 16% for *H. coriacea* and *P. reclinata* models, respectively. Both species suitability was affected in the same way by average annual NDVI, decreasing when average annual NDVI was over 0.3. This NDVI value is typical of shrub and grassland areas (Weier and Herring, 2000) and the palm savanna of the study area. The effects of NDVI on habitat suitability obtained in the SDM are consistent with the ones obtained from the participatory mapping. Participatory mapping participants stated that the two species have preferences for open vegetation, and that they are rarely found inside closed forests (according to Weier and Herring (2000) closed forests usually have NDVI between 0.6-0.8). Tomlinson (1962) categorized African palms into two groups: species tolerant of arid and exposed conditions, which are never encountered in close forests; and drought and light exposure intolerant species, which are the forest palms. Svenning (2001) argues that the preference for open areas found in some palm species is due to the increased light availability in these areas. Therefore, light radiance appears to also play a role on distribution of these two palm species.

Distance to villages contributed about 14% and 16% for the *H. coriacea* and *P. reclinata* SDM, respectively. *H. coriacea* suitability had a slightly tendency to decrease with increasing distance to villages, while *P. reclinata* suitability was the opposite. The effect of distance to villages on the two species SDM may indicate that their distribution is also shaped by anthropogenic factors. Martins and Shackleton (2017) found that anthropogenic factors had a statistically significant impact on the abundance and population structure of both species in the study area. The opposite response of the two species to the variable distance to village, may indicate different species-specific reactions to harvesting. Indeed Martins and Shackleton (2017) found that tapping positively influenced *H. coriacea* density, while having a negative effect on *P. reclinata*. Additionally *H. coriacea* showed higher resilience to palm tapping than *P. reclinata*, as expressed by the higher stem survival (Martins and Shackleton, 2017).

Temperature had a minor influence on *H. coriacea* and *P. reclinata* suitability, with less than 10% contribution of maximum temperature of the warmest month, mean temperature of the driest quarter and mean temperature of the warmest quarter. This results corroborate those obtained by Blach-Overgaard *et al*. (2010) in their study of determinants of African palms distribution. They found that of 29 African palm species only four were influenced by temperature variables, and neither *H. coriacea* nor *P. reclinata* were among them. Contrary, Blach-Overgaard *et al*. (2009) and Idohou *et al*. (2017) found that temperature impacted the distribution of some palm species in Africa. Blach-Overgaard *et al*. (2009) observed decreases on the probability of *H. petersiana* occurrence for temperature over 23˚C, while Idohou *et al*. (2017) found that *H. thebaica* and *Borassus aethiopum* were strongly influenced by temperature. Eiserhardt *et al*. (2011) argued that the influence of most of predictors of palm species distribution is scale dependent. For instance, the influence of temperature seasonality and cold on palm species distributions appear to be more relevant at broader scales, such as regional and continental, than at local scale (Eiserhardt *et al*., 2011). Temperature only became relevant at local scale when there is a sufficient variability in the temperature gradients (Gatti *et al*., 2008).

Although some previous studies had demonstrated the importance of soils in the distribution of palms in Africa (Barot and Gignoux, 2003; Blach-Overgaard *et al*., 2009), in this study, soil type was among the least relevant variables to SDM of both species, contributing less than 0.5% to the models. According to Eiserhardt *et al*. (2011) soils are more important predictors for dry climate species. However, often the effect of soils underlie the influence of the hydrological conditions of the soils, such as high soil water retention and high groundwater table (Blach-Overgaard *et al*., 2009; Blach-Overgaard *et al*., 2010; Eiserhardt *et al*., 2011). The lack of soils influence in the present study could be related with this hydrological conditions being better captured by other variables such as distance to rivers and distance to water bodies. Similar to this study, Idohou *et al*. (2017) found that soils had a weak contribution to the distribution of *H. thebaica* and *Borassus aethiopum* in Africa, contributing four and nine percent for their SDM, respectively.

Even though Blach-Overgaard *et al*. (2015) forecasted decreases in climate suitability throughout nearly the entire range of palm occurrence in Africa due to climate change, this study found that under future climate change scenarios the potential habitat suitability of *H. coriacea* was deemed to expand significantly, while *P. reclinata* suitability was projected to experience low variation from the current conditions. The area covered by the three most suitable classes for *H. coriacea* were increased by 30%-40%, going from less than six percent to over 30% of the area. On the other hand, for the middle term and under moderate climate change (RCP4.5-2050), *P. reclinata* was projected to be negatively impacted by climate change, with the area covered by the three most suitable classes expected to decrease by about three percent. The habitat suitability for *P. reclinata* was projected to improve slightly as climate change advances, with the area covered by the three most suitable classes increased by 1%-3%. Similarly, Idohou *et al*. (2017) in their assessment of distribution of economically important palms in West Africa, reported increases in highly suitable habitat for seven out of eight palm species under future climate scenarios. This author found that the area covered by high suitability for *P. reclinata* was expected to increase by 34%-45%, while for *H. thebaica* the increase was by 29%-51%. Likewise Aguilar *et al*. (2017) found expansion of the habitat suitability of the palm *Trachycarpus fortunei* in New Zealand under climate change.

These modelled future habitat suitability results are encouraging, given that these two species are important for livelihoods in Zitundo area. But, the projections should be treated with caution, since several factors not accounted for during the model building also affects species distribution, and many times can even interact with the climate projections, worsening or lessening its' effects (Eiserhardt *et al.*, 2011; Blach-Overgaard *et al.*, 2015; Moncrieff *et al.*, 2015). According to Eiserhardt *et al.* (2011) biotic factors such as inter-species and intra-species competition, herbivory, pests and diseases, pollinators, seed production and dispersal factors (mode, barriers and occurrence and abundance of dispersers) influence a species distribution, especially at a local scale. Dispersal factors can play a vital role in palm species distribution (Blach-Overgaard *et al.*, 2009, 2010; Eiserhardt *et al.*, 2011). Most palm species are considered to be poor dispersers (Cunningham and Milton, 1987; Dransfield, 1988), the spatial clustering of individuals, typical of many palm species (including the two species in this study) has been attributed to the poor dispersion ability (Eiserhardt, *et al.*, 2011). Dispersal factors were also reported by Blach-Overgaard *et al.* (2009, 2010) to limit the distribution of palms in Africa. Therefore, these unaccounted biotic factors could prevent the two species from colonizing and occurring in areas, under various climate change scenarios.

Additionally, beside the above mentioned biotic factors, unsustainable exploitation of palms can constrain dispersal and therefore, expansion into potentially suitable areas. Negative anthropogenic impacts on abundance and population structure in Zitundo area of these two species have already been noted by Martins and Shackleton (2017). Unsustainable palm harvesting techniques in the area have been linked to high rates of stem mortality after tapping and reduction of seed production that negatively impact recruitment (Martins and Shackleton, 2017). With climate change the anthropogenic pressure on these palms may increase, since many crops and other useful plants utilized by local people, may fail to cope with the rapid change on climate, therefore making the local people more dependent on these resources.

Another reason for caution when considering the future projection of habitat suitability is the uncertainty liked to the future climate (Blach-Overgaard *et al.*, 2015; Moncrieff *et al.*, 2015; Chakraborty *et al.*, 2016). According to Blach-Overgaard *et al.* (2015) these uncertainties result from the model algorithms, the GCMs and the future gas emission scenarios. To reduce the uncertainties linked to the future climate and improve modelling it has been suggested to use different GCM and SDM methods (Shabani *et al*., 2012; Blach-Overgaard *et al*., 2015; Chakraborty *et al*., 2016). However, Chakraborty *et al*. (2016) reported that this is time and resource demanding and sometimes does not change outcomes. Therefore, the projected future habitat suitability for the two species should be taken as a tendency response of these species to future climate change and assume that the species will not occupy all the modelled suitable habitat.

The present study only used one SDM algorithm and one GCM to model the future habitat suitability for the two species. The results should be seen as an initial step in the assessment of the impact of climate change on these important resources. Further model improvements should incorporate other GCM suitable for the study area, as well as other SDM methods, including the ones that use presence/absence species data. Additionally, future models should include other variables linked to hydrology and anthropogenic factors as well as biotic interactions to improve the species distribution modelling prediction.

6.6 Conclusion

This study assessed the present and future distribution of two important palm species, *H. coriacea* and *P. reclinata* and the factors influencing their distribution using SDM and participatory mapping. Currently, over 90% of the study area was deemed to be unsuitable or barely suitable for either palm species. The results of both SDM and participatory mapping had similar spatial patterns, showing that currently the distribution of *H. coriacea* and *P. reclinata* was mostly confined in the east of the study area. The two mapping methods also showed that the two species occupied almost the same habitat as reflected by the same habitat suitability distribution pattern for both species. This result can indicated that Maxent accurately modelled the current distribution of these two palm species. The coincidence between the modelling results and the participatory mapping ones also indicate that the two species most likely occupy nearly all of their realizable range, therefore being in quasi-equilibrium with the environment of the area.

The SDM results demonstrated that the distribution of both species were influenced mostly by water related variables, such as precipitation, and the ones linked to hydrology and groundwater availability, such as distance to rivers and distance to water bodies. These water related variables contributed over 50% to models for both species models. *P. reclinata* appear to be more dependent than *H. coriacea* on the hydrology and groundwater related variables. Additionally, light availability and anthropogenic factors also play a role in the distribution of the species, as revealed by the significant influence of the average annual NDVI and distance to villages on the distribution of both species. The most important variables for both species models produced by Maxent and participatory mapping are comparable. The results of this study highlights the usefulness of LEK and the necessity of incorporating this type of knowledge in future biodiversity surveys, the conceptual development of SDMs as well as in conservation and management strategies.

The habitat suitability for *H. coriacea* was expected to increase under future climate scenarios, going from less than six percent of the study area to over 30%. While, little change was projected for *P. reclinata* distribution, a slight increase in habitat suitability was noted. These are important results given the vital role these two species play in the livelihoods of people from Zitundo area. With the advance of climate change and the possibility of associated rain-fed agriculture failure, these resources may become more important. Therefore, government and rural development agencies should be prepared to make use of the opportunities given by the increased habitat suitability of these resources and include them in future local development and climate change adaptations strategies. I recommend further model refinement with comparisons between different SDM methods and GCM as well as the incorporation of other variables to better capture the hydrological and anthropogenic influence, therefore improving modeling projection. To help counteract the future possible increase in human utilization pressure on these species, I recommend the development of participatory management plans, with inclusion of activities that would help these palms colonize their suitable habitat such as replanting and even future species domestication, since a certain level of landscape domestication is already apparent in the study area.

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CHAPTER SEVEN: SYNTHESIS, CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

Poverty reduction has been at the heart of Mozambique's development priorities and agendas for almost twenty years as evidenced by the establishment of several national action plans for the reduction of poverty, such as PARPA I 2001-2005; PARPA II 2007-2010 and PARP 2011-2014 (Governo de Moçambique, 2001; 2006; 2011). With over 70% of the national people living in rural areas, these programs promoted improvements in agricultural production, as well as the development of extractive industries (minerals, gas and petroleum oil) and energy as the way to promote development and reduce poverty (Governo de Moçambique, 2001; 2006; 2011). Some success has been achieved as shown though a decline in the relative incidence of poverty from 80% in 1990 to about 45% in 2015 (MEF, 2016). Although a noteworthy decline, the number of poor people hardly changed, being approximately 12 million in the 1990s and 11.8 million in 2015 (MEF, 2016). This limited reduction in the number of poor people was due to the high population growth over the corresponding period, which was estimated to be around 50% (MEF, 2016).

Development researchers nationally have extensively debated a variety of reasons why poverty remains so high despite the multiple poverty reduction programs. The most commonly debated explanations include the low agricultural productivity in many parts of the country, market constraints for agricultural products, a "one size fit all" approach of these programs, and a lack of local contextualization (Brito, 2012; World Bank, 2016). The lack of local contextualization can be seen as the major bottleneck of these programs. One example of the lack of local contextualization is the exclusion of NTFPs in areas where they currently or potentially contribute significantly to local livelihoods. Although the collection and trade in NTFPs are vital part of livelihoods of most people in rural Mozambique, there is no mention of NTFPs in national debates or poverty reduction programs. This is not unique to Mozambique, with commentators elsewhere also noting the 'invisibility' of NTFP use and markets in development policies, strategies and plans (Campbell and Luckert, 2002; Sills *et al*., 2011; Shackleton and Pandey, 2014), even in settings where they provide a large share, or even the majority share of household cash and non-cash income. Shackleton and Pandey (2014) summarize 12 reasons why NTFPs are commonly absent from development agendas, and emphasize that is often a combination of multiple reasons, which is probably the case in Mozambique. This needs to change in situations where NTFPs make meaningful contributions to livelihoods and incomes and make sustainable use of local resources, cultures and knowledge. The various chapters of this thesis have shown this to be the case with respect to the Zitundo area generally, and with palm-based activities specifically, and palm wine in particular. The results indicate palm-based livelihoods provide some of the highest per capita incomes, better than more conventional agricultural activities in the region, and reduce poverty by a significant margin. Thus, in the Zitundo area, a case can be made for investment and support to be offered towards promoting sustainable management, use and marketing of palm products alongside or in favour to agricultural support programs.

If NTFPs generally, or palms specifically, are to be included in development and poverty alleviation programs, it is best achieved on the basis of a thorough assessment of the current status of the resource, management knowledge and options, local livelihoods, current and potential markets, and possible future changes (Sieben, 2011; Shackleton and Pandey, 2014). This provided the broad motivation and basis for the research and understandings presented in this thesis, using two palm species widely used in the Zitundo area of Mozambique as a case example. The thesis was designed to answer the following questions: i) what are the uses of these two palms? ii) what factors underlie this use? iii) how does their use contribute to the livelihoods of people in the area? iv) what are the impacts of this use in the abundance and population structure of these palms? v) what is the potential effects of the climate change in the viability of these resources and hence use? The knowledge and insights gained from this study markedly increase the currently limited formal body of knowledge on the role of NTFPs in livelihoods in Mozambique, especially the role of palm species. This knowledge will be communicated in appropriate ways to policy makers and planners in the area to contribute to the development of locally based, adaptive and relevant programs that are integrated with other livelihood strategies to alleviate poverty or mitigate the effects of poverty whilst sustaining the populations of the two palm species.

7.2 Key findings

7.2.1 *Hyphaene coriacea* and *Phoenix reclinata* abundance and population structure

Both *Hyphaene coriacea* and *Phoenix reclinata* are abundant palm species in Zitundo. The former, *H. coriacea*, exhibited higher stem densities than *P. reclinata*, confirming Cunningham (1985) results in the nearby South African Maputaland palm savanna. The slopes of the size class distributions (SCD) of both species were steep and negative, characteristic of populations with more individuals in small size classes than taller one, denoting regular recruitment and a generally healthy, growing population (Condit *et al*., 1998). However, there was some evidence that the recruitment of both species may experience some discontinuities because the density of seedlings and juveniles were lower than the size class 1-50 cm tall. Indeed, the seedling size class only corresponded to five and seven percent of *H. coriacea* and *P. reclinata* populations, respectively. This recruitment limitation may be linked to low seed production, because many stems are tapped for palm wine production before they attain reproductive size. The study found that only 2 % of *H. coriacea* and 4 % of *P. reclinata* stems had reproductive structures or evidence of reproductive structures. The size class 1–50 cm was the most common class, comprising about 56% and 54% of population of *H. coriacea* and *P. reclinata*, respectively. The dominance of short size classes may be related to the high coppicing ability of both these species. Cunningham (1985) also noted high levels of vegetative reproduction through coppicing in these two species. The reduction in sexual reproduction may have a long-term impact on the viability of these palm populations through reduction of genetic variability, but this needs to be assessed. If there is some genetic erosion it could impact the future survival of these species if conditions change.

The above-described disturbance on the SCD of both species was captured by the three measures of population stability used in the study. The Simpson index of dominance above 0.1, the permutation index above zero and the fluctuating quotients between the consecutive size classes all indicated a certain level of instability on the population structure of both species. Results from the regression analyses suggested that anthropogenic factors, especially palm tapping, influence the population structure and stability of both species.

Cunningham (1985) suggested that the current palm population structure, characterized by short, multi-stemmed palm plants, is the result of long-term anthropogenic pressure in the form of excessive fire frequency regimes, and palm tapping methods, that have been taking place since the establishment in the area of the agrarian and pastoral society around 1500 before present. This may indicate that the Maputaland palm savanna has been experiencing a certain level of landscape domestication. According to Clement (1999) landscape domestication is an intentional process of human management of the landscape, through the use of partial forest clearance, extension of the forest borders, transplanting of desired plants or planting of desired seeds, addition of amendments to promote plant growth, and decrease competition from non-useful plants, which results in modifications in the landscape ecology and population demography of its plants and animals.

The study showed that there is selective palm cutting, both in terms of species and size, in the area. *H. coriacea* was prefered for tapping over *P. reclinata.* For *H. coriacea* tapping, tappers only avoided one out of six size classes, while preferring only one for *P. reclinata*. Palm tappers also stated their preferences for *H. coriacea* for palm wine production (Chapter 3). This result confirms Cunningham (1985) findings that in the Maputaland coastal palm savanna *H. coriacea* is the preferred species for palm wine production. This preference can be linked to a number of attributes, including the higher abundance of the species and lower stem toughness both of which facilitate the tapping process, along with the tappers' perception of a higher sap production of this species. For both species, intermediate size classes with heights between 101cm and 150 cm were preferred for cutting. However, the majority of tappers mentioned that the preferred stem size for tapping is between 10 cm to 50 cm (Chapter 3). Selective palm cutting was also detected by other authors (Cunningham, 1985; Babitseng and Teketay, 2013; Kinnaird, 1992). *H. coriacea* is not only preferred for tapping, but appears to also be more resistant to it, because it exhibited higher stem survival after tapping than did *P. reclinata*, corroborating the findings of Cunningham (1985).

Since the assessment of SCD provides only a snapshot census, it is not the best indicator of the dynamics and sustainability of a given population. Long-term demographic studies are required to better understand the dynamics of these NTFP populations and the impact of harvesting, in tandem with other possible anthropogenic drivers (such as fire or browsing regimes). Therefore I recommend further long-term studies that include among others controlled experiments, population dynamics such as: i) growth rates, ii) fruit and seed production, iii) survivorship curves and iv) factors that influence the demographic rates, including the impact of anthropogenic factors. The harvesting experiment plots were permanently marked, and so the basis for longer term monitoring and modelling has been established.

7.2.2 Palm use and the role of palm income in local livelihoods

The knowledge about the uses of the two species is widespread among Zitundo residents, though only a low proportion engaged in palm exploitation. Only 32% of households in the area used palms for consumption and cash income generation, against the 99% who knew at least one palm use. Lack of correlation between known uses and practiced uses were also obtained by Byg and Balslev (2001), Martins de Andrade *et al*. (2015) and Campos *et al*. (2015). This is not uncommon for species that are common in an area and are used by reasonable proportion of households for one or more purposes. In such circumstances use of the NTFP is widely observed even by non-users.

Thirteen palm products were used in the area, but with a clear focus on those with the highest commercial values, such as palm wine, brooms and baskets. Both species were used to produce palm wine, although there was a preference for *H. coriacea* over *P*. *reclinata*. This preference was verified through the harvest selection (Chapter 2), as well as the interviews with palm tappers (Chapter 3) and households (Chapter 4). Sixty percent of palm wine tappers use solely *H. coriacea* to produce wine. This confirms the preference to harvest results, where five out of six size classes from *H. coriacea* showed positive preference ratios whilst there was only one for *P*. *reclinata* (Chapter 2). Tappers mentioned the tougher stem, the lower sap production and the lower abundance of *P*. *reclinata* as constraints or deterrents to using *P*. *reclinata* for palm wine production. Basketry and brooms were produced from *H. coriacea* fronds and *P*. *reclinata* stems, respectively. The long unopened leaf, typical of the genus *Hyphaene*, and the strength of its fibers were the chief reasons to use *H. coriacea* for basketry. There are parallels reports of *Hyphaene* species use in basketry in various parts of Africa (Cunningham, 1985; Cunningham and Milton, 1987; Konstant *et al*., 1995; McKean, 2003; Amwatta, 2004; Sola *et al*., 2006). Preference for *P*.

reclinata for broom production is linked to the numerous flexible fibers, typical of the stem of this species. Broom and brush production from *P. reclinata* have also be mentioned in other parts of Africa (Orwa *et al*., 2009; Kinnaird, 1992; Gyan and Shackleton, 2005; Mjoli and Shackleton, 2015). Additional to the contribution of both species to consumptive households uses and cash generation, the two species also play a vital role in the culture, folklore and traditional belief system of people in Zitundo. These species fulfill most of requisites to be considered cultural keystone species (Garibaldi and Turner, 2004) in the area, lending credence to the suggestion of Cámara-Leret *et al*. (2014) that numerous palms are cultural keystone species in many parts of the globe. Because of the high abundance and dominance of *H. coriacea* in large parts of the area, it is quite likely that it will also play a keystone role in the community ecology too, thereby being both a biological and cultural keystone species, or a biocultural keystone (Shackleton *et al*., 2018). This further emphasizes the need to ensure that palm use is sustainable and that other land uses and practices in the area are not detrimental to population viability and persistence. It also accentuates the importance of integrating palm use and conservation into local development plans and projects, building on local knowledge and sensitive to local culture.

In common with many rural areas of developing countries, households in Zitundo engage in a certain level of livelihood diversification. However, the level of diversification measured in this study was less than that from several other rural areas in sub-Saharan Africa (Agyeman *et al*., 2014; Chilongo, 2014; Addisu, 2017). This study identify seven livelihood diversification strategies in the area, including a palm-based livelihood strategy. Although the returns from palm products trade are among the most significant in the area, with traders earning almost double the income of non-traders, and the palm-based livelihood strategy being one of the most remunerative, few households trade palms products or based their livelihoods solely on palm income. This echoes Shackleton (2005), Shackleton and Shackleton (2004) and Mugido and Shackleton (2017) from neighbouring South Africa, who all report relatively low proportions of households engaging in NTFP trade. However, those studies still report that for some households NTFP trade can be especially lucrative. This result, and the finding that the majority of households in the Zitundo area engaged in the wage-based strategy, despite it being one of the least remunerative, may indicate that in Zitundo non-economic factors may play a major role in the choice of livelihoods strategies. For example, perceived stability of earning a cash wage even if it is lower than what can be earned through being a palm tapper, or that tapping might be regarded by some as being too physically demanding. Although palm income was not widely adopted in the area, it plays a vital role for the livelihoods of people involved in palm trade, being the main income source for most of them and contributing almost 60% of their total annual cash income. This rate of contribution was even higher for palm wine tappers which was greater than 80%.

Palm wine tapping is an important activity in the area, and is mainly done in the palm savannas of the study area. Palm wine income was the major source of palm income among palm product traders, contributing to over 80% of all palm income (Chapter 5). Palm wine is a highly commercial and profitable commodity in the area. Over 60% of palm wine produced was for sale, as measured via the commercialization index (Chapter 3). The gross palm wine returns per tapper averaged over R20 000. This is one of the highest returns from NTFP local trade in southern Africa (Shackleton, 2004; Shackleton *et al.,* 2007b; Mugido and Shackleton, 2017). Such returns also surpass up to three times the national minimum wage for the agricultural and forestry sector in Mozambique. These results contradict various authors who emphasize the often low economic returns from localized NTFP trade (Neumann and Hirsch, 2000; Emery and Zasada, 2001; Pearce and Pearce, 2001; Shackleton *et al.,* 2007a). Factors underlining the high returns from palm wine may include the higher abundance of palms in parts of the study area, the year-round availability of the resource, the existence of a large and seemingly reliable local market and the low costs involved in tapping palms and marketing the product. With much of the trade being across the border with South Africa also provides some insurance against local economic downturns or vagaries of the Mozambican currency.

The study results consistently showed that palm income plays a key role in alleviating poverty in the area. Results from the influence of palm wine income on poverty incidence of tappers, as well as the incidence of poverty among households adopting a palm-based livelihood strategy corroborated one another. There was more than a 60% reduction in poverty incidence among palm tappers due to the cash income from palm products, while adopting a palm-based livelihood strategy resulted in a 23% - 60% lower poverty incidences than the alternative strategies. This is particularly important given the higher poverty incidence in the rural areas (MEF, 2016). This confirms the reports of Stanley *et al*. (2012) that in Africa and Latin America NTFP incomes helps lift unskilled people out of poverty. Shackleton *et al*. (2007a; 2008) argued that this is especially true for individuals who exploit NTFPs on a fully time basis, as the main source of income, and usually with some level of specialization in a given NTFP (Belcher *et al*., 2005; Shackleton *et al*. 2011; Pullanikkatil and Shackleton, 2018). This appears to be the case among households adopting a palm-based livelihood strategy in the Zitundo. Specialization is likely to require sound knowledge of the resource, at least in the early stages. For example, Weyer and Shackleton (in press) show that high individual knowledge about a specific NTFP predisposes adoption of its harvest and sale as a safety-net strategy. The corollary being that low knowledge about a specific NTFP constrains the option of individuals or households to use it as a safety and hence enter the trade.

7.2.3 Factors affecting palm use, income dependency and adoption of palm-based livelihood strategies

Village of residency was consistently found to be one of the most important factors determining the level of palm use knowledge, the engagement on palm products exploitation, the dependency on palm income, and the household livelihood strategies adopted. Households residing in areas with high palm abundance were more likely to engage in palm exploitation, adopt a palm-based livelihood strategy, and were more dependent in palm income. In contrast, in villages of low palm abundance, there was a lower tendency to engage in palm exploitation, a lower dependency on palm income and a reduced likelihood of adopting a palm-based livelihood strategy. This also interacted with the prospects for local job opportunities, such that areas near the coast, where there are high opportunities for wage employment, were associated with lower engagement in palm activities. The influence of village was probably linked to differences in palm availability and other biophysical features surrounding the villages, and the job opportunities and market marginalization or integration among the villages. This results accords to Paniagua-Zambrana *et al*. (2017) suggestion that the influence of village in palm use is usually connected to the level of marginalization or integration with employment or trade markets, the composition of the villages local vegetation and the ethnicity of its residents. The significance of village location accentuates the importance of local level studies and understandings to inform development plan, options and programs, as mentioned previously. Broad-scale planning risks missing local development opportunities.

Beside the influence of village, some household socio-economic and demographic characteristics also contributed to the likelihood of engagement in palm use and commercialization, households' choice of livelihood strategies and palm income dependency. For instance, palm income dependency was negatively influenced by being from Ronga ethnicity and owning a boat, and positively affected by education. The results also showed that being a female reduced the likelihood of using palms, while being native of the village of residency positively influenced palm use.

7.2.4 Perceptions of palm abundance and local management practices

The widespread belief in Zitundo area is that palms are an abundant resource and have been increasing over the years. Thirty-two percent of household heads and over 60% of palm tappers perceive the abundance to have increased over the past five years. Vegetative growth through lateral coppicing after tapping was the main reason stated for this perceived increase. Thus, there may well be more stems, as a result of coppicing, but that does not mean there are more individuals. Any overall impression of an increase may serve to initially mask any decline in the number of individuals. However, without longitudinal data it is impossible to disaggregate trends in the number of stems from trends in the number of plants. Vegetative growth is usually an effective strategy to counteract environmental stresses (Traoré *et al.*, 2012), which in African savannas are often death of the dominant stem due to fire, drought or depredations of large herbivores (Shackleton, 1993). In the Zitundo area tapping is likely to be an additional source of stress to mature palm trees. This confirms the instability of the population structure detected by this study (Chapter 2). However, palm wine tappers considered that their activity was not detrimental to palm growth and reproduction. However, results from this study (Chapter 2) suggest otherwise. Tapping was found to reduce seed production, because palms are normally tapped before reaching reproductive size, consequently impacting recruitment via seeds. Furthermore, low stem survival after being tapped was also detected in this study (Chapter 2), although the coppice response ensured that most individual plants were resilient to tapping. Palms are exploited as an open access resource in Zitundo. Most of the respondents stated that there is no control over palm harvesting, but over 60% of palm wine tappers reported needing permission to start the tapping activity in the area. There appeared to be no local or formal management systems for the palms, or the communal landscapes in general. However, some voluntary management practices were followed by tappers to conserve these resources for future use (Chapter 3).

7.2.5 Projected palm distribution under future climate change scenarios

H. coriacea and *P. reclinata* occupied almost the same habitat, and were mainly restricted to the east of the study area. The modeling results showed that more than 90% of the study area was considered to be unsuitable or barely suitable for either palm species. Water related variables, such as precipitation and hydrology, measured as distance to rivers and distance to water bodies, were the factors most correlated with the species distributions, confirming findings by Dransfield *et al*. (2008), Blach-Overgaard *et al*. (2010) and Eiserhardt *et al*, (2011) that precipitation and/or a high groundwater table are key factors in palm species distribution. These two species preferred open habitats with low precipitation, as demonstrated by the optimum habitat suitability around 350 mm and NDVI of 0.33. The NDVI influence denotes that light availability could be an important factor shaping these species presence or absence. The correlation with open habitats and low precipitation is a typical feature of palms from the genus *Hyphaene* (Blach-Overgaard *et al*., 2009; 2010). Groundwater availability appeared to be more important for *P. reclinata*, influencing positively its habitat suitability. Distance to the nearest village also influenced the distribution of both species; being positive for *H. coriacea* distribution and negative for *P. reclinata*. Distance to village is a proxy for the intensity of anthropogenic factors (such as harvesting pressure, browsing pressure and perhaps fire incidence) on the abundance and population structure of both species in the study area. The opposite response of the two species to distance to village is an indication that these species react differently to the human pressure. This was also revealed in Chapter 2, with *H. coriacea* being more resilient to tapping than *P. reclinata*. These two species appear to be in equilibrium with the environment since each nearly occupied all of the potential realizable range as denoted by the coincidence of habitat suitability results and the participatory mapping of their occurrence.

There was much coincidence between SDM results and the participatory mapping results in terms of the distribution of each species and factors determining their distribution and occurrence. These results confirm the usefulness of LEK stated by previous studies, and the importance of combining the LEK with the scientific knowledge in the biological census, conservation and management plans (Anadón *et al*., 2009; Hill *et al*., 2010; Polfus, 2010; Ticktin, 2015; Lima *et al*., 2017; Constant and Tshisikhawe, 2018).

The two species are expected to respond differently to future climate scenarios. *H. coriacea* habitat suitability was projected to increase by over 24%, going from less than six percent to more than 30%. On the other hand, *P. reclinata* habitat suitability was expected to maintain its current status. These results should be used with caution and be interpreted as a tendency response of each species to future climate rather than a definitive calculation. It is unlikely that either species will occupy all projected suitable habitat, because not all factors that shape species distribution, such as biotic factors and other anthropogenic factors (such as level of harvesting) were accounted for during the SDM exercise. Further model improvement is required through inclusion of comparisons between different SDM methods and GCM, and incorporation of other variables to better capture the potential of the hydrological and anthropogenic influences.

7.3 Conclusions, recommendations and challenges and lessons learnt

7.3.1 Conclusion

This study has shown that *H. coriacea* and *P. reclinata* are important resources in the livelihoods of people from Zitundo area. Palm product use and trade contribute to generate a relatively high cash income and help alleviate the extent and intensity of poverty in the area. Additionally, the two species are an integral part of the culture, traditions and folklore in the area. Palm abundance, wage-earning job opportunities and some household characteristics shape engagement in palm use and trade. The use of palms, especially palm tapping for palm wine, appear to have some negative effects on the abundance and population structure of both species, which is likely to be constraining, especially seed production and consequently recruitment of new individuals through seedlings. If recruitment is constrained, there would be declines in population density over the longer term, which would likely compromise the livelihoods of people using and depending on them. At a broader scale, both species, especially *H. coriacea*, appear to be resilient to future climate change projections, with *H. coriacea* possibly increasing its habitat suitability by over 25%. This is an encouraging result given the vital role this species plays in Zitundo livelihoods. However, if climate change were to undermine other livelihood strategies in the area, such as arable farming or animal husbandry, more people may seek to engage in palm use and trade, which could limit any species expansion, and further constrain seedling recruitment. In Zitundo, palms are exploited in an open access resource system. No local or state management plans exist to support, or if needed regulate, the use of local NTFPs including the two palm species. However, some voluntary management activities, to secure the future use are practiced by the tappers. A simplified schema of the above described palm use system in the area is presented in Figure 7.1.

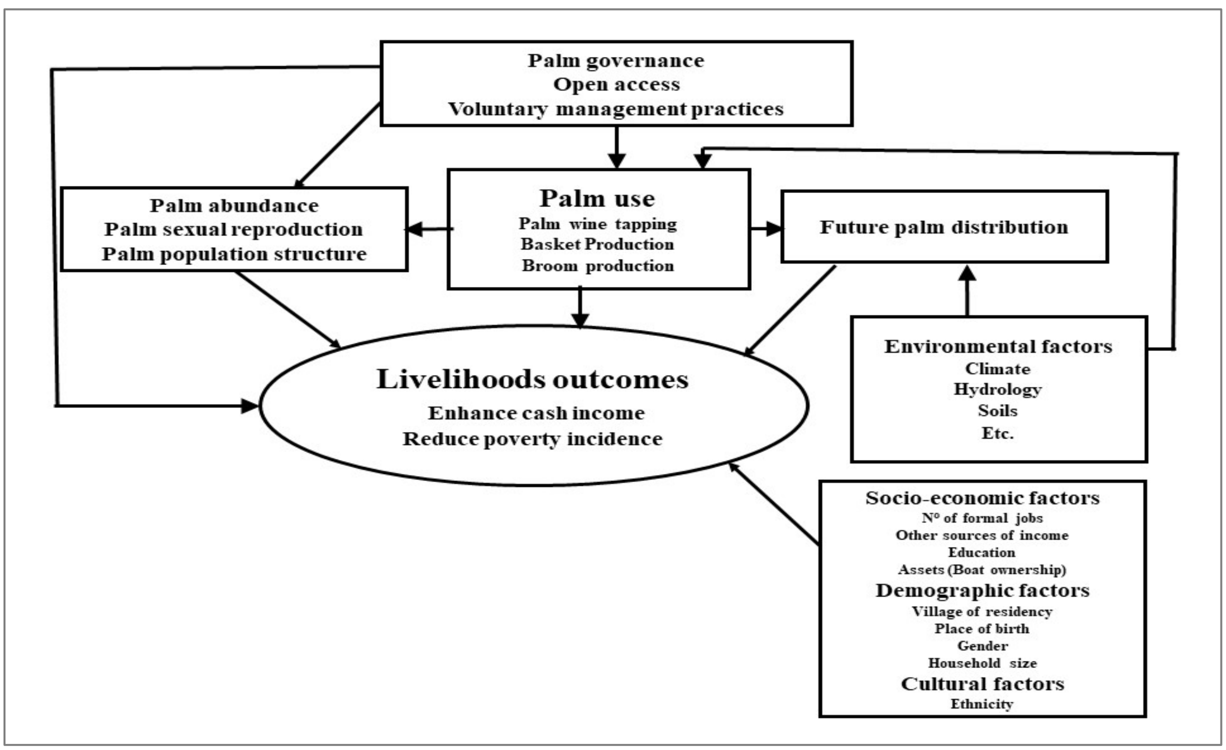

Figure 7.1: Integrated representation of palm use and viability in Zitundo

7.3.2 Recommendations

Palm products such as wine, baskets and brooms, each have potential for future and additional commercial development. They provide significant contributions to local livelihoods and poverty mitigation as well as alleviation for some, which should be acknowledged by government and development agencies and incorporated into local development plans and poverty reduction strategies. The promotion of palm-based livelihood benefits suggests a role for participatory conservation and management strategies for these resources. Any management strategies need to be based on scientific and traditional knowledge to guide and foster sustainable use. The suggested actions aim at encouraging resource sustainability, promoting sound palm governance and enhancing palm income. Table 7.1 summarizes the proposed recommendations. Further description of recommended strategies are presented below.

Table 7.1: Summary of proposed recommendations to encourage palm exploitation sustainability, promote sound governance and enhance income

Aim	Potential strategies	Example actions
Promote sustainability of the resource	Promote palm recruitment	Discourage harvesting of stems taller than 2 m Ensure there are at least 5 stems/ha taller than 2 m Harvesters to scatter ripe seeds when they encounter them Encourage tappers to retain one tall, reproductive stem per plant
	Promote the recovery of tapped stem	Encourage tappers to leave part of apical meristem during the tapping process to allow for recovery through regrowth and vegetative reproduction Promote the use of insecticide against palm weevil in the tapped stem left to recover
	Provide spatial or temporal refugia	Develop a zonation plan for each village and implement rotational harvesting with 20 % of the area unharvested per year. Encourage planting of palms near homesteads and around fields Encourage tappers to leave small stems
	Monitor palm populations	Develop a set of robust indicators of population viability and train interested tappers to make readings at an agreed and appropriate frequency Establish a set of permanent plots with repeat measures every 2-3 years
	Promote participatory governance of the palm resource	Encourage the development of palm exploitation committee with involvement of all palm user groups and the already existent traditional and local institutions and systems to undergo collective actions activities
Local and broader-scale resource governance	Promote resource tenure security	Encourage the formalization of collective rights for palm exploitation
Increase income generation from palms	Increase cooperation in management and marketing	Encourage palm product harvesters and traders organizations thought associations and cooperatives
	Diversify palm products	Develop training programs to teach new skills to manufacture new palm products Stimulate the improvement and/or establishment of local markets for the new palm products
	Integrate palm products into local and regional development plans	Develop incentives for palm products micro-enterprises Promote palm products via fairs and special markets

7.3.2.1 Promote the sustainability of exploited resource

According to Ticktin (2015), the harvesting of NTFPs is only sustainable if it has no or limited immediate or future negative effects on the population and in the ecosystems in which the species are found. Usually, a viable seed bank and good recruitment levels are key factors for long-term maintenance of NTFP populations (Condit *et al*., 1998). This study demonstrated that the level of seed recruitment of *H. coriacea* and *P. reclinata* is constrained. Therefore, actions to promote palm recruitment are suggested. Options to increase palm recruitment could include: discourage harvesting of stems taller than 2 m, ensure that there are at least 5 stems/ha taller than 2 m, encourage tappers to retain one tall, reproductive stem per plant. These measures will safeguard that some stems can reach reproductive sizes and allow seed production. Izabela *et al*. (2018) reported that Ramón (*Brosimum alicastrum*) nuts harvesters in Guatemala leave 20% of the nuts on the tree to guarantee the propagation of the species. Furthermore, harvesters could scatter ripened seeds when they encounter them to increase recruitment and expand the population of these species. For example, Duvall (2007) reported a successful increase in baobab recruitment through seed dispersal in West Africa. Also, the spreading of golden grass (*Syngonanthus nitens*) seeds, a NTFP species used for basket weaving, is part of the management practices in Jalapão region in Brazil (Schmidt *et al*., 2015).

Another source of concern detected by this study is the low survival rate after tapping. Possible actions to increase the chances of stem survival include (1) leaving part of apical meristem during tapping to allow for recovery through regrowth and vegetative reproduction and (2) the use of insecticide against palm weevil in the tapped stem. Although leaving part of the apical meristem to allow for stem recovery is a traditional palm tapping technique in Southern Africa (Cunningham, 1990a), very few tappers reported doing it in Zitundo area. According to Cunningham (1990a) and Sola *et al*. (2006) this practice is vital for stem recovery after tapping, so I suggest the dissemination of this practice in the area. Palm weevil infestations that destroy the tapped stems were mentioned by over 50% of tappers as one of the main challenges and hence control of palm weevil infestations may increase the rate of stem survival after tapping.

Shackleton *et al*. (2015) highlighted the importance of refugia in the sustainability of many NTFP populations under harvesting pressure. The authors argued that refugia function as a center for the species re-establishment. They may be physical or temporal refugia. One that combines both would be a rotational harvest system. Consequently, I suggest the development of a zonation plan for each village and implementation of rotational harvesting with 20 % of the area unharvested per year. Tappers mentioned that it takes about three to four years for a new coppice to reach the desirable size for tapping. This recover period is close to the 3-5 years reported by Felgate (1965, 1982) and lower than the 6-8 years stated by Cunningham (1990b). Therefore, the recovery period after tapping in Zitundo needs to be further investigated with the help of the tappers and be used as the basis for the designated rotational harvest systems. Rotational harvesting has been successfully used in Nepal to manage the use of several medicinal and aromatic species (Subedi, 1997). Rotation in Camedor palm harvesting was also reported by farmers who plant this species under coffee plantations in Mexico (Becerra *et al*., 2018). Additionally, planting of palms near homesteads and around fields, as well as excluding small stems from tapping could be encouraged. An example of NTFP product cultivation comes from the Limpopo Province in South Africa, where EcoProducts, a baobab commercialization company, promotes the cultivation of this species by community members to mitigate population declines species (Welford *et al*., 2015). In Zitundo, avoiding tapping small stems is already practiced by a few tappers, consequently it is an existing practice that could be encouraged.

Long-term monitoring of NTFP populations is vital to safeguard their sustainability (Ticktin, 2015; Shackleton and Pandey, 2014). Participatory monitoring by resource users can play a significant role, since it allows for a early detection of changes in the population and implementation of adaptative management, with adjustments on the way the resource is exploited when necessary (McLain and Lawry, 2015; Shackleton *et al*., 2015; Ticktin, 2015). To monitor palm populations, this study suggests the development of a set of robust indicators of population viability and health, and training of interested tappers to make readings at an agreed and appropriate frequency. LEK held by tappers and other resource users could be combined with scientific information to inform the establishment of these indicators. A successful example of such is the annual, participatory monitoring of baobab populations in South Africa (Welford *et al*., 2015), which measures changes in the baobab population and fruit production to inform EcoProducts, a baobab trade company, for determination of sustainable quotas (Welford *et al*., 2015). Additionally, LEK has been used to inform sustainable management strategies for golden grass flower harvesting (Schmidt *et al*., 2015) and janaguba (*Himatanthus drasticus*) latex tapping (Baldauf *et al*., 2015) in Brazil. I also propose the establishment of set of permanent plots with repeat measures every 2-3 years. Indeed this study set the foundation for this kind of monitoring with the establishment of 24 permanent plots in the area.

NTFPs governance is also an important factor in shaping sustainability of NTFP populations and use (Shackleton and Pandey, 2014; McLain and Lawry, 2015). Participatory governance was one of the options suggested to counteract the so often unsuccessful centralization of management systems inherited from colonial periods (McLain and Lawry, 2015; Persson and Prowse, 2017). Participatory management usually comes with the decentralization and devolution of the resource rights and empowerment of the local and traditional institutions for the management of these resources (McLain and Lawry, 2015; Persson and Prowse, 2017). This study proposes the development of a palm committee in each village involving of all palm users and the traditional and local institutions and systems to undergo collective actions activities relate to palm resources governance. Collective actions to be undertaken by this committee may include setting local context based rules for access and use of palm resources, as well as participatory monitoring of resource exploitation (suggested above) and participatory rules enforcement. McLain and Lawry (2015) reported a thriving traditional governance structure for Agave in Mexico which included the use of rotational harvesting, monitoring to safeguard that only mature plants are collected, fines for harvesters that do not comply with the use rules, and provisional harvesting suspensions in the event of resource decline. Resource governance is a complex field and varies according to traditions, context and specific stakeholders. It is therefore important that any institutions and practices are adaptive and self-learning.

7.3.2.2 Local and broader-scale resource governance

According to McLain and Lawry (2015) resource users' perceptions on the security of their rights to resource exploitation influence their behavior towards the long-term sustainability of those resources. More secure rights are usually linked to more sustainable resource use (Heltberg, 2002; McLain and Lawry, 2015). Rights formalization, either individual or collective rights, is usually used to increase security and consequently promote resource sustainability. Although this study did not focus on the governance aspects of palm use, there is an apparent lack of palm resource governance in the area. Therefore, linked to the previous suggestion of the promotion of palm use committees, I further propose the formalization of collective rights for palm harvesting be granted to the palm use committee. Such formalization is particularly important given the increased land acquisition for cattle farming occurring in the palm savanna of Zitundo. Several authors reported that collective rights are able to secure both conservation and economic gains, in some instance even better that the state managed resources (Ostrom, 2010; Persha *et al*., 2010; Shahabuddin and Rao, 2010; McLain and Lawry, 2015). Well-defined collective rights are a stimulus for local people to use resources sustainably and to protect them from outsiders (Velez, 2011). Such rights appropriation by a palm use committee should be accompanied by the collective actions that relate to palm resource governance described above to effectively promote the sustainable use and conservation of the palms.

7.3.2.3 Increase income generation from palms

NTFP collectors and traders often face several constrains to increasing the level of their trade (Shackleton *et al*., 2007b). Lack of organizations among resource harvesters and traders, as well as limitations in technology, assets, access to credit contacts and skills have been mentioned as some of the factors that hinder the growth of NTFP trade (Shackleton *et al*., 2007b; Sills *et al*., 2011). Shackleton *et al*. (2007b) argues that this situation can be changed with the right policies and local level interventions. To improve palm products trade in Zitundo, and thus income generation, this study suggests the following actions: promotion of palm product harvesters and traders organizations thought associations and cooperatives, promotion of new palm products through training, and improvement and/or establishment of local markets for the new palm products.

Several authors have highlighted the advantages of cooperatives and associations of harvesters and traders. Such organizations help participants overcome some of the limitations mentioned above. The advantages of NTFP associations and cooperatives include among others: increased bargaining power for better prices, better access to credit and other assets such as transportation and storage, allow for legal representation, and better information and technology sharing, all of which may serve to reduce risks and costs (Tostão and Mlay, 2002; Scherr *et al*., 2003; Pullanikkatil and Shackleton, 2018b). Many examples of successful NTFPs collectors and traders' groups can be found in the literature. An example from Peru is the Brazil nut collector's association, which once created allowed the nut collectors to get better prices for their products and to acquire a Fairtrade International Certification for their product (Condori *et al*., 2018).

Additionally, group members benefit from access to credit, transportation, tools and training in sustainable harvesting (Condori *et al*., 2018). Another example of an effective association is the case of acai berry trade through the Cooperative of Bailique Extractive Producers (AmazonBai). Acai collectors were able to double the price of their product due to the association and certification (Alves and Ramos, 2018).

In Zitundo area the main palm product is palm wine. This commodity has a large and apparently reliable market. Baskets and brooms are also commercialized, however to a lesser extent. Therefore, there is still space for new products development. For example, furniture building using *H. coriacea* is a possible lucrative activity (Nhancume and Martins, 2018) though is not usually practiced in the area. Another product with potential is basket weaving. In Zitundo baskets are made for household use. But in many regions of southern Africa, baskets are sold as decorative items in tourist markets (Cunningham and Terry, 2006; Adam and Shackleton, 2016). There are growing tourism activities along the coastal sections of the study area, which could provide a ready market for ornamental baskets. Therefore, this study suggests the development of training programs to develop such products and transfer basketry skills for the development of quality products to interested people as well as stimulate the improvement and/or establishment of local markets for these products. Training have been used by development agencies to build new skills and improve the added-value of NTFP products throughout the developing world. Two examples of the importance of training come from India. In one instance training was used to help a village create value added products such as furniture, baskets, and crafts using *Lantana camara*, an invasive shrub (Rangasamy *et al*., 2018). In another instance, a bamboo crafting community received intensive training to improve their skills and learn to produce bamboo furniture, which was a more remunerative product (Ben *et al*., 2018).

The importance of palms in the livelihoods of Zitundo households and communities should be acknowledged by the local government and development agencies and be integrated into local development plans and poverty reduction strategies. Some actions to do that include the development of an incentive pack to facilitate the establishment of palm-based micro-enterprises. Incentives could include facilitation and simplification of the regulatory processes needed to acquire business licenses and facilitate access to credit. Additionally, promotion of palm products thought organization of palm product fairs and special markets at local and regional scales is also suggested. Nepal is one of the leading countries in terms of integration of NTFP activities, products and markets into their policies and local development strategies. For example, the Government of Nepal, in conjunction with a Research Centre for Applied Science and Technology, the Tribhuvan University and the International Centre for Integrated Mountain Development, set up a conservation and development program for allo (*Girardinia diversifolia*) in Khar, a Nepalese village. Some of the incentives provided through the program included training in design and knitting of cloth using allo as well as sustainable harvesting and propagation techniques. Additionally markets for clothes produced from allo were developed, along with fuel efficient stoves for processing allo (Singh *et al*., 2018).

In conclusion, this study has provided significant data, information and insights about the use and importance of palms in the Zitundo region. The palms represent an abundant resource which, if conserved and well managed, can continue to provide substantial cash and non-cash contributions to local livelihoods, traditions and culture, along with alleviating poverty for a meaningful proportion of households in the region. There are even likely to be opportunities to increase the cash incomes earned from palm products through product diversification and improved marketing. The current benefit flows have been developed by local entrepreneurs with very little government interventions or support. The resource and use systems may well continue to flourish without government support into the future. However, circumstances are dynamic and land use and environmental systems are changing in the region, mostly notably the development of tourism enterprises along the coast, increasing interests in cattle production and climate change. This requires that local institutions and government be vigilant regarding how such changes will undermine or syngerize with the role of palms products in local livelihoods. In being vigilant they will also need to be responsive and adaptive in the face of such changes, to build on opportunities as they arise and address threats or constraints to the sustainability of the palm populations and the products they provide.

7.3.3 Challenges and lessons learnt

The biggest challenge I have encountered during the study was getting the trust of the palm users, especially the palm tappers. Although before the interviews I briefed the respondents about the purpose of the research and the researcher's institutional affiliation, it was difficult to make interviewees understanding that this was an academic study, that I was not from the government and that I was not there to prohibit the exploitation of palms in the area. Having the support of the local traditional leaders and having a field assistant/translator that was a native from the area and who spoke Ronga fluently helped me clarify the issue and gain the trust of the local people. Therefore, having support from the local traditional authorities and working with members of the local community is vital in having success in studies that involve local people.

Another challenged I faced during the interviews has to do with the translation process. Although I can understand perfectly the Ronga language, I cannot speak it fluently therefore a needed a translator to communicate with the respondents. This translator was subjected to a training on the interviewing process and working with local communities, however in the initial stages of the census, I noticed some problems with the fidelity of translation of the questions I was asking. Fortunately, because I understand the language, it was possible to detect that the translation of some questions was incorrect and correct it. Since I was working with the same translator, this problem disappeared as the census progressed. Another issue I faced with the translation process, was that in the beginning of the study I was not aware that some people in Zitundo administrate post only speak Zulu (a South African Language) my translator did not speak Zulu. To overcome this difficulty when I encounter this case, I had to re-seclude the interview and found within the village another translator to do the Ronga to Zulo translation. Understanding the local language of the people I was working with was very opportune, however the study would have benefited more if I had a better knowledge of the culture and awareness of the all languages that are spoken in the area.

Another challenge I faced was to quantify the amount of agriculture products households' use for their own consumption. Very few households were able to quantity the amount of agriculture products their use for household consumption, since their harvest most of them on demand. To overcome this issue, for the livelihood chapter (chapter five) I decided only to use the cash income. One of the ways to mitigate this issue is to do a trimestral household census instead of only one snapshot census.

Finally lack of some data in an appropriate spatial scale was also challenging during the modeling of the distribution of the two studied species. This led to change in the use of some variables I had planned during the proposal development and the usage of the best available data. For example, although I had planned to include the drought index as an environmental variable (according to the literature this variable affects the distribution of plants) I could not find data in a spatial format on the drought index. Therefore, I decided to use distance to rivers and waterbodies as an indicator of moisture availability. This data issue and the limitations I have previously mentioned on the modelling exercise made me realize that the species modelling exercise is ongoing process.

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APPENDIXES

APPENDIX 1: HOUSEHOLD QUESTIONNAIRE

A. Identification

Date of interview:…………………………………………………..

Code of household:……………………………………….………..

Village Code……………………………………………………..

Household GPS Coordinates:……………………………………..

B. *Hyphaene coriacea* use

1. Does your family collect products from *Hyphaene coriacea?* Yes ( ) No ( )

2. If yes, which

Products collected from HC	Where are products collected	Who collects	Distance from the house	Months when collected	Amount collected per trip	Nº of trips/week	Costs of collection	Costs of transport	Collection hours/week	Years collecting

3. If no, why you don't collect?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………

4. If no, did you used to collect in the past? Yes ( ), No ( )

5. If yes, what did you used to collect, and when was the last time you collect?

Products used to collect	Purpose of the collection[2]	Why the HH stop collecting	When the HH stop collecting

6. Purposes of collection?

Products collected from HC	Purpose of collection[2]	Amount consumed by HH/week	Amount sold/week	Price/ unit	Months of the year when sales a higher	Months of the year when sales a lower	Who buy	Where is product sold	How far is the selling place	Costs of transport to market

[2] own consumption (0); sale (1)

7. Do you process the products collected in number 2? Yes ( ); No ( )

8. If yes, which kind of processing?

Product	Processing	Who processes?	Time/unit	Costs

9. Is there any control over *Hyphaene coriacea* use? Yes ( ); no ( ); don't know ( )

10. If yes, who controls the resource? Communal ( ); state ( ); private ( ); local leaders ( )

11. Is the resource available to everyone who wishes to collect? Yes ( ); No ( );

12. If no, why……………………………………………………………………………….

……………………………………………………………………………………………………

………………………………………………………………………………………

13. During which months of the year is the product available? ……………………………………………………………………………………………………

………………………………………………………………………………………

14. Has the number of plants of this species changed in the last 5 to 10 years?

Yes ( ); No ( )

15. If yes, increasing ( ), decreasing ( )

16. If there was a change, what do you think is the reason for these change?

……………………………………………………………………………………………

……………………………………………………………………………………………

17. Has the quantity of products you collect from this species changed in the last 5 to 10 years? Yes ( ); No ( )

18. If yes, increasing ( ), decreasing ( )

19. If there was a change, what do you think is the reason for these change?

……………………………………………………………………………………………………

………………………………………………………………………………………

20. Has the number of people selling *Hyphaene coriacea* products changed in the last 5 to 10 years? Yes ( ); No ( )

21. If yes, increasing ( ), decreasing ( )

22. If there was a change, what do you think is the reason for these change?

……………………………………………………………………………………………………

………………………………………………………………………………………

23. Are there any management practices that you or others make on the resource?

......................……………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………..

24. Do you cultivate the species? Yes ( ); No ( )

25. Have you seen anyone else cultivate it?   Yes ( );   No (   )

C. *Hyphaene coriacea* cultural use

1. Is this species used on any traditional ceremonies/celebrations?   Yes ( ); No ( )
2. If yes, how is the species used in the ceremonies/celebrations?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………3. Are there any proverbs and/or sayings about the species?   Yes ( ); No (   )

4. If yes, what are they?

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……………………………………………………………………

5. What is the meaning of the proverbs and/or sayings?

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…………………………………………………………………………………………………
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……………………………………………………………

6. Are there any traditional games in which the species is used?   Yes (   ); No (   )

7. If yes, what are they and how they are played?

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…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………8. Are there any traditional songs in which the species is mentioned?   Yes ( ); No ( )

9. If yes, what are they and when the songs are sang?

………………………………………………………………………………………………

10. Are there any stories related to this species?   Yes ( ); No ( )

11. If yes, what are they?

……………………………………………………………………………………………………

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……………………………………………………………………………………………………

D. *Phoenix reclinata* use

1. Does your family collect products from *Phoenix reclinata?* Yes ( ) No ( )

2. If yes, which

Products collected from PR	Where are products collected	Who collects	Distance from the house	Months when collected	Amount collected per trip	Nº of trips/week	Costs of collection	Costs of transport	Collection hours/week	Years collecting

3. If no, why you don't collect?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………………………………………………………………………………………

4. If no, did you used to collect in the past? Yes ( ), No ( )

5. If yes, what did you used to collect, and when was the last time you collect?

Products used to collect	Purpose of the collection[2]	Why the HH stop collecting	When the HH stop collecting

6. Purposes of collection?

Products collected from PR	Purpose of collection[2]	Amount consumed by HH/week	Amount sold/week	Price/ unit	Months of the year when sales a higher	Months of the year when sales a lower	Who buy	Where is product sold	How far is the selling place	Costs of transport to market

[2] own consumption (0); sale (1)

7. Do you process the products collected in number 2? Yes ( ); No ( )

8. If yes, which kind of processing?

Product	Processing	Who processes?	Time/unit	Costs

9. Is there any control over *Phoenix reclinata* use? Yes ( ); no ( ); don't know ( )

10. If yes, who controls the resource? Communal ( ); state ( ); private ( ); local leaders ( )

11. Is the resource available to everyone who wishes to collect? Yes ( ); No ( );

12. If no, why……………………………………………………………………………….
……
………………………………………………………………………………………

13. During which months of the year is the product available?
……
………………………………………………………………………………………

14. Has the number of plants of this species changed in the last 5 to 10 years?

Yes ( ); No ( )

15. If yes, increasing ( ), decreasing ( )

16. If there was a change, what do you think is the reason for these change?

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…………………………………………………………………………………………………

17. Has the quantity of products you collect from this species changed in the last 5 to 10 years?

Yes ( ); No ( )

18. If yes, increasing ( ), decreasing ( )

19. If there was a change, what do you think is the reason for these change?

………………………………………………………………………………………………………

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20. Has the number of people selling *Phoenix reclinata* products changed in the last 5 to 10 years?

Yes ( ); No ( )

21. If yes, increasing ( ), decreasing ( )

22. If there was a change, what do you think is the reason for these change?

………………………………………………………………………………………………………

……………………………………………………………………………………………

23. Are there any management practices that you or others make on the resource?

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……………………………………………………………………………..

24. Do you cultivate the species? Yes ( ); No ( )

25. Have you seen anyone else cultivate it? Yes ( ); No ( )

E. *Phoenix reclinata* cultural use

1. Is this species used on any traditional ceremonies/celebrations? Yes ( ); No ( )

2. If yes, how is the species used in the ceremonies/celebrations?

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3. Are there any proverbs and/or sayings about the species? Yes ( ); No ( )

4. If yes, what are they?

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5. What is the meaning of the proverbs and/or sayings?

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6. Are there any traditional games in which the species is used? Yes ( ); No ( )

7. If yes, what are they and how they are played?

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……………………………………………………………………8. Are there any traditional songs in which the species is mentioned? Yes ( ); No ( )

9. If yes, what are they and when the songs are sang?

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10. Are there any stories related to this species? Yes ( ); No ( )

11. If yes, what are they?

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F. Species differences

1. Comparing both species which is better? For each product? And why?

	Species		Why
	H. C	*PR*	
Palm Wine			

G. Income sources

1. Do you have other cash income generating activities? Yes ( ), No ( )

2. If yes, which? Formal job ( ), Selling of NTFP ( ), Agriculture ( );
Livestock production ( ); Fishing ( ); Remittances ( );
Pension ( ); other ( ), specify……………………………

3. Members of HH with formal job?

N^o	Household member code	Relation to household head	Place of work	Monthly income
1		Household head		
2				
3				
4				
5				

3. Monthly amount of remittances received by HH………………………………..
4. Monthly amount of pension received by HH……………………………………

5. Which NTFP used and traded by household?

Product	Freq.of collection	Amount collected /trip	Amount consumed by HH/week	Amount sold/week	Price/unit	Time of the year when collection/sales is higher	For how long	Time of the year when collection/ sales a lower	For how long	Costs of collection	Costs of transport
honey											
charcoal											
firewood											
medicinal plants											
mats											

6. Crops produced and traded by household?

Crops	Season	Amount produced	Amount consumed by HH/season	Amount sold/season	Price/unit

7. What were the costs incurred during crop production?

Crops	Seeds	Fertilizers	manure	Pesticides	Machinery	labour	Land	Transportation	Other, specify

8. Livestock produced and traded by household?

Animal		Qt owned	Qt consumed	Qt Sold	Price
Chicken	Eggs				
	Meat				
Ducks					
goats					
sheep					
Pigs					
Rabbits					
cattle	Milk				
	Meat				
	Ploughing				
	Dung				
Other, specify					

9. What were the costs incurred during livestock production?

Animal	Feed/fodder	Vaccinations	Labour	Land rental	Transportation	Other, specify
Chicken						
Ducks						
goats						
sheep						
Pigs						
Rabbits						
cattle						
Other, specify						

10. Fishing activity?

Type of fish	Where do you fish	Amount fished per trip	Nº of trips/week	Amount consumed by HH/week	Amount sold/week	Price/unit	Costs of fishing	Costs of transport

H. Head of Household Characteristics

1. Gender: Male ( ) Female ( )
2. Age:……………..
3. Ethnic group:……………….
4. Number of school years: …………………………
5. Do you know how to read? Yes ( ) No ( )
6. Do you know how to write? Yes ( ) No ( )
7. Were you born in this village? Yes ( ) No ( )
8. How long have you been living in this village? ………………….
9. What is your status in the community?

   Simple citizen ( ); Community leader ( );

   Traditional leader ( ); Religious leader ( )

I. Household Composition

1. Who are the members of the household (Group of people who normally live in the same dwelling space and eat their meals together)?

Nº	Household member Code	Relation to household head	Age	Gender	Number of school years	Occupation	Money Income	In kind Income
1		Household head						
2								
3								
4								
5								
6								
7								
8								
9								
10								

J. Household Assets

1. Household Land

N° plots owned	Types[1]	Area (m^2)	N° plots Rented	Types[1]	Area (m^2)

[1]cropland in use (1), cropland in pousio (2), forest (3), pasture (4); other (5), specify

2. Type of material of the house

material	Roof	Walls	Floor
Reeds			
Stones			
Bricks			
N° of Rooms			

3. Other assets.

Do you own?	N°	Do you own?	N°
Car/vehicle		Bicycle	
Tractor		Radio	
Motorcycle		Cattle	
Goats			

10. Do you have any questions for me?

APPENDIX 2: PALM SAP TAPPERS QUESTIONNAIRE

Date of interview:…………………………………………………..

A. Palm Sap Tapping

1. How many years have you been tapping palms? ………………………………

2. Which kind of palm do you tap?

   Hyphaene coriacea (   ), Why ……………………………………………………

   Why Not…………………………………………………………………………

   Phoenix reclinata (   ), Why ……………………………………………………..

   Why not ………………………………………………………………………..

3. Do you tap during whole year? Yes (.......)   No (…….)

4. If no, which months during the year do you tap?..

Why……………………………………………………………………………….

…………………………………………………………………………………

…………………………………………………………………………………

5. If you tap all year what are the months that the production is best? ……………

…………………………………………………………………………………..

Why? ………………………………………………………………………………

…………………………………………………………………………………

………………………………………………………………………………….

What are the months that the production is least? ....

………………………………………………………………………………….

Why?...

……………………………………………………………………………......

…………………………………………………………………………………..

…………………………………………………………………………………..

6. How many days per week do you tap?..

7. How many hours per day do you spend?

Activity	Hours	Minutes
Walking to the site		
Collecting sap in morning		
Burning and cutting new stems		
Collecting sap in the afternoon		
Walking home		

8. Do you do anything else during the day when tapping? Yes ( ), No ( )

9. If yes what …………………………………………………………………………...

……………………………………………………………………………………..

10. Do you collect anything during the day while tapping? Yes ( ), No ( )

9. If yes what …………………………………………………………………………...

……………………………………………………………………………………..

10. How many stems do you tap per day?..

11. How many liters does one stem produces per day?..

12. Do some plants produce more sap than others? yes ( ), No ( ), Don't know ( )

13. If yes, Why…………………………………………………………………………….

……………………………………………………………………………………………

……………………………………………………………………………………………

14. How many months do you tap each stem before you abandon it?

....

15. How big must the stem be before one can tap it? ....

16. How long does it take to grow to that size? ………………………………………

17. Does tapping affect?

	Stem				Plant			
	Yes	No	D'Know	Why	Yes	No	D'Know	Why
Growth								
Reproduction								
Longevity								

18. Who taught you to tap? ....

19. Sometimes all stems of a plant are tapped but sometimes a few are tapped and some are untapped why? ……………………………...

……………………………………………………………………………………………

………………………………………………………………………………

20. Why do you tap palms instead of some other occupation?

....

21. Has the number of tappers changed in the last 5 to 10 years?

Yes ( ) No ( ) Don't know ( )

22. If yes,

Increased? ( ) why?...

Decreased? ( ) why?...

23. Do you need permission to tap the palms? Yes ( ) No ( ) Don't Know ( )

24. If yes, from whom? ……………………………………………………………

25. If you need permission, do you have to pay for permission? Yes (.......) No (…….)

26. If yes, How much? …………………………………………………………….

27. How are different trees allocated to different tappers?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………....

……………………………………………………………………………………..

28. Has the number of plants of these species changed in the last 5 to 10 years?

Yes (.......) No (…….)

29. If yes, increasing ( ), decreasing ( )

30. If there was a change, what do you think is the reason for these change?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

31. Has the quantity of palm sap you collect from these species changed in the last 5 to 10 years? Yes ( ); No ( )

32. If yes, increasing ( ), decreasing ( ),

33. If there was a change, what do you think is the reason for these change?

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………

34. Is there any differences in the yield or quality of sap between *Hyphaene coriacea* and *Phoenix reclinata*?

	Yield					Quality				
	Yes	No	Dk	What is the Diff	Why	Yes	No	DK	What is the Diff	Why
H coriacea										
P reclinata										

35. Are there any management practices that you make on the resource?

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………

36. Do you cultivate the species? Yes ( ); No ( )

37. Have you seen anyone else cultivate it? Yes ( ); No ( )

38. Do you ever experience any problems when tapping or to your tapped plants?

………………………………………………………………………………………

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

B. Palm wine trade

1. Do you sell the palm wine produced from palm sap? Yes ( ); No ( )

2. Where do you sell?...

3. To whom do you normally sell?..

4. How far is the selling point (market) from the collecting site?.......................................

5. How many containers do you sell per market day?...

6. How many days a week do you sell? …………………………………………………

7. What is the price per container?..

8. Is the price the same during all year? …………………………………………………

9. If not, what was the price last year? …………………………………………………..

10. How do you decide the price? ………………………………………………………….

…………………………………………………………………………………………………

…………………………………………………………………………………………………

8. During which months is the demand for palm wine higher?..

9. During which months is the demand for palm wine lowest?..

10. What are the palm wine production costs?

items	Costs
Transport to the market	
Container costs	
How long does a container lasts	
Cost per funnel	
Longevity of funnel	
Anything else	

11. Do you employ people to tap for you? Yes (   ); No (   )

12. If yes, How many?............................

13. If yes, how much do you pay them ……………………………………………

What are the costs incurred to transport palm wine to the selling point?........................

14. Has the demand for palm wine changed over the last 5-10 years?

....

If yes, why? …………………………………………………………………………………...

………………………………………………………………………………………………

15. Is tapping palm sap your family main source of cash income? Yes (…….); No (…….)

16. If no, what is your main source of income? ………………………………………..

17. What is your monthly income from your main source of income? ………………….

18. Please rank your sources of income in order from highest to lowest.

N/O	Source of income	Monthly amount

19. If you did not tap and sell palm wine, what would you do?

C. Collector Identification

1. Collector Code:……………………………………….:…….
2. Gender: Male (…….) Female (…….)
3. Ethnic group: ……………………………………….
4. Age: ……………………………………………………
5. Number of school years: ……………………………….
6. Do you know how to read? Yes (.......) No (…….)
7. Do you know how to write? Yes (…….) No (…….)
8. How long have been living in this area
9. Where did you live before moving here?
10. Why did you move here?
11. How many people leave in your household? ……………………………………

12. How many people are employed in the household?...

13. Collectors assets

Land owned

Nº plots owned	Types[1]	Area (m^2)	Nº plots Rented	Types[1]	Area (m^2)

[1]cropland in use (1), cropland in pousio (2), forest (3), pasture (4); other (5), specify

Type of material of the house

material	Roof	Walls	Floor
Reeds			
Stones			
Bricks			
Nº of Rooms			

Other assets.

Do you own?	Nº	Do you own?	Nº
Car/vehicle		Bicycle	
Tractor		Radio	
Motorcycle		Cattle	
Goats			

14. Location of the collection site: ……………… GPS Coordinates: ………

15. Do you have any questions for me?

Thank You

APPENDIX 3: ORIGINAL VERSION OF THE PUBLISHED JOURNAL PAPERS

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Abundance, population structure and harvesting selection of two palm species (*Hyphaene coriacea* and *Phoenix reclinata*) in Zitundo area, southern Mozambique

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ABSTRACT

In southern Mozambique, the sap and leaves of the palms *Hyphaene coriacea* and *Phoenix reclinata* are harvested by local people as sources of traditional beverages, weaving, roofing, fencing and furniture material. The harvesting of these palm products may affect palm population structure, dynamics and viability. This work evaluates the abundance, population structure and harvesting selection of these two heavily harvested palm species. *Hyphaene coriacea* was more abundant, with a mean density of 601.5 ± 455.9 stems ha^{-1} against the 251.9 ± 527.3 stems ha^{-1} of *Phoenix reclinata*. Both species exhibited steeper negative slopes in the regression analyses of the size class distribution, indicating the presence of more individuals in smaller size classes. Although there was a dominance of shorter over taller size classes, limited recruitment was observed through low densities of seedling and juvenile size classes compared to the size class 1–50 cm. The Simpson index of dominance, the permutation index, and the fluctuating quotients between the consecutive size classes showed a degree of instability in both populations. *Hyphaene coriacea* appears to be more resilient to tapping than *Phoenix reclinata*, evident in the higher rate of stem survival after tapping. *Hyphaene coriacea* is favored for tapping compared to *Phoenix reclinata*. Tappers exhibited positive selection for five out of the six *Hyphaene coriacea* size classes, against only one *Phoenix reclinata* size class. The most preferred size class to tap for both species was between 101 cm and 150 cm tall. The instability detected by the indices of population stability, the coincidence between the size classes with high numbers of dead stems and the most preferred and the low level of the sexual reproduction encountered in both population emphasizes the need for long-term monitoring as well as management measures that integrate the resource users, to ensure the long-term sustainability of these populations.

1. Introduction

Palm species are substantial sources of non-timber forest products (NTFPs) and therefore are frequently heavily harvested, especially in the tropics, where they are often abundant (McCurrach, 1960; Martínez-Ballesté et al., 2008). Balick and Beck (1990) recorded more than 390 goods obtained from palms. Palms are a source of food; beverages; syrup; sugar; fibres; construction materials for houses, boats, and furniture; ornaments; medicines, and are also used for traditional purposes (Cunningham, 1990; Johnson, 1992; Kinnaird, 1992; O'Brien and Kinnaird, 1996; Dalibard, 1999; Sambou et al., 2002; McKean, 2003; Pizo and Vieira, 2004; Sola et al., 2006; Chowdhury et al., 2008; Martínez-Ballesté et al., 2008; Calvo-Irabién et al., 2009; Manzi and Coomes, 2009; Duarte and Montúfar, 2012; Babitseng and Teketay, 2013; Isaza et al., 2013). These goods are exploited for subsistence and commercial purposes (Johnson, 1992), thus playing a significant role in the lives of many people in South America, Asia, and Africa (Kinnaird, 1992).

The impacts of palm products harvest on the population of the exploited species are variable across species and locations (Moll, 1972; Kovoor, 1983; Cunningham, 1990; O'Brien and Kinnaird, 1996; Sambou et al., 2002; Endress et al., 2006; Sola et al., 2006; Zuidema et al., 2007; Martínez-Ballesté et al., 2008; Calvo-Irabién et al., 2009; Lopez-Toledo et al., 2011; Babitseng and Teketay, 2013) depending on the part harvested, the amount and method of harvest and the local context; making it difficult to generate general recommendations. Therefore, each species and context

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must be investigated individually before guidelines or conclusions can be developed.

In southern Mozambique, *Hyphaene coriacea* and *Phoenix reclinata* are important palm species used by local people as sources of weaving material employed to make furniture, baskets, sieves, and other utensils. Fronds are used as roofing material, and the petioles are used as poles to build cattle sheds and fences. A traditional palm wine, locally called *sura* or *ntchemane*, is produced from the sap and contributes significantly to the household income in the area. Furthermore, the fruits of *Phoenix reclinata* are edible and its stem is used to make brooms. Despite the importance of these palm species for the rural people in southern Mozambique no previous studies have assessed their population status. In neighbouring South Africa, McKean (2004) showed that heavy harvesting of *Hyphaene coriacea* has resulted in population declines.

The distribution, abundance, population structure and dynamics of plant species are influenced by environmental and anthropogenic factors (Boll et al., 2005; Herrero-Jáuregui et al., 2012). This is especially so for NTFP species. The rate and nature of resource exploration is one of these anthropogenic factors (Herrero-Jáuregui et al., 2012). Harvesting NTFPs may influence the survival, growth, and reproduction of an exploited species, having impacts on the plant and population structure and dynamics (Ticktin, 2004) as well as at higher scales (Ruwanza and Shackleton, 2017).

Sound management plans and policies for NTFP species need knowledge about the ecology, abundance, population structure and dynamics of the exploited species (Herrero-Jáuregui et al., 2012), as well as the long-term impacts of harvesting on such parameters (Venter and Witkowski, 2010). This knowledge is not only important for the species conservation but also for the people depending on that resource for a living (Shackleton et al., 2015).

According to Ticktin (2015), the harvesting of NTFPs is only sustainable if it has no or limited immediate or future negative effects on the population and in the ecosystems in which the species is found. To investigate these effects, medium to long-term studies of population dynamics are required (Obiri et al., 2002; Ticktin, 2015). Life tables, survival curves, and time-series data evaluate the dynamics of populations over time and are therefore, appropriate measures to study population structures and dynamics (Kai et al., 2013; Ticktin, 2015). However, these are costly in terms of time and resources needed (Obiri et al., 2002; Ticktin, 2015).

Although long-term data are preferable to study plant population dynamics, static data obtained from a snapshot survey can still be used to gain insight into the population trends (Obiri et al., 2002). Static approaches such as determination of the size class distribution of the exploited species can reflect the level of recruitment, growth and mortality that a given species has undergone over several years or decades (Wiegand et al., 2000). Wiegand et al. (2000) found that rare recruitment events over many years was a major determinant of the size class distribution of *Acacia raddiana* in the Negev de Desert in Israel. Size class distributions have been successfully used by several authors to gain insight on NTFP species population trends and stability (Botha et al., 2002; Obiri et al., 2002; Shackleton et al., 2005; Venter and Witkowski, 2010; Traoré et al., 2012).

According to Condit et al. (1998), frequently ecologists postulate that a growing, stable population will have a high number of seedlings and juveniles which would be reflected in a reverse-J population curve shape. In contrast, unimodal or even flat population distributions show a lack of recruitment, which in the long run could jeopardize the existence of that population (Obiri et al., 2002). Exceptions are made for long-lived species which normally present a unimodal curve due to the sporadic recruitment events typical of this kind of species, especially in arid and semi-arid environments (Venter and Witkowski, 2010).

While the size class distribution of a population is not the best approach to assess population dynamics and sustainability, several measures such as the slope of the relationship between the size classes and the frequency of individuals in each class, the Simpson index of dominance, the permutation index, as well as the quotients between successive size classes, are useful in adding interpretive insights into the dynamics and stability of the exploited population (Wiegand et al., 2000; Botha et al., 2002; Shackleton et al., 2005; Venter and Witkowski, 2010; Traoré et al., 2012; Shen et al., 2013). The slope of the relationship between the size classes and the frequency of individuals in each class describes the shape of the size class distribution and the relative level of the recruitment on a given population. Healthy, growing populations exhibit steep negative slopes (Condit et al., 1998). The Simpson index of dominance assesses the stability of a given population, through determining if the size classes of that population are evenly distributed or not (Wiegand et al., 2000). Values of the Simpson index below 0.1 suggest that the size classes are evenly distributed and that the population is stable (Wiegand et al., 2000). The permutation index was first introduced by Wiegand et al. (2000) to also assess the stability of a given population. This index measures the departure from a uniform decline in the size class distribution of a given population. A population that does not decline uniformly is considered unstable (Wiegand et al., 2000). Although the Simpson index of dominance and permutation index both assess the stability of population, each measures a different dimension of that stability (Wiegand et al., 2000). The present study assesses the abundance, population structure and harvesting selection of two palm species, *Hyphaene coriacea* and *Phoenix reclinata*, in the Zitundo area, Matutuine district, southern Mozambique. We used the indices of size frequency distribution to characterize the population structure of the two palm species.

2. Methods

2.1. Study area

Zitundo Administrative Post with an area of 864 km^2 (INE, 2009), is located in southern Mozambique and lies in what Van Wyk and Smith (2001) called the Maputaland Centre of Endemism, within the Maputaland-Pondoland biodiversity hotspot. It borders South Africa to the south, the Indian Ocean on the east, Maputo River on the west, and Bela Vista Administrative Post on the north (Fig. 1).

The climate of the area is tropical to sub-tropical, with the average annual temperature around 22.6 °C and annual rainfall varies between 750 mm and 888 mm (Mander and Pollett, 1994). The topography is characterized by a low coastal plain alongside the Indian Ocean (Momade and Achimo, unpublished), with elevations around 50 m (McKean, 2003). The soils are sandy, gray and infertile in many areas (McKean, 2003).

Palm savannas alongside dry forests, swamp forests, grasslands, wetlands, and estuarine vegetation, are the common vegetation types in the area (Kirkwood, 2014). Common tree species include *Hyphaene coriacea*, *Phoenix reclinata*, *Dichrostachys cinerea*, *Strychnos madagascariensis*, *Syzygium cordatum* and *Schotia brachypetala* (McKean, 2004; Kirkwood, 2014). The grass layer is dominated by the genera *Themeda*, *Aristida*, *Perotis* and *Eragrostis* (McKean, 2004).

The main livelihood activities of the residents in the area include rain-fed, subsistence agriculture, wild fruits and wild plant collection, honey production, fishing, hunting, and production of charcoal, crafts and palm wine (Governo do Distrito de Matutuine, 2008). Common crops are cassava, sweet potatoes, peanuts, corn, collards, garlic, lettuce, onions, tomatoes and beans.

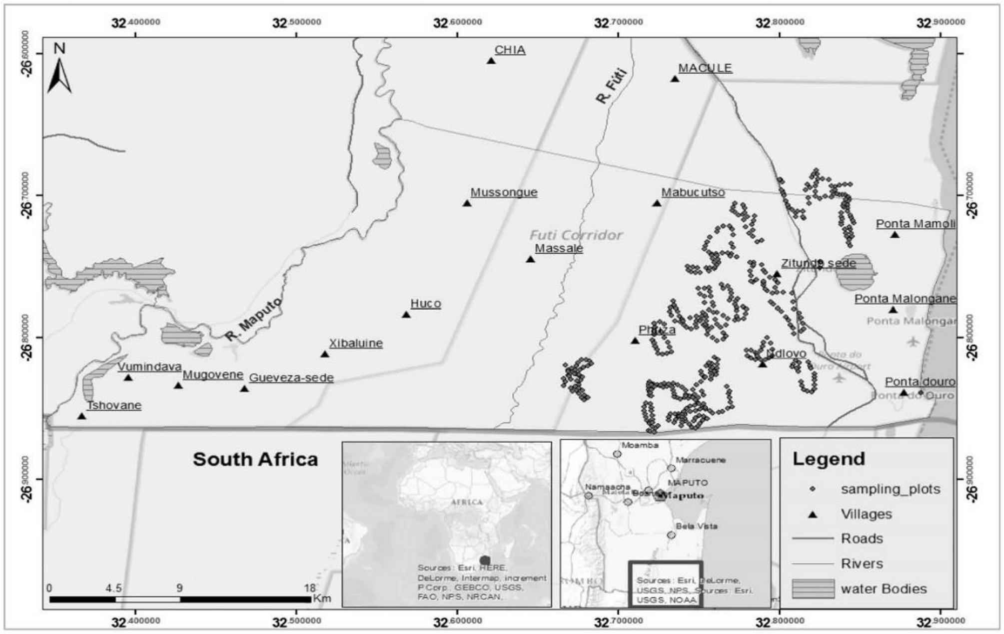

Fig. 1. Study area indicating the location of sampling plots.

Common livestock include chickens, cattle, goats and ducks (Governo do Distrito de Matutuine, 2008).

The study was carried out in the palm savanna, where *Hyphaene coriacea* and *Phoenix reclinata* are the dominant species. At Zitundo Administrative Post, palm savanna is mainly located to the west of the Futi River and east of the coastal dune forest and includes the villages of Phuza, Mabucutso, Ndovo and Zitundo-Sede and their surroundings (Fig. 1).

2.2. Study species

Hyphaene coriacea is a dioecious palm and is one of the two species of the genus *Hyphaene* that grow in southern Africa (SANBI, 2016a). It occurs individually or in clusters (McKean, 2004), mainly in coastal lowland regions, from Somalia to South Africa and in Madagascar (Hyde et al., 2016a), on nutrient-poor, sandy soils (McKean, 2004). This species seldom extends to inland areas (Hyde et al., 2016a). *Phoenix reclinata* is a multi-stemmed dioecious palm, forming clusters or sometimes extensive thickets (SANBI, 2016b). It is distributed throughout Sub-Saharan Africa from Egypt to South Africa (Hyde et al., 2016b). It occurs from sea level to up to 3000 m altitude, in a range of habitats such as inundated areas, riverine forest, coastal savanna, open grassland and rain forests (Segu, 2011; Hyde et al., 2016b; SANBI, 2016b).

2.3. The palm sap tapping process in Zitundo

After choosing the palms clusters to be tapped, tappers burn them to reduce the dead biomass, clear the area and disperse possible animals that have been hiding in them (Fig. 2A). After that the remaining leaves are removed and the stems are debarked and cut, until the sap starts flowing (Fig. 2B). The sap of each tapped stem drips into a bottle and is collected twice or three times a day (Fig. 2C). Each time the sap is collected the tapper cuts a small piece off the tip of the stem to promote sap flow. After the above-ground portion of the stem is completely cut, the tapper digs around the stem continuing to tap the below ground portion of the stem (Fig. 2D). The tapping process ends when the stem stops producing sap and dries up.

2.4. Field data collection

A palm population census was carried out from October 2015 to August 2016.The study used a randomized cluster sampling approach since it is an effective option in large areas where the vegetation occurs in clusters as in this case. A grid of 1 km × 1 km was overlaid on the distribution map of the two species, each block was numbered, and 25 blocks were randomly selected using ArcGIS. In each block, 20 plots of 30 m × 30 m size were randomly situated resulting in a total of 500 plots.

In the field, the location of each plot was determined using a Global Positioning System (GPS). Measurements in each plot for each species included: (i) the number of clusters, (ii) the number of live stems, (iii) the number of seedlings, (iv) the number of dead stems (stumps), (v) the height of each stem, measured from the ground to where the youngest leaf starts, (vi) the number of stems with evidence of being tapped (denoted cut stems), (vii) the number of stems with evidence of being tapped that were still alive (denoted cut and alive stems), (vii) the number of stems with reproductive organs (flowers, fruits or old raceme) and (viii) the number of stems with fire scars (denoted burnt stems).

2.5. Data and statistical analyses

Palm species abundance was expressed in terms of frequency and density. Frequency was calculated as the proportion of plots

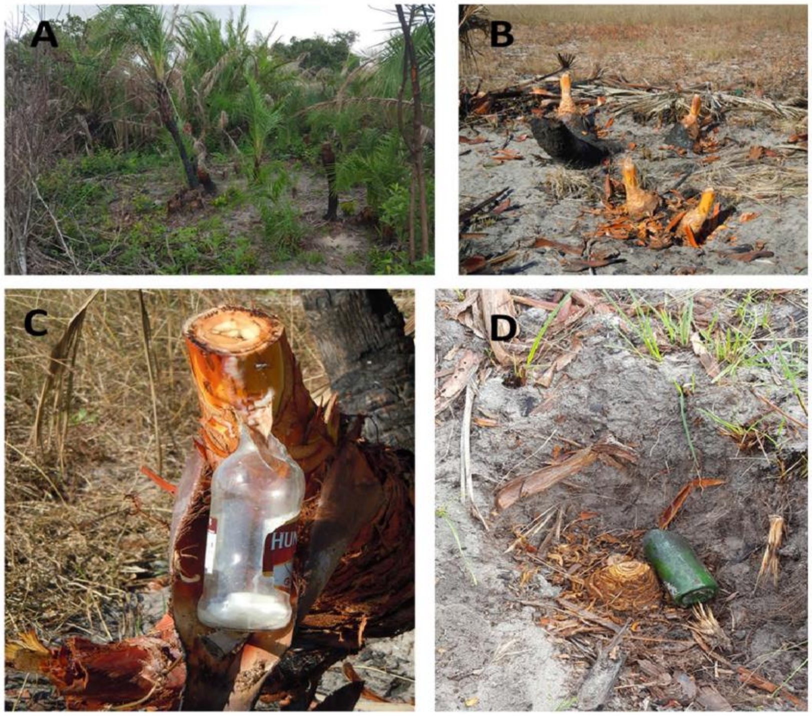

Fig. 2. The Sap tapping process to produce palm wine in Zitundo. (A) Burnt site with *Phoenix reclinata* palm stems to be tapped. (B) Debarked and cut *Hyphaene coriacea* stems ready to be tapped. (C) *Hyphaene coriacea* stem being tapped, with a container to collect the sap. (D) Below ground portion of tapped stems.

in which a species is present, ranging from 0% to 100%. Frequency indicates the species abundance and its distribution range in the community. The mean density for all the population parameters for each species was calculated and expressed as the number of stems per hectare. Population parameters investigated per species were: density of clusters, established stems, seedlings, dead stumps, reproductive stems, cut stems, cut and alive stems and burnt stems.

In palms, the size class distribution is better investigated using the stem height since the diameter does not vary much (Cunningham, 2001). Therefore, to analyze the population structure, the palms were divided in eight size classes, based on height of palm stem and leaf development (Joyal, 1994; Lopez-Toledo et al., 2011) as follows: Seedlings (individuals originated from seed germination with only one undeveloped leaf); juveniles (individuals without stems, but with developed leaves); individuals with stems with a height of between 1 cm and 50 cm (1–50 cm); then, four classes of 50 cm increments (i.e. 51–100 cm, 101–150 cm, 151–200 cm, 201–250 cm) and lastly those taller than 250 cm. The mean density of established stems, reproductive stems, cut and alive stems and dead stumps were computed for each size class and expressed as number of stems per hectare.

To investigate the *Hyphaene coriacea* and *Phoenix reclinata* size class distribution (SCD) shape and population stability, the size classes for seedlings and juveniles were pooled, since the stem height of both were zero and the size class seedlings did not include stems derived from vegetative reproduction. Size class distribution analysis was performed following the method described by Condit et al. (1998), Obiri et al. (2002), Venter and Witkowski (2010) and Traoré et al. (2012). A least square linear regression analysis was conducted between the midpoint of each size class as the independent variable and the mean density of established stems as the dependent variable. Both the independent and dependent variables were transformed by Ln (midpoint +1) and Ln (mean density of stems +1), respectively, as explained by Condit et al. (1998).

The shape of the SCD and the level of recruitment were inferred using the slopes obtained from the regression analysis as described by Obiri et al. (2002), Venter and Witkowski (2010) and Traoré et al. (2012). Negative slopes suggest that the population has a reverse-J SCD curve, implying good recruitment with more individuals in smaller size classes and fewer individuals in larger size classes. Populations with a unimodal SCD curve have positive slopes and more individuals in larger size classes and fewer individuals in smaller size classes, denoting limited or sporadic recruitment. Populations with a flat SCD curve have similar proportions of individuals in smaller and larger size classes and slopes of zero or approaching zero. The relative degree of the recruitment can also be deduced from the steepness of the slope. Steep, negative slopes imply a higher recruitment level relative to superficial negative slopes (Venter and Witkowski, 2010).

Hyphaene coriacea and *Phoenix reclinata* population stability was investigated using the Simpson index of dominance (S), permutation index (P) and the quotient between successive size classes (Wiegand et al., 2000; Botha et al., 2002; Shackleton et al., 2005; Venter and Witkowski, 2010; Traoré et al., 2012; Shen et al., 2013). According to Shackleton et al. (2005), it is worthwhile to use multiple indices to describe population structures because each has distinctive weightings and sensitivity.

The Simpson index of dominance was employed to assess the size class evenness as described in Wiegand et al. (2000), Botha et al. (2002) and Shackleton et al. (2005). It indicates if the size class distribution is even, regardless of the order in which the size classes are positioned (Wiegand et al., 2000 and Botha et al., 2002). According to Wiegand et al. (2000), this index expresses the likelihood that two stems drawn at random from the same population are from the same size class. Values below 0.1 indicate that the size classes are more evenly distributed while values above 0.1 indicate that the size class frequency is steeper than what would have been expected from a stable population (Botha et al., 2002). The Simpson index of dominance equation is (Wiegand et al., 2000):

$$S = 1/\mathrm{N}(\mathrm{N}-1)\sum_{i=1}^{7} \mathrm{N}i(\mathrm{N}i-1) \qquad (1)$$

where N is the total number of stems and Ni the number of stems in class i.

According to Wiegand et al. (2000) the permutation index is the aggregation of the absolute distances between the predicted and the actual ranking of all size classes and assesses the departure from a uniform decline that is characteristic of an undisturbed population. For this to occur, the ranking of the size classes should correspond to the enumeration of the size classes from the smallest (most frequent) to the largest (least frequent) (Wiegand et al., 2000). For populations with a discontinuous distribution, the ranking diverges from the enumeration (Wiegand et al., 2000). An undisturbed population will have a permutation index approaching zero, while a population with discontinuous distribution will have a permutation index above zero (Wiegand et al., 2000; Botha et al., 2002). The higher the permutation index the more disturbed is the population. The permutation index equation is (Wiegand et al., 2000):

$$P = \sum_{i=1}^{7} |Ji - i| Ji = 1, \ldots, 7 \qquad (2)$$

where Ji is the rank of size class i (i = 1 for the smallest trees), with the top rank (Ji = 1) given to the most frequent size class.

To further investigate the stability of both species population, quotients between consecutive size classes were computed and presented graphically. Stable populations exhibit steady quotients between consecutive size classes while oscillating quotients are characteristic of the unstable populations (Botha et al., 2002; Venter and Witkowski, 2010; Traoré et al., 2012; Shen et al., 2013). The quotients were calculated as the ratio of the mean number of stems in successive size classes following Eq. (3) (Meyer, 1952; Leak, 1964).

$$Q = N(i-1)/\mathrm{N}i \qquad (3)$$

where Ni is the number of stems in class i and N $(i-1)$ is the number of stems in the i previous class.

A generalized linear mixed model was used to evaluate the influence of diverse anthropogenic factors on each species population density and size class densities. Explanatory variables used in the model were: distance to market (measured as the distance from the plots to the neatest market where palm wine is sold), distance to roads (measured as the distance from plots to the nearest road), distance to villages (measured as the distance from plots to the nearest village); the number of stems with fire scars and the number of stems with evidence of being tapped.

The preference to harvest a specific size class was evaluated using the preference ratio, which contrasts demand and availability, as presented in Eq. (4) (Dzerefos et al., 2003; Shackleton et al., 2003; Pote et al., 2006). Demand was expressed as the percentage of cut stems in a specific size class and availability was expressed as the percentage of available stems in that size class (alive stems and dead stumps). Since the seedling and juveniles have no stem, they are not cut and therefore were excluded from this analysis. Preference ratios vary from zero to infinite. Preference ratios above one denote active selection, below one, suggests avoidance and approaching one denotes a random selection (Dzerefos et al., 2003; Shackleton et al., 2003).

$$PRi = \mathrm{PD}i/\mathrm{PA}i \qquad (4)$$

where PRi is the preference ratio for class i, PDi is the percentage of cut stems in a size class i (demand), PAi is the percentage of available stems in size class i (availability).

All statistical analyses were performed on statistical package SAS 9.4. A Kolmogorov-Smirnov test was used to check for data normality. Since the data were not normally disturbed, a Mann-Whitney U test was used to compare the mean density of the population parameters between the two species and Kruskal-Wallis test was used to compare the mean density of the population parameters among the height size classes for each species. Following a significant Kruskal-Wallis test results, we further investigated differences between size classes performing a Dunn's post hoc multiple comparison test, using SAS based macro protocol developed by Elliott and Hynan (2011). We selected the generalized linear mixed model approach to account for the non-normal data distribution and the spatial dependence of plots which generated the block random effect. The model was fitted using a Poisson distribution, a Log link function and the block as random effect.

3. Results

3.1. *Hyphaene coriacea* and *Phoenix reclinata* population parameters

Within the 500 plots sampled *Hyphaene coriacea* was relatively more widespread, occurring in 93% (465 plots) of the plots while *Phoenix reclinata* occurred in 53.8% (269 plots). For *Hyphaene coriacea* we found 31 008 stems within 4847 clusters; eighty-seven

Table 1
Population density (mean ± standard deviation) of *Hyphaene coriacea* and *Phoenix reclinata* in the study area.

Stem type	*Hyphaene coriacea*	*Phoenix reclinata*	*P* value <0.0001
Clusters (clusters ha $^{-1}$)	107.7 ± 115.8	27.0 ± 52.6	χ^2 = 291.0
Established stems (stems ha $^{-1}$)	601.5 ± 455.9	251.9 ± 527.3	χ^2 = 261.6
Seedlings (stems ha $^{-1}$)	30.5 ± 87.0	17.9 ± 65.8	χ^2 = 32.1
Dead stumps (stems ha $^{-1}$)	57.1 ± 58.8	5.4 ± 27.6	χ^2 = 449.1
Reproductive stems (stems ha $^{-1}$)	9.8 ± 17.9	11.8 ± 40.9	χ^2 = 43.6
Cut stems (stems ha $^{-1}$)	79.5 ± 73.8	6.1 ± 28.5	χ^2 = 520.5
Cut and alive stems (stems ha $^{-1}$)	22.5 ± 29.4	0.8 ± 4.5	χ^2 = 352.1
Burnt stems (stems ha $^{-1}$)	201.4 ± 283.6	85 ± 276.6	χ^2 = 150.3

percent of stems (27068 stems) were alive and established, eight percent (2568 stems) were dead and four percent (1372 stems) were seedlings. For *Phoenix reclinata* we found 12 389 stems within 1216 clusters; ninety-two percent of them (11337 stems) were alive and established, two percent (245 stems) were dead and seven percent (807 stems) were seedlings. *Hyphaene coriacea* had significantly higher mean densities of clusters, live established stems, seedlings and dead stumps than *Phoenix reclinata* (Table 1). The opposite applied for reproductive stems. The prevalence of reproductive structures (flowers/fruits/old racemes) was low for both species, being on only two percent of live stems of *Hyphaene coriacea* and four percentage of live *Phoenix reclinata* stems (see Table 2).

Twelve percent (3579 stems) of all *Hyphaene coriacea* stems showed evidence of being tapped (denoted cut stems), with the corresponding figure for *Phoenix reclinata* being two percent (276 stems). The rate of stem survival after being tapped was low for both species. From all *Hyphaene coriacea* and *Phoenix reclinata* with evidence of being tapped only 28% (1011 stems) and 11% (31 stems) survived, respectively. The frequency of burnt stems in the *Hyphaene coriacea* population was 29% (9065 stems) against the 12% of *Phoenix reclinata* population. *Hyphaene coriacea* showed significantly higher mean densities of cut stems, burnt stems, as well as cut and alive stems while *Phoenix reclinata* had higher mean densities of reproductive stems.

3.2. Size class distribution

The mean density of stems was statistically different among the size classes. Both populations followed the same trend with the smaller size classes being the most common. In *Hyphaene coriacea* population the 1–50 cm size class, was the most frequent, representing 56.4% of the population. The juvenile size class presented the second highest density. In the *Phoenix reclinata* population the 1–50 cm and the juvenile size classes were the most frequent, representing 53.6% and 33.6% of the population, respectively. Thus, approximately 95% of all stems encountered for both species were less than 1 m tall.

The results of regression analyses of SCD curves revealed that the slopes for both species were negative and steep (Table 3). The slope of *Hyphaene coriacea* population was - 0.88, while the slope of *Phoenix reclinata* was - 0.84, indicating the presence of more individuals in shorter size classes. Moreover, the Simpson index of dominance (S) of the two species was above 0.1 showing that the size classes of both populations are not evenly distributed (Table 3). The permutation index (P) of the both species was different from zero (Table 3). The *Hyphaene coriacea* population had a permutation index of six and *Phoenix reclinata* of two, indicating that *Hyphaene coriacea* has a more discontinuous size class distribution than *Phoenix reclinata*. The quotients for *Hyphaene coriacea* and *Phoenix reclinata* were not constant, fluctuating between consecutive size classes (Fig. 3). This can be an indication of a certain level of instability in population through growth between successive size classes (see Table 4).

Table 3
Size class distribution slopes, Simpson index of dominance and permutation index for *Hyphaene coriacea* and *Phoenix reclinata* populations.

	Hyphaene coriacea	*Phoenix reclinata*
Slope	−0.88	−0.84
P (level of significance)	0.02	0.02
R^2 (%)	69	72
Simpson index of dominance (S)	0.46	0.45
Permutation Index (P)	6	2

There are significant differences in the average density of population parameters between the size classes. For *Hyphaene coriacea* populations, the 1–50 cm size class had the highest proportions of cut stems, cut and alive stems and dead stumps. The tallest size class (>250 cm tall) had the highest proportion of reproductive stems however, this was not statistically different from the four size classes between 51 cm and 200 cm tall. For the *Phoenix reclinata* population, the 1–50 cm had higher proportions of cut stems and dead stumps. This same size class, conjointly with 51–100 cm size class, had the highest proportions of cut and alive stems and reproductive stems.

3.3. Anthropogenic influence on the palms density and population structure

The results of the generalized linear mixed model indicated that the density and population structure of the two palm species were significantly influenced by most of the explanatory variables (Tables 5 and 6). According to the sign of the regression estimates, distance to market and distance to villages were negatively related to the density of established stems of both populations, while distance to roads and the number of stems with fire scars had a positive relationship. The variable "number of stems with evidence of being tapped" had opposite effects on each population density, being positive for *Hyphaene coriacea* and negative for *Phoenix reclinata*.

The influence of the explanatory variables on the size classes distribution of each species was variable. For *Hyphaene coriacea* population, the distance to market was positively related to the density of seedling and stems on the height classes above 50 cm; while the distance to roads had a positive relationship on seedlings and juveniles densities. Furthermore, distance to villages was only positively related to the number of stems of juveniles, and of size class between 151 cm and 200 cm. The number of stems with evidence of being tapped negatively influenced the density of seedlings and stems of the size classes above 100 cm. Inversely, the number of stems with fire scars was positively related to all size classes. For the *Phoenix reclinata* population, distance to market

Table 2
Population density (mean ± standard deviation) among the eight height size classes. Unlike letters denote significant differences ($p < 0.05$) between the size classes within a species.

Size class	*Hyphaene coriacea* $\chi^2 = 2322.9$		*Phoenix reclinata* $\chi^2 = 795.6$	
	Density (stems ha^{-1})	%	Density (stems ha^{-1})	%
Seedlings	30.5 ± 87^{a}	4.8	17.9 ± 65.8^{a}	6.6
Juveniles	206.2 ± 231.8^{b}	32.6	90.8 ± 202.4^{b}	33.6
1–50 cm	356.2 ± 270.6^{c}	56.4	144.9 ± 325.9^{b}	53.6
51–100 cm	26.8 ± 33.7^{d}	4.2	11.5 ± 35.2^{a}	4.3
101–150 cm	5.1 ± 11.2^{e}	0.8	2.8 ± 1.3^{c}	1.0
151–200 cm	$2.8 \pm 7.6^{e,f}$	0.4	1.4 ± 7.3^{c}	0.5
201–250 cm	1.2 ± 5.1^{f}	0.2	0.6 ± 4.0^{c}	0.2
>250 cm	$3.2 \pm 9.5^{e,f}$	0.5	0.4 ± 3.9^{c}	0.2

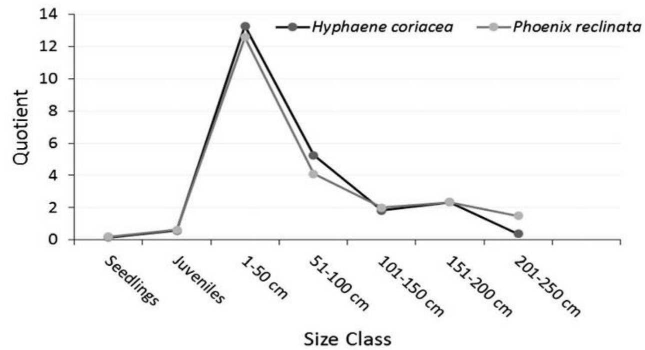

Fig. 3. Quotients between each successive size class for *Hyphaene coriacea* and *Phoenix reclinata* populations.

Table 4
Hyphaene coriacea and *Phoenix reclinata* populations parameters density (mean ± standard deviation) among the size classes. Unlike letters denote significant differences ($p < 0.05$) between the size classes within a species.

Size class	Species	Reproductive stems (stems ha^{-1})	Cut stems (stems ha^{-1})	Cut and alive stems (stems ha^{-1})	Dead atumps (stems ha^{-1})
Seedlings	*Hyphaene coriacea*	0 ± 0 (0%)^{a}	0 ± 0 (0%)^{a}	0 ± 0 (0%)^{a}	0 ± 0 (0%)^{a}
	Phoenix reclinata	0 ± 0 (0%)^{c}	0 ± 0 (0%)^{f}	0 ± 0 (0%)^{e}	0 ± 0 (0%)^{e}
Juveniles	*Hyphaene coriacea*	0 ± 0 (0%)^{a}	0 ± 0 (0%)^{a}	0 ± 0 (0%)^{a}	0 ± 0 (0%)^{a}
	Phoenix reclinata	0 ± 0 (0%)^{c}	0 ± 0 (0%)^{f}	0 ± 0 (0%)^{e}	0 ± 0 (0%)^{e}
1–50 cm	*Hyphaene coriacea*	0.5 ± 3.1 (5.3%)^{a}	59.0 ± 66.9 (74.4%)^{b}	13.0 ± 22.9 (57.8%)^{b}	46.1 ± 53.8 (80.3%)^{b}
	Phoenix reclinata	6.7 ± 25.1 (56.4%)^{d}	4.5 ± 19.8 (71.7%)^{g}	0.3 ± 2.1 (42.9%)^{f}	4.2 ± 19.4 (77.3%)^{f}
51–100 cm	*Hyphaene coriacea*	2.1 ± 6.3 (20.9%)^{b}	13.0 ± 19.7 (16.4%)^{c}	5.6 ± 12.7 (24.9%)^{c}	7.4 ± 13.4 (13.1%)^{c}
	Phoenix reclinata	2.8 ± 12.7 (23.9%)^{d}	1.2 ± 8.0 (19.1%)^{h}	0.3 ± 2.4 (42.9%)^{f}	0.9 ± 7.3 (16.5%)^{g}
101–150 cm	*Hyphaene coriacea*	1.9 ± 6.2 (19.4%)^{b}	3.7 ± 7.9 (4.7%)^{d}	1.5 ± 5.0 (6.7%)^{d}	2.2 ± 5.6 (3.7%)^{d}
	Phoenix reclinata	1.1 ± 5.9 (9.4%)^{e}	0.5 ± 3.3 (8.0%)^{f,h}	0.1 ± 1.6 (14.3%)^{e,f}	0.3 ± 2.7 (6.7%)^{e,g}
151–200 cm	*Hyphaene coriacea*	1.7 ± 5.8 (17.4%)^{b}	2.0 ± 4.9 (2.5%)^{e}	1.0 ± 4.4 (4.4%)^{a}	1.0 ± 3.9 (1.8%)^{a}
	Phoenix reclinata	0.7 ± 4.6 (6.2%)^{c,e}	0.04 ± 0.7 (0.6%)^{f}	0.02 ± 0.5 (0%)^{e}	0.02 ± 0.5 (0%)^{e}
201–250 cm	*Hyphaene coriacea*	0.8 ± 4.1 (7.7%)^{a}	0.6 ± 4.1 (0.8%)^{a}	0.5 ± 2.9 (2.2%)^{a}	0.2 ± 2.2 (0.2%)^{a}
	Phoenix reclinata	0.2 ± 2.3 (1.9%)^{c,e}	0.02 ± 0.5 (0.3%)^{f}	0.02 ± 0.5 (0%)^{e}	0 ± 0 (0%)^{e}
>250 cm	*Hyphaene coriacea*	2.9 ± 8.7 (29.3%)^{b}	1.0 ± 3.8 (1.3%)^{a,e}	0.9 ± 3.7 (4.0%)^{a,d}	0.1 ± 0.9 (0.9%)^{a}
	Phoenix reclinata	0.3 ± 3.2 (2.3%)^{c}	0.02 ± 0.5 (0.3%)^{f}	0 ± 0 (0%)^{e}	0.02 ± 0.5 (0%)^{e}

was positively related to all size classes with the exception of juveniles, while distance to roads had a positive influence on the density of seedlings, of stems on size classes between one centimeter and 150 cm and size class with stems above 250 cm. Distance to villages had no significant influence on the density of seedlings and a positive influence on juveniles and the size class 151–200 cm. The number of stems with fire scars and the number of stems with evidence of being tapped had a similar influence on the size classes of this species population, both had a negative influence only on the density of stems of the size class 151–200 cm.

3.4. Size class selection for cutting

Stems between 1 and 50 cm were the only size class avoided for *Hyphaene coriacea*. All the other size classes had a preference ratio above one, indicating a positive selection to harvest these size classes. The most preferred size class to harvest was 151–200 cm (Table 7). On the other hand, for *Phoenix reclinata*, the only size class with a positive selection for stems between 101 cm and 150 cm, with a preference ratio of 4.2. The size class with stems above 250 cm had a preference ratio of one, signifying that the cutting on this size class was random. All other size classes were avoided (Table 7). Analyzing both species combined, the most preferred size class was between 101 cm and 150 cm.

4. Discussion

The results indicate that *Hyphaene coriacea* is more widespread than *Phoenix reclinata* in Zitundo area. This is in concordance with Cunningham (1985) who observed that, in the neighbouring South African Maputaland palm savanna, *Hyphaene coriacea* was more abundant than *Phoenix reclinata*. The density of *Hyphaene coriacea* measured in this study was higher than those found by Moll (1972) for the same species in Kwazulu-Natal, South Africa. Moll (1972) found an average of 489.4 stems ha^{-1} while this study found an average of 601.5 stems ha^{-1}. Inversely, Babitseng and Teketay (2013), in Botswana, found over a 1000 established stems (excluding seedlings) ha^{-1} for *Hyphaene petersiana*, a closely related species to *Hyphaene coriacea*. On the other hand, the number of established stems of *Phoenix reclinata* encountered in the study area was higher than those obtained by Kinnaird (1992) in Kenya, and Mjoli and Shackleton (2015) in the Eastern Cape, South Africa. Differences in the stem densities of these species across the studies are likely to be related to differences in soils, climate and disturbance specific to each locality. Anthropogenic causes such as harvesting of different palm products, harvesting techniques as well as fire regimes are also likely to result in differences in densities across studies. Results from the generalized linear mixed model obtained in this study showed that anthropogenic factors indeed had a statistically significant impact on the density of established stems of the two palm species.

Table 5
Generalized linear mixed models parameters estimates for *Hyphaene coriacea* population density and structure.

Dependent variable	Independent variable	Estimates	P-value
Established stems	Distance to market	−0.0001	<0.0001
	Distance to roads	0.0001	<0.0001
	Distance to villages	−0.000003	0.007
	Burnt stems	0.0005	<0.0001
	Cut stems	0.0022	<0.0001
Seedlings	Distance to market	0.00004	<0.0001
	Distance to roads	0.0003	<0.0001
	Distance to villages	−0.0001	<0.0001
	Burnt stems	0.0014	<0.0001
	Cut stems	−0.0024	<0.0001
Juveniles	Distance to market	−0.0001	<0.0001
	Distance to roads	0.0002	<0.0001
	Distance to villages	0.0001	<0.0001
	Burnt stems	0.0005	<0.0001
	Cut stems	0.0016	<0.0001
1–50 cm	Distance to market	−0.0001	<0.0001
	Distance to roads	−0.00003	<0.0001
	Distance to villages	−0.00004	<0.0001
	Burnt stems	0.0004	<0.0001
	Cut stems	0.0030	<0.0001
51–100 cm	Distance to market	0.00002	<0.0001
	Distance to roads	−0.0001	<0.0001
	Distance to villages	−0.0001	<0.0001
	Burnt stems	0.0005	<0.0001
	Cut stems	0.0026	<0.0001
101–150 cm	Distance to market	0.0001	<0.0001
	Distance to roads	−0.00004	0.1353
	Distance to villages	−0.0002	<0.0001
	Burnt stems	0.0011	<0.0001
	Cut stems	−0.00002	0.96
151–200 cm	Distance to market	0.0002	<0.0001
	Distance to roads	−0.0004	<0.0001
	Distance to villages	0.0001	0.0061
	Burnt stems	0.0018	<0.0001
	Cut stems	−0.0037	<0.0001
201–250 cm	Distance to market	0.0002	<0.0001
	Distance to roads	−0.0004	<0.0001
	Distance to villages	−0.0002	<0.0001
	Burnt stems	0.0016	<0.0001
	Cut stems	−0.0036	<0.0001
>250 cm	Distance to market	0.0002	<0.0001
	Distance to Roads	−0.0003	<0.0001
	Distance to villages	−0.0002	<0.0001
	Burnt stems	0.0017	<0.0001
	Cut stems	−0.0084	<0.0001

Table 6
Generalized linear mixed models parameters estimates for *Phoenix reclinata* population density and structure.

Dependent variable	Independent variable	Estimates	P-value
Established stems	Distance to market	−0.00003	<0.0001
	Distance to roads	0.0003	<0.0001
	Distance to villages	−0.0001	<0.0001
	Burnt stems	0.0016	<0.0001
	Cut stems	−0.0030	<0.0001
Seedlings	Distance to market	0.0001	<0.0001
	Distance to roads	0.0001	0.0004
	Distance to villages	−0.00001	0.5149
	Burnt stems	0.0019	<0.0001
	Cut stems	0.0044	<0.0001
Juveniles	Distance to market	−0.000003	<0.0001
	Distance to roads	−0.00001	0.1056
	Distance to villages	0.0001	<0.0001
	Burnt stems	0.0015	<0.0001
	Cut stems	0.0072	<0.0001
1–50 cm	Distance to market	0.00003	<0.0001
	Distance to roads	0.0002	<0.0001
	Distance to villages	−0.0002	<0.0001
	Burnt stems	0.0015	<0.0001
	Cut stems	0.0064	<0.0001
51–100 cm	Distance to market	0.0001	<0.0001
	Distance to roads	0.0003	<0.0001
	Distance to villages	−0.0003	<0.0001
	Burnt stems	0.0021	<0.0001
	Cut stems	0.0061	<0.0001
101–150 cm	Distance to market	0.0002	<0.0001
	Distance to roads	0.0003	<0.0001
	Distance to villages	−0.0004	<0.0001
	Burnt stems	0.0029	<0.0001
	Cut stems	0.0049	<0.0001
151–200 cm	Distance to market	0.0002	<0.0001
	Distance to roads	−0.0004	<0.0001
	Distance to villages	0.00004	<0.0001
	Burnt stems	−0.0061	<0.0001
	Cut stems	−0.0070	<0.0001
201–250 cm	Distance to market	0.0003	<0.0001
	Distance to roads	−0.0001	0.4543
	Distance to villages	−0.0003	<0.0001
	Burnt stems	0.0026	<0.0001
	Cut stems	0.0063	<0.0001
>250 cm	Distance to market	0.0002	<0.0001
	Distance to Roads	0.0003	0.0027
	Distance to villages	−0.0003	<0.0001
	Burnt stems	0.0011	0.010
	Cut stems	0.0058	<0.0001

About 57 dead stumps ha^{-1} of *Hyphaene coriacea* were found in the study area. This result is within the range obtained by Babitseng and Teketay (2013) in Botswana for *Hyphaene petersiana* and lower than the rate found by Sullivan et al. (1995) also for *Hyphaene petersiana* in Namibia. Sullivan et al. (1995) observed that *Hyphaene petersiana* dead stumps comprised up to 63% of the adult population of that species, while in this study dead stumps correspond to only eight percent of *Hyphaene coriacea* population.

The results illustrated that 12% of *Hyphaene coriacea* stems showed evidence of being tapped against two percent of *Phoenix reclinata* stems. Higher proportions of tapped stems of *Hyphaene coriacea* than *Phoenix reclinata* were also noted by Cunningham (1985). In the South African Maputaland palm savanna, 69% of all tapped stems were *Hyphaene coriacea* against 31% of *Phoenix reclinata* (Cunningham, 1985). The low rate of stem survival after being tapped observed in this study for both species was also found by Cunningham (1985). We found that 28% and 11% of *Hyphaene coriacea* and *Phoenix reclinata* stems, respectively, survived after being tapped, while Cunningham (1985) found that about 14% and zero percent of *Hyphaene coriacea* and *Phoenix reclinata*, respectively, survived after being tapped. According to Cunningham (1990), Sola et al. (2006) and Chowdhury et al. (2008) the probability of stem survival after being tapped many times is determined by the harvesting technique used for sap extraction and the skill and experience of the tapper. Furthermore, palm weevil infestation on tapped stems may negatively influence the probability of survival of tapped stems (tappers, pers. comm.). Given the results of this study as well as by Cunningham (1985), we can imply that *Hyphaene coriacea* is more resilient to tapping than *Phoenix reclinata*.

The population structures of *Hyphaene coriacea* and *Phoenix reclinata* in Zitundo are similar. Both species exhibited steep negative slopes in the regression analyses of SCD, indicating the presence of more individuals in small size classes. Nearly 95% of all stems encountered for both species were less than one meter tall. Although there was a dominance of shorter over taller size classes, both seedling and juvenile size classes presented a lower stem den-

Table 7
Preference ratio of to harvest *Hypahene coriacea* and *Phoenix reclinata* populations.

Size class	Species	Demand (% cut stems)	Availability (% of total stems)	Preference ratio	Selection
1–50 cm	*Hyphaene coriacea*	74.4	88.9	0.8	Avoided
	Phoenix reclinata	71.7	92.3	0.8	Avoided
51–100 cm	*Hyphaene coriacea*	16.4	7.6	2.2	Preferred
	Phoenix reclinata	19.1	76.7	0.3	Avoided
101–150 cm	*Hyphaene coriacea*	4.7	1.6	2.9	Preferred
	Phoenix reclinata	8	1.9	4.2	Preferred
151–200 cm	*Hyphaene coriacea*	2.5	0.8	3.0	Preferred
	Phoenix reclinata	0.6	0.9	0.7	Avoided
201–250 cm	*Hyphaene coriacea*	0.8	0.3	2.7	Preferred
	Phoenix reclinata	0.3	0.4	0.8	Avoided
>250 cm	*Hyphaene coriacea*	1.3	0.7	1.9	Preferred
	Phoenix reclinata	0.3	0.3	1	Random

sity compared to the 1–50 cm size class. The seedling size class corresponded to only 5% and 7% of *Hyphaene coriacea* and *Phoenix reclinata* populations, respectively. This indicates some limitation in the recruitment levels of these two populations. Recruitment levels can be influenced by seed production, seed germination, seedling survivorship, and seedling growth. Our results showed a low prevalence of stems with reproductive structures; only two percent of *Hyphaene coriacea* and four percent of *Phoenix reclinata* stems. This low prevalence of stems with reproductive structures can hamper the seed production and therefore the recruitment in the palm populations. The low prevalence of reproductive structures obtained in the study area could be linked to the majority of stems being tapped before reaching the reproductive stage. This was particularly evident on *Hyphaene coriacea*, where about 74% of all reproductive stems were taller than 50 cm and preferred for tapping as indicated by the preference ratio. Additional reasons that could be limiting recruitment include: (i) the trampling of seedlings during tapping activities contributing to seedling mortality; (ii) The use of fire to clear the area for tapping perhaps killing some seedlings; (iii) the harvesting of the edible fruit of *Phoenix reclinata* may reduce the number of seedlings; (iv) the long period that *Hyphaene coriacea* fruits take from production until dispersal (*Hyphaene coriacea* fruits take about four years from production until fruit fall (SANBI, 2016a)), and (v) demanding seed germination requirements for *Hyphaene coriacea* such as scarification by heat or passing through the digestive tract of an animal (Palgrave, 2002), which can reduce the number of recruits. The results from the generalized linear mixed model indicated that anthropogenic factors such as proximity to the market and to roads had a diminishing effect on the density of seedling of *Hyphaene coriacea* and *Phoenix reclinata*. Additionally increasing tapping also contributed to the reduction of *Hyphaene coriacea* seedlings.

Steep negative slopes are commonly associated with inverse-J shaped SCDs. This pattern is a typical attribute of long-lived species (Chhetri et al., 2016) and is a common demographic feature of healthy, growing populations (Condit et al., 1998). We anticipated that the size class distribution of these two heavily utilized species would deviate from this 'ideal' SCD. However, Sampaio et al. (2008) also found an inverse-J shaped SCD in a heavily harvested population of *Mauritia flexuosa* palm in Brazil. Inversely, the SCD of a similarly exploited population of *Hyphaene petersiana* in Botswana did not show an inverse-J shaped curve (Babitseng and Teketay, 2013). A unimodal SCD was also found by Mjoli and Shackleton (2015) in a *Phoenix reclinata* population in the Eastern Cape, South Africa, of which the leaves were being harvested. The shape of a plant population SCD reflects the interaction between several intrinsic and extrinsic factors such as: (i) the rate of seed production, (ii) size specific growth rates, (iii) death rates, (iv) intra- and inter-specific competition and (v) size specific attacks by natural enemies (Hutchings, 1997). *Hyphaene coriacea* and *Phoenix reclinata* SCDs appeared to also be influenced by some of these above mentioned factors. The rate of seed production seems to be negatively affected by tapping, therefore having impacts on the seedling density, and the observed dominance of small size classes exhibited by both species appear to be linked to their strong ability to undergo vegetative reproduction through root coppicing (Cunningham, 1985). Vegetative reproduction is a successful recruitment option that allows burdened species to thrive in a harsh environment (Traoré et al., 2012). On the other hand, the intermediate size classes of these species populations are the ones that exhibited high proportions of dead stumps. We found that 97% and 100% of all dead stumps of *Hyphaene coriacea* and *Phoenix reclinata* were amongst the intermediate size classes (1–150 cm tall), which were also amongst the preferred size classes for harvesting. Thus, a significant share of stems from intermediate size classes are not able to grow to higher size classes. The generalized linear mixed model results substantiated the impact of anthropogenic factors in shaping the SCD of these species. It indicated that sap harvesting had a negative impact on the density of larger size classes. The density of *Hyphaene coriacea* stems higher than 100 cm as well as the density of *Phoenix reclinata* stems between 151 and 200 cm decreased when the number of stems with evidence of being tapped increased. In addition, the density of *Hyphaene coriacea* stems above 50 cm decreased with increasing proximity to the market. Proximity to market is associated with lower transportation costs promoting, therefore, higher levels of resource exploration.

The preference ratios for *Hyphaene coriacea* and *Phoenix reclinata* populations showed that there was a positive selection to tap certain size classes. The most preferred size class to tap for both species was between 101 cm and 150 cm. Evidence of selective cutting for *Hyphaene petersiana* in Botswana and *Phoenix reclinata* in Kenya were also implied by Babitseng and Teketay (2013) and Kinnaird (1992), respectively. Intermediate size classes were probably preferred to tap because they yield more sap than smaller size classes, and require less effort than taller size classes. Furthermore tappers exhibited positive selection for five out of the six *Hyphaene coriacea* size classes analyzed, while it was positive for only one size class of *Phoenix reclinata*. This may be an indication that *Hyphaene coriacea* is favored for tapping compared to *Phoenix reclinata*. Preference for tapping *Hyphaene coriacea* in Kwazulu-Natal was also implied by Cunningham (1985) who suggested that this preference was due to the high relative abundance of this species. *Hyphaene coriacea* preference over *Phoenix reclinata* can also be due to the stem hardiness. Tappers report that *Phoenix reclinata* is denser and more difficult to tap than *Hyphaene coriacea* (tappers, pers. comm.).

The three indices of population structures calculated in the study describe different properties of SCDs that are expected in 'ideal' populations, and each has distinctive weightings and sensitivities. The Permutation index reflects the ranking of size classes regardless of the number of stems in the size class, therefore is insensitive to small changes in the number of stems. Quotients can easily detect size classes with disproportionally high or low numbers of stems and the Simpson index of dominance measures the occurrence of dominant size classes. The Simpson index of dominance above 0.1, the permutation index above zero and the fluctuating quotients between the consecutive size classes obtained for both species are an indication that the size structures of these species population deviate from a stable population. *Hyphaene coriacea* and *Phoenix reclinata* populations are probably undergoing a certain level of instability in terms of through put between size classes. Tapping may well play a role because: (i) the biggest decline between size classes is also for the most preferred size; (ii) for *Hyphaene coriacea* the only avoided size class for tapping (1–50 cm) was the one with the highest density and (iii) relatively low levels of seedlings that appear to be linked to the low reproductive stems density. According to Botha et al. (2002), unstable populations are a recurrent feature in savanna species, considering that they are exposed to high levels of environmental and anthropogenic disturbances. Cunningham (1985) suggested that the current physiognomy of the palm savanna structure in Maputaland area, characterized by short, multi-stemmed palm plants, is the result of long-term anthropogenic pressure in the form of excessive fire frequency regimes, and the damaging palm tapping methods, that have been taking place since the establishment in the area of the agrarian and pastoral society around 1500 before Present.

5. Conclusion and management recommendations

The exploitation of palm species in Zitundo area is being done under an open access resource use system, and no management plans have been designed to regulate the use of this resource. This study was the first evaluation of the status of the population structure of these two palm species in the area. Our results show that the population structures of *Hyphaene coriacea* and *Phoenix reclinata* exhibited steep negative slopes, indicating the presence of more individuals in small than in tall size classes. Although there was a dominance of small size classes, some degree of recruitment hindrance was noted by lower densities of seedlings and juveniles compared to the 1–50 cm size class. Human induced factors in the form of tapping appeared to contribute to shaping the structure and abundance of these palm species through active selection for taller size classes. This active selection hindered the ability of many stems to attain sexually reproductive sizes, therefore negatively impacting seedling production. Reduction of sexually produced individuals may potentially reduce the genetic variability within the species, and chances of species survival in the case of fluctuating environments. Additionally, the greatest number of dead stumps was encountered in the most preferred size class.

The findings of this study represent an important starting point for future demographic studies and management plans. Since the SCD profile is not the best indicator of the dynamics and sustainability of a given population, more long-term demographic studies that include controlled experiments, population dynamics such as: (i) growth rates, (ii) fruit and seed production, (iii) survivorship curves, (iv) factors that influence the demographic rates, including the impact of anthropogenic factors, are required to provide sound, sustainable harvesting and management plans for these two palm species. Until long-term demographic data are available, we recommend that (i) palm tappers should be encouraged to avoid harvesting stems with reproductive structures to secure a continuous flow of seed that will enhance the seed bank and the seedling recruitment; (ii) palm tappers should, where possible, be promoted to leave part of the apical meristem during the tapping process to allow for recovery through regrowth and vegetative reproduction (the actual harvesting technique appears to be destructive as indicated by the low rate of stem survived after being tapped); (iii) rotation of the harvesting sites be considered to allow for stem recovery and regrowth and limit site-specific overexploitation, and (iv) development of community resource conservation and management systems with the participation of all stakeholders such as local government authorities, traditional leaders and the palm tappers.

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The production and commercialization of palm wine from *Hyphaene coriacea* and *Phoenix reclinata* in Zitundo area, southern Mozambique

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ABSTRACT

In southern Mozambique a traditional wine is produced using the sap from two palm species, *Hyphaene coriacea* and *Phoenix reclinata*. Production of palm wine is one of the main livelihood activities in the Zitundo area. We examined the local production and trade of palm wine in the area. Using structured interviews we investigated the tapping activity, local management practices and the palm wine market, and assessed the incomes derived from palm wine sales and the tappers' perceptions on productivity, abundance and sales fluctuation. Tapping palms was practiced year round in five of the sixteen villages in the area and the mean number of palms tapped per day was 102 ± 52 per tapper. Tappers spent an average of 25 ± 18 h per week on tapping activities resulting in an average return to labour of R39 (±US$3) per hour. The mean, annual, net income from palm wine sales was R24,981 ± R12,094 (US$1878 ± 909) per tapper, which accounted for 85% ± 22% of the tappers' annual household income. Palm wine is a highly commercial commodity in Zitundo area, with an average commercialization index of 63% ± 23%, and is likely to help alleviate poverty in the area. *Hyphaene coriacea* was tapped more than *Phoenix reclinata*, although most tappers regard the wine from the latter to be of a better quality. The importance of palm tapping in local livelihoods and poverty alleviation needs greater acknowledgement by government and development agencies in the area, towards inclusion in sectoral development policies and conservation programmes.

1. Introduction

Harvesting and trading non-timber forest products (NTFPs) is an important source of income to many rural households, particularly in areas where other economic opportunities are scarce (Dovie et al., 2005; Angelsen et al., 2014). According to Shanley et al. (2016) about 1.5 billion people globally utilize or sell NTFPs. Although some NTFPs can enter international markets, most are traded at local and regional level (S. Shackleton et al., 2007; Shanley et al., 2016), which, according to S. Shackleton et al. (2007), are growing via the entry of new products and the expansion of the existing trade. These local markets are especially important for marginal groups who, due to their lack of formal education, skills and isolation, have limited formal sector income-earning opportunities (Shackleton et al., 2008).

Shackleton et al. (2011) listed four main reasons for individuals or households to participate in NTFP trade, including i) as a short-term safety-net to smooth household shocks, fill income gaps, and cope with special needs when facing emergencies or tribulations; ii) diversifying livelihood strategies by using NTFP income to complement other sources of income; iii) as the main source of income, when some level of specialization in a given NTFP generally occurs; and iv) as a last resort strategy due to the lack of other income earning or livelihoods opportunities. In southern Africa, there are multiple examples and case studies of each, but as yet the relative magnitude of each of these has not been ascertained.

Frequently the economic returns derived from local NTFP sales are considered to be modest (Emery and Zasada, 2001; Pearce and Pearce, 2001; S. Shackleton et al., 2007), and are often insufficient to fully support a household (Wilkie et al., 2001). However, most studies do not disaggregate part-time or casual traders from full-time ones, which serves to underestimate mean incomes for full-time traders. For example, C.M. Shackleton et al. (2007) demonstrated that returns per unit time worked are frequently higher for NTFP trade than other unskilled wage opportunities, were such opportunities available. Both absolute income from NTFPs as well as dependency on this source of income varies across countries and regions (Heubach et al., 2011; Saha and Sundriyal, 2012; Stanley et al., 2012; Adam et al., 2013; Angelsen et al., 2014). The meta-analysis of Stanley et al. (2012) on ecological and economic sustainability of NTFPs, found that, on average, in African and Latin American countries, NTFP income accounts for 25%

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of the total household income, only slightly higher than the share of 23% in Asian countries. Additionally Angelsen et al. (2014) conducted a global comparative analysis of environmental income across 24 developing countries, and found that both absolute environmental income and dependency were higher in Latin America ($US 1473 per annum and 32% for absolute income and dependency, respectively), with Africa ranking third in absolute income ($US 304 per annum) and second in dependency (30%). Income from NTFPs, as well as dependency, can be influenced by several factors, such as i) ecological conditions (Coomes et al., 2004; Mugido and Shackleton, 2017); ii) seasonality of resource exploited (Shackleton, 2004); iii) trader's socio-economic characteristics including age, household size, education, assets, income opportunities, residency time and ethnicity (Gavin and Anderson, 2007; Heubach et al., 2011; Angelsen et al., 2014; Khosravi et al., 2016; Mjoli and Shackleton, 2015); and iv) market accessibility (Barbier, 2010; Adam et al., 2013; Mugido and Shackleton, 2017). From the studies mentioned above, it is clear that the effect of NTFP trading on livelihoods must be understood within the specific social-ecological context of individuals and households.

An important NTFP produced and traded by households in many countries is palm wine. Palm wine is a fermented beverage produced from the sap of various species of palms (Mbuagbaw and Noorduyn, 2012), and is common in areas of Asia, Africa and Latin America with high palm abundance (Johnson, 1992; Tapsoba et al., 2014). In these areas, palm wine has a nutritional, sociocultural and economic importance (Lasekan et al., 2007; Mbuagbaw and Noorduyn, 2012). According to Campbell (1969) palm sap is rich in riboflavin, vitamin B and nicotinic acid, thereby contributing to the diet of people who use it. Palm wine is also a mandatory beverage for many traditional ceremonies in many African societies (Okon and Okorji, 2014), and has been used in Nigerian traditional medicine to treat malaria, measles, and jaundice and to promote breast milk production in nursing women (Bassir, 1968; Okon and Okorji, 2014). The trade in palm wine is also an important economic activity in many areas, providing income, not only to the palm tappers, but also to a variety of other market chain participants (Okereke, 1982; Cunningham, 1990a, 1990b; Naidu and Misra, 1998; Dalibard, 1999; McKean, 2003; Mbuagbaw and Noorduyn, 2012; Babitseng and Teketay, 2013; Okon and Okorji, 2014).

Hyphaene coriacea and *Phoenix reclinata* are the two dominant species in the palm savanna of the Maputaland coastal plain which covers the southeastern parts of Maputo province in southern Mozambique and northeastern parts of Kwazulu-Natal in South Africa. These species are a source of edible fruits, weaving materials and palm wine. Cunningham (1985, 1990a, 1990b) and McKean (2003) investigated the role of these species in the local economy and the effects of harvesting on the species in the same ecoregion in neighbouring South Africa. According to Cunningham (1985, 1990a, 1990b) although individual profits from palm wine sales are small (R30 - R70), the regional income from palm wine sales, transportation and resale is large (about R158,000 or R410,000 p.a. in current terms), providing income for nearly 500 people in the area. Furthermore Cunningham (1985, 1990a, 1990b) suggested that the exploitation of *H. coriacea* for palm wine at the time of his study was close to maximum capacity in the area, while the level of domestic and commercial harvesting of *H. coriacea* leaves for basketry was low and below the optimal capacity (Cunningham, 1988). McKean (2003) found that *H. coriacea* leaf harvesting in KwaZulu-Natal (South Africa) had negligible impact on leaf production.

Palm wine production from *H. coriacea* and *P. reclinata* is an ancient activity in southern Mozambique. According to Cunningham (1990a), palm wine tapping has been practiced in this area since the early Iron Age around 1500 BP. Presently, production and trade of palm wine is regarded as one of the main livelihood activities in the Zitundo area, southern Mozambique. However, the level of production and trade is unknown, as are local practices and management. Local data on harvesting, trading and management practices, along with biological data such as the ecology, abundance, population structure, and dynamics of the exploited species, are important to assess the conservation status of traded species and in designing conservation and development plans (Svarrer and Olsen, 2005; te Velde et al., 2006; Ticktin, 2015). Therefore, this study examined the local production and trade of palm wine in the Zitundo area of southern Mozambique. Specifically we i) describe the tapping activities, local management practices, local trade and the perceptions on productivity, abundance and sales fluctuations; ii) determine the incomes derived from palm wine sales, the level of dependency on palm wine income and the palm wine commercialization index; and iii) identify the factors that influence the income earned, the level of dependency and palm wine commercialization index.

2. Methods

2.1. Study area

The study was conducted in five of 16 villages that compose the Zitundo Administrative Post in Matutuine district, southern Mozambique, namely Phuza, Ndovo, Mabucuti, Zitundo-sede and Huco. They were selected because they are the sites where palm wine tapping activities occur. With the exception of Huco, these villages are within the palm savanna, where *H. coriacea* and *P. reclinata* are the dominant tree species, with approximately 602 and 252 stems per hectare, respectively (Martins and Shackleton, 2017). Beside palm savannas, dry forests, swamp forests, grasslands, wetlands, and estuarine vegetation are found in the Zitundo area (Kirkwood, 2014). The climate is tropical to sub-tropical with mean annual temperatures of approximately 23 °C, and precipitation between 750 mm to 888 mm p.a. (Mander and Pollett, 1994). Physiographically the area is a low coastal plain with elevations around 50 m (McKean, 2003). The soils are sandy and gray with low agricultural potential (McKean, 2003).

The Zitundo Administrative Post covers an area of 864 km^2 (INE, 2009), with a population of 6674 people (MAE, 2012) in 1777 households, and an average of four people per household (INE, 2009). Fifty-two percent of the Zitundo population is male, the illiteracy rate is 27% and the poverty incidence was 78% in 2005 (MAE, 2012).The majority of the population are of the Ronga ethnic group, which have occupied the area for more than 500 years (Shaffer, 2010). The main livelihood activities in the area include subsistence agriculture, goat and cattle herding, wild fruits and wild plant collection, beekeeping, fishing, hunting, charcoal production, craft and mat production as well as palm wine production (Governo do Distrito de Matutuine, 2008; Shaffer, 2010).

2.2. Data collection

Thirty-seven tappers were interviewed between February and August 2016. Preceding the commencement of the survey permission was obtained from the Zitundo traditional leader (Zitundo Régulo) and the local community leaders, and ethical clearance was obtained from Rhodes University. All participants were briefed about the purpose of the research and informed that participation was voluntary. We obtained the consent from the interviewees and the confidentiality of the information received was assured. We identified and selected the first tappers with the help of local leaders, and interviewed all other tappers as identified by their fellow tappers working in these areas. We were not able to interview all the tappers in the area (around 50 tappers work in the area) because some were out of the country (in South Africa) in the days the interviews took place and a few declined to participate. The interviews were conducted in the tappers native language Ronga and took place in the locations where they harvest the species on a regular basis as well as in Phuza market. A questionnaire survey was conducted to gather information on: i) tapper demographics and socioeconomic characteristics; ii) sources of income and assets; iii) amounts harvested, activity timing, and techniques used;

iv) quantities traded, selling prices, costs involved and income derived; v) management practices and potential constraints; vi) perceptions on resource abundance, rate of regrowth, changes over time, drivers of change and sustainability of the activity.

2.3. Data and statistical analyses

Descriptive statistics (mean, standard deviation, and frequencies) were used to summarize the data. Frequencies were expressed as number and percentage of tappers. Hierarchical cluster analysis was used to group tappers according to different characteristics and tapping strategies. Parameters used in the analysis are presented in Table 1. After the different clusters were identified, ANOVA was used to test for differences among the different clusters.

To assess the contribution of palm wine sales to household income, palm wine weekly returns were calculated based on the quantity of palm wine sold, multiplied by the selling price. The weekly amounts were converted to annual figures conservatively assuming 40 weeks of trade per year. Annual profit was calculated by subtracting from the gross annual returns all costs associated with the palm wine extraction and transport to the market. Returns to tapping-labour were calculated by dividing the palm wine profit by the time spent in tapping activities (Eaton and Sarch, 1997; Avocevou-Ayisso et al., 2009). Total household income was calculated as the sum of all income generated from all activities reported by the tappers. The level of dependency on palm wine income was subsequently calculated as the share of income from palm wine trade to total income (Vedeld et al., 2004; Tugume et al., 2015; Moe and Liu, 2016). The dependency level was adjudged high when the contribution of palm wine sales to the total income was above 60%; moderate (40%–60%) and low if it was below 40% (Singh et al., 2010). To assess the contribution of palm wine income to poverty alleviation we estimated the proportion of tappers with incomes below the national (MEF, 2016) and international poverty line (World Bank, 2015) for the different types of income (total income, palm wine income, other than palm wine income). The national poverty line is 26.7 Meticais/day (MEF, 2016) equivalent to 5.3 Rands and US$1.90/day (World Bank, 2015), and the international one US$1.90 per day, equivalent to 25.3 Rands (exchanged rate used: 1 Rand = 5 Meticais and 1 USD = 13.3 Rands as of August 2016). Values were expressed in Rands because this is the currency used by the tappers in the region.

A palm wine Commercialization Index (CI) was adapted from the Household Commercialization Index (HCI) proposed by Govereh et al. (1999) and Strasberg et al. (1999) and modified to estimate the level of commercialization of palm wine following Abu (2015) and Baiyegunhi and Oppong (2016). The palm wine Commercialization Index was calculated by dividing the quantity of palm wine traded by the quantity of palm wine produced. The quantity of palm wine produced per tapper per day was obtained by multiplying the number of palms tapped per day by the average sap production per stem per day. Daily sap production was then converted to weekly sap production by multiplying by five days. We used five days instead of seven for conservative purposes since two days a week the tappers participate in the palm wine market which reduces tapping time and consequently sap production. The palm wine Commercialization Index was categorized in high when the index was above 50%; moderate (25% and 50%) or low when 25% (Abu, 2015).

Inferential statistics were used to determine the factors affecting sales profit, the level of dependency on palm wine income, the palm wine Commercialization Index, and the adoption of conservation practices. Ordinary Least Square multiple regression was used to determine the factors that influence the sales profit, and Fractional Logistic Regression (Papke and Wooldridge, 1996) was used to analyze the factors that influence the tappers' dependency and Commercialization Index. Since regression estimates from a logistic model are difficult to interpret because the model is nonlinear in parameters, marginal effects were calculated to assess the magnitude of change in the dependent variable due the explanatory variable. Furthermore binominal logistic regression was used to analyze the effects of tappers' characteristics on adoption of conservation practices. The explanatory variables used in the models are presented in Table 1.

Statistical analyses were performed using SAS 9.4 and Stata 13.1. A variance inflation factor, and the Breusch Pagan test were used to check for multicollinearity and heteroscedasticity in the data, respectively, used for the multiple regression analyses. Because both multicollinearity and heteroscedasticity were detected, the tests on the regression coefficients used heteroscedasticity consistent standard

Table 1
Description of variables used in the statistical analysis ([a] are variables used in the cluster analysis, [b] are explanatory variables used in the regression analysis and [c] are variables dropped from the regression analysis).

Variables		Description
Demographic	Gender[a, b]	One for male, zero otherwise
	Age[c]	Age of the tapper (years)
	Age group[a]	≤20, 21–30, 31–40, 41–50, 51–60 and >60 (years)
	Ethnicity[a, b]	One if was Ronga, zero otherwise
	Place of birth[a, b]	One if was born in Zitundo administrative post, zero otherwise
	Years living in the area[a, c]	Number of years the tapper is being living in Zitundo administrative post
	Household size[a, b]	Number of people living in the tappers house
Formal education	Education[a, c]	Number of years of schooling
	Literacy[a, b]	One if knowns how to read and write, zero otherwise
Socio-economics	Reason for moving to Zitundo[a, b]	One if moved to area to tap palms, zero otherwise
	Main source of income[a, c]	One if tapping is the main source of income, zero otherwise
	Other sources of income[a, b]	One if tapper has, zero otherwise
	Palm wine sales profit[a]	Annual tappers net profit from palm wine sales
	Total annual tappers income[a]	Annual tappers net total income
Tapping site	Tapping in Phuza area[a, b]	One if tapper taps in Phuza area, zero otherwise; this was the dropped dummy for tapping site to avoid perfect multicollinearity and therefore was used as the reference
	Tapping in Ndovo area[a, b]	One if tapper taps in Ndovo area, zero otherwise
	Tapping in Mabucuti area[a, b]	One if tapper taps in Mabucuti area, zero otherwise
	Tapping in Zitundo-Sede area[a, b]	One if tapper taps in Zitundo-Sede area, zero otherwise
	Tapping in Huco area[a, b]	One if tapper taps in Huco area, zero otherwise
	Tapping only *Hyphaene coriacea*[a, b]	One if tapper taps only *Hyphaene coriacea*, zero otherwise
Tapping characteristics	Years tapping[a, b]	Number of years each tapper have been tapping
	Tap entire year[a, b]	One if tapper taps the entire year, zero otherwise
	Palms tapped per day[a, b]	Number of palms each tapper taps per day
	Time spending in tapping activities[a, b]	Number of hours each tapper spend in tapping activities
	Distance to market[a, b]	distance from the tapping site to the market (km)

errors. The multicollinearity was resolved by dropping the variables that were causing it (tappers age, years living in the area, tapping as main source of income, and years of schooling, since these variables were highly correlated to respectively number of years tapping, move to Zitundo to tap palms, other activities while tapping, and know how to read and write). The variables chosen to remain in the model were believed to be more relevant and could better explain the dependent variable. We selected the Fractional Logistic Regression to model dependency and Commercialization Index since both variables are fractions bounded between zero and one (Papke and Wooldridge, 1996). The estimation procedure utilizes robust standard errors in case residuals are heteroscedastic.

3. Results

3.1. Profile of tappers

The palm wine tapping activity was dominated by males (92%) between 21 and 40 years old (Table 2). The mean age was 37 ± 12 years old. With an average of only four years of schooling, the level of literacy among the tappers was low, with only 41% of tappers knowing how to read and write. The majority of tappers (68%) belonged to the Ronga ethnic group. Job-seeking emigration is widespread, since only 35% of tappers were born in the Zitundo area, and 27% were born in South Africa. Twenty-seven percent of the tappers live in South Africa and cross the border to Mozambique almost every day to tap. Thirty-two percent of tappers affirmed that they moved to Zitundo to tap. A lack of other job opportunities was the main reason (stated by 73% of tappers) to enter the palm wine trade, while 22% said that they entered this activity to increase their household income. On average, tappers have been in the trade for 12 ± 12 years, and many of the tappers had learnt to tap from their parents (32%) or friends (27%). The mean size household size was 5 ± 3 persons. Tapping palms was the main source of household income for 78% of the tappers. Other household cash income sources included: working as a shepherd (22%), other activities (palm wine transportation to the market, selling baskets, and cleaning work) (8%), cattle trade (8%), old-age pension (5%) and child pension (3%).

Table 2
Profile of palm wine tappers in Zitundo area.

Characteristic	Categories	No.	%
Gender	Male	34	92
	Female	3	8
Age (years)	≤20	2	5
	21–30	11	30
	31–40	14	38
	41–50	4	11
	51–60	5	14
	>60	1	3
	Mean ± SD	37 ± 12	
Education	Can read and write	15	41
	Years of school (mean ± SD)	4 ± 4	
Ethnicity	Ronga	25	68
	Matsua	5	14
	Changana	3	8
	Other	4	11
Place of birth	Zitundo area	13	35
	South Africa	10	27
	Inhambane Province	6	16
	Other	8	22
Reason for moving to Zitundo area	Already lived in Zitundo	11	30
	Tapping	12	32
	Work	11	30
	Harvest *H. coriacea* leaves	1	3
	Make furniture using *H. coriacea*	1	3
Reason for entering tapping activity	Increase household income	8	22
	Lack of job opportunities	27	73
	Good business	1	3
	Opportunity to work for oneself	1	3
Years tapping	Mean ± SD	12 ± 12	
Household size (no. of persons)	Mean ± SD	5 ± 3	
Main source of income	Tapping	29	78
	Work as a shepherd	8	22
Other cash income sources	Yes	9	38
	None	23	62

3.2. Tapping palm sap for wine production

Tapping activities for commercial purposes occurred in five of out of the sixteen villages in Zitundo Administrative Post. The majority of tappers carried out their activities in Ndlovo area (46%) followed by Phuza area (43%) (Table 3), Huco (5%) and 3% each for Mabubuti and Zitundo-Sede. *Hyphaene coriacea* was the main species tapped, with 60% of tappers saying that they only used this species, against the 3% that used solely *P. reclinata*, and 38% that used both species. The main reasons for favoring *H. coriacea* was its softer stem than that of *P. reclinata*, which made tapping easier, and its higher abundance in the area.

Tappers tapped an average of 102 ± 52 palms per day and they spent an average of 25 ± 18 h per week on tapping activities, which includes walking to and from the tapping site, site and stem preparation, as well as tapping. The tapping process starts with the selection of clonal palm clusters which contain most stems of a desirable size. A tapper then fills the cluster with dry leaves and grass and burns it to clear the area. The remaining leaves are then cut off and the stems are debarked and sliced until the sap start flowing. The sap that flows in the first day is disposed, because they believe that it causes stomach ache and diarrhea. After that, the sap is collected two to three times a day until the stems dries up. Each time the sap is collected the stems are sliced to stimulate sap flow. If the sap continues flowing even after the above-ground section of the stem is cut down to ground level, they dig around it to uncover the below-ground section and tap it. Palm wine production is a year-round activity for most tappers (89%). The other 12% tap at different periods of the year and invoked reasons such as: i) the need for rest because tapping is a hard activity (5%), ii) having other activities to do (3%), and iii) tapping only in periods when sales are high (3%). The main challenges faced by tappers include (i) palm weevil infestations that destroy the tapped stems (51%), (ii) bees sucking the sap from tapped stems, which reduces the amount of sap collected (43%), and (iii) elephants that eat and destroy the tapped stems (22%).

The cluster analysis separated the tappers into three clusters and a single outlier (Table 4). The largest cluster comprised of 73% of the tappers and other two clusters 14% and 11%, respectively. The variables responsible for the significant differences between the clusters were (i) whether or not the tapper was born in Zitundo Administrative Post, (ii) if they could read and write, (iii) years living in the tapping

Table 3
Characteristics of tapping activity in Zitundo area.

Characteristic	Categories	No.	%
Species tapped	*Hyphaene coriacea*	22	60
	Phoenix reclinata	1	3
	Both	14	38
No. of palms tapped per day	Mean ± SD	102 ± 52	
No. of hours per week spent tapping	Mean ± SD	25 ± 18	
Tapping season	All year	33	89
	Several months	4	11
Problems faced	Palm weevil infestation	19	51
	Bees suck the sap	16	43
	Elephants eat and trample tapped stems	8	22
	Birds destroy the tapped stem	3	8
	Other	5	13
Who taught them how to tap	Parents	12	32
	Grandfather	4	11
	Other family	6	16
	Friend	10	27
	Seeing others tapping	4	11

Table 4
Characteristics of palm wine tappers per cluster.

Parameters	Clusters				P-value
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	
No. of tappers (% of total tappers)	27 (73)	4 (11)	5 (14)	1 (3)	
Place of birth (% of clusters tappers)	4 (15)	4 (100)	4 (80)	1 (100)	<0.0001
Years living in the area (mean ± SD)	8 ± 12	44 ± 11	32 ± 17	38 ± 0	0.004
Literacy (% of clusters tappers)	14 (52)	0 (0)	0 (0)	1 (100)	0.020
Total net annual tappers income (mean Rands ± SD)	30,275 ± 13,824	19,754 ± 9148	67,144 ± 42,681	78,256 ± 0	0.040
Tapping in Ndovo area (% of clusters tappers)	16 (59)	0 (0)	0 (0)	0 (0)	0.001
Tapping in Huco area (% of clusters tappers)	0 (0)	0 (0)	1 (20)	1 (100)	0.010
No. of palms stems tapped per day (mean ± SD)	91 ± 37	75 ± 36	174 ± 75	150 ± 0	0.010

area, (iv) tapping palms at Ndovo and Huco sites, (v) the number of palms tapped per day, and (vi) the total annual tappers income.

3.3. Palm wine trade

The tappers sell their product on local markets, averaging about 173 l per week per tapper (Table 5). The average price in 2016 was R4.1 ± 0.4 per litre. The mean weekly return per tapper was R716 ± 334 while the mean annual return was R28,649 ± 13,352. The mean annual fixed costs were R180 ± 99, mostly for containers, while the mean annual transport cost was R3489 ± 2387, summing to a mean annual total cost of R3668 ± 2465 per tapper. Consequently, the mean annual profit from palm wine sales was R24,981 ± 12,094 per tapper, while the hourly return to labour from tapping was R39 ± 41 (Table 5).

3.4. Palm wine income dependency, commercialization index and role in poverty alleviation

On average, income from palm wine sales accounted for 85% ± 22% of a tapper's annual income, with the dependency level ranging from 35% to 100%. Most (78%) tappers had dependency levels above 60% being therefore, highly dependent on palm wine sales income, against the only 3% that showed low dependency (less than 40%). Palm wine is a highly commercial commodity in the Zitundo area, as demonstrated by the commercialization index, and appears to have a positive impact on alleviating poverty (Fig. 1). The palm wine commercialization index ranged from 23% to 100%, with an average of 63% ± 23%. The majority of tappers (65%) sell more than 50% of the palm wine they produce, whilst only 5% sell less than 25%. When palm wine income is not included accounted about 73% and 65% of tappers fall under the World Bank international poverty line and the national poverty lines, respectively. When palm wine income is included only 5% fall below the national poverty line, and none below the international poverty line.

3.5. Factors affecting palm wine profit, dependency level and commercialization index

The results of the regression analysis indicated that 70% of the variation in sales profit is accounted by the explanatory variables included in the regression model (Table 6). Additionally, these variables explained 34% of variation in palm wine income dependency, but only 14% of variation in the commercialization index (Table 7). Five variables had a significant influence on palm wine profit; place of birth, tapping only *H. coriacea*, and the number of palms tapped per day had a positive influence on profits, while tapping in Zitundo-sede area, and the number of years tapping palms had a negative influence (Table 6).Tapping in Mabucuti and Zitundo-sede, as well as the number of years tapping palms, increased the level of dependency on palm wine income, whereas tapping in Ndovo site and having other sources of income decreased the level of dependency (Table 7). On the other hand, bigger households and tapping in Huco site increased the Commercialization Index while tapping more palms per day and tapping in Zitundo-sede site decreased the index (Table 7).

Palm wine is an export commodity. The majority of the tappers sold the palm wine at Phuza market (87%) which is close to the international

Table 5
Average annual costs and income from palm wine production and sales.

Parameter		Mean ± SD
Income	Palm wine sales per week (l)	173 ± 79
	Weekly returns (R)	716 ± 334
	Annual returns (R)	28,649 ± 13,352
Costs	Containers (R/yr)	180 ± 99
	Transportation (R/yr)	3489 ± 2387
	Total costs (R/yr)	3668 ± 2465
Profit	Palm wine sales profit (R/yr)	24,981 ± 12,094
Labour	Time spending in tapping activities (hours/yr)	1013 ± 720
	Returns for labour (R/h)	39 ± 41

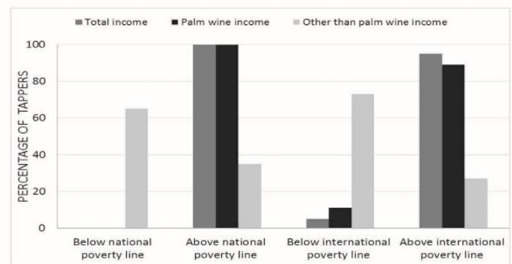

Fig. 1. Proportion of tappers under national and international poverty lines for different kinds of income.

Table 6
Ordinary Least Square regression estimates for palm wine sales profit.

Independent variable	Estimates	P-value
Gender	4210.22	0.48
Ethnicity	- 6785.60	0.1344
Place of birth	15,114	0.01
Size of household	584.79	0.20
Literacy	3655.79	0.32
Reason to move to Zitundo	3372.91	0.34
Other sources of income	−2452.34	0.36
Tapping in Ndovo area	−1174.60	0.70
Tapping in Mabucuti area	−572.20	0.93
Tapping in Zitundo-Sede area	−15,346	0.001
Tapping in Huco area	−7361.20	0.56
Tapping only *Hyphaene coriacea*	5962.80	0.03
Years tapping	−391.99	0.02
Tap entire year	5189.47	0.36
Palms tapped per day	167.12	<0.0001
Time spending in tapping activities	−56.92	0.38
Distance to market	−364.46	0.93
R-square	0.70	

Table 7
Fractional Logistic Regression estimates and marginal effects for level of dependency on palm wine income and commercialization index.

Independent variable	Dependency level			Commercialization index		
	Estimates	Marginal effects	P-value	Estimates	Marginal effects	P-value
Gender	1.93	0.17	0.08	0.33	0.11	0.14
Ethnicity	−1.13	−0.10	0.19	014	0.05	0.70
Place of birth	0.10	0.01	0.94	−0.07	−0.02	0.86
Size of household	−0.16	−0.01	0.20	0.07	0.02	0.01
Literacy	1.85	0.16	0.12	0.25	0.08	0.31
Reason for moving to Zitundo	2.88	0.25	0.03	0.18	0.06	0.43
Other sources of income	−1.72	−0.15	0.03	−0.22	−0.07	0.29
Tapping in Ndovo area	−2.51	−0.22	0.01	−0.03	−0.01	0.91
Tapping in Mabucuti area	15.40	1.35	<0.0001	−0.15	−0.05	0.59
Tapping in Zitundo-Sede area	15.75	1.38	<0.0001	−0.49	−0.16	0.02
Tapping in Huco area	−1.46	−0.13	0.56	1.01	0.33	0.03
Tapping only *Hyphaene coriacea*	0.73	0.06	0.25	0.69	0.22	<0.000
Years tapping	0.07	0.01	0.02	−0.01	−0.003	0.17
Tap entire year	−1.76	−0.15	0.18	0.60	0.19	0.05
Palms tapped per day	0.02	0.001	0.19	−0.01	−0.002	0.002
Time spending in tapping activities	−0.06	−0.05	0.11	0.01	0.003	0.05
Distance to market	1.06	0.09	0.25	0.50	0.16	0.09
R-square		0.34			0.14	

border with South Africa and where most buyers come from South Africa and purchase the wine for resale (Table 8). Forty-six percent of the tappers stated that the palm wine sales were higher during Christmas and Easter holiday seasons, while 22% of tappers believed that the sales did not vary through the year. Ninety-two percent of tappers affirmed that the price is adjusted annually and the new price is set by the tappers at a tappers meeting (Table 8).

3.6. Perceptions on productivity, abundance and sales fluctuation

The tappers estimated that each tapped stem produces an average of 0.6 ± 0.3 l of sap per day, and lasts for about 56 ± 24 days before the sap flow ceases. Sixty-two percent of tappers believed that sap production is highest during winter (Table 9). This is because the cool temperatures during winter do not dry out the tapped stem as is the case during summer. Ninety-seven percent of tappers said that *H. coriacea* produces more sap than *P. reclinata*, mainly because the stem of *H. coriacea* is thicker than the *P. reclinata* (35%) and lasts longer before drying out (35%). However, 38% of the tappers felt that *P. reclinata* sap produces a better wine against the 27% who believed that *H. coriacea* does so. The higher alcohol content (22%) and sugar (16%) present in *P. reclinata* wine were the main reasons it was considered better.

Sixty-eight percent of tappers believed that the palm abundance in the area had increased in the past five years, against only 19% that believed that it had decreased. The high rate of lateral shoot production after being tapped was mentioned by 60% of tappers as the main reason for the increase in palm abundance. Tappers that considered palm abundance to have decreased mentioned several reasons for the decrease: i) increase in the number of tappers (8%), ii) the removal of the stem meristem (3%), iii) increase in trade (3%) and iv) that tapped stems take a long time to recover (3%). Seventy percent of respondents said that the number of tappers in the area had increased, and that the increase was mainly due to the lack of job opportunities in the area (27%) and because sales of palm wine provide a high profit (14%). Fifty-seven percent of tappers considered that the number of palm wine buyers had increased, attributed to higher profitability of palm wine resale in South Africa (32%), while 5% believed that the increase was due to a rise in the number of consumers.

3.7. Local management of palms for palm wine production

Tappers in Zitundo stated that they follow some local conservation practices. All respondents said that they do not tap all palm stems within a cluster. Ninety-six percent mentioned leaving the smaller

Table 8
Palm wine markets in Zitundo area.

Characteristic	Categories	No.	%
Markets	Phuza	32	87
	Pontinha bridge	2	5
	Huco	2	5
	Phuza and S. Africa	1	5
Main buyers	South African women	14	38
	South African men and women	19	51
	Migrant workers from S. Africa	2	5
	Neighbours	2	5
Price decision	Annual tappers meeting	25	68
	Traditional leader decides	5	14
	Other	5	14
	Don't know	2	5
Season with higher sales	Christmas and Easter holiday	17	46
	Same throughout the year	8	22
	Summer	7	19
	Other	3	9
	Don't know	2	5

Table 9
Perceptions on productivity, abundance and sales changes.

Characteristic	Categories	No.	%
Daily sap production (l/stem)	Mean ± SD	0.6 ± 0.3	
No. of days the stem lasts	Mean ± SD	56 ± 24	
Season with highest sap production	Winter	23	62
	Summer	5	14
	Same	6	16
	Don't know	3	8
Species with highest sap production	*Hyphaene coriacea*	22	60
	Phoenix reclinata	8	22
	No difference	2	5
	Don't know	5	14
Species that produces the best wine	*Phoenix reclinata*	14	38
	Hyphaene coriacea	10	27
	No difference	5	14
	Don't know	8	22
Change in palm abundance over last five years	Increased	25	68
	Decreased	7	19
	Same	3	8
	Don't know	2	5
Change in number of tappers over last five years	Increased	26	70
	Decreased	4	11
	Same	4	11
	Don't know	3	8
Change in the number of buyers over last five years	Increased	21	57
	Decreased	1	3
	Same	12	32
	Don't know	3	8

stems to grow to be used in future. The mean stem height targeted for tapping was 57 ± 42 cm. Forty-three percent of tappers affirmed that the minimum stem height used was between 10 and 30 cm while 35% believed that it should be between 31 and 50 cm. Twenty-two percent of tappers believed that it takes one to two years growth to reach the minimum stem size for tapping. Seventy percent of tappers believed that tapping activities do not affect the growth and reproduction of the palms while 11% believed that it does. The results show that although the reasons for doing so may vary, there are local management practices followed by tappers with regard to number of stems left uncut and leaving smaller steams to grow (Table 10).

Sixty-eight percent of tappers stated that permission is required to start tapping in the area either from tappers already in the area (43%), by the traditional leaders (22%) or the site owner (3%) and that there is no need to pay for that permission. Regarding the distribution of tapping sites among tappers 76% stated that is made through agreement between the tappers already in the area and the new tapper and 14% said that the traditional leader is the one who assigns tapping sites for the new tapper. Sixty-two percent of tappers stated that they don't do anything to conserve the palms while 38% said that they conserve the palms. Practices used by the tappers to conserve the resource include: i) not tapping small stems (22%), ii) not finish the entire tapped stem (11%), iii) use insecticide to protect tapped stems from palm weevil attack (3%), iv) not tap *P. reclinata* because it bears edible fruits and v) a traditional ceremony made in Phuza by traditional leaders to protect palms from dying (3%). None of the tappers said that they cultivate the palms and never saw anyone cultivate them. The binomial logistic regression (Likelihood ratio = 6.73, P-value = 0.45) could not explain the factors that influence the adoption of palm conservation practices by the tappers.

4. Discussion

The results revealed that palm wine tapping and trading in southern Mozambique was dominated by young males, aged between 21 and 40 years. This accords with other studies showing that palm wine tapping and trading is mainly a man's activity (Okereke, 1982; Lebbie and Guries, 2002; Babitseng and Teketay, 2013; Okon and Okorji, 2014; Asa and Eyo, 2015). The dominance of young men in this activity can be related to the perception that tapping palms is a physically strenuous activity. Blockhus et al. (2002) also found gender differentiation patterns in NTFP collection in Sri Lanka, where women were typically exempted from more physically demanding tasks. The majority of tappers had limited formal education, with an average of four years of schooling, and only 41% could read and write, thereby limiting their ability to compete in the formal employment sector. The level of illiteracy among tappers is higher than those reported for Zitundo Administrative Post region at 27% MAE (2012). Low levels of formal education and high illiteracy levels were also found by Makhado and Kepe (2006) among mat and basket crafters in Eastern Cape, South Africa; Gyan and Shackleton (2005) and Mjoli and Shackleton (2015) among *P. reclinata* hand brush traders in the Eastern Cape, South Africa; Shackleton et al. (2008) among NTFP sellers in a South African semi-arid savanna; Adam and Pretzsch (2010) among fruit vendors in Sudan and Okon and Okorji (2014) among palm wine tappers in Nigeria.

Table 10
Local management practices of palms in Zitundo area.

Characteristic	Categories	No.	%
Minimum stem height target for tapping (cm)	10–30	16	43
	31–50	13	35
	51–100	6	16
	>100	2	5
	Mean ± SD	57 ± 42	
Years required to reach minimum size	Don't know	16	43
	1–2	8	22
	3–4	5	14
	5–6	5	14
	>6	3	8
Permission to tap	Don't need	12	32
	From the tappers already in the area	16	43
	From the area traditional leaders	8	22
	Site owner	1	3
Effects of tapping on plants	Doesn't affect	26	70
	Reduces stem growth	4	11
	Reduces sexual reproduction	4	11
	Only if over tapped	5	14
	Don't know	2	5
Activities used to conserve palms	Don't cut small stems	8	22
	Don't cut the entire stem	4	11
	Use insecticide against palm weevil	1	3
	Don't cut *P. reclinata* because it bears edible fruits	1	3
	Traditional ceremony to protect the palms	1	3
	Nothing	23	62

Palm tapping is an important livelihood activity in the area, being the main source of household income for 78% of the tappers. On average, tappers have been in the palm wine trade for 12 years. Lack of other job opportunities was the main reason stated by the tappers to enter the palm wine trade, probably being the reason for the relatively long period tappers stayed in the palm wine business. This is in the line with Shackleton et al. (2011) who mentioned that individuals and households frequently enter the trade of NTFPs due to lack of other livelihood or cash earning alternatives and this becomes a long-term source of income. Tapping palms yielded an average return to labour of R39 per hour, well above the local wage rate of R6 per hour working as a shepherd. Taking into account that other cash earning activities are scarce in the study area, these returns to labour can provide an important incentive to the people to enter and remain in the palm wine trade.

The majority of tappers carried out their activities at Ndlovo and Phuza areas, probably due to the comparatively high palm abundance in these two areas (Martins and Shackleton, 2017). *H. coriacea* was the main species used to produce palm wine. This confirms the findings of Cunningham (1985) in Kwazulu-Natal to the south and Martins and Shackleton (2017) in the same study area. Cunningham (1985) reported that 69% of all stems being tapped were *H. coriacea*.

The average number of stems tapped per day was higher than reported by other studies. We found that a tapper taps on average 102 stems daily against the 71 stems found by Cunningham (1985) for the same species in neighbouring Kwazulu-Natal, South Africa. This result can be related to differences in abundance between the two sites. According to Martins and Shackleton (2017), the density of *H. coriacea*, the preferred species for tapping, was higher in the study area than in Kwazulu-Natal, which means that distances between palms are shorter. Additionally, Cunningham (1985) estimated the number of tappers in Kwazulu-Natal to be around 200 against the around 50 tappers involved in tapping in Zitundo area (tappers, pers. comm.) suggesting that there is potentially more competition in the former. The lower number of stems tapped per day than the ones obtained in this study were also obtained for other palm species by Okereke (1982) and Lebbie and Guries (2002) for oil palm, *Elaeis guineensis*, in Nigeria and Sierra Leone, respectively; by Babitseng and Teketay (2013) for *H. petersiana* in Botswana and Okon and Okorji (2014) for *Raphia* palm, *Raphia* spp., in Nigeria. This can be an indication that tappers in southern Mozambique are trying to maximize their returns by increasing the number of palms tapped per day, since the palms in the study area are small, with lower sap yields, compared to the higher yields of the above mentioned studies (Cunningham, 1985).

The tappers sell their product on local markets. Phuza market, located adjacent to the South African border, was the main market, and major buyers came from South Africa and purchase the wine for resale. This echoes the findings of Kloppers (2005), who stated that undiluted palm wine is one of main products sold in Phuza market, which is then transported for resale in Manguzi and other areas outside of the palm savanna in South Africa. This consumption and trading of a given product among related ethnic groups living on both sides of a border is a common practice due to their shared cultural background (Ruíz Pérez et al., 2000), as well as a disparity in incomes and purchasing power across the border.

Several authors have highlighted the low economic returns derived from local NTFP sales (Neumann and Hirsch, 2000; Emery and Zasada, 2001; Pearce and Pearce, 2001; S. Shackleton et al., 2007). Yet, the palm wine trade appears to be a profitable business is southern Mozambique as demonstrated by relatively good returns to labour. The results indicated that tappers earn average of R24,981 per annum, which is about three times higher than the Mozambican minimum wage for the agricultural and forestry sector. These results are within the range obtained by Lebbie and Guries (2002) for palm wine trade in Freetown, Sierra Leone, where sales income ranged between USD 2.18 and USD 10.63 (corresponding to USD 2.9 and USD 14.2 currently; R39 to R189) per tapper per day. However, the results obtained in this study are higher than those obtained by Cunningham (1985), Naidu and Misra (1998), Ndoye and Awono (2005) for palm wine sales income in South Africa, India and Democratic Republic of Congo, respectively, as well as Angelsen et al. (2014) for NTFPs in general at a global scale. Cunningham (1985) and Naidu and Misra (1998) reported that tappers annual income in South Africa and India were R390 (corresponding to about R4578 in 2016 values) and 103 Indian Rupee (corresponding to about 319 today value, equivalent to R70), respectively, whereas Ndoye and Awono (2005) found that annual income per household from palm wine ranged between USD 13.2 and USD 228 (corresponding to USD 16.2 and USD 280.2, equivalent to R216 and R3727).

Several factors may underlie the relatively high incomes encountered in this study. For instance, the daily number of stems tapped per tapper as well as the price of palm wine encountered by Cunningham (1985) was lower than those of this study. The price per litre of palm wine in Cunningham's (1985) study was 20 cents (equivalent to R2.4 now), compared to R4 of this study. Furthermore, market proximity as well as the costs involved during the product collection, processing and transportation such as: labour, technology, advertisement and transportation costs can also have a role in the profitability of NTFPs (Avocevou-Ayisso et al., 2009). For the Zitundo area, the palm wine market is close to the majority of tapping sites and most of the above-mentioned costs were not encountered; 95% of the costs were for transport to the market. The results of the regression analysis indicated that the number of palms tapped per day increased the palm wine sales income, while tapping in Zitundo-sede area, the village located farthest away from the Phuza market, decreased the palm wine income. Neumann and Hirsch (2000) acknowledged that proximity between NTFP production and sales sites may contribute to high returns from some NTFPs sales.

The importance of palm tapping in the area was substantiated by the level of dependency on palm wine income. On average, income from palm wine sales accounted for 85% of the tappers' annual cash income and 78% of all tappers had dependency levels above 60%. These results are well above those found by Stanley et al. (2012), Angelsen et al. (2014), Melaku et al. (2014) and Tugume et al. (2015) for NTFPs in other African countries. Stanley et al. (2012) and Angelsen et al. (2014), in their respective studies, found that in African countries the dependency levels were 25% to 30%, while Melaku et al. (2014) and Tugume et al. (2015) found dependency levels in Ethiopia and Uganda were 47% and 40%, respectively. Factors such as, ecological conditions of the area (Coomes et al., 2004), seasonality of the resource (Shackleton, 2004), socio-economic characteristics of the traders (Gavin and Anderson, 2007; Heubach et al., 2011; Angelsen et al., 2014; Khosravi et al., 2016) and market accessibility (Barbier, 2010; Adam et al., 2013) can influence the level of dependency on NTFP income and, therefore, account for the differences in the above-mentioned studies. High palm abundance, year-round resource availability, existence of a reliable market, low skills needed and lack of other income earning opportunities are likely to underlie the high dependency on palm wine income in the Zitundo area.

The results from regression analysis showed that the level of dependency is higher for tappers who moved to the area to tap. This may indicate that these tappers lack skills to compete in the formal labour market and therefore turn to tapping as an alternative, therefore increasing their reliance in the exploitation of NTFPs for their livelihoods. According to S. Shackleton et al. (2007) some characteristics of local NTFP trade, such as low barriers of entry, minimal startup capital needed and low-intensity operational costs, make them appealing for those with limited formal education skills or with few other cash earning opportunities. Being engaged in this activity for long periods also increased the level of dependency. Shackleton et al. (2011) mentioned that when individuals enter the NTFP trade due to the lack of other livelihood opportunities and cash earning alternatives, the trade can become a long-term livelihood or cash earning choice, if the circumstance that propelled them into it persists. This appears to be the case of the palm wine trade in Zitundo. As expected, the results show that having other sources of income decreased the level of dependency on palm wine income, which is in line with results obtained by Illukpitiya and Yanagida (2008) in Sri Lanka and Tugume et al. (2015) in Uganda.

Palm wine is a cash oriented commodity in the Zitundo area, as demonstrated by the average commercialization index of 63%. Tappers with large households had a higher commercialization index. Baiyegunhi and Oppong (2016) also found that having more people in a household increased levels of commercialization of mopane worm in South Africa. Baiyegunhi and Oppong (2016) believed that households with high dependency ratios (i.e. more consumers than workers within the household) propel them to increase their income, and thus increasing the level of commercialization. Tapping site also had an influence in the level of palm wine commercialization; tapping at Huco increased it while tapping in Zitundo-sede site decreased it. This is probably related to the transportation costs. At Huco tappers sell palm wine from their houses, and therefore do not incur any transportation costs, while the Zitundo-sede site is located the farthest away from the Phuza market, therefore requiring high transport costs. Baiyegunhi and Oppong (2016) observed a similar result within South Africa where there was a decrease in the level of mopane worm trade with increasing distance to the market.

Palm tapping is clearly an important poverty reducing activity in Zitundo. The inclusion of palm wine income in total income resulted in a reduction in the proportion of tappers falling under the international and national poverty line from 73% to only 5% and from 65% to zero, respectively, a 65% to 68% reduction in poverty incidence. This is stark in the context of the high poverty incidence in Matutuine district, with Zitundo administrative at 78% (MAE, 2012). A high reduction in poverty among gum and resin traders was similarly noted by Abtew et al. (2014) in eastern Africa. Stanley et al.'s (2012) meta-analysis found that the income from NTFPs were above the international poverty line or the local wage rate in the majority of the cases studies for Africa and Latin America, suggesting therefore that NTFP exploitation can represent an appealing alternative to lift some relatively unskilled people above the poverty line. However, one must consider the amount of effort or time spent and report incomes accordingly, as those seeking to simply earn supplementary income by working a few hours per week will clearly earn less than those for whom NTFP trade is their primary livelihood activity in which they spend many hours per week (S. Shackleton et al., 2007, 2008).

The tappers estimated that each tapped stem produces approximately 0.6 ± 0.3 l of sap per day, and lasts for about 56 ± 24 days. The majority of tappers believed that *Hyphaene coriacea* is more productive than *Phoenix reclinata*, although the latter species yields a better wine. The daily sap yields mentioned by the tappers are above the 0.06–0.45 l range recorded by Cunningham (1985) for the same species in South Africa. These differences are likely to be related to specific climate and soils conditions. Samsudeen et al. (2013) found that higher temperatures, cloudiness and wind velocity had a negative impact on sap production from *Cocos nucifera*, while higher precipitation increased the production of sap. The period tapped stems last before drying out mentioned by the tappers is within the ranges found by other authors (Cunningham, 1985; Naidu and Misra, 1998; Babitseng and Teketay, 2013) and are in line with findings of Cunningham (1985) during field observations of a selected tapper in Kwazulu-Natal, where he observed that *Hyphaene coriacea* and *Phoenix reclinata* sap production decreased around the 44th day of tapping.

The majority of tappers believed that both the number of tappers and buyers in the study area had increased over the past five years. A shortage of other cash earning opportunities in the area, alongside the attractive profitability of palm wine sales, was perceived by the tappers to be the reasons driving the increase in the number of participants. Expansion in the number of people engaging in NTFPs trade was similarly reported by Shackleton et al. (2008) and Weyer et al. (2017). Shackleton et al. (2008) observed an increase in the number of traders of marula beer and brooms and mats, and Weyer et al. (2017) in the number of sellers and producers of several NTFP products. Both authors revealed that scarcity of other cash earning options were among the main reasons stated for the expansion of market participation. The expansion in palm wine trade does not appear to be currently driving a decline in palm abundance. The majority of tappers believed that palm abundance had increased in the past five years. The high rate of lateral shoot production after being tapped was mentioned by 60% of tappers as the main reason for this. This is supported by Martins and Shackleton (2017) who observed that the population structures of *H. coriacea* and *P. reclinata* in the study area are dominated by individuals in shorter size classes due to high vegetative reproduction via root coppicing. Many of the tappers consider that tapping does not affect the growth and reproduction of palms. However, Martins and Shackleton (2017) found a low rate of stem survival after being tapped along with low prevalence of stems with reproductive structures, because palms are normally tapped before reaching reproductive size, thus impacting recruitment through seeds. This may have long-term implications for recruitment and consequently requires monitoring.

Most of the tappers affirmed that the minimum stem height for tapping is between 10 and 50 cm, and it takes one to two years growth to reach this height. These results are below the 101 to 150 preferred size class for tapping for both species found by Martins and Shackleton (2017) in the study area, and 500 to 1500 cm stated by Botswana tappers for *H. petersiana* (Babitseng and Teketay, 2013). This may indicate a level of over exploitation. Furthermore, Cunningham (1985) reported that it takes five to eight years for a new coppice shoot to achieve a suitable size for tapping. Results show that although the reasons for doing so may vary, there are some local management practices followed by tappers in the area. For example, all interviewed tappers said that they do not tap all stems in a cluster, leaving the smaller stems to grow and to be used in future. This accords with results of Cunningham (1985) in South Africa. The palm wine tapping practice is done under a communal resource use system, and some level of permission by tappers already in the area and the traditional leaders is required to start the tapping activity in the area.

5. Conclusion

This study has demonstrated that palm wine is currently an abundant and valuable resource for tappers in the Zitundo area, southern Mozambique, being the main source of household income for more than 70% of tappers and contributing with more than 80% of tappers' total annual income. Palm wine tappers earn up to three times more than the national minimum wage for the agricultural and forestry sector. This income is high in comparison to other NTFP trade in local markets in southern Africa and locally it plays a key role in alleviating poverty. Demographic and socio-economic characteristics of the tappers, along with tapping strategies, appeared to determine the level of palm wine sales returns, commercialization index and the dependency on palm wine income. The high and continuous palm availability in the area, in conjunction with market presence and a shortage of other livelihood options appear to have encouraged the palm wine trade and contributed to the high level of dependency on it. The significant contribution of palm wine income to local livelihoods and poverty mitigation should be acknowledged by government and rural development agencies and incorporated into local development plans and agendas.

Hyphaene coriacea was favoured to produce palm wine above *P. reclinata*. The perceptions among the tappers are that palm tapping does not have many detrimental effects on the species abundance, growth and reproduction due to their higher capacity to coppice after being tapped. Yet previous studies have suggested that tapping palms has a negative impact on the recruitment of both palms species, consequently participatory population monitoring of the effect of tapping on palms should be implemented. Palms in Zitundo area are exploited in a communal tenure system, where some level of voluntary local management exists to try to conserve the resource for future use. However, with the expansion of the trade these measures might be tested in the future. Consequently, participatory conservation and management strategies should be designed and implemented by tappers and others stakeholders.

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