Composition and Stand Dynamics of the Ntabelanga Natural Forests around Maclear, Eastern Cape, South Africa

By

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Declaration

I Thomas AROMYE, hereby declare that this Thesis, which I hereby submit for the degree of MSc at the University of Pretoria is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

SIGNATURE: Thom

DATE: 14 April 2020

Dedications

This Thesis is dedicated to my Mother and late Father who inspired me to study hard despite of Challenges. Without their support, I would have not reached this level. “*Father may your soul rest in Eternal Peace!*”

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Abstract

Management of the large Ntabelanga Catchment for development of a water reservoir in the Eastern Cape has to consider the scattered, very small and fragmented natural forests within the matrix of montane grasslands. The forests cover altitudinal, topographical and disturbance gradients, and are affected by fires and intensive utilization of forest resources by rural society; and they are surrounded by alien plant invasions. The forests have not been studied before and their relationship with the national forest types are not clear. Therefore, a management plan framework for the natural forests within the catchment management plan needs to be developed. The objectives of this study are therefore to assess the composition and stand dynamics of natural forests within this catchment as basis for sustainable management of their ecological status and resources, and ecological restoration where needed.

The study of the forest patches was done in all five catchments of the Ntabelanga in the Maclear area in the Eastern Cape. Sampling of forest floristic and structural composition covered the altitudinal, topographical and disturbance gradients within the catchment representatively. Each randomly selected point on a forest patch was a point on a transect line to locate plots to sample the variation through the forest. Circular sample plot 11.3 m radius (0.04 ha) was used to conform to South African forest sampling standards. Sub-sampling within each sample plot was used for trees regeneration and understory vegetation. Data analyses included forest type classification, ordination between species and environmental variables, stem diameter class distributions, and related analyses on species diversity patterns, and response of species to resource use.

In total, 63 species of trees and large shrubs were identified from 56 plots. These species represented 49 genera in 30 families. The TWINSPAN output table has revealed four forest communities: two mixed low altitude forest communities, each with sub-communities (*Scolopia zeyheri-Cussonia spicata* regrowth forest, *Scolopia zeyheri-Celtis africana-Afrocarpus falcatus-Elaedendron croceum* high forest, *Dovyalis zeyheri-Allophylus decipiens-Calodendrum capense* disturbed forest, *Cussonia spicata-Commiphora harveyi* scrub-forest), and two mixed high-altitude forest communities, one with three sub-communities (*Podocarpus latifolius-Halleria*

lucida-Olinia emarginata high forest, *Olinia emarginata-Euclea undulata-Cryptocarya woodii* regrowth forest, *Podocarpus latifolius-Olinia emarginata-Pleurostylia capensis* regrowth forest). The *Leucosidea sericea* and *Hippobromus pauciflorus* stands are different communities on their own, hence resulting into six forest communities. Grain result has shown that at low altitude sub-community *Scolopia zeyheri-Cussonia spicata regrowth forest* is very fine grained, However, sub-communities *Cussonia spicata-Commiphora harveyi scrub-forest* and *Scolopia zeyheri-Celtis africana-Afrocarpus falcatus-Elaedendron croceum* high forest) are fine grain. In contrast, sub-community *Dovyalis zeyheri-Allophylus decipiens-Calodendrum capense* disturbed forest is coarse grained. In high altitude forests, sub-community *Podocarpus latifolius-Halleria lucida-Olinia emarginata* high forest) is fine-grained. Nonetheless, sub-communities *Olinia emarginata-Euclea undulata-Cryptocarya woodii regrowth forest* and *Podocarpus latifolius-Olinia emarginata-Pleurostylia capensis* regrowth forest) are coarse-grained forests. The size class distributions were assessed at different levels: firstly, for all canopy and sub-canopy tree species in each sub-community; secondly, for different groupings of canopy tree species; and thirdly, for different groupings of sub-canopy tree species. For all histograms where canopy trees are included, the X-axis show stem diameter (DBH) classes up to 35+ cm DBH. For histograms with only sub-canopy tree species, the X-axis show DBH classes up to 25+ cm DBH. The Y-axis scales varied, depending on the maximum number of stems included in specific DBH classes.

The canopy and sub-canopy species have shown the diameter class of 35+ cm DBH and 25+ cm DBH along the X-axis respectively. The general trend of size class distributions across most sub-communities is towards the inverse J-Shaped DBH class distribution for both canopy and sub-canopy tree species. However, the trend is not strong in *Cussonia spicata-Commiphora harveyi* Scrub-forest, *Podocarpus latifolius-Halleria lucida-Olinia emarginata* high forest and *Podocarpus latifolius-Olinia emarginata-Pleurostylia capensis* regrowth forest. Species which have shown good presence at both low and high altitude forest sub-communities are *Podocarpus latifolius, Scolopia mundii, Scolopia zeyheri, Cussonia spicata complex and Ilex mitis.* Some species are mainly confined at low-altitude forests (*Afrocarpus falcatus, Celtis africana* and *Commiphora harveyi*) or mainly high altitude forests (*Olinia emarginaata*) or both (*Calodendrum capense* and *Ptaeroxylon obliquum*) across identified forest sub-communities.

In conclusion, the natural forests within the Ntabelanga catchment that lie at low altitude is related to Transkei Mistbelt forests and those which lie at high altitude is related to Drakensberg forests. Altitude is the strongest environmental gradient accounting for most variation within the forest communities and is strongly correlated to CCA1 by 99%. However, other environmental variables, such as Slope and the Radiation Index, have contributed 34% and 29% respectively to variation in species composition. The main natural and human disturbances noted within the catchment were resource use for firewood and poles, and bark for medicinal use. Nevertheless, other disturbances (e.g. grassland fires, crown breaks) were common at high altitude. Wattle remains the main source of firewood and non-wood for the rural communities within the catchment.

A sustainable resource use framework was developed to guide the resource use and natural forest rehabilitation within the catchment.

Keywords: Altitude, Composition, Dynamics, Fire, Plant invasion, Resource use.

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List of Abbreviations and Acronyms

CITES	Convention on International Trade in Endangered Species
CCA	Canonical Correspondence Analysis
DCA	Detrended Correspondence Analysis
DWAF	Department of Water Affairs and Forestry
DWA	Department of Water Affairs
DBH	Diameter at Breast Height
ECBCP	Eastern Cape Biodiversity Conservation Plan
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
IAPs	Invasive Alien Plants
IVs	Important Values
NTFPs	Non-Timber Forest Products
NFTC	National Forest Types Classification
NPAES	National Protected Areas Expansion Strategy
RI	Radiation Index
RF	Relative Frequency
RD	Relative Density
RBA	Relative Basal Area
SCD	Size Class Distribution
SP	Sample Plot
TWINSPAN	Two Way Indicator Species Analysis

Chapter 1: A study of Ntabelanga natural forests – A conceptual framework

1.1 Introduction

Natural forests in a specific area are studied for different reasons. Sometimes it is to understand their floristic and structural composition in relation to other natural forests in a larger area (Von Maltitz et al. 2003). Moreover, their floristic and structural composition form the basis for their sustainable management for different products and services (Geldenhuys 1993). In the case of the natural forests in the Ntabelanga catchments in the Maclear area in the Eastern Cape, South Africa, it was important to know how they are affected by the use of various products in relation to resource use from invader plant stands that are to be cleared from the area. What would be the impacts on the conservation status of those forests if the invader plant stands would be cleared and use of products by the rural society for their livelihoods would revert back to the natural forests?

Generally, forests provide a wide range of ecosystem services such as species conservation, controlling erosion, and serve as habitat for plants and animals (Armenteras et al. 2009). In addition, forests contribute to the livelihoods of hundreds of millions of people in both rural and urban areas (Emanuel et al. 2005). However, overexploitation has resulted in rapid forest degradation; considered to be one of the major environmental and economic challenges worldwide (Mani and Parthasarathy 2006). This utilization vary over time and space (Taylor et al. 2008), has varied impacts on forests (Thapa and Chapman 2010), and consequently, may result in an ecological change in structure and composition of forest ecosystem; by affecting the survival rate, growth and reproduction of harvested species (Denslow 1995). Therefore, understanding tree species composition and structure are necessary to achieve sustainable management of forests (Farhadi et al. 2013).

Previous studies indicated that unsustainable resource use has serious impacts on natural forests in South Africa, especially by the rural communities (Willis 2004). The subsistence use of wood and non-wood products (e.g. laths, poles, bark and fuelwood) is one of the major disturbances facing the natural forests (Obiri et al. 2002). This creates gaps that result in specific forest structure (Scott and Steenkamp 1996; Scott et al. 1997). However, forest response to disturbance depends on the ecology of a specific forest type and its grain (i.e. the regeneration status in terms of shade tolerance of canopy tree species) (Midgley et al. 1990; Everard et al. 1995; Geldenhuys 1996).

Studies have shown that there is a gap in understanding the natural ecological processes which may result in insufficient and costly management approaches (Geldenhuys 1997a). Geldenhuys and Bezuidenhout (2011) indicated that clearance of invasive alien plants to recover natural forests as many people perceived, may lead to massive invasive alien plant stands under high operational cost. This is due to the fact that the natural vegetation and invader plant stands have the same ecological requirement (i.e. they are adapted to disturbance and intolerant to shade), hence they directly compete for the same site. Nevertheless, this approach has shown success in fynbos and grassland biomes (Richardson and van Wilgen 2004). On the contrary, in the forest biome, this practice is inadequate because major disturbances created by the clearance of invader plants tend to simulate massive recruitment of light demanding invader plants as in the case of Buffeljagsrivier (Geldenhuys and Bezuidenhout 2008). In addition, a study by Atsame-Edda (2014) at Buffeljagsrivier in Western Cape Province has confirmed the spread of indigenous forest species into the invading wattle stands developing on the abandoned agricultural land along the riverine terraces. Furthermore, studies have shown that in several disturbed forest ecosystems, invasive species have emerged, and ecosystem services were reduced (Cannon et al. 1998). Therefore, there is a need to understand human-related disturbance that affects biodiversity and forest vegetation structure to help conservationists to suggest best forest management practices (Pinard et al. 2000). Geldenhuys et al. (2016) have highlighted that there is a need for implementing sustainable resource use through relevant institutional structures, practical guidelines for sustainable resource use and control of wattle invasion within the Ntabelanga catchment.

The Mzimvubu River in Eastern Cape is one of South Africa’s largest rivers and the most undeveloped water catchment within the country (Iliso 2014). It accounts for 5.5% of the total river flow in the country and has major tributaries, namely the Mzintlava, Kinira, Tina and Tsitsa Rivers. DWAF (1996) indicated that water is a fundamental resource that ultimately underlies development in South Africa; efficient management of water resources is therefore a national imperative. The Eastern Cape Provincial Government identified development towards social and economic upliftment of the poor rural communities within the area as a priority. This integrated, multi-purpose project (domestic water supply, power generation, agriculture, transport, industry and conservation) meant to provide socio-economic opportunities for the poor rural communities within the Mzimvubu River catchment area (DWA 2014). The communities in the Ntabelanga catchment are subsistence farmers that are growing crops, keeping cattle and using wood and non-wood resources. The natural forests within the catchment provide various forest products, mainly wood for poles and firewood, and non-wood resources such as traditional medicines and fruits for food, as well as a wide range of ecosystem services (Geldenhuys et al. 2016). However, this study formed part of a bigger project within Ntabelanga catchment which was being implemented by Working for Water (WfW) and had three main components; (i) Spatial distribution of natural forests in relation to invasive wattle, commercial forestry and resource users; (ii) Composition and structure of the natural forests; and (iii) Resource use by rural society from the natural forests and wattle stands. Observations in the area suggested that the composition and dynamics of the Ntabelanga forests had to be considered in the context of the distribution and categories of the South African forests, the disturbance-recovery processes affecting them, including their response to invasive alien plants, and resource use practices for rural livelihoods. Their management is also dependent on what institutional structures are in place within the catchment area.

1.1.1 General distribution of natural forests in South Africa

Natural forests are the smallest biome represented in South Africa with an estimate of 0.56% of the total land area of the country (Cooper 1985; Rutherford and Westfall 1986; Geldenhuys and MacDevette 1989). They are highly fragmented and distributed in patches (Geldenhuys 1991, 1994, Mucina and Geldenhuys 2006). Despite being small in area, fragmented and degraded, it supports a high proportion of the country’s floral and faunal diversity (Geldenhuys and MacDevette 1989; Geldenhuys 1992).

Forests extend in the archipelago of patches from the Cape Peninsula at the southwest and to the southern and eastern parts of the country to Limpopo in the far northeast. Forests were also noted to extend to the inland of the Great Escarpment in the northern parts of South Africa, and along the West Coast north to Oorlogskloof near Nieuwoudtville in Namaqualand (Von Maltitz et al. 2003). The largest forest complex in the country exists on the southern coast along the Garden Route around Knysna and Tsitsikama (Geldenhuys 1991). Forests are found on a wide range of geological formations and sometimes limited to areas having mean annual rainfall >525 mm in all-year and winter rainfall areas and >725 mm in summer rainfall areas (Rutherford and Westfall 1986). In lower rainfall areas, forests are found along rivers, protected kloofs or gorges (Von Maltitz et al. 2003). In both the drier and high rainfall areas, mountains provide a favorable habitat for the persistence of forests as noted in the southern slopes of the Soutpansberg (Geldenhuys and Murray 1993; Geldenhuys 1997b) and sheltered valleys in the south-western Cape (McKenzie 1978; Geldenhuys 1997b). However, there is no account of the natural forests in the Maclear area, inland of the Southern Mistbelt Forests in the Eastern Cape.

The distribution of natural forests in South Africa and southern Africa in general has long been debated. Studies have mentioned that this was due to the clearing of forests (Geldenhuys 1991), use of fire during the past >300 years (Granger 1984) and limiting environmental factors (edaphic factors) (Rutherford and Westfall 1986). However, natural forests in South Africa are also expanding in places with an overall increase of 14% between 1990 and 2013, and over 51% increase in the Eastern Cape coastal areas (GTI 2015a, b). Such expansion in forest cover has various reasons, such as changing fire regimes to cooler fires, protection against fires in commercial forestry areas, intensive agriculture, urban and infrastructure development, etc. (Geldenhuys 2013).

The land use practices such as cultivation and veld burning for grazing and surface runoff within the catchments has aggravated the fragmentation (Cooper 1985; Geldenhuys and MacDevette 1989; Geldenhuys 1991). Evidence suggests that the distribution pattern of natural forests is fire driven during the hot, dry season whereby forest remain intact between the mountainous landscape, gullies, and below the cliffs on steep slopes in ‘fire refuge sites’ or wind ‘shadow areas’ (Geldenhuys 1994). Moreover, van Wilgen et al. (1990) argued that the natural forests which are sheltered from regular fires tend to have fuel properties that do not promote fire, whereby maintaining their survival in the fire-prone landscape. However, this is a similar situation as for the case of Ntabelanga natural forests in which forest patches are observed to persist in true fire shadow areas (e.g. gullies, cliffs on steep to very steep slopes) in relation to prevailing wind direction (mainly Bergwinds) during the fire season. These had made them to become inaccessible for easy resource use or conversion to crop fields. Field observations have shown that in many places there is a good dense and diverse tree regeneration along the forest margins which are disturbed by fire. This is an evidence that forest can expand when a fire regime below a cliff face change for unknown reasons.

1.1.2 Composition, biogeography and structure of forests in South Africa

The floristics and structural composition of forests are essential components of their ecology and ecosystem function; they provide a basis for identifying economically important tree species (Farhadi et al. 2013). However, it varies depending on biogeography, habitat and disturbance (Clark and Clark 1996). Studies have shown that the composition and species population structure indicate species adaptation to that particular environment (Geldenhuys 2010). Therefore, the floristic and structural composition of the forests, and their internal stand dynamics is a base to develop a management plan framework as guide for sustainable forest management (Geldenhuys et al. 2016). The South African indigenous forests are floristically part of the Afromontane forests and Indian Ocean Coastal Belt forests and have many species in common with the natural forests as far north as the Ethiopian forests (White 1983; Geldenhuys 1992; Geldenhuys 2011a).

Different subdivisions of the South African natural forests were based on descriptive accounts by Acocks (1953), Cooper (1985), and Low and Rebelo (1998). The National Forest Type Classification (NFTC) of Von Maltitz et al. (2003) was the first comprehensive, nationwide objective and quantitative classification of the indigenous forests of South Africa. It classified the indigenous forests into eight forest groups, described in more detail by Mucina and Geldenhuys (2006) as basis for the national vegetation map of South Africa (Mucina and Rutherford 2006): Southern Afrotemperate, Northern Afrotemperate, Southern Mistbelt and Northern Mistbelt Forests that are all basically part of the inland Afrotemperate zone, Northern Coastal and Southern Coastal Forests as part of the Indian Ocean coastal zone, the Scarp Forests linking the Afrotemperate and Coastal zones, and the Azonal Forest types (Sand forest, Ironwood Dry forest, Lowveld Riverine forest, Swamp forest and Mangrove forest). Each Group was subdivided into several types, based on their floristic affinities, resulting in a total of 24 National Forest Types (Von Maltitz et al. 2003).

The natural forests within the Ntabelanga catchment (focus of this study) are located between the Northern Afrotemperate Forests (Drakensberg Montane Forests, including *Leucosidea sericea* scrub forest) at higher altitude, and the Southern Mistbelt Forests (Transkei and Eastern Mistbelt Forests) at lower altitude. They may be a transition between the two zones (Geldenhuys et al. 2016).

1.1.3 Natural disturbance and recovery processes

Disturbances at different scales are natural and integral parts of ecosystem dynamics (White 1979; Hansen and Walker 1985). Geldenhuys (2011b) mentioned that "*A forest is not a museum piece – it is actually a very dynamic system to have survived some severe landscape and habitat changes over millions of years!*" Pickett and White (1985) defined disturbance as "*any relatively discrete event in time that disrupts the ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment*". Generally, a disturbance is viewed as any discrete event that removes organisms, by freeing both space and resources to be used by the new individuals (Townsend and Hildrew 1994).

Hansen and Walker (1985) noted that biological components of all vegetation types represent their adaptation to different site conditions and disturbance regimes. The types of vegetation (e.g. growth/life forms, and kinds of bark, leaves, fruits/seeds) and biodiversity patterns in a landscape represent adaptations to different site conditions and disturbance regimes in that particular landscape (Geldenhuys 2010).

Ecosystem functioning is normally driven by the main type of disturbance (Geldenhuys 2011b). For example, the evergreen forests are being driven by relative shade-tolerance (or demand for light) in relation to gap size. Deciduous woodlands are often driven by their relative tolerance to fire during the dry season with an adaptation to grazing or browsing being a secondary driver.

Many forests have been subjected to severe disturbances due to high demand on forest resources. However, human activities in a forest simulate one or other of natural disturbances to which some components of natural system are adapted, directly or indirectly (Geldenhuys 2010). Hansen and

Walker (1985) suggested that a disturbance can be classified with regards to its impact at the level of the individual, a species, a community and ecosystem. This implies that a disturbance can be a non-event if it does not alter the composition of the ecosystem (i.e. the frequency or impact is too minor to cause a response); an incorporated disturbance if it is within the adaptation and tolerance limit of an entity; or a disaster if it alters the entity into a new state.

1.1.4 The role of invasive alien plants in natural forests

Globally, invasive alien plants (IAPs) (introduced from other countries and becoming invasive in natural vegetation systems) are considered to pose a major threat to the conservation of biodiversity (Rejma´nek et al. 2005). They affect the natural biodiversity in an area in various ways, for example, by changing the nutrient cycle and disturbance regimes (Brooks et al. 2004). Altering resource availability, whether due to natural processes or management may ultimately result in changes in the composition of the plant communities (Theoharides and Dukes 2007). Studies revealed that IAPs disrupt the natural occurring mutualisms and consume much water, light and oxygen, hence limiting resources for native species, stabilizing sand or promoting erosion (Traveset and Richardson 2006). However, contrary to the global concern towards invasive species, recent studies have shown that IAPs can facilitate the rehabilitation and recovery of natural forests, instead of threatening the biodiversity and functioning of natural forest ecosystems (Geldenhuys and Bezuidenhout 2011; Geldenhuys 2013). Shade-tolerant natural forest species benefit from the shade provided by the light demanding plantation forestry and invader plant species, which are unable to establish under their own canopies. IAPs may facilitate forest recovery by nursing the establishment and growth of natural forest species (Van Wyk et al. 1995; Geldenhuys 1997a, 2013; Geldenhuys and Bezuidenhout 2011).

However, the rural communities consider wattle (invader plant) as a valuable wood resource in terms of firewood and building materials, whereas the society in general needs the wattle to be controlled (Geldenhuys et al. 2016). Geldenhuys and Bezuidenhout (2011) suggested that clearance of wattle may increase pressure on natural forests and facilitate the invasion of wattle.

The mandate of Working for Water program launched in 1995 by the Department of Water Affairs is to increase the flow of water from within the catchments by clearing the IAPs, with the aim of improving the water quality and creating jobs to the poor rural communities. Therefore, understanding the ecological drivers that facilitate the invasion of an alien plant in an area is key to develop a management plan of an ecosystem (Geldenhuys 2011c, 2013).

1.1.5 Institutional structures, forest legislation, management system and conservation

In South Africa, forests are protected by several legal instruments against uncontrolled use and degradation. These laws include the National Environmental Management Act (Act No. 107 of 1998), National Environmental Management: Biodiversity Act (Act No. 10 of 2004), National Forests Act (Act No. 84 of 1998) and Provincial legislation. These laws provide for and facilitate access to natural resources.

Conserved forests in South Africa are those proclaimed under the Forest Act; these include forests in private, tribal ownership, forest in conservancies, natural heritage sites, forests in nature reserves, national parks and wilderness areas. Geldenhuys and Macdevette (1989) defined conserved forest as "*those forests in the custody of the government authorities, including National Parks Board and city councils*". Many of these forests are well conserved and are not proclaimed by the Forest Act but are insecure in terms of conservation status (Geldenhuys and MacDevette 1989; Von Maltitz et al. 2003). However, despite the law enforcement and legal structures, the uncontrolled harvesting of forest resources is a challenge, and a threat to several protected tree species resulting in degradation of forest composition and structure (Mander 1998).

1.2 Study area

The Ntabelanga Catchment lies between the towns of Maclear, Tsolo and Mount Fletcher in the Eastern Cape Province (Figure 1.1) within the District Municipalities of Joe Gqabi, OR Tambo and Alfred Nzo. The local Municipalities include Mhlontlo, Nyandeni, Umzimbuvu and Elundini. Maclear, the nearest town, lies at 1, 280 m above mean sea level.

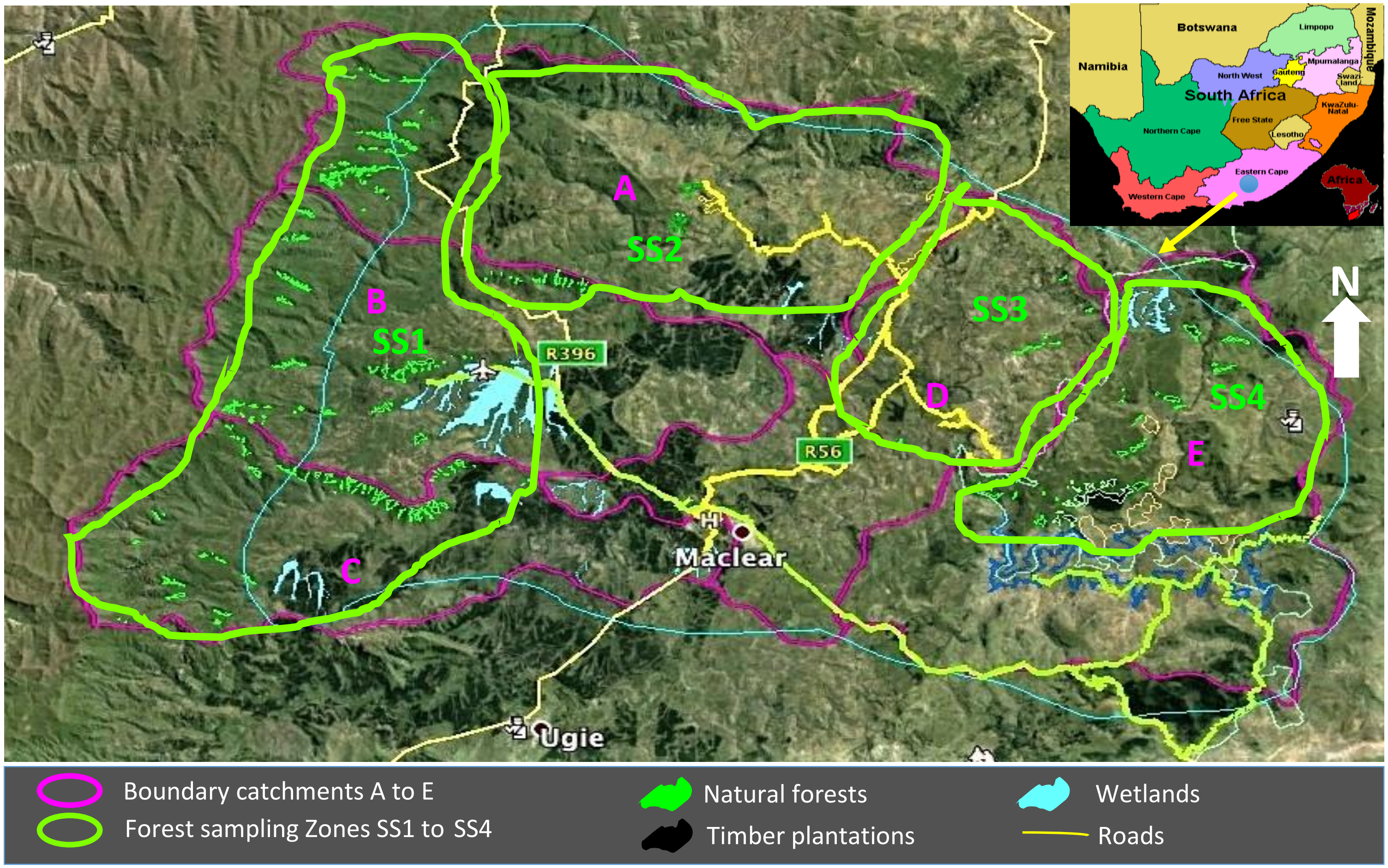

Figure 1. 1: Distribution of natural forests (light green) within the five quaternary catchments of the Ntabelanga Dam area in the upper reaches of the Mzimvubu River catchment, around Maclear in the Eastern Cape (Adapted from Geldenhuys et al. 2016).

The climate of the area is temperate with an average annual rainfall of 786 mm and the wettest month being January with an average monthly rainfall of 130 mm. June and July are the driest months with an average rainfall of 13 mm per month. January is the hottest month with an average maximum temperature of 20.1°C and July is the coldest month with temperatures as low as 0°C (Table 1.1).

Table 1. 1: Average of rainfall and temperature of Maclear town for the period 1982-2012.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall (mm)	130	121	113	46	24	13	13	21	38	64	88	115
Temperature (°C)	20.1	19.9	18.7	15.9	12.8	8.6	8.1	10.9	14.5	16.2	17.8	19.1
Min. Temp. (°C)	13.9	13.9	12.6	9.3	5.6	0.8	0	3.1	7.3	9.5	11.3	12.6
Max. Temp. (°C)	26.3	26	24.8	22.5	20	16.4	16.3	18.8	21.7	23	24.3	25.7

(Source: www.Climate-Data.org)

Geologically, the area has traces of mudflake conglomorates with low level of tectonic deformations. Dolerite Sills and Dykes are found with thermally metamorphosed adjacent sediments. Beaufort sediments are characteristically erodible (Parwada and Van Tol 2016). In addition, there is high evidence of severe gully erosion especially along streams (Van Tol et al. 2016). The bedrock is the main constituent in the study area with some thick colluvial soil deposits covering it. Hard dolerite outcrops and sub-outcrops occur in places. Alluvial sand occurs in the course of the Tsitsa River and major tributary rivers and streams. Due to the steep and incised nature of the rivers, sand is mainly confined to the river channel, with few and only localized over-bank deposits (DWA 2014).

Most of the areas (forests, grassland and wetlands) within the project area were identified by the Eastern Cape Biodiversity Conservation Plan (ECBCP in 2007) and the National Protected Areas Expansion Strategy (NPAES in 2008), as one of the important conservation areas due to the presence of Red Data species, endemic species and potential habitat for these species to exist (Berliner and Desmet 2007).

The natural forests within the area are small, fragmented patches and occur within the fire-prone grassland matrix. They cover altitudinal, topographical and disturbance gradients (e.g. fire, snow and resource use). A total of 495 natural forest patches within the catchment were mapped on Google Earth Pro (Google earth 2015), covering the total of 1570 ha (Geldenhuys et al. 2016). The majority of forest patches were less than 5 ha in area. However, the large forest patches comprise of 6.1% of the number and 46.4% of the total area. Furthermore, the mean forest patch size decreased from 7.02 ha below 1200 m asl to 0.91 ha above 2000 m asl. Fire flow patterns controls forest location pattern and limit forests to fire shadow areas within the landscape of steep slopes and gullies.

The presence of forest patches in mountainous landscape of the area maintains high water quality and yield, which is critical to the rural communities' consumption and reduce soil erosion. Therefore, the management of natural forest biodiversity, use and conservation in the upper reaches of the Tsitsa River, part of the Mzimvubu River System, is essential in the socio-economic development of the proposed Ntabelanga dam in the Mzimvubu Water Project (Geldenhuys et al. 2016).

1.2.2 Problem statement

The natural forests within the Ntabelanga catchment around Maclear provide various forest products, mainly wood for poles and firewood, and non-wood resources such as traditional medicines and fruits for food, as well as a wide range of ecosystem services. However, these products, values and services need to be effectively managed and conserved for sustainable use and value of the forests (Geldenhuys et al. 2016). Cocks et al. (2004) has shown that the rate of use of forest resources in South Africa is increasing and in some instance unsustainable. Moreover, a study in the Eastern Cape indicated that use of forest resources in both forests and woodland are unsustainable (Gugushe et al. 2009).

The aim of the Working for Water program (WFW) operating in the area, is to clear the invasive alien wattle (*Acacia mearnsii*) and other invasive species, within the catchment, with the aim of improving the quality of water and creating job opportunities to the undeveloped impoverished communities (DWA 2014). Nonetheless, wattle is an important source of wood to the rural communities in Ntabelanga catchment area and is widely and abundantly used for fencing, roof construction, cooking and heating, especially during the winter season. Concern have been raised whether or not the clearance of wattle stands within the catchment may increase the pressure on the small natural forest patches within the catchments (Geldenhuys et al. 2016). Evidence has shown that uncontrolled use of forest resources can cause serious impact on the natural forests (Denslow 1995), hence leading to an ecological change in structure and composition (Ticktin, 2004).

However, the natural forests in the Ntabelanga catchment occur as small, fragmented patches along altitudinal, topographical and disturbance gradients within the fire-prone grassland matrix. These forests have not been included in the National Forest Type Classification of Von Maltitz et al. (2003). Their biogeographic relationship with adjacent national forest types is not clear. In addition, the variation in their floristic and structural composition along the different environmental gradients, and their resource potential in relation to the resource use needs of the rural society, is not known. There is a need to understand the status of resource use from these forests in terms of products and species, and the impact of former and current resource use in relation to natural disturbance processes and the population structure and regeneration status of the key species. One question is if the WfW programme clear the extensive stands of wattle and other invasive alien species within the catchment, what would be their impact on the natural forests within the catchment in relation to resource use. The outcome of this study will guide and pave the way for sustainable forest management within the Ntabelanga Catchment.

1.3 Objectives of the study

The main objective of the study is to assess the floristic and structural composition and stand dynamics of natural forests within Ntabelanga catchment around Maclear, Eastern Cape in relation to site and disturbances factors.

1.3.2 Specific objective 1

To assess how the floristic composition of natural forests varies along the main altitudinal, topographical and disturbance gradients within the Ntabelanga catchments as a basis for the development of sustainable forest management strategies. This objective is pursued through answering the following research questions:

1. What is the biogeographic relationship in terms of species composition of Ntabelanga forest communities with the national forest types of South Africa?
2. How does the floristic composition of the natural forests vary along the macro and local altitudinal gradients within the catchment?
3. How do environmental gradients (altitude, aspect, slope and radiation index) affect the floristic and structural composition of the forest communities?

1.3.3 Specific objective 2

To determine the scale of disturbances that influence the composition of the forests and their regeneration status at community and population levels. This objective is pursued through answering the following research questions:

1. What is the relationship between the regeneration and canopy composition of the canopy species within the different forest communities?
2. What are the main disturbances (natural or manmade) and what kind of impact do they cause on the population structure of tree species at community and population level?
3. What is the relation between disturbances (e.g. snow, fire and resource uses) and the regeneration status of targeted tree species and how would it guide the silvicultural management systems for sustainable resource use in different forest communities?

1.4 Study conceptual framework

The conceptual framework highlights the overall and specific objectives of the study needed to address the components of the study (Figure 1.2). It was developed based on composition, biogeography and structure of natural forests in Ntabelanga area in relation to type and scale of disturbances and its relation to the national forest types. This study will pave a way towards sustainable resource use from the forest to better conserve its values.

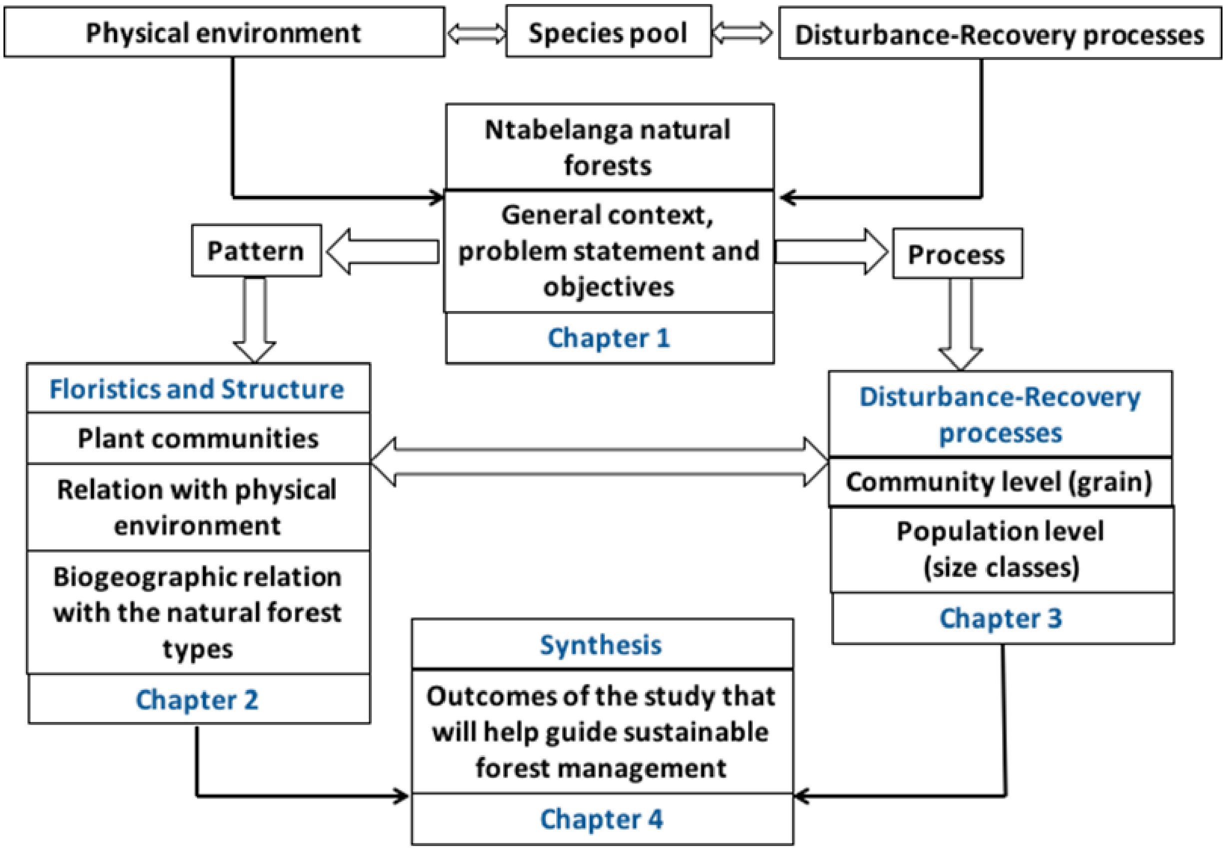

Figure 1.2: Conceptual framework for the study of Ntabelanga natural forests to develop a guide for sustainable use of the products and services provided by the forests.

1.5 General methodology

The sampling of the natural forests was done in individual forests along macro and local altitudinal gradients existing in the study area. The sampled data included the species and size of individual stems and biophysical variables of the sites at each sample plot. Consequently, data analyses were based on multivariate techniques and stem diameter class distribution of individual species across identified forest communities.

1.6 Thesis structure

This Thesis is divided into four (4) chapters (Figure 1.1):

1. Chapter one gives the general context of Ntabelanga forests based on the physical/biogeographic environment and states the problem and objectives of the study. Text in some are repeated in each Chapter to make it stand-alone for easy publication.
2. Chapter two describes the floristic composition of Ntabelanga natural forests and how they relate to national forest types of South Africa.
3. Chapter three describes the stand dynamics of different tree species by investigating the forest grain within different communities and population structure (diameter class distribution pattern) of key ecological and used species across the different communities in relation to disturbance processes.
4. Chapter four provides a synthesis of the results from the two main studies in relation to the stated objectives and key questions as basis of a forest management framework to guide sustainable resource use management of the natural forests within the catchment.

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www.Climate-Data.org.

Chapter 2: Floristic composition of Ntabelanga natural forests

2.1 Introduction

Some little-known natural forests in South Africa in a remote area became the focus of a study because of the needs to clear extensive stands of an invasive alien tree *Acacia mearnsii* (Geldenhuys et al. 2016). The question was raised how the rural society in the area use the *A. mearnsii* for poles and firewood in their households and what would happen to the natural forests in this area if the invasive alien plants (IAPs) will be cleared from the surrounding areas. These forests were not mapped or studied before; their relationship with the South African National Forest Types (Von-Maltitz et al. 2003) was not clear. It was therefore necessary to understand the variation in floristic and structural composition of these natural forests along altitudinal, topographical and disturbance gradients in the Ntabelanga catchment near Maclear in the Eastern Cape Province, how they are being used by the local rural society in the context of use of the IAP stands, and their relationship with the national forest types.

The natural forests within the Ntabelanga catchment occur as small, very fragmented patches within the fire-prone grassland matrix on steep slopes in a highly- dissected landscape. They are also affected by disturbances such as heavy snow falls, fire and use of resources for mainly poles and medicine and browsing by cattle. The extensive areas of invader plants occur mostly in the grassland, with some small patches along the forest margins and occasionally inside the forests. In some stands of *A. mearnsii* within the Ntabelanga catchment, some patches of natural forests are establishing. Atsame-Edda (2014) has highlighted that the invasive plant stands can facilitate the establishment of natural forest species, because such species, such as *Acacia mearnsii,* are light-demanding and cannot regenerate under their own canopies. A study at Buffeljagsrivier in the Western Cape has shown that in areas where *A. mearnsii* was cleared in the conventional method of total clearing, by the Working for Water programme (WfW), it has regenerated into more dense stands (Geldenhuys and Bezuidenhout 2006). Geldenhuys (1997) have reported the establishment of indigenous forest species under the canopy of *Acacia* and *Pinus* stands. In forest hsuccession, light-demanding species (invader plants or indigenous pioneer species) take over to form dense, even-aged and mono-specific stands. These stands will grow until some stems die as a result of competition. This will give opportunity to shade-tolerant natural forest species to established

(Lugo 1997; Parrotta et al. 1997). Geldenhuys and Bezuidenhout (2012) indicated that the cycle gets completed once the canopy is overtaken by indigenous tree species, hence forming climax state of forests. The concept of forest succession suggests that trees often get established in groups then later other species will succeed, hence resulting into bigger forests (Clements 1936).

It is important to understand the variation in plant associations (forest types and communities) in an area, and the reasons for such variation, to develop a framework for sustainable forest management in terms of resource use, invader plant control and conservation (Geldenhuys and Venter 2002). The knowledge of the component species and the variation in their composition in the forest communities is important in understanding the nature and distribution of forests in a landscape (Lotter and Beck 2004). It provides a basis for forest conservation at a regional level based on the characteristics of species in the context of other forest types within the region (Von Maltitz et al 2003). It also provides a basis for the zonation of the forest into management classes (resource use, recreation and nature reserves etc.), primarily depending on the extent and sensitivity of forest types in the area (Seydack 1991). The extent to which forest resources are used differs between species and between forest communities. The characteristics of species and their performance in different communities, particularly in terms of their requirements for regeneration, establishment and growth, are important inputs into resource use planning. They vary in particular in terms of their relative shade and fire tolerance (Geldenhuys and Venter 2002). Relative gap size from natural disturbances and resource use also influence the invasion potential of IAPs in the natural forest environment (Geldenhuys 2013).

Forest ecologists have used different approaches of categorizing forests into associations or communities using number of stems of each species in the sampled plots. The most commonly multivariate techniques used include Non-Metric Multidimensional scaling, Principal Coordinate analysis and TWINSPAN. TWINSPAN (two-way indicator species analysis) is a programme package of Hill (1979) which categorizes sample plots based on their similarity in the stands. The relationship between the species and their association with the environmental gradients, either direct (using environmental gradients) or indirect (using environmental gradients) is determine using CCA. CCA is one of the statistical analysis offered by CANOCO to determine the relationship between species and their environmental variables. Kent and Coker (1992) indicated that having complementary results of two multivariate analyses lead to an accurate interpretation and description of plant communities.

A study in the Southern Cape Forests has shown that the environment and biogeography have influenced the distribution and composition of species (Geldenhuys 1993; Lugo 1997). Other studies have shown that floristic and structural composition of forests vary depending on the site conditions, disturbance history and development stage, hence paving a way for sustainable resource-use management (Geldenhuys 1992). Forest ecosystems undergo different ecological processes of disturbance and recovery. For instance, the equilibrium between early and late successional species (forest grain) depends on the disturbance regimes (Midgley et al. 1990; Geldenhuys 2011). Therefore, identifying the forest communities will help forest managers to understand various factors determining the charateristics of a particular forest for making better decisions in resource use management (Geldenhuys and Venter 2002).

However, the Ntabelanga natural forests have not been studied before and their relationship with the national forest types is not clear. A framework for the forest management plan that relates to this study needs to provide for different stakeholders, sustainable resource use and conversion of invader plant stands (Black wattle) to rehabilitate the natural forests where relevant. Such a plan needs to be simple and practical, for use by the local resource users. The plan should address resource use from natural forests with specific guidelines for harvested species and products, provide that they will not degrade the harvested species. Moreover, it needs to address resource use from the invasive alien plant stands in a way that could facilitate the conversion of invasive alien tree stands to natural forest, in the forest environment.

The objective of this study was to assess the variation in the floristic composition of natural forests along the main altitudinal, topographical and disturbance gradients within the Ntabelanga catchments as a basis for the development of sustainable forest management strategies. This objective is pursued through answering the following research questions:

1. What is the relationship in terms of species composition of the Ntabelanga forest communities with the national forest types of South Africa?

2. How does the floristic composition of the forests vary along the macro and local altitudinal gradients within the catchment?
3. How do altitude, aspect and slope affect the floristic and structural composition of the forest communities?

2.2 Study area

The Ntabelanga Catchment lies between the towns of Maclear, Tsolo and Mount Fletcher in the Eastern Cape Province (Figure 2.1) within the District Municipalities of Joe Gqabi, OR Tambo and Alfred Nzo. The local Municipalities include Mhlontlo, Nyandeni, Umzimbuvu and Elundini. Maclear, the nearest town, lies at 1, 280 m above mean sea level.

The climate of the area is temperate with an average annual rainfall of 786 mm and the wettest month being January with an average monthly rainfall of 130 mm. June and July are the driest months with an average rainfall of 13 mm per month. January is the hottest month with an average maximum temperature of 20.1°C and July is the coldest month with temperatures as low as 0°C (Table 2.1).

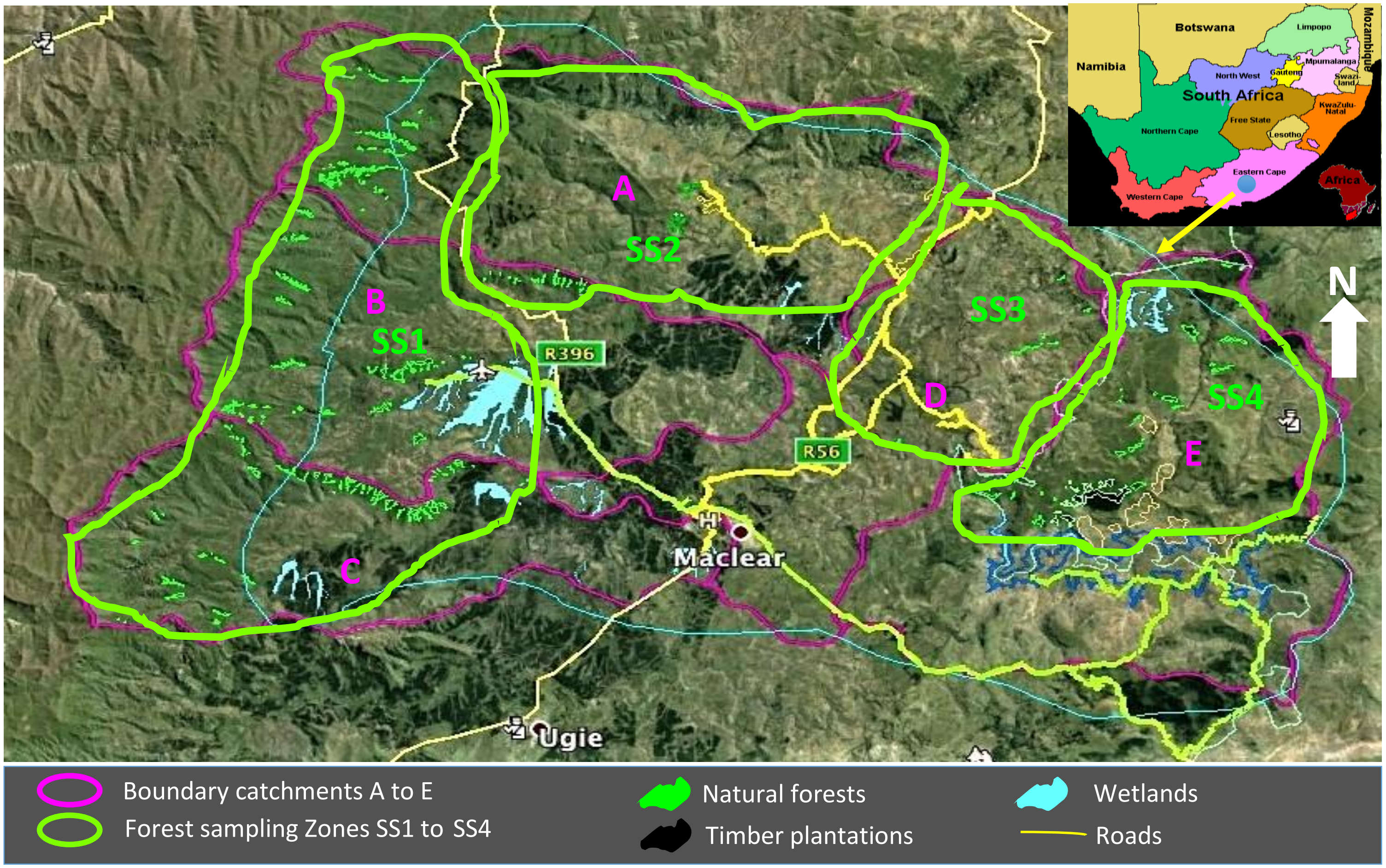

Figure 2. 1: Distribution of natural forests within the catchment of Ntabelanga Dam in the upper reaches of Mzimbuvu River catchment around Maclear, in Eastern Cape Distribution of natural forests within the catchment of Ntabelanga Dam in the upper reaches of the Mzimvubu River catchment, around Maclear in the Eastern Cape (Adapted from Geldenhuys et al. 2016).

Table 2.1: Average of rainfall and temperature of Maclear town for the period 1982-2012.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall (mm)	130	121	113	46	24	13	13	21	38	64	88	115
Temperature (°C)	20.1	19.9	18.7	15.9	12.8	8.6	8.1	10.9	14.5	16.2	17.8	19.1
Min. Temp. (°C)	13.9	13.9	12.6	9.3	5.6	0.8	0	3.1	7.3	9.5	11.3	12.6
Max. Temp. (°C)	26.3	26.0	24.8	22.5	20.0	16.4	16.3	18.8	21.7	23.0	24.3	25.7

(Source: www.Climate-Data.org)

In the Mzimvubu and Tsitsa River catchments, soil erosion is high due to the steep nature of the landscape. Geologically, the area has traces of mudflake conglomorates with low level of tectonic deformations. Dolerite Sills and Dykes are found with adjacent thermally metamorphosed sediments. Beaufort sediments are characteristically erodible (Parwada and Van Tol 2016). Moreover, there is high evidence of severe gully erosion especially along streams (Van Tol et al. 2016). Due to the steep and incised nature of the rivers, sand is mainly confined to the river channel, with few and only localized over-bank deposits (DWA 2014).

The vegetation of the area forms part of the sub-escarpment grassland and sub-escarpment savanna bioregions and is dominated by moist grassland and *Acacia* species (Mucina and Rutherford 2006). Furthermore, this vegetation lies between altitude 880 to 1860 m asl. The Eastern Cape Biodiversity Conservation Plan (ECBCP in 2007) and the National Protected Areas Expansion Strategy (NPAES in 2008) identified most of the areas (forests, grassland and wetlands) within the project area, as one of the important conservation areas due to the presence of Red Data species, endemic species and potential habitat for these species to exist (Berliner and Desmet 2007).

The natural forests within the area are small, fragmented patches and occur within the fire-prone grassland matrix. They cover altitudinal, topographical and disturbance gradients (e.g. fire, snow and resource use). A total of 495 natural forest patches within the catchment were mapped on Google Earth Pro (Google Earth 2015), covering a total area of 1570 ha (Table 2.2; Geldenhuys et al. 2016). The majority of forest patches were less than 5 ha in area (47.3% of <1 ha and 37.6% of 1.0-4.9 ha in size). However, the larger forests (10 to 147 ha) represent 6.1% of the number of forest patches combined (Table 2.2). Furthermore, the mean forest patch size decreased from 7.02 ha below 1200 m a.s.l to 0.91 ha above 2000 m a.s.l. Fire flow patterns controls forest location pattern and limit forests to fire shadow areas within the landscape of steep slopes and gullies (Figure 2.2).

Table 2.2: Number and total area of mapped natural forest patches by patch size and altitude in each of the Ntabelanga catchments.

1. Patch size

Catchment	Forest size categories, ha				
	<1.0	1.0-4.9	5.0-9.9	10+	Total
Number of natural forest patches					
A	88	87	12	6	191
B	61	37	7	4	109
C	42	30	9	5	86
D	1	1	-	-	2
E	42	31	17	17	107
Total	234	186	45	30	495
Total area (ha) of all forest patches					
A	33.87	185.82	86.04	79.00	384.73
B	27.99	89.09	50.06	63.40	230.54
C	21.10	66.84	60.95	74.50	223.39
D	0.59	1.10	-	-	1.69
E	21.00	80.28	116.42	511.90	729.60
Total	104.55	423.13	313.47	728.80	1569.95

(b) Altitude

Catchment	Altitude categories, m above mean sea level (lower limit)						
	<1200	1200	1400	1600	1800	2000	Total
Number of natural forest patches							
A	-	-	33	65	76	17	191
B	-	1	33	31	31	13	109
C	-	2	26	47	8	3	86
D	-	-	2	-	-	-	2
E	33	53	19	2	-	-	107
Total	33	56	113	145	115	33	495
Total area (ha) of all forest patches							
A	-	-	59.85	193.76	112.51	18.61	384.73
B	-	0.27	61.78	105.65	52.53	10.31	230.54
C	-	2.14	39.40	176.08	4.63	1.14	223.39
D	-	-	1.69	-	-	-	1.69
E	231.68	374.13	114.19	9.60	-	-	729.60
Total, ha	231.68	376.54	276.91	485.09	169.67	30.06	1569.95
Mean, ha	7.02	6.72	2.45	3.35	1.48	0.91	3.17

Source: Geldenhuys et al. (2016)

The presence of forest patches in the mountainous landscape of the area maintains high water quality and yield, which is critical to the rural communities' consumption and reduce soil erosion. Therefore, the management of natural forest biodiversity, use and conservation in the upper reaches of the Tsitsa River, part of the Mzimvubu River System, is essential in the socio-economic development of the proposed Ntabelanga dam in the Mzimvubu Water Project (Geldenhuys et al. 2016).

Figure 2.2 Discreet forest patches in true fire shadow locations in the vicinity of SP 4-19. Note the location of younger wattle stands, possibly spreading, along the streams (in the fire zone) and on the ridge (top right of photo)

2.3 Study methodology

2.3.1 Sampling design

The mapped forest patches were used to develop a stratified random sampling design, to represent the main environmental gradients, i.e. the main macro east-west altitudinal gradient and the local topographical gradient from the foot slope to upper slope within a particular selected forest complex. Four sampling zones were marked (Figure 2.3): Zone 1 was the higher-lying areas west of road R396 (to Rhodes) in Catchments A to C; Zone 2 was the area between road R396 and road R56 between Maclear and Mount Fletcher, and mainly catchment A. Zone 3 was primarily all of Catchment D. Zone 4 was all of Catchment E. Twenty-one points in total were selected at random from the numbered points, and proportional to the number of points marked in each zone. The forest patches occurring around a selected sample point were studied on Google Earth and in the field (Figure 2.3) to select (a) forests that were accessible for sampling, (b) zones in the selected forests that would cover an altitudinal gradient, and (c) stand conditions that would represent the variation in forest condition in the selected sampling point. Parts that were too steep were excluded from sampling.

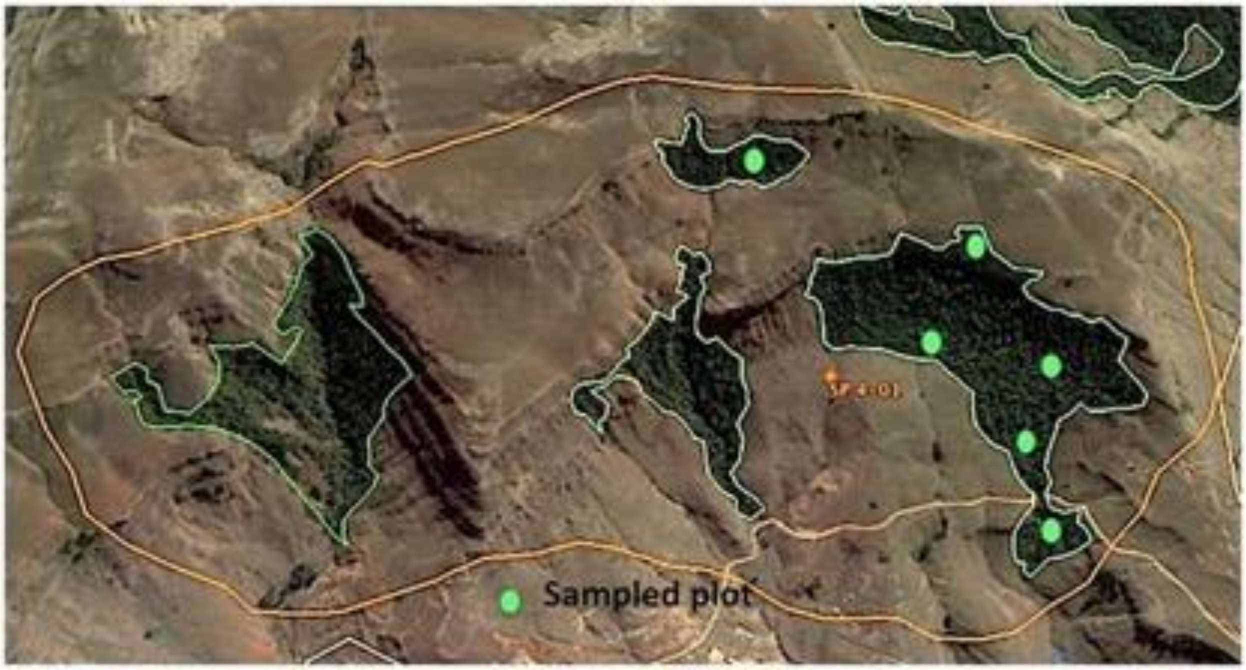

Figure 2.3: Distribution of plots sampled for floristic and structural composition of parts of the forest complex to capture mainly altitudinal variation. Note that the sampled forest had easier access to good forest over a wider area and provided a good altitudinal range.

The number of plots sampled varied between sample points, depending on the size of the area, the number of forest patches included and variation in composition and structure of the forest patches in an area. The sampling protocol followed the standard procedures used for sampling natural forests in South Africa to enable the data to be used during the improvement of the national forest type classification. Each plot was located in a relatively uniform part of the forest in a specific zone selected for sampling. At each site, the midpoint of a plot was randomly determined. Nested circular plots were used, consisting of a main plot of 11.28 m radius (0.04 ha or 400 m^2) and sub-plot of 5.65 m radius (0.01 ha or 100 m^2) around the same mid-point.

2.3.2 Data collection

A total of 56 plots were sampled. Inside the main 0.04 ha plot, all trees ≥5 cm diameter were measured at 1.3 m above ground level (breast height or DBH) and recorded by DBH and species. In the 0.01 sub-plot the cover-abundance (Braun-Blanquet scale) of all the main species <5 cm DBH (woody and non-woody species) were recorded. Multi-stemmed or forked trees below 1.3 m height were recorded separately but given the same number to indicate that they belong to the same tree. General information recorded on a plot included: geographic coordinates using a Geographical Positioning System (GPS) for plot location, aspect, slope (level, gentle to steep), canopy conditions (smooth/ rough), presence of gaps (small/large), geomorphology (foot-slope, mid-slope, and upper slope), and substrate (deep soil, shallow soil, rocky, gully, rocky).

A field guide from the local community has assisted the field team with the identification of tree species. Plant names were recorded by local Xhosa names, or by botanical name when known.

Plant material was collected for identification of unknown or uncertain plant names. However, leaves of some of the species were not accessible and, resulted in inadequate collection of samples. One species appeared to be Unkown i.e. could not be identified. This may affect the result if species occurs in many plots. In addition, specific notes were taken on harvested plants and their response after being harvested. Botanical names are based on Van Wyk et al. (2011).

Species lists were compiled from the species listed from Von Maltitz et al. (2003) and Lawes et al. (2007), for the three nearby National Forest Types, i.e. Eastern Mistbelt Forests, Transkei Mistbelt Forests and Drakensberg Montane Forests. The species recorded in the Ntabelanga forests were listed separately for the higher altitude and lower altitude forests (based on the TWINSPAN classification in this study), to compare with the species from the adjacent natural forest types. Only woody species that were positively identified in the Ntabelanga study were used, including species that were recorded outside the sampled plots.

2.3.3 Data analysis

The biogeographic relationships between the Ntabelanga forests and the three nearby National Forest Types were compared based on the percentage species of the Ntabelanga natural forests (i.e. low and high altitude forests) that were shared with species listed for the three National Forest Types, based on Von Maltitz et al. (2003) and Lawes et al. (2007).

The variation in floristic composition between the sampled forest stands was analyzed with the classification program TWINSPAN (Hill and Šmilauer 2005). The classification was based on the number of stems ≥5 cm DBH of a species in a plot. Five pseudo-species cut levels were used: 0, 2, 5, 10, and 20. The cut levels define the value that must be exceeded for a pseudo-species to occur. For instance, for pseudo-species 1, a species must have 1 to 2 stems, for pseudo-species 2, the species must have 3 to 5 stems, and for pseudo-species 5 the species must have more than 20 stems in a plot. The data set contained 56 plots and the analysis was constrained to give a minimum group size of five plots and a maximum of seven indicator species per division.

The classification was complemented with an indirect gradient analysis, i.e. Detrended Correspondence Analysis (DCA), Direct gradient analysis was also done using Canonical Correspondence Analysis (CCA) using vegan package software build under R version (R 3.2.4) to determine the relationship between the identified forest communities, species and environmental variables (Hill and Gauch, 1980; Oksanen and Minchin, 1997; Shaw, 2003; Sheikh, 2010). The following environmental variables were included in the CCA: Altitude, slope and Radiation Index (RI). RI was used as environmental variable based on aspect and slope, using tables of Frank and Lee (1966). The mono-specific plots of *Leucosidea sericea* and of *Hippobromus pauciflorus* were excluded from the analyses.

The Importance Value (IV) of a species in each identified community and sub-community was calculated as follows (Curtis and Mclntosh, 1951; DWAF, 2005), for the stems ≥5 cm DBH:

IV = (RF + RD + RBA)/3, where

RF = Relative Frequency, calculated as (100 × number of plots in a community in which the species occurs / total number of plots recorded in that community).

RD = Relative Density, calculated as (100 × number of stems recorded for the species in a community / number of stems recorded for all species in that community)

RBA = Relative Basal Area, calculated as (100 × total basal area of a species in a community / basal area of all species in that community), with basal area calculated as ($\pi \times (\mathrm{DBH})^2/40000$), where $\pi = 3.14$.

2.4 Results

2.4.1 Plant species of the Ntabelanga Natural forests

In total, 63 species of trees and large shrubs were identified from 56 plots (Appendix 2.2). Out of this, only 55 species were positively identified by their botanical names. These species represented 49 genera in 30 families. The following families were present and the number of species per family is shown between brackets: Anacardiaceae (2), Araliaceae (1), Aquifoliaceae (1), Apocynaceae (1), Apiaceae (1), Burseraceae (1), Celastraceae (8), Capparaceae (2), Celtidaceae (1), Ebenaceae (3), Flacourtiaceae (5), Hamamelidaceae (1), Icacinaceae (2), Lauraceae (1), Myrtaceae (2), Monimiaceae (1), Myrsinaceae (2), Oliniaceae (1), Ptaeroxylaceae (1), Podocarpaceae (2), Pittosposraceae (1), Rosaceae (2), Rhamnaceae (2), Rubiaceae (6), Rutaceae (3), Strychnaceae (2), Sapindaceae (2), Solanaceae (1), Scrophulariaceae (1) and Tiliaceae (2).

The most dominant families include: Celastraceae (8), Rubiaceae (6), Flacourtiaceae (5), Ebenaceae (3) and Rutaceae (3).

The sampled species (Appendix 2.2) represented 40% canopy tree species, 36% sub-canopy tree species, 12% shrub species, and 12% other species (scramblers, lianas and ferns). The majority of tree species were evergreen (71%), with 19% deciduous and 10% semi-deciduous.

2.4.2 Biogeographic relationships between Ntabelanga forests and nearby National Forest Types

A total of 49 woody species from the Ntabelanga low-altitude forests, and 28 woody species from the Ntabelanga high-altitude forests, were used to show the biogeographic relationships with the three nearby South African National Forest Types (Appendix 2.3). The actual number of species shared with the other national forest types, as well as the percentage sharing, suggest that the Ntabelanga forests have an intermediate, linking position, between these national forest types, for both the Ntabelanga low- and high-altitude forests (Table 2.8). The lowest sharing is between the Ntabelanga low-altitude and high-latitude forests (36.7%). In both Ntabelanga forest systems (low- and high-altitude forests), the sharing of species was very similar with the Eastern Mistbelt and Drakensberg Montane Forests (respectively, 63.3% and 65.3% for the Ntabelanga low-altitude forests, and 85.3% and 73.5% for Ntabelanga high-altitude forests), and lower with the Transkei Mistbelt Forests (respectively 57.1% and 71.4%). Note that the sharing of the Ntabelanga species between the three nearby national forest types is high (73.5% to 85.3%).

Several of the Ntabelanga woody species were not shared with the three nearby national forest types. Eight of the Ntabelanga low-altitude forest species were confined to those forest communities: *Capparis sepiaria* var. *citrifolia, Capparis tomentosa, Commiphora harveyi, Diospyros lycioides* subsp. *lycioides, Euclea undulata, Morella serrata, Mystroxylon aethiopicum* subsp. *aethiopicum* and *Zanthoxylum capense*. No such species were found for the Ntabelanga high-altitude forests. Other species confined to the Ntabelanga high altitude forests include *Canthium inerme, Canthium kuntzeanum, Cassinopsis ilicifolia, Maytenus acuminata and Maytenus undata.*

Table 2.3: The sharing (actual numbers and percentages) of the Ntabelanga woody species with three nearby National Forest Types.

Forest types	Ntabelanga LAFs*	Ntabelanga HAFs*	Transkei Mistbelt	Eastern Mistbelt	Drakensberg Montane
Ntabelanga LAFs*	49	36.7	57.1	63.3	65.3
Ntabelanga HAFs*	18	28	71.4	75.0	82.1
Transkei Mistbelt	28	19	33	85.3	73.5
Eastern Mistbelt	31	21	28	36	75.7
Drakensberg Montane	32	23	25	28	40

* LAFs - Low-altitude forests; HAFs = High-altitude forests

Note: The shaded diagonal values indicate the number of the listed Ntabelanga woody species that are present in each forest types. The values below the diagonal show the actual number of Ntabelanga species in the forests shown as row headings that are shared with forests listed as column headings. The values above the diagonal show the sharing as percentage.

2.4.3 Classification of tree communities of the Ntabelanga natural forests

The TWINSPAN classification grouped the 56 plots into four forest communities; two mixed-species low altitude forest communities, each with two sub-communities (1.11, 1.12; 1.21, 1.22) and two mixed-species high altitude forest communities, with three sub-communities (2.10 and 2.21, 2.22) (Figure 2.4, Appendix 2.4).

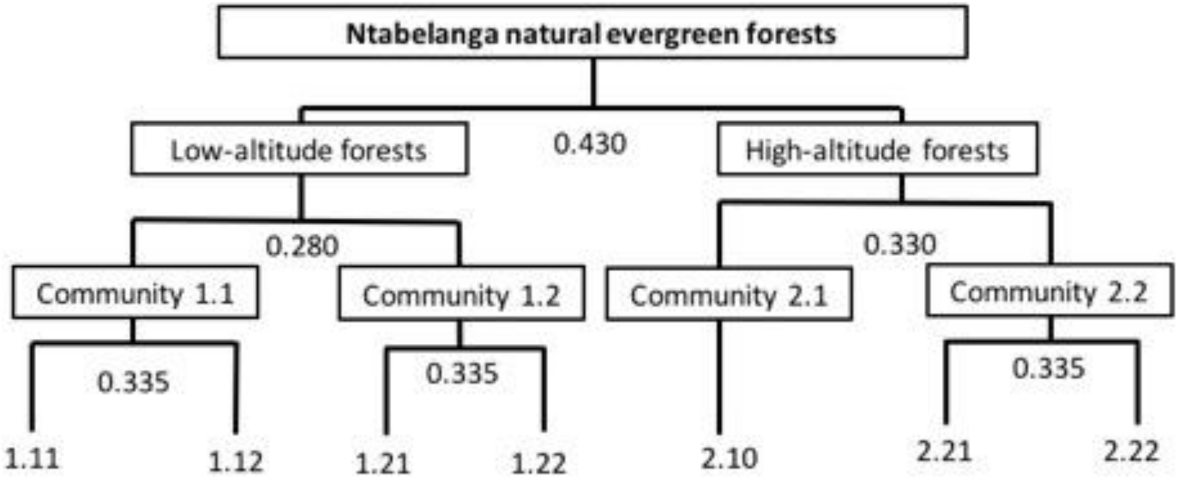

Figure 2.4: Classification of Ntabelanga natural forest communities based on stems >5 cm DBH, using TWINSPAN.

The first level subdivision (eigenvalue 0.430) separated the plots into Low-altitude forest, with indicator species *Celtis africana*, *Allophylus decipiens*, *Searsia dentata* and *Gymnosporia buxifolia* at pseudospecies level 2; and high-altitude forest with indicator species *Olinia emarginata*, *Pleurostylia capensis*, *Euclea undulata and Podocarpus latifolius* at pseudospecies level 5.

The Low-altitude forest (with eigenvalue 0.280) was sub-divided into forest community 1.1 with indicator species *Celtis africana*, and forest community 1.2 with indicator species *Allophylus decipiens*, *Celtis africana*, *Searsia dentata* and *Gymnosporia buxifolia*. High-altitude forest was subdivided (with eigenvalue 0.33) into forest community 2.1 with indicator species *Olinia emarginata*, *Euclea undulata* and *Podocarpus latifolius*, but was not further subdivided, and forest community 2.2 with indicator species *Olinia emarginata*, *Euclea undulata*, *Podocarpus latifolius* and *Canthium ciliatum.*

The third level subdivision separated forest community 1.1 (eigenvalue 0.335) into sub-community 1.11 with indicator species *Scolopia zeyheri* and *Celtis africana*, and sub-community 1.12 with indicator species *Scolopia zeyheri and Afrocarpus (Podocarpus) falcatus.* Forest community 1.2 separated (eigenvalue 0.335) into sub-community 1.21 with indicator species *Scolopia zeyheri* and

Dovyalis zeyheri, and sub-community 1.22 with indicator species *Cussonia spicata complex* and *Commiphora harveyi*. Forest community 2.2 separated (eigenvalue 0.335) into sub-community 2.21 with indicator species *Olinia emarginata and Euclea undulata,* and sub-community 2.22 with indicator species *Olinia emarginata and Pleurostylia capensis*.

Out of 63 species sampled, 26 were positively represented and 37 were negatively represented as displayed on the TWINSPAN output document. Among the negatively represented species, *Celtis africana* has shown high occurrence in sub-community 1.11. However, it gradually declined from low to high altitude. Similarly, *Cussonia spicata* complex has shown high presence at low altitude in sub-community 1.11 and 1.22 but was notably absent at sub-community 2.22 at high altitude. Conversely, some species have common ecological preferences at both low and high altitude. These include *Diospyros whyteana* and *Gymnosporia buxifolia*. The former exists in sub-community 1.12 and 1.22 at low altitude forests. However, the latter has shown similar distribution pattern but with high occurrence at sub-community 1.22.

Eight species with only one occurrence at pseudospecies level 1 were removed from the Twinspan output table for better view. Out of these seven low alitutde species include; *Burchellia bubalina*, *Solanum mauritianum*, *Strychnos species*, *Diospyros lyiciodes,* Ilothane species*, Maytenus penduncularis* and Lusitshane. The high altitude species include *Canthium kuntzeanum*.

2.4.4 Importance values of species across communities

The IVs of the more important species in each community, i.e. IV of at least 4 in at least one of the communities, are shown in Table 2.3. The relative frequency (RF), relative density (RD) and relative basal area (RBA) for all the different species for stems ≥5 cm DBH in each of the identified communities are respectively shown in Appendices 2.5 to 2.7.

Table 2.4: Importance Values (IVs) of trees and large shrubs (>5 cm DBH) in Ntabelanga natural forests, for species with an IV of at least 4 out of 21 in at least one of the communities and sub-communities.

Species	**Low altitude forest communities**				**High altitude forest**		
	1.11	**1.12**	**1.21**	**1.22**	**2.10**	**2.21**	**2.22**
Afrocarpuss falcatus	2.5	13.0	-	4.0	-	-	-
Allophylus decipiens	-	0.9	6.0	6.0	-	-	-
Calodendrum capense	2.5	-	6.3	1.0	-	-	-
Canthium ciliatum	-	-	-	-	2.3	4.0	-
Cassinopsis ilicifolia	-	-	-	2.4	4.0	-	-
Celtis africana	16.1	5.3	4.0	3.0	1.0	-	-
Cryptocarya woodii	-	1.8	-	2.2	2.3	5.0	3.8
Cussonia spicata complex	15	-	-	9.0	2.1	2.0	-
Diospyros whyteana	1.5	14.1	9.3	15.0	9.3	12	17.1
Dovyalis zeyheri	-	-	10.0	2.0	-	-	-
Elaedendron croceum	-	11.4	-	1.0	-	-	-
Euclea undulata	-	-	-	-	4.0	4.0	5.0
Gymnosporia buxifolia	5.1	7.7	19.0	7.2	4.3	3.0	-
Halleria lucida	1.4	-	-	3.0	8.2	1.0	-
Heteromorpha arborescens	-	-	-	0.4	6.4	2.3	2.2
Leucosidea sericea	-	-	-	-	1.0	4.3	2.5
Olinia emarginata	-	-	-	3.0	8.0	21.0	10.0
Pleurostylia capensis	-	-	-	-	-	-	9.0
Podocarpus latifolius	7.3	7.2	-	2.0	16.0	6.5	13.0
Ptaeroxylon obliquum	3.4	-	7.0	-	-	3.0	-
Scolopia mundii	14.3	14.1	6.0	8.0	3.2	1.3	-
Scolopia zeyheri	18.0	6.1	7.0	3.4	6.0	3.0	2.0
Scutia myrtina	2.5	-	7.0	2.0	4.0	3.0	6.2
Searsia dentata	5.6	2.6	6.0	7.3	-	1.0	4.0
Solanum mauritianum+	-	1.0	-	-	-	-	7.4
Trimeria grandifolia	4.3	-	-	2.0	5.3	4.3	-
Vepris lanceolata	-	5.0	2.1	4.1	-	-	-

+ = Introduced species

The most dominant species in terms of importance at low altitude forests are *Scolopia zeyheri* (IV=18), *Celtis africana* (IV=16) and *Cussonia spicata complex* (IV=15). At high altitude forests, the most important species include *Olinia emarginata* (IV=21), *Diospyros whyteana* (IV=17.1) and *Podocarpus latifolius* (IV=16).

Some species were noted to have importance across all the forest communities at both low and high altitudes. These include *Diospyros whyteana*, *Gymnosporia buxifolia*, *Podocarpus latifolius*, *Scolopia mundii*, *Scolopia zeyheri*, *Searsia dentata* and *Scutia myrtina*. However, few species, such as *Cussonia spicata complex, Calodendrum capense and Ptaeroxylon obliquum*, have shown importance at low altitude forests in sub-communities 1.11 and 1.21 respectively. At high altitude forest, *Canthium ciliatum* and *Pleurostylia capensis* were important only in sub-communities 2.21 and 2.22 respectively.

2.4.5 Indirect gradient analysis (DCA)

The DCA ordination (indirect gradient analysis) grouped the high-altitude forest plots on the negative side of axis 1 and the low-altitude forest plots on the positive side of axis 1 (Figure 2.5), strongly supporting the results from the TWINSPAN classification. Axis 1 explains 56.9% of the variation in the species composition of the plots, whereas axis 2 explains 28.7% and axis 3 explains 25.5% of the variation (Table 2.5). Within the low-altitude forests, plots of sub-community 1.22 are all located in the negative part of axis 2 and clearly separated from the other three sub-communities, which show some overlap in their distribution on the positive side but may be separated from each other along axis 3 (not shown here). The plots of the high-altitude forests show a similar separation along axis 2, with most plots of sub-community 2.10 on the negative side and some overlap in the distribution of the plots of the other two sub-communities on the positive side but which may be separated along axis 3.

The table (2.5) below indicates that the species variation within the catchment is high at axis 1 displaying the axis length of 3.8 with high Eigen value of 0.5692. However, axis (2, 3 and 4) have shown similar pattern in species variation. Based on ordination, these values for the three axes are more than 50% which is approximately axis length of 1 Standard Deviation.

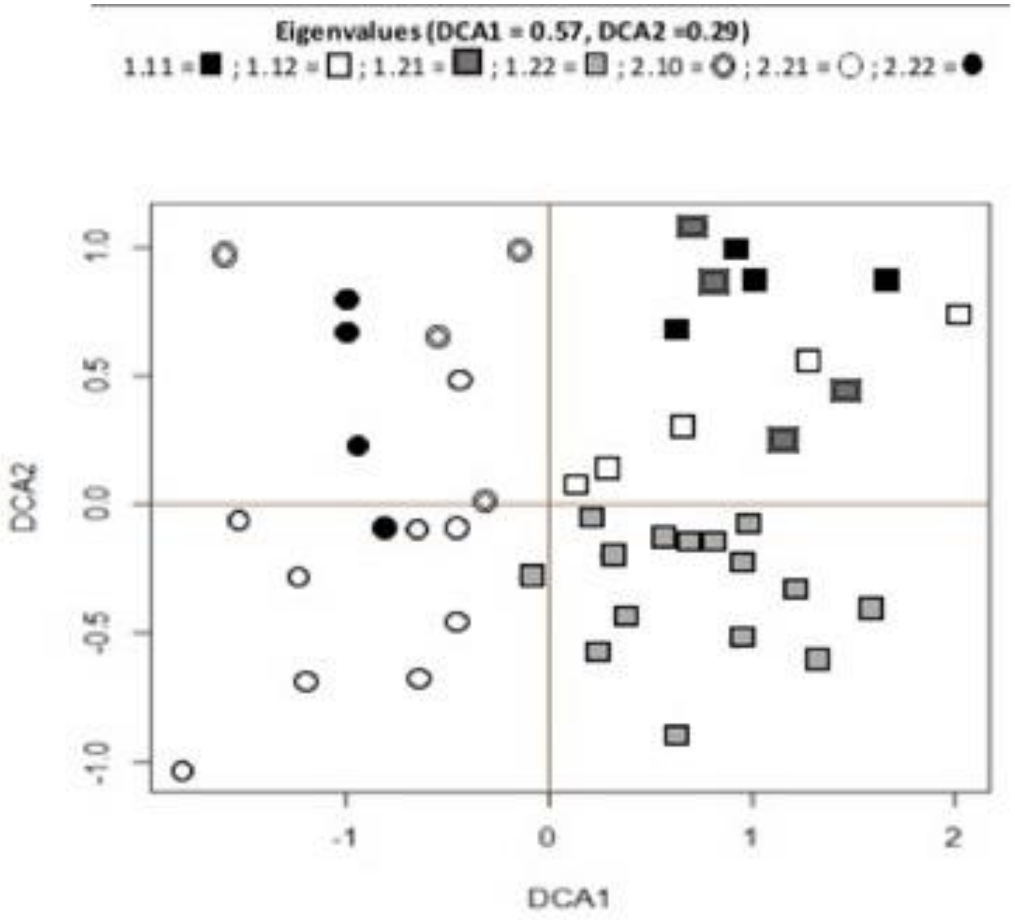

Figure 2.5. The distribution of plots in ordination space, from the Detrended Correspondence Analysis (indirect gradient analysis) with exclusion of the *Leucosidea sericea* and *Hippobromus pauciflorus* stands.

Table 2.5: Heterogeneity of species on plots at Ntabelanga natural forests along the axes

	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.5692	0.2866	0.2551	0.1969
Decorana values	0.5715	0.2555	0.2226	0.1385
Axis lengths	3.8203	2.1121	2.4174	2.3148

2.4.6 Direct gradient analysis (CCA)

The distribution pattern of the plots in ordination space following the CCA analyses (Figure 2.6), using species composition and environmental variables (altitude, radiation index and slope), showed a similar pattern as the DCA (Figure 2.5). However, the plots of the Low-altitude forests are now scattered along the negative side of axis 1, i.e. below the mean value for altitude, whereas the plots of the high-altitude forests occur along the positive side of axis 1 (Figure 2.6). This axis is strongly related to altitude, which explains 98.6% of the variation along axis 1, which explains 60.4% of the variation in the composition of the plots (Table 2.6). Radiation Index explains 95.7% of the variation along axis 2. Slope shows a strong negative relationship with axis 2 (-0.60%), but a strong positive relationship with axis 3 (0.72%).

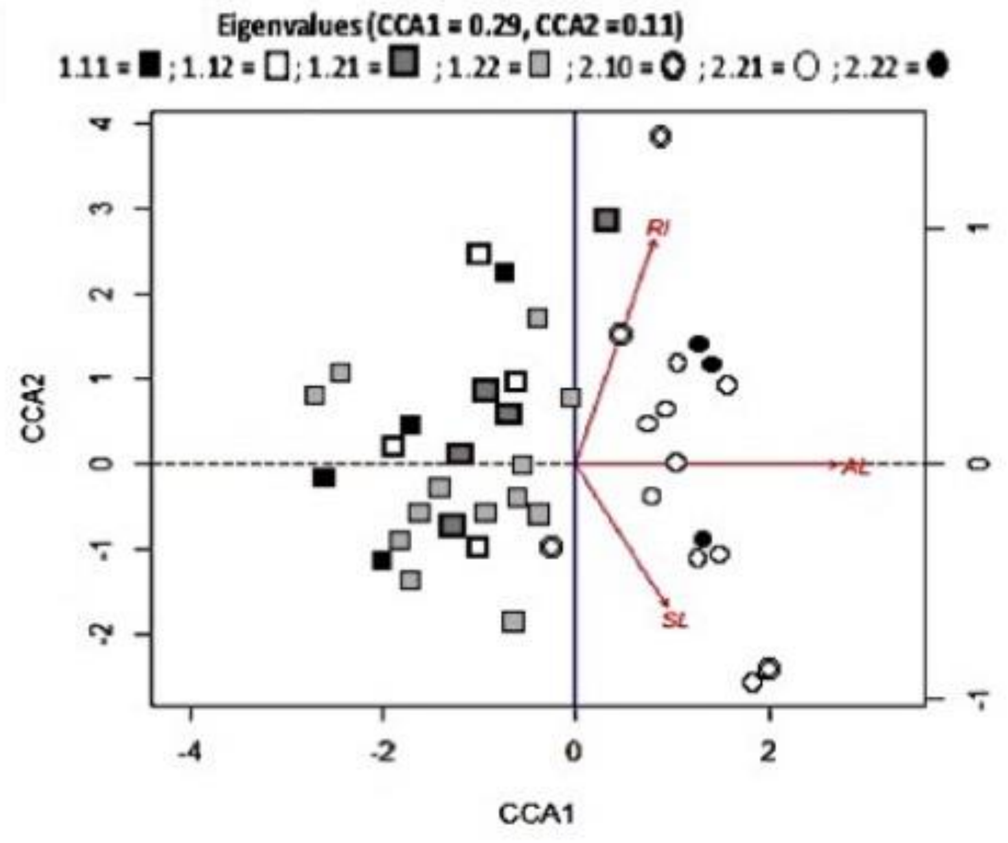

Figure 2.6: An Ordination diagram (direct analysis) showing the relationship between the environmental gradients (SL: Slope, Al: Altitude, RI: Radiation Index) and the plots. The length and the position of the arrow indicate the strength of the relationship.

Table 2.6: The eigenvalues and the relative importance of variables along different axes.

	CCA1	CCA2	CCA3
Eigenvalues	0.2909	0.1098	0.08126
Proportion Explained	0.6036	0.2278	0.16860
Cumulative Proportion	0.6036	0.8314	1.00000
Altitude (AL)	0.9859	-0.000566	-0.172348
Slope (SL)	0.3399	-0.600467	0.720166
Radiation Index (RI)	0.2930	0.957010	0.003752

2.5 Discussion

2.5.1 Plant species of the Ntabelanga Natural forests

This study focused on trees and important shrubs within the Ntabelanga natural forests. The listed species (Appendix 2.2) recorded during the study did not represent all the species within Ntabelanga natural forests, since it was a rapid inventory. Several species were only known by their local Xhosa names, because they could not be positively identified due to the inadequate collection of specimens (out of reach, or material of poor quality). However, none of the species of inadequate identification were among the important species in the classification. The Unkown species was rarely found at low and high-altitude forests, which could have affected the overall result if this species occurs across many plots. Among the 63 species that were recorded and used in the calculation of importance values, only 26 species were considered important across the forest communities.

The dominant families amongst the 30 families represented in the Ntabelanga forests, included Celastraceae, Flacourtiaceae, Rubiaceae, Rutaceae and Ebenaceae. In the Southern Cape forests, Flacourtiaceae, Celastraceae and Ebenaceae were listed among the largest families (Geldenhuys 1992).

2.5.2 Biogeographic relationships between Ntabelanga forests and nearby National Forest Types

The difference in percentage of species shared with the Eastern Mistbelt and Drakensberg Montane Forests (respectively 63.3% and 65.3% for the low-altitude forests, and 85.3% and 73.5% for the high-altitude forests) (Table 2.8), suggest that Ntabelanga natural forest is related to these two nearby national forest types. This sharing is lower with the Transkei Mistbelt forest (57.1% for low-altitude forests and 71.4% for high-altitude forests). It may be useful to combine the Ntabelanga natural forests data with the data of nearby national forest types with similar plot data, to give a clearer insight whether Ntabelanga natural forest is a transition between the Southern Mistbelt forest Group (represented by the Eastern and Transkei Mistbelt Forests) and the Drakensberg Montane Forest.

2.5.3 Forest subdivision into subtypes, communities and sub-communities

The TWINSPAN output showed a clear separation of the vegetation into forest communities and sub-communities. The ordination analyses (indirect and direct) provided additional understanding of the observed patterns (Figure 2.5, Figure 2.6 and Appendix 2.4). The eigenvalues are the measure of the strength or level in the separation of data; for instance, a low eigenvalue means that the value explains only a small part of the difference or variation between the communities and vice-versa (Jongman et al. 1987). The TWINSPAN classification showed a strong division into low and high-altitude forests. This was supported in the CCA analysis, with axis 1 strongly correlated with the altitudinal gradient, with the eigenvalue of 0.3085 accounting for most of the beta diversity across the forest communities. The high-altitude forests are grouped on the negative part of Axis 1 and low-altitude forests at positive side of Axis 2 in figure 2.5 .and vice-versa in figure 2.6. Similarly, on the TWINSPAN output table the low altitude forests were grouped at the left side and the high altitude at the right side of the dendrogram. Species which are shared at both low and high-altitude forest were also clearly sorted. Furthermore, the direct gradient analysis has clearly marked the relationship between the environmental variables and forest communities. Among the environmental variables, altitude was found to have high influence in determining species variation within the catchment.

However, some species (canopy and sub-canopy) have shown high occurrence at the low altitude forests but absent at high altitude. These included the canopy species of *Afocarpus falcatus, Celtis africana*, *Cussonia spicata* complex, *Allophylus decipiens, Commiphora harveyi and Ptaeroxylon obliquum*, and sub-canopy species of *Clausena anisata*, *Grewia lasiocarpa* and *Dovyalis zeyheri.* Other species showed a low occurrence at low altitude but absent at the high altitude, such as the canopy species of *Calodendrum capense*, *Mystroxylon aethiopicum*, *Vepris lanceolata,* and *Pittosporum viridiflorum*, and sub-canopy species of *Capparis tomentosa*, *Elaeodendron croceum*, *Canthium mundianum* and *Carissa bispinosa.* Conversely, some species were common at both low and high altitude forests within the catchment, such as the canopy species of *Scolopia zeyheri*, *Podocarpus latifolius, Olinia emarginata*, *Scolopia mundii*, *Cussonia spicata complex, and Ptaeroxylon obliquum*; and sub-canopy species of *Gymnosporia buxifolia*, *Searsia dentata*, *Diospyros whyteana* and *Halleria lucida.* Similar observations were recorded at New Forest in the KwaZulu-Natal Midlands (higher altitude Eastern Mistbelt Forests) in which *Scolopia mundii* was found to dominate at both low and high-altitude areas (Starke 2014). The Afromontane forests in Mpumalanga share tree species with coastal Scarp Forests as far as Umtamvuna (Geldenhuys 1992). Hence, the common occurrence of species in the Ntabelanga natural forests resulted in the overlap in plot pattern noted in the ordination results. The floristics composition of species varies due to variation in biogeography, habitat and disturbances (Sagar et. al 2003). Similarly, the character of a community differs with aspect, slope and altitude (Srivastava et. al 2005). In the Ntabelanga natural forests, *Commiphora harveyi* and *Clausena anisata* are rarely found. These two species are only found at low altitude forests with low importance values in sub-community 1.22.

The tree species with high importance values included canopy species of *Olinia emarginata* (IV=21, high altitude), *Scolopia zeyheri* (IV=18, high altitude), *Podocarpus latifolius* (IV=16, high altitude) and *Celtis africana* (IV=16.1, low altitude), and sub-canopy species of *Gymnosporia buxifolia* (IV=19, low altitude) and *Diospyros whyteana* (IV=17.1, high altitude).

The *Leucosidea sericea* and *Hippobromus pauciflorus* monospecific stands within the Ntabelanga catchment were excluded from the analyses (both Ordination and TWINSPAN). These are based on ecological preferences of the species in relation to environmental variables. The *Leucosidea* *sericea* stands at higher altitude often occur as dense scrub-forest to scrub, and monsopecific, The *Hippobromus pauciflorus* monospecific stand developed in response to an unknown disturbance event; it had not yet developed into a mixed-species stand.

2.6 Conclusion

The objective of this study had been achieved and all the stated research questions had been answered.

The research has found that there is variation in floristic composition across the Ntabelanga natural forests. However, the study did not cover all the plant species within the catchment, since it was a rapid survey. Nonetheless, some species were only identified by their Xhosa names due to inadequately collected specimens. Moreover, none of them were among the 26 important species.

Altitude strongly influenced species distribution across the catchment. This was clearly shown in the first level of division of the sampled plots into low-altitude and high-altitude forest communities and sub-communities. The *Hippobromus pauciflorus* monospecific stand developed in response to an unknown disturbance event and had not yet formed a mixed species stand. There is need to conduct a detail study to understand this disturbance event, since this was not analyzed in this study.

Celtis africana was the most important canopy species at lower altitude, whereas *Olinia emarginata*, *Scolopia zeyheri* and *Podocarpus latifolius* were prominent at high altitude. *Gymnosporia buxifolia* in low-altitude forests and *Diospyros whyteana* in high-altitude forests were the most common sub-canopy species.

There was a low sharing of species between the Ntabelanga low and high-altitude forests. However, the species pool from both low-altitude and high-altitude Ntabelanga forests showed a high sharing with both the Eastern Mistbelt and Drakensberg Montane forests, suggesting that the Ntabelanga natural forests provide a link between the nearby national forest types.

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Appendix 2.0

Appendix 2.1: Field forms used for the inventory of Ntabelanga natural forests

Form 1: General description of location and environment

Assessed by: .... Date of Assessment: ....

Catchment: .... Forest ……..… Sample point …….. Plot …… Canopy height …. m

Coordinates ……………… ºS ……………… ºE Altitude ………… m

Aspect ….. Slope: Level Gentle Steep

Plot location: Interior / Margin Canopy condition: Smooth / Uneven / Rough

Gaps: None Small Large

Geomorphology: Ridge / Upper-slope / Mid-slope / Foot-slope / Valley / Stream / Gulley Geology: …………….

Substrate: Rocky Boulders / Deep/Shallow soil / Seepage / Wetland / Other ………………

General comments:

Form 2: DBH of stems ≥5 cm DBH by species on 0.04 ha plot (lines were added for field use)

No*	Species	DBH cm	No*	Species	DBH cm

Mark tree with * to indicate when harvested, and record details in part 3

Form 3: Listing of harvested trees (lines were added for field use)

Tree no	Species	DBH	Type Use	Response	Comments

Form 4: Floristic sampling (qualitative – BB cover abundance, 100 m^2 plot)

Species	BB/H	Species	BB/Ht	Species	BB/Ht
Trees (plants ≥5 cm DBH)					
Shrubs & Climbers (main species)					
Vines (main species)					
Ferns (main species)					
Graminoids (main species)					
Other herbs (main species)					

Appendix 2.2: List of species recorded within Ntabelanga natural forests

Family	**Species name**	**Species code**	**Growth form & Function**	**Local name**	**Common name**
		Umbh ong	Tree, subcanopy	Umbhongisa	
Sapindaceae	*Allophylus decipiens (E)*	Allo dec	Tree, subcanopy	Umcandathambo	Small leaf false-currant
Icacinaceae	*Apodytes dimidiata (E)*	Apod dim	Tree, canopy	Umdzakne	White pear
Aspleniaceae	*Asplenium rutifolium*	Aspl rut	Fern		
Rubiaceae	*Burchellia bubalina (L.f.)Sims (E)*	Burc bub	Tree, subcanopy		Wild-pomegranate
Rutaceae	*Calodendrum capenseThunb (E)*	Calo cap	Tree, canopy	Umbhaba	Cape-chestnut
Rubiaceae	*Canthium ciliatum (Klootzsch ex. Ecki. & Zeyh) Kuntze(D)*	Cant cil	Tree, subcanopy	Umdakana	Hairy Turkey-berry
Rubiaceae	*Canthium inerme (L.f.)Kuntze (E)*	Cant ine	Tree, canopy	Isiphingo	Turkey-berry
Rubiaceae	*Canthium mundianum Cham. & Schltdl.(IAP)*	Cant mun	Tree, subcanopy	Umnqayi-mbila	Rock Turkey berry
Rubiaceae	*Canthium kuntzeanum*	Cant kun	Tree, subcanopy	Ubuchopho	Mountain Turkey-berry
Capparaceae	*Capparis sepiaria var citrifolia*	Capp sep	Liana		Long-hair Caper-bush
Capparaceae	*Capparis tomentosa (D)*	Capp tom	Liana	Intshihlo	Wolly Caper bush
Apocynaceae	*Carissa bispinosa (E)*	Cari bis	Shrub	Isbehankunzi	Num-num
Icacinaceae	*Cassinopsis ilicifolia (Hochst) Kuntze (E)*	Cass ili	Tree, subcanopy	Umsangoma	Lemon thorn

Family	**Species name**	**Species code**	**Growth form & Function**	**Local name**	**Common name**
Celastraceae	*Cassina peragua*	Cass per	Tree, canopy	Umbhovane	Forest Spoonwood
Celtidaceae	*Celtis africana Burm.f. (D)*	Celt afr	Tree, canopy	Umvumvu	White-stinkwood
Rutaceae	*Clausena anisata (Wild.)Hook.f.ex. Benth (D)*	Clau ani	Tree, subcanopy	Isifuthu	Horsewood
Commelinaceae	*Commelina africana*	Comm afr	Herb		Poison-grub Corkwood
Burseraceae	*Commiphora harveyi (Engl.) Engl. (D)*	Comm har	Tree, canopy	Umbangandlala	Copper-stem Corkwood
Lauraceae	*Cryptocarya woodii (E)*	Cryp woo	Tree, subcanopy	Isithungwa	River Wild-quince
Araliaceae	*Cussonia spicata complex (E)*	Cuss spi	Tree, canopy	Umsenge	Cabbage tree
Ebenaceae	*Diospyros lyicioides (IAP)*	Dios lyc	Tree, subcanopy		Karoo bluebush
Ebenaceae	*Diospyros whyteana (Hiern) F.White (E)*	Dios why	Tree, subcanopy	Umkhanzi	Bladder-nut
Flacourtiaceae	*Dovyalis zeyheri (E)*	Dovy zey	Tree, subcanopy	Umqokolo	Apricot Kei-apple
Celastraceae	*Elaedendron croceum (E)*	Elae cro	Tree, subcanopy	Ingqotha, Inqotha	Bushveld Saffron
Ebenaceae	*Euclea undulata (E)*	Eucl und	Tree, subcanopy		
Myrtaceae	*Eugenia zuluensis (E. simii/capensis)*	Euge zul	Tree, subcanopy	Umpofana	Dune Myrtle
Moraceae	*Ficus craterostoma Warb. Ex Mildbr. & Burret (E)*	Ficu cra	Tree, canopy	Uluzi	Blunt-leaf Fig

Family	**Species name**	**Species code**	**Growth form & Function**	**Local name**	**Common name**
Tiliaceae	*Grewia lasiocarpa E.Mey.ex Har(E)*	Grew las	Scrambler	Uhlolo, Ihlolo	Forest Raisin
Tiliaceae	*Grewia occidentalis L.(IAP)*	Grew occ	Scrambler	Uhlolo-oluncinci	Cross-berry Raisin
Celastraceae	*Gymnosporia buxifolia (L.) Szyszyl (E)*	Gymn bux	Tree, subcanopy	Umqaqoba, Umnqaqoba	Common spike-thorn
Scrophulariaceae	*Halleria lucida L. (E)*	Hall luc	Tree, subcanopy	Umbinza, Ubinza	Tree-fuchsia
Apiaceae	*Heteromorpha arborescens Cham. & Schldl (D)*	Hete arb	Tree, canopy	Umbangandlatho	Parsley-tree
Sapindaceae	*Hippobromus pauciflorus (L.f.) Radlk. (SD)*	Hipp pau	Tree, subcanopy	Lutwile	False Horsewood
		Ibiz spp	Tree, subcanopy	Ibiza	
		Ilat spp	Tree, subcanopy	Ilatile	
Aquifoliaceae	*Ilex mitis (L) Radlk.var.mitis (E)*	Ilex mit	Tree, canopy	Umdoduma	Cape Holly
		Ilot han	Tree, sub-conopy	Ilothane	
		Isik uza	Tree, sub-canopy	Isikuza	
Rosaceae	*Leucosidea sericea Eckl. & Zeyh (E)*	Leuc ser	Tree, canopy	Umtyityi	Ouhout
		Lusi tsh	Tree, sub-canopy	Lusitshane	
Celastraceae	*Maytenus accuminata (E)*	Mayt acu	Tree, subcanopy	Umzungulwa	Silky-bark
Celastraceae	*Maytenus peduncularis (E)*	Mayt ped	Tree, canopy	not in plots	Cape-blackwood

Family	**Species name**	**Species code**	**Growth form & Function**	**Local name**	**Common name**
Celastraceae	*Maytenus undata (Thunb.) Blakelock (E)*	Mayt und	Tree, canopy	Umbatancwephe/Sibi yabandla	Koko-tree
		Mnqa yim		Mnqayimpafu	
Myricaceae	*Morella serrata (lam.) Killick (D)*	More ser	Tree, subcanopy		Lance-leaf Waxberry
Celastraceae	*Mystroxylon aethiopicum subsp.burkeanum (Sond.)R.H.Archer (E)*	Myst aet	Tree, canopy	Umnqayi	Kooboo-berry
Buddlejaceae	*Nuxia floribunda Benth (SD)*	Nuxi flo	Tree, canopy		Forest Nuxia
Oliniaceae	*Olinia emarginata Brutt Davy (E)*	Olin ema	Tree, canopy	Iqudu	Mountain Hard-pear
Pittosposraceae	*Pittosporum viridiflorum Sims (E)*	Pitt vir	Tree, canopy	Umkhwenkwe	Cheesewood
Celastraceae	*Pleurostylia capensis (Turcz.)*	Pleu cap	Tree, canopy	Umbovane	Coffee-pear
Podocarpaceae	*Afrocarpus falcatus(Thunb) C.N. Page (E)*	Podo fal	Tree, canopy	Umsontsi	Small-leaf or common yellow wood
Podocarpaceae	*Podocarpus latifolius (Thunb) R.Brex Mirb (E)*	Podo lat	Tree, canopy	Umcheya, Omcheya	Broad-leaf Yellowwood
Rosaceae	*Prunus africana (Hook.f.)Kalkman(E)*	Prun afr	Tree, canopy	not in plots	African Almond
Ptaeroxylaceae	*Ptaeroxylon obliquum (Thunb) Radlk (SD)*	Ptae obl	Tree, canopy	Umthathi	Sneezewood

Family	**Species name**	**Species code**	**Growth form & Function**	**Local name**	**Common name**
Myrsinaceae	*Rapanea melanophloeos (E)*	Rapa mel	Tree, canopy	Isiqalati	Cape-beech
Rhamnaceae	*Rhamus prinoides (E)*	Rham pri	Tree, subcanopy	Umamfobe	Glossy-leaf
Anacardiaceae	*Searsias chirindensis (SD)*	Rhus chi	Tree, canopy	Incakotshi	Red Currant
Flacourtiaceae	*Scolopia mundii (Eckl. & Zeyh) Warb (E)*	Scol mun	Tree, canopy	Umnqanqa	Red Thorn-pear
Flacourtiaceae	*Scolopia zeyheri (Nees) Harv (D)*	Scol zey	Tree, canopy	Iqumza	Thorn-pear
Rhamnaceae	*Scutia myrtina (Burm.f.) Kurz (E)*	Scut myr	Scrambler	Iqhakula, Iqhkula	Cat-thorn
Anacardiaceae	*Searsia dentata (D)*	Sear den	Tree, subcanopy	Intolokotshane, Intlokotshane, Umchotshane	False Nana-berry
Solanaceae	*Solanum mauritianum+*	Sola mau	Tree, subcanopy	Umbangabanga	Bugweed
Strychnaceae	*Strychnos madagascariensis Pior*	Stry mad	Tree, canopy	Umhlala (S)	Black monkey-Orange
Strychnaceae	*Strychnos spp*	Stry spp	Tree, canopy		
Hamamelidaceae	*Trichocladus ellipticus (E)*	Tric ell	Tree, subcanopy	Umgqonci	White Underbush
Flacourtiaceae	*Trimeria grandifolia (D)*	Trim gra	Tree, subcanopy	Isithebe	Wild-mulberry
Flacourtiaceae	*Trimeria trinervis Harv. (D)*	Trim tri	Tree, subcanopy	Ikomanci	Small-leaf Wild-mulberry
		Umqw rha	Tree, canopy	Umqwirha	

Family	**Species name**	**Species code**	**Growth form & Function**	**Local name**	**Common name**
		Unkn own	Tree. canopy	Unknown	
Rutaceae	*Vepris lanceolata (Lam.) G.Don (E)*	Vepr lan	Tree, canopy	Umzane	White-ironwood
Monimiaceae	*Xymalos monospora (Harv.)Baill (E)*	Xyma mon	Tree, canopy	Uvethe	Lemonwood
Rutaceae	*Zanthoxylum capense (Thunb.) Harv. (E)*	Zant cap	Tree, subcanopy	Umlungu mabela	Small knobwood

Evergreen = E, Deciduous = D, Semi-deciduous = SD, Introduced = +

Appendix 2.3: The species recorded in the low and high altitude Ntabelanga forests and their presence in the nearby National Forest Types

Species	National forest Types			Ntabelanga forests	
Only species that were positively identified are included, and also species that were found outside the sampled plots	Eastern Mistbelt	Transkei Mistbelt	Drakensberg Forests	Low altitude forests	High altitude forests
Afrocarpus falcatus	1	1	1	1	
Allophylus decipiens		1		1	
Apodytes dimidiata	1	1	1	1	
Burchellia bubalina		1	1	1	
Calodendrum capense	1	1	1	1	
Canthium ciliatum	1	1	1		1
Canthium inerme	1	1			1
Canthium mundianum	1		1	1	
Canthium kuntzeanum					1
Capparis sepiaria var. citrifolia				1	
Capparis tomentosa				1	
Carissa bispinosa subsp. zambesiaca	1		1	1	
Cassine peragua			1	1	
Cassinopsis ilicifolia	1	1	1		1
Celtis africana	1	1	1	1	1
Clausena anisata	1	1	1	1	
Commiphora harveyi				1	
Cryptocarya woodii	1	1	1	1	1
Cussonia spicata complex	1	1	1	1	1
Diospyros lyicioides				1	
Diospyros whyteana	1	1	1	1	1
Dovyalis zeyheri			1	1	
Elaeodendron croceum	1	1		1	

Species	National forest Types			Ntabelanga forests	
Only species that were positively identified are included, and also species that were found outside the sampled plots	Eastern Mistbelt	Transkei Mistbelt	Drakensberg Forests	Low altitude forests	High altitude forests
Euclea undulata				1	
Eugenia zuluensis (E. capensis/simii?)	1		1	1	1
Ficus craterostoma	1		1	1	
Grewia lasiocarpa	1			1	
Grewia occidentalis			1		1
Gymnosporia buxifolia	1	1	1	1	1
Halleria lucida	1	1	1	1	1
Heteromorpha arborescens	1		1	1	1
Hippobromus pauciflorus			1	1	
Ilex mitis		1	1	1	1
Leucosidea sericea			1		1
Maytenus acuminata			1		1
Maytenus peduncularis	1	1	1	1	
Maytenus undata			1		1
Morella serrata				1	
Mystroxylon aethiopicum				1	
Nuxia floribunda	1	1		1	
Olinia emarginata		1	1	1	1
Pittosporum viridiflorum	1	1	1	1	1
Pleurostylia capensis		1		1	
Podocarpus latifolius	1	1	1	1	1
Prunus africana	1	1		1	
Ptaeroxylon obliquum	1	1		1	1
Rapanea melanophloeos	1	1	1		1
Rhamnus prinoides			1	1	
Scolopia mundii	1	1	1	1	1

Species	National forest Types			Ntabelanga forests	
Only species that were positively identified are included, and also species that were found outside the sampled plots	Eastern Mistbelt	Transkei Mistbelt	Drakensberg Forests	Low altitude forests	High altitude forests
Scolopia zeyheri	1	1	1	1	1
Scutia myrtina	1			1	1
Searsia chirindensis	1	1	1	1	
Searsia dentata			1	1	
Trichocladus ellipticus	1	1		1	1
Trimeria grandifolia	1		1	1	1
Trimeria trinervis	1	1	1		1
Vepris lanceolata	1	1	1	1	
Xymalos monospora	1	1	1	1	
Zanthoxylum capense				1	
Total species present	37	34	40	49	28

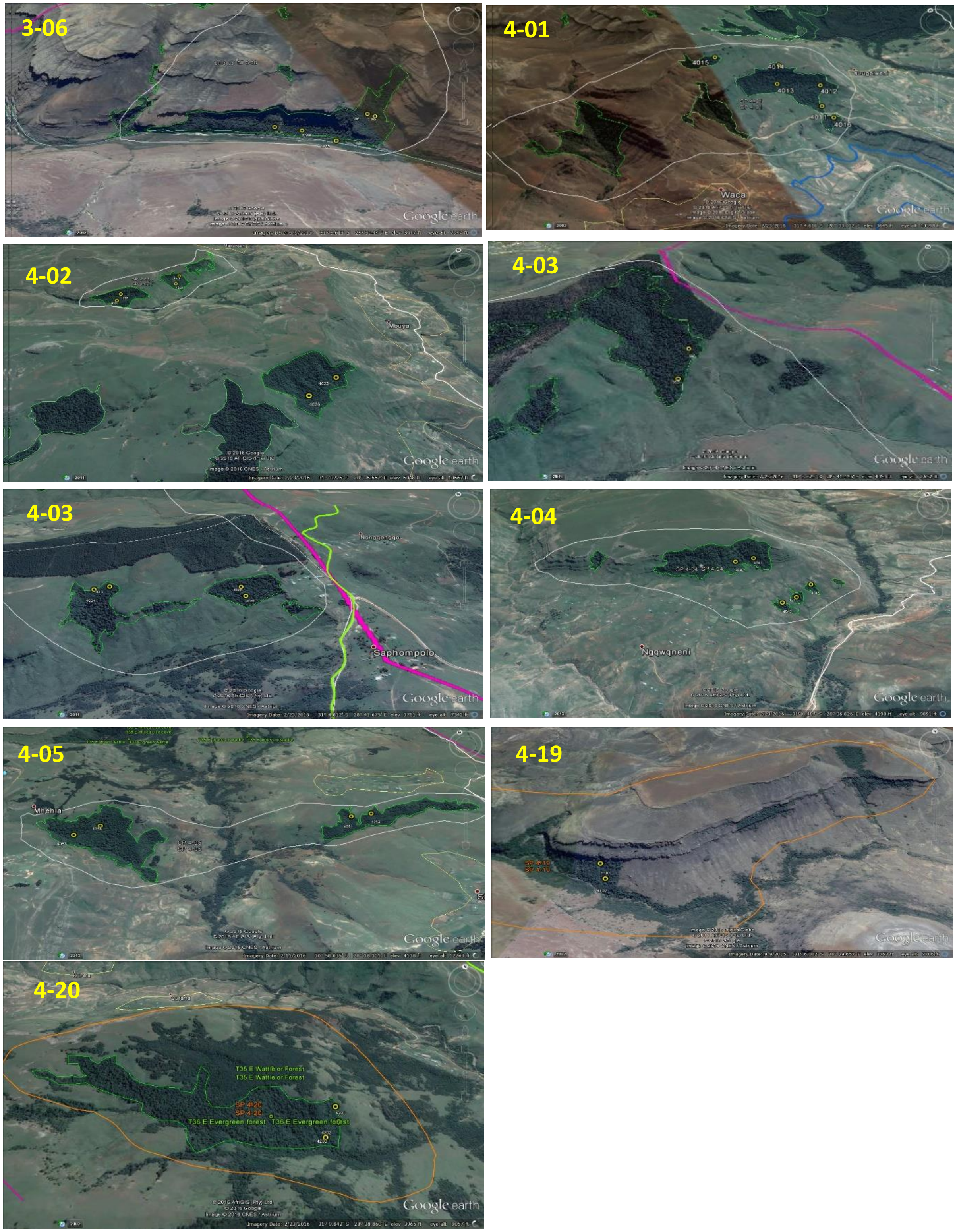
Appendix 2.4: General plot information for Ntabelanga natural forests

Date	**Plot code**	**Latitude S**	**Latitude S**	**Longitude E**	**Longitude E**	**Altitude (m)**	**Aspect**	**Slope**
		Degrees	**Minutes**	**Degrees**	**Minutes**			
05.10.2015	H1	31	4.703	28	33.505	1083	WSW	Gentle
06.10.2015	H2	31	4.593	28	33.568	1144	SSW	Gentle
06.10.2015	H3	31	4.515	28	33.364	1141	SSW	Gentle
07.10.2015	H4	31	4.422	28	33.426	1276	SW	Gentle
07.10.2015	H5	31	4.296	28	33.121	1321	SW	Gentle
08.10.2015	H6	31	4.775	28	33.524	1023	SSW	Steep
09.10.2015	H7	31	4.805	28	41.688	1144	SSW	Steep
09.10.2015	H8	31	4.774	28	41.689	1160	SSW	Steep
12.10.2015	J1	31	3.550	28	41.341	1223	NW	Gentle
12.10.2015	J2	31	3.654	28	41.211	1161	NW	Gentle
13.10.2015	J3	31	4.692	28	41.360	1219	SSW	Steep
13.10.2015	J4	31	4.688	28	41.320	1210	SSW	Steep
15.10.2015	K1	31	0.312	28	37.079	1361	S	Gentle
15.10.2015	K2	31	0.303	28	36.992	1336	S	Gentle
16.10.2015	K3	31	0.571	28	37.071	1214	SE	Steep
16.10.2015	K4	31	0.554	28	37.152	1220	SE	Steep
16.10.2015	K5	31	0.506	28	37.259	1236	E	Steep
17.10.2015	I1	31	2.238	28	35.155	1290	SSW	Steep
17.10.2015	I2	31	2.191	28	35.192	1322	SW	Steep
17.10.2015	I3	31	2.092	28	35.579	1265	SSE	Gentle
19.10.2015	I4	31	2.019	28	35.629	1335	SSW	Gentle
20.10.2015	L1	30	58.105	28	38.915	1369	SW	Gentle
20.10.2015	L2	30	58.125	28	39.028	1376	SE	Steep
22.10.2015	L3	30	57.812	28	37.481	1424	SSW	Steep
22.10.2015	L4	30	57.792	28	37.619	1448	SSW	Gentle
02.11.2015	G1	31	3.750	28	30.829	1052	SE	Steep
02.11.2015	G2	31	3.762	28	30.853	1027	SE	Steep
04.11.2015	D1	30	49.363	28	15.555	1501	SSE	Steep

04.11.2015	D2	30	49.319	28	15.561	1553	SSE	Steep
05.11.2015	C1	30	51.326	28	27.042	1635	NW	Steep
05.11.2015	C2	30	51.361	28	27.043	1638	NW	Steep
06.11.2015	D3	30	49.263	28	15.621	1582	SSW	Steep
06.11.2015	D4	30	49.270	28	15.397	1580	SSE	Steep
07.11.2015	C3	30	51.678	28	26.150	1551	SSW	Steep
07.11.2015	C4	30	51.705	28	26.327	1530	SSW	Steep
07.11.2015	C5	30	51.725	28	26.369	1569	SW	Gentle
09.11.2015	G3	31	3.675	28	30.517	1004	NW	Steep
09.11.2015	G4	31	3.719	28	30.596	971	NW	Steep
09.11.2015	G5	31	3.810	28	30.664	956	W	Steep
10.11.2015	F1	30	52.576	28	22.179	1465	SSE	Steep
10.11.2015	F2	30	52.621	28	22.204	1427	SSE	Gentle
11.11.2015	E1	30	53.872	28	19.980	1512	SW	Steep
11.11.2015	E2	30	53.929	28	19.957	1452	SW	Steep
13.11.2015	N1	31	9.854	28	39.193	1105	SSW	Steep
13.11.2015	N2	31	9.904	28	39.198	1047	SSW	Gentle
13.11.2015	N3	31	9.960	28	39.145	1009	SSW	Gentle
17.11.2015	B1	30	59.213	28	11.171	1415	NW	Steep
17.11.2015	B2	30	59.238	28	10.923	1456	NW	Gentle
17.11.2015	B3	30	59.248	28	10.687	1469	NW	Gentle
18.11.2015*		30	50.493	28	10.662	1850	SSE	Steep
18.11.2015*		30	50.505	28	10.503	1830	SSE	Gentle
19.11.2015*		30	52.033	28	9.824	1786	SW	Gentle
20.11.2015	A1	31	3.837	28	9.368	1477	SSW	Steep
20.11.2015	A2	31	3.865	28	9.347	1470	SSW	Steep
22.11.2015	M1	31	6.092	28	29.333	1099	SSE	Steep
22.11.2015	M2	31	6.130	28	29.352	1074	SE	Gentle

* indicate plots with pure stands of *Leucosidea sericea* (not included in the analysis)

Appendix 2.5: Sampling points across Ntabelanga Natural Forests patches



Appendix 2.6:

TWINSPAN Classification of trees and large shrubs (≥5 cm DBH) in Ntabelanga natural forests based on number of stems per plot

```
                HHHH HHHHK KLLLL KKIIJOOKMNIIJJJ CNDDDCCN EEMAFFACC BBBD

                5678 34121 21234 453441232212132 53123121 121112234 1234

                2222 22123 34444 332334534422333 14111  4 114 11       1

                3456 12905 60123 899049075778132 08123676 564178289 3454



  51 Scol zey   2254 12-32 352-1 11-1222--2-1-1- 43-----3 331--2--- ---3  00

  11 Cass per   ---- -3--- ----- --------------- -------- --------- ----  010000

  20 Elae cro   ---- 32--- ----- --------------3 -------- --------- ----  010000

  31 Isik uza   ---- -1--- ----- --------------- -------- --------- ----  010000

  44 Afro fal   -3-- 1242- ----- -------2------1 -------- --------- ----  010000

  48 Rham pri   ---- ---2- ----- --------------- -------- --------- ----  010000

   6 Cant mun   ---- -1-1- -2--- --1------------ -------- --------- ----  010001

   9 Cari bis   ---- 2-1-- ----- -------------3- -------- --------- ----  010001

   3 Calo cap   -2-- ----- 22--- ----------1---- -------- --------- ----  01001

  12 Celt afr   2333 11121 --122 ----2-12--11123 --1----- --------- ----  01001

  61 Vepr lan   ---- -2--2 -11-- -----------22-- -------- --------- ----  01001

  25 Gymn bux   -3-2 1-252 23455 122334254432-3- -2122--4 -221--11- ----  0101

  50 Scol mun   2145 24322 --1-2 3-2-334---45232 --13--22 3----1--- ----  0101

  16 Cuss spi   2123 ----- ----- --222222322323- -2------ --3------ ----  0110

  42 Pitt vir   ---- ----- ----3 --1---3---2---- -------- --------- 211-  0110

  53 Sear den   22-- 1--11 -3243 3332434---22453 -------- ------2-- 21-2  0110

  23 Grew las   1-1- -1--- ----- -2-1--32-1-2--- -------- --------- ----  011100

   1 Allo dec   ---- ---1- 242-2 14225422--44-33 -------- --------- ----  011101

  13 Clau ani   ---- ----- ----- ----3--1-3-1222 -------1 --------- ----  011101

  14 Comm har   ---- ----- -2--- 21-2231112----- -------- --------- ----  011101

  28 Ilat spp   ---- ----- ----- -2------------- -------- --------- ----  011101

  38 Mnqa yim   ---- ----- -21-- --------------- -------- --------- ----  011111

  40 Myst aet   ---- ----- -21-- ----------2---- -------- --------- ----  011111

  46 Ptae obl   2-1- ----- --51- --------------- -------- 53------- ----  100

  52 Scut myr   11-- ----- 3-423 -----2-12-22-22 ----2232 1211---2- 3-21  100

  18 Dios why   1--- 45133 -5313 24444442535532- 53243233 555553555 4545  101

  26 Hall luc   1--- ----- ----- 3211-1-1-2---2- 3-423221 -----1-1- ----  101

  29 Ilex mit   ---- ----- 3---- -----2---22---- 1---2--3 ---1----- ---2  101

  56 Tric ell   ---- ----- ----- ---------2----2 -3------ ---1----- ----  101

  10 Cass ili   ---- ----- ----- 2------3-12-221 12324--- -324-411- ----  1100
```

```
15 Cryp woo   ---- -3--- ----- --------1-23-1- -------3 -4-3--221 --4-  1101

45 Podo lat   3-2- 331-- ----- --3--11---1---- 31---442 32-21521- 3331  1101

57 Trim gra   -1-2 ----- ----- -------122----- --25--22 214---1-- 2-25  1101

60 Unkn own   ---2 ----- ----- --------------- -1------ ---1----- ----  1101

32 Leuc ser   ---- ----- ----- --------------- -1------ ---343--3 22--  111000

34 Mayt abb   ---- ----- ----- --------------- -------- --------2 --2-  111000

41 Olin ema   ---- ----- ----- 33-----2------- 1--53-1- 3345555-2 3323  111000

43 Pleu cap   ---- ----- ----- --------------- -------- --------- 4143  111000

47 Rapa mel   ---- ----- ----- --------------- -------- ------1-- --2-  111000

21 Eucl und   ---- ----- ----- --------------- ---4--12 -1-2253-- 12-3  111001

22 Grew fla   ---- ----- ----- --------------- -2------ -------11 ----  11101

24 Grew occ   ---- ----- ----- --------------- -------1 -------1- ----  11101

37 Mayt und   ---- ----- ----- --------------- ---2---- ------2-- 11--  11101

27 Hete arb   ---- ----- ----- ---1----------- --2421-2 11-1-1--- ---2  11110

 5 Cant ine   ---- ----- ----- --------------- 13434223 --1------ -1-3  111110

 4 Cant cil   ---- ----- ----- --------------- --32---2 --------- ----  111111

35 Mayt acu   ---- ----- ----- --------------- --12---- --------- ----  111111

58 Trim tri   ---- ----- ----- --------------- ---2---- --------- ----  111111

Community     1.11 1.12   1.21       1.22       2.10      2.21    2.22

              0000 00000 00000 000000000000000 11111111 111111111 1111

              0000 00000 11111 111111111111111 00000000 111111111 1111

              0000 11111 00000 111111111111111 00111111 000000000 1111

                   00111 00111 000000000011111   000111 000111111

                                000000011100001             000111

                                0011111
```

Appendix 2.7: Relative Frequency (RF) of trees and large shrubs (≥5 cm DBH) in Ntabelanga natural forests

Species	**Low altitude forest communities**				**High altitude forest**		
	1.11	**1.12**	**1.21**	**1.22**	**2.10**	**2.21**	**2.22**
Allophylus decipiens	-	1.8	7.3	16.4	-	-	-
Burchellia bubalina	-	1.8	-	-	-	-	-
Calodendrum capense	1.8	-	3.6	1.8	-	-	-
Canthium ciliatum	-	-	-	-	5.5	-	-
Canthium inerme	-	-	-	-	14.5	1.8	3.6
Canthium mundianum	-	3.6	1.8	1.8	-	-	-
Canthium pauciflorum	-	-	-	-	1.8	-	-
Capparis tomentosa	-	-	1.8	1.8	-	-	-
Carissa bispinosa	-	3.6	-	1.8	-	-	-
Cassinopsis ilicifolia	-	-	-	11	9.1	10.9	-
Cassina peragua	-	1.8	-	-	-	-	-
Celtis Africana	7.3	9.1	5.5	11	1.8	-	-
Clausena anisata	-	-	-	11	1.8	-	-
Commiphora harveyi	-	-	1.8	13	-	-	-
Cryptocarya woodii	-	1.8	-	7.3	1.8	9.1	1.8
Cussonia spicata complex	7.3	-	-	18.2	1.8	1.8	-
Diospyros lyicioides	-	-	-	1.8	-	-	-
Diospyros whyteana	1.8	9.1	7.3	22	14.6	16.4	7.3
Dovyalis zeyheri	-	-	7.3	4	-	-	-
Elaedendron croceum	-	3.6	-	1.8	-	-	-
Euclea schimperi	-	-	-	-	5.6	9.1	5.5
Grewia flavescens	-	-	-	-	1.8	3.6	-
Grewia lasiocarpa	3.6	1.8	-	9.1	-	-	-
Grewia occidentalis	-	-	-	-	1.8	1.8	-
Gymnosporia buxifolia	3.6	7.3	9	20	9.1	9.1	-
Halleria lucida	1.8	-	-	13	12.7	3.6	-
Heteromorpha arborescens	-	-	-	1.8	9.1	7.3	1.8
Hippobromus pauciflorus	-	-	-	-	-	-	-
Ilatile	-	-	-	1.8	-	-	-
Ilex mitis	-	-	1.8	4	5.5	1.8	1.8
Ilothane	-	-	-	1.8	-	-	-
Isik uza	-	1.8	-	-	-	-	-
Leucosidea sericea	-	-	-	-	1.8	7.3	3.6
Lusitshane	-	-	1.8	-	-	-	-
Maytenus species	-	-	-	-	-	1.8	1.8
Maytenus accuminata	-	-	-	-	3.6	-	-
Maytenus peduncularis	-	-	-	1.8	-	-	-
Maytenus undata	-	-	-	-	1.8	1.8	3.6
Mnqayimpafu	-	-	3.6	-	-	-	-
Morella serrata	-	-	-	-	-	-	-

Species	**Low altitude forest communities**				**High altitude forest**		
	1.11	**1.12**	**1.21**	**1.22**	**2.10**	**2.21**	**2.22**
Mystroxylon aethiopicum	-	-	3.6	1.8	-	-	-
Olinia emarginata	-	-	-	5.5	7.3	14.5	7.3
Pittosporum viridiflorum	-	-	1.8	3.6	-	-	5.5
Pleurostylia capensis	-	-	-	-	-	-	7.3
Afrocarpus falcatus	1.8	7.3	-	1.8	-	-	-
Podocarpus latifolius	3.6	5.5	-	3.6	9.1	12.9	7.3
Ptaeroxylon obliquum	3.6	-	3.6	-	-	3.6	-
Rapanea melanophloeos	-	-	-	-	-	1.8	1.8
Rhamus prinoides	-	1.8	-	-	-	-	-
Rhus chirindensis	-	-	-	1.8	-	-	-
Scolopia mundii	7.3	9.1	3.6	12.7	7.3	3.6	-
Scolopia zeyheri	7.3	7.3	7.3	10.9	5.5	7.3	1.8
Scutia myrtina	3.6	-	7.3	10.9	7.3	9.1	7.3
Searsia dentata	3.6	5.5	7.3	16.3	-	3.6	5.5
Solanum mauritianum	-	1.8	-	-	-	-	-
Strychnos spp	-	1.8	-	-	-	-	-
Trichocladus ellipticus	-	-	-	1.8	1.8	-	-
Trimeria grandifolia	3.6	-	-	5.5	7.3	9.1	5.5
Trimeria trinervis	-	-	-	-	1.8	-	-
Umqwirha	-	-	-	5.5	-	-	-
Unknown	1.8	-	-	-	1.8	1.8	-
Vepris lanceolata	-	3.6	3.6	3.6	-	-	-
Xymalos monospora	-	-	1.8	-	-	-	-
Zanthoxylum capensis	1.8	-	1.8	3.6	1.8	-	-

Appendix 2.8: Relative Density (RD) of trees and large shrubs (≥5 cm DBH) in Ntabelanga natural forests

Species	**Low altitude forest communities**				**High altitude forest**		
	1.11	**1.12**	**1.21**	**1.22**	**2.10**	**2.21**	**2.22**
Allophylus decipiens	-	3.7	3.7	2.4	-	-	-
Burchellia bubalina	-	0.03	-	-	-	-	-
Calodendrum capense	0.3	-	0.3	0.03	-	-	-
Canthium ciliatum	-	-	-	-	5.5	-	-
Canthium inerme	-	-	-	-	14.5	1.8	3.6
Canthium mundianum	-	0.2	0.2	0.03	-	-	-
Canthium pauciflorum	-	-	-	-	1.8	-	-
Capparis tomentosa	-	-	0.1	0.1	-	-	-
Carissa bispinosa	-	0.2	-	0.1	-	-	-
Cassinopsis ilicifolia	-	-	-	0.5	9.1	10.9	-
Cassina peragua	-	0.2	-	-	-	-	-
Celtis africana	1.6	1.6	1.6	0.3	1.8	-	-
Clausena anisata	-	-	-	0.6	1.8	-	-
Commiphora harveyi	-	-	1	0.4	-	-	-
Cryptocarya woodii	-	2.2	-	0.4	1.8	9.1	1.8
Cussonia spicata complex	2.3	-	-	0.9	1.8	1.8	-
Diospyros lyicioides	-	-	-	0.03	-	-	-
Diospyros whyteana	26.6	27	27	5.7	14.6	16.4	7.3
Dovyalis zeyheri	-	-	1.6	0.6	-	-	-
Elaedendron croceum	-	0.4	-	0.1	-	-	-
Euclea schimperi	-	-	-	-	5.6	9.1	5.5
Grewia flavesens	-	-	-	-	1.8	3.6	-
Grewia lasiocarpa	0.5	0.5	-	0.3	-	-	-
Grewia occidentalis	-	-	-	-	1.8	1.8	-
Gymnosporia buxifolia	6.6	6.6	6.6	2.2	9.1	9.1	-
Halleria lucida	1.9	-	-	0.4	12.7	3.6	-
Heteromorpha arborescens	-	-	-	0.03	9.1	7.3	1.8
Hippobromus pauciflorus	-	-	-	-	-	-	-
Ilatile	-	-	-	0.1	-	-	-
Ilex mitis	-	-	1	0.2	5.5	1.8	1.8
Ilothane	-	-	-	0.03	-	-	-
Isik uza	-	0.03	-	-	-	-	-
Leucosidea sericea	-	-	-	-	1.8	7.3	3.6
Lusitshane	-	-	0.03	-	-	-	-
Maytenus species	-	-	-	-	-	1.8	1.8
Maytenus accuminata	-	-	-	-	3.6	-	-
Maytenus peduncularis	-	-	-	0.03	-	-	-
Maytenus undata	-	-	-	-	1.8	1.8	3.6
Mnqayimpafu	-	-	0.1	-	-	-	-
Morella serrata	-	-	-	0.1	-	-	-

Species	**Low altitude forest communities**				**High altitude forest**		
	1.11	**1.12**	**1.21**	**1.22**	**2.10**	**2.21**	**2.22**
Mystroxylon aethiopicum	-	-	0.4	0.1	-	-	-
Olinia emarginata	-	-	-	0.4	7.3	14.5	7.3
Pittosporum viridiflorum	-	-	0.6	0.1	-	-	5.5
Pleurostylia capensis	-	-	-	-	-	-	7.3
Afrocarpus falcatus	0.8	0.8	-	0.1	-	-	-
Podocarpus latifolius	3.9	3.9	-	0.3	9.1	12.9	7.3
Ptaeroxylon obliquum	2.2	-	2.2	-	-	3.6	-
Rapanea melanophloeos	-	-	-	-	-	1.8	1.8
Rhamus prinoides	-	0.05	-	-	-	-	-
Rhus chirindensis	-	-	-	0.2	-	-	-
Scolopia mundii	5	5	5	1.8	7.3	3.6	-
Scolopia zeyheri	3.7	3.7	3.7	0.3	5.5	7.3	1.8
Scutia myrtina	2.8	-	2.8	0.3	7.3	9.1	7.3
Searsia dentata	4.6	4.6	4.6	2.4	-	3.6	5.5
Solanum mauritianum	-	0.03	-	-	-	-	-
Strychnos spp	-	0.03	-	-	-	-	-
Trichocladus ellipticus	-	-	-	0.1	1.8	-	-
Trimeria grandifolia	3.1	-	-	0.3	7.3	9.1	5.5
Trimeria trinervis	-	-	-	-	1.8	-	-
Umqwirha	-	-	-	0.11	-	-	-
Unknown	0.1	-	-	-	1.8	1.8	-
Vepris lanceolata	-	0.5	0.5	0.2	-	-	-
Xymalos monospora	-	-	0.1	-	-	-	-
Zanthoxylum capensis	0.5	-	-	0.4	1.8	-	-

Appendix 2.9: Relative Basal Area (RBA) of trees and large shrubs (≥5 cm DBH) in Ntabelanga natural forests

Species	**Low altitude forest communities**				**High altitude forest communities**		
	1.11	**1.12**	**1.21**	**1.22**	**2.10**	**2.21**	**2.22**
Allophylus decipiens	-	0.01	0.2	0.73	-	-	-
Burchellia bubalina	-	0.002	-	-	-	-	-
Calodendrum capense	0.2	-	0.9	0.23	-	-	-
Canthium ciliatum	-	-	-	-	0.11	-	-
Canthium inerme	-	-	-	-	0.43	0.002	0.2
Canthium mundianum	-	0.002	0.02	0.002	-	-	-
Canthium pauciflorum	-	-	-	-	0.01	-	-
Capparis tomentosa	-	-	0.003	0.07	-	-	-
Carissa bispinosa	-	0.01	-	0.07	-	-	-
Cassinopsis ilicifolia	-	-	-	0.13	0.09	0.14	-
Cassina peragua	-	0.3	-	-	-	-	-
Celtis africana	1.1	0.32	0.21	0.58	0.95	-	-
Clausena anisata	-	-	-	0.19	0.003	-	-
Commiphora harveyi	-	-	0.03	0.45	-	-	-
Cryptocarya woodii	-	0.01	-	0.06	0.47	0.8	0.3
Cussonia spicata complex	1.4	-	-	2.56	0.46	0.3	-
Diospyros lyicioides	-	-	-	0.007	-	-	-
Diospyros whyteana	0.03	0.41	0.38	1.78	0.43	2.2	0.6
Dovyalis zeyheri	-	-	0.61	0.23	-	-	-
Elaedendron croceum	-	2.9	-	0.11	-	-	-
Euclea schimperi	-	-	-	-	0.44	0.2	0.2
Grewia flavesens	-	-	-	-	0.05	0.01	-
Grewia lasiocarpa	0.002	0.01	-	0.09	-	-	-
Grewia occidentalis	-	-	-	-	0.03	0.003	-
Gymnosporia buxifolia	0.2	0.3	1.61	0.8	0.39	0.1	-
Halleria lucida	0.01	-	-	0.12	1.06	0.04	-
Heteromorpha arborescens	-	-	-	0.009	0.6	0.13	0.2
Ilatile	-	-	-	0.008	-	-	-
Ilex mitis	-	-	0.01	0.23	0.4	0.13	0.1
Ilothane	-	-	-	0.006	-	-	-
Isikuza	-	0.01	-	-	-	-	-
Leucosidea sericea	-	-	-	-	0.02	0.42	0.03
Lusitshane	-	-	0.004	-	-	-	-
Mytenus abbottii	-	-	-	-	-	0.01	0.01
Maytenus accuminata	-	-	-	-	0.03	-	-
Maytenus peduncularis	-	-	-	0.005	-	-	-
Maytenus undata	-	-	-	-	0.1	0.03	0.01
Mnqayimpafu	-	-	0.11	-	-	-	-
Morella serrata	-	-	-	0.04	-	-	-
Mystroxylon aethiopicum	-	-	0.1	0.1	-	-	-

Species	Low altitude forest communities				High altitude forest communities		
	1.11	**1.12**	**1.21**	**1.22**	**2.10**	**2.21**	**2.22**
Olinia emarginata	-	-	-	0.66	1.42	3.5	1.03
Pittosporum viridiflorum	-	-	0.05	0.025	-	-	0.03
Pleurostylia capensis	-	-	-	-	-	-	0.9
Afrocarpus falcatus	0.03	2.4	-	1.9	-	-	-
Podocarpus latifolius	0.6	0.9	-	0.45	4.1	0.8	1.1
Ptaeroxylon obliquum	0.6	-	0.4	-	-	0.3	-
Rapanea melanophloeos	-	-	-	-	-	0.03	0.1
Rhamus prinoides	-	0.02	-	-	-	-	-
Rhus chirindensis	-	-	-	-	-	-	-
Scolopia mundii	0.5	1	0.7	2.4	0.24	0.1	-
Scolopia zeyheri	1.1	0.8	0.42	0.57	0.81	0.1	0.1
Scutia myrtina	0.03	-	0.26	0.07	0.2	0.1	0.1
Searsia dentata	0.3	0.05	0.37	0.86	-	0.01	0.1
Solanum mauritianum	-	0.002	-	-	-	-	-
Strychnos spp	-	0.002	-	-	-	-	-
Trichocladus ellipticus	-	-	-	0.16	0.07	-	-
Trimeria grandifolia	0.3	-	-	0.46	0.5	0.3	0.3
Trimeria trinervis	-	-	-	-	0.01	-	-
Umqwirha	-	-	-	0.02	-	-	-
Unknown	0.06	-	-	-	0.01	0.01	-
Vepris lanceolata	-	0.1	0.07	2.08	-	-	-
Xymalos monospora	-	-	0.003	-	-	-	-
Zanthoxylum capense	0.003	-	0.02	0.16	0.002	-	-

Chapter 3: Disturbance-Recovery processes within Ntabelanga natural forests

3.1 Introduction

The natural forests in the Ntabelanga catchment are very fragemented and patchy (Geldenhuys et al. 2016). A total of 495 patches of natural forests covering an area of approximately 1570 ha occur within the catchment. The majority of forest patches were less than 5 ha in area (47% of <1 ha and 38% of 1-4.9 ha in size). However, the larger forests (10 to 147 ha) represented 6% of the total number of forest patches. The study further indicated that mean forest patch size decreased from 7.02 ha below 1200 m a.s.l to 0.91 ha above 2000 m a.s.l. This raised the question as to what are the main disturbance factors confining forest patch size, and how would such factors contribute to disturbances affecting the forest interior and species dominance.

The main threats to biodiversity conservation worldwide are habitat loss, fragmentation and degradation related to landuse practices such as logging, agriculture, burning, hunting and grazing (Cannon et al. 1998; Haugo et al. 2010). Field observations in the Ntabelanga catchment have indicated that the common disturbances are crown breaks, especially for canopy tree species at high altitude due to heavy wind and snow fall, and fire, grazing and resource use at the low altitude forests situated closer to settlements. Disturbances such as tree fall gaps, fire spotting and resource use, may influence forest structure which change over time due to stand dynamics.

The biological components of all vegetation types respresent their adaptation to different site conditions (geology and soils) and various types and scales of disturbances (Hansen and Walker 1985; Geldenhuys 2010). Moreover, they compete with each other in the same stand for available resources (light, space, nutrients, etc.). Each species became adapted to specific site conditions and bears characteristics that enable it to function better in some of different stand developmental stages, to respond to different scales of disturbance. Understanding species ecological characteristics (response to disturbance or site conditions) will form the basis for different resource use needs within the Ntabelanga catchment.

3.1.1 Spatial scales of disturbance

The disturbance regime of specific forest areas and zones within a forest, are very important to consider in resource use management. A disturbance regime includes the frequency, intensity, spatial scale and seasonality with which it occurs (Pickett and White 1985). The frequency of a disturbance can maintain an area as a forest (with very infrequent major disturbances), or change it into a grassland (with very frequent fires), as in the Ntabalenga area, with forest persisting in fire shadow areas, and the matrix in the fire pathways burnt at regular intervals. Even with the fires burning annually, as in the seasonal woodlands, the season of the fire can change the vegetation into a grassy understory with annual late dry season fires (of high intensity) and a woody understory with early dry season (cool) fires (Geldenhuys 1977). In a forest, the spatial scale of the gaps created by different kinds of disturbances (such as trees dying standing, tree falls, fire spotting, lightning with or without fire, snow fall) (Geldenhuys & Maliepaard 1983) has a definite influence on what kind of tree species would grow in such a gap, such as generally shade-tolerant species in small gaps and light-demanding species in large gaps, For example, the light-demanding Australian Blackwood (*Acacia melanoxylon*) grew much faster in large canopy gaps than in small gaps in the natural evergreen forest in the Southern Cape, South Africa (Geldenhuys 1996a). The conditions prevailing in a specific forest system, or part of the system, will determine the regeneration strategies of canopy tree species in that system.

The concept of grain (the relative spatial scales of canopy gaps) measures the distance (difference) in ordination space in the composition of the canopy tree species, between those in the regeneration and those in the canopy of the same stand (Midgley et al. 1990; Everard et al. 1995; Geldenhuys 1996b, 2010). This can be achieved in two ways. The practical approach is to observe in the field where the regeneration of canopy tree species in the canopy, occur in the stand - below the canopy of those species, or only in larger gaps. A more objective analytical approach is to use inventory data of only canopy tree species. The data for each plot are then sorted into two data sets, i.e, regeneration data (trees below a diameter threshold) and canopy data (trees above a diameter threshold) for an ordination analysis. The distance in ordination space between the mean regeneration and mean canopy points for each identified tree community are used to categorize a community as fine (small distance, i.e. more similar composition of the regeneration and canopy trees), intermediate and coarse grained (long distance, i.e. big difference in composition of the regeneration and canopy components) stands. This information, combined with species composition and stem diameter class distribution, gives an insight into the dynamics of forest communities, their resource potential and relevant management options to be used (Geldenhuys 1993a, 2010).

3.1.2 Impact of resource use on the population structure of key species

Studies have shown that an optimal harvesting system should consider the availability of a resource (abundance), its level of utilization, its recruitment potential and overall population status (Lawes and Obiri 2003). This requires a management system that improves the natural demography and standing biomass of targeted species, and at a harvesting level that does not exceed production rate or severely undermines recruitment potential of target species (Lawes and Obiri 2003). Harvesting of poles of different sizes and a range of species is common. Species are harvested based on preferences for specific uses such as construction and other social uses. The basis for developing a management plan framework for resource use is an understanding of the floristic-structural composition and internal dynamics of the Ntabelanga natural forests (Geldenhuys et al. 2016).

In Ntabelanga Natural Forests, field observations indicated that, though resource harvesting from the forest was minimal, most harvesting was for relatively small poles (<30 cm stem diameter) of mainly canopy species (Geldenhuys et al. 2016). Garden, livestock and yard fences represented the dominant use of poles in the households. Some preferred species for poles included *Olinia emarginata*, *Afrocarpus falcatus*, *Scolopia mundii*, *Scolopia zeyheri* and *Podocarpus latifolius*. People collected firewood when they needed it. Other uses included the harvesting of roots and bark of some species for traditional medicine, and berries and roots of some species for food (e.g. *Scolopia mundii* and *Cussonia spicata* complex respectively). These are man-made disturbances which if not managed wisely, can affect the population status of the harvested species. Within the catchment, the invasive introduced Black wattle (*Acacia mearnsii*) is an important source of firewood for both cooking and heating during winter season, which may reduce the pressure on the forests for indigenous tree species (Geldenhuys et al. 2016).

Studies indicated that the direct ecological consequences of resource use are the alteration in survival rate, growth and reproduction of harvested species. However, these may affect the structure and composition of harvested populations (Ticktin 2004). In Africa, the harvesting of trees has focused on the selection of large individual tree species (Poorter et al. 1996). In most of the rural areas, small-size poles are used at subsistence levels, which could be a major concern if they are harvested from canopy tree species (Obiri et al. 2002). In Cameron, harvesting the bark of *Prunus africana* (CITES appendix 2 listed species) on Mount Cameroon and Mount Oku, has negatively affected the population status of the species, killing 50% of harvested trees (Hall et al. 2000; Stewart 2001). In South Africa, *Prunus africana* is noted to be rare in Eastern and Transkei Mistbelt Forests (between Mthatha and Pietermaritzburg), but its bark is used at subsistence level and sometimes exported worldwide (Geldenhuys 2004). Similarly, repeated harvesting of the bark of *Waburgia salutaris* in South Africa resulted in decreased basal diameter, and higher rate of fungal attack and mortality (Botha et al 2004). In Zambia, a decline was noted in the population of *Brachystegia boehmii* trees, highly used by charcoal makers for meshing ropes over charcoal bags (Syampungani 2008). This species is preferred due to its strong fibre and its ease to peel (Clarke et al. 1996). However, concerns have been raised in Zimbabwe (Bradley and Dewee 1993) and in Tanzania (Mbwambo 2000) over the depletion of some species due to over-exploitation, agricultural expansion and hot fires. Others indicated that this population decline could be due to mismanagement over resource use leading to harvesting of easily accessible species within the area (Moore and Hall 1987; White 1988). Denslow (1995) argued that the unsustainable use of forest resources, leading to changes in their floristics and structure, could potentially impact on the forest ecosystem functions.

3.1.3 Population structure

Knowing the development stages of targeted species is paramount for sustainable resource use (Geldenhuys 2010). A forest inventory is therefore an essential tool in classifying different forest communities and in understanding species importance values. In addition, it enables the forest ecologist to understand the scale of ecological processes (or forest grain, i.e. the relation between the composition in the canopy and regeneration of canopy species within the same stand). The Size Class distribution (SCD) of a species provides an understanding of the population structure of key species across different forest communities, the regeneration status (ratio of juvenile and mature trees in a stand) or constraints for that species, the population stability and how this relates to community dynamics. The variation in the number of stems of important species at smaller and larger ends of the SCD across and within forest communities indicates success or failure of their recruitment and establishment and hence population status in that specific forest (Geldenhuys 1993b; Everard et al. 1995). Species that adequately regenerate under specific conditions of closed evergreen forests (shade-tolerant) or deciduous woodland with regular fire (fire-tolerant) may attain an inverse-J shape SCD. However, species with a Bell-shaped SCD are those species that regenerate successfully during specific conditions that may occur infrequently, such as a large gap in the evergreen forest (light demanding species) or reduced fire in fire-prone woodlands (fire-sensitive species).

Geldenhuys (2010) indicated that in homogenous forest stands, species that regenerate regularly, develop during each regeneration event, a normal or bell-shaped SCD, and a number of such even-aged cohorts over time. Within each even-aged cohort, the form of the bell-shaped SCD (height and basal width) change because of mortality, competition and differential stem growth, i.e. some stems grow faster and others grow slower than the mean stem size. New cohorts may establish regularly (even annually) under suitable site conditions (e.g. for shade tolerant species in closed canopy forest; fire adapted species in woodland). The combined SCD of all even-aged cohorts then shows a typical inverse J-shaped curve. However, when new cohorts do not establish regularly because suitable site conditions are widely spaced in time, a species shows widely spaced ‘bells’ that differ in height and base-width of the ‘bells’, as observed in the light-demanding *Acacia melanoxylon* (Geldenhuys 1996a).

The objective of this chapter is to determine the scale of disturbances that influences the composition of forests and their regeneration status at community (grain analyses) and population levels (stem diameter distribution). This objective is pursued through answering the following research questions:

1. What are the main natural and human disturbances (e.g. snow, fire, tree falls and resource use) impacting on the forests and species in the Ntabelanga forests?
2. What is the relationship between the composition of the canopy species in a stand in the regeneration and canopy of the same stand within the different forest communities?
3. What are the characteristic stem diameter class distributions (population structure) of key ecologically and used tree species across different identified communities in the

Ntabelanga Forests, and how can they be used to guide the development of silvicultural management systems for sustainable resource use in different forest communities?

3.2 Study area

The Ntabelanga Catchment lies between the towns of Maclear, Tsolo and Mount Fletcher in the Eastern Cape Province (Figure 3.1) within the District Municipalities of Joe Gqabi, OR Tambo and Alfred Nzo. Maclear, the nearest town, lies at 1, 280 m above mean sea level.

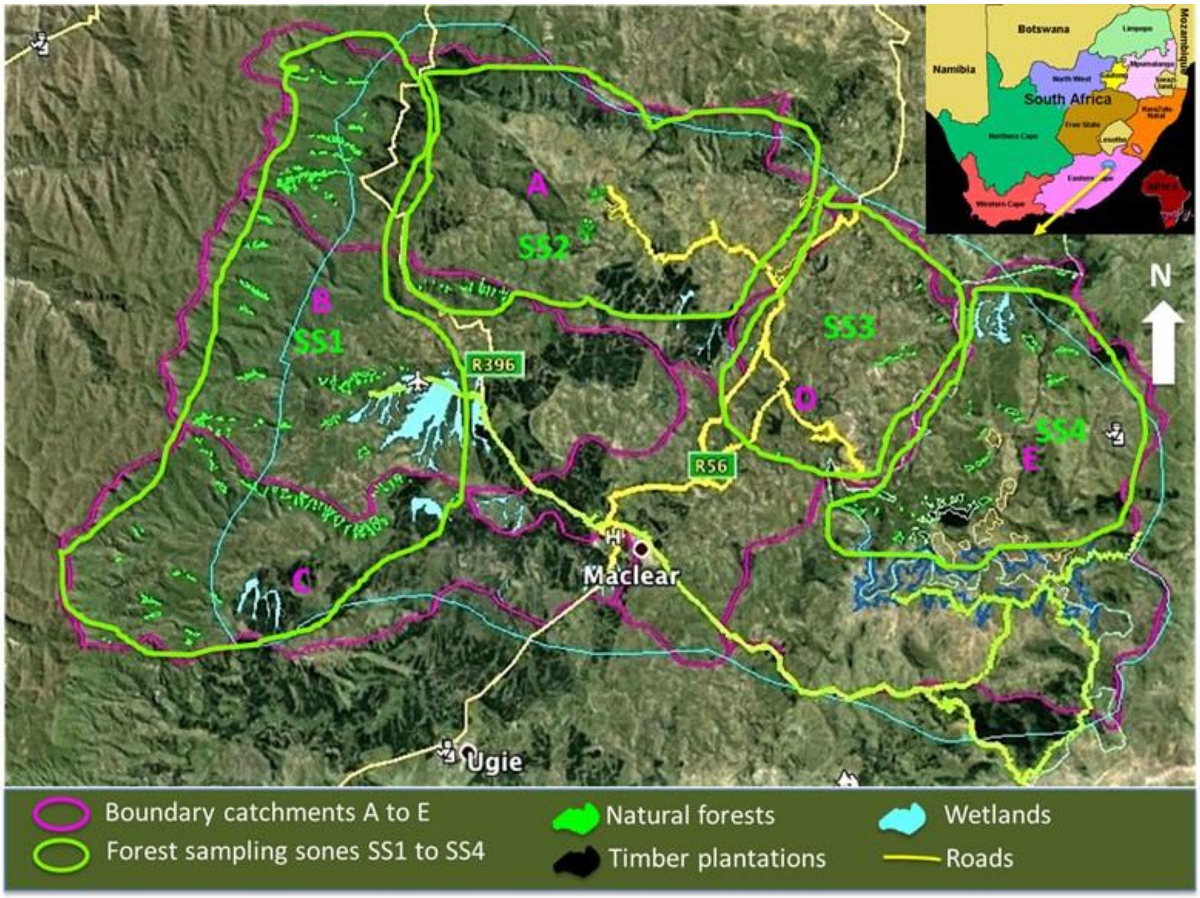


Figure 3.1: Distribution of natural forests within the catchments of the Ntabelanga Dam area in the upper reaches of the Mzimvubu River catchment, around Maclear in the Eastern Cape (Adapted from Geldenhuys et al. 2016).

The climate of the area is temperate with an average annual rainfall of 786 mm and the wettest month being January with an average monthly rainfall of 130 mm. June and July are the driest months with an average rainfall of 13 mm per month. January is the hottest month with an average maximum temperature of 20.1°C and July is the coldest month with temperatures as low as 0°C (Table 3.1).

Table 3.1: Average of rainfall and temperature of Maclear town for the period 1982-2012.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall (mm)	130	121	113	46	24	13	13	21	38	64	88	115
Temperature (°C)	20.1	19.9	18.7	15.9	12.8	8.6	8.1	10.9	14.5	16.2	17.8	19.1
Min. Temp. (°C)	13.9	13.9	12.6	9.3	5.6	0.8	0	3.1	7.3	9.5	11.3	12.6
Max. Temp. (°C)	26.3	26	24.8	22.5	20	16.4	16.3	18.8	21.7	23	24.3	25.7

(Source: www.Climate-Data.org)

Geologically, the area has traces of mudflake conglomorates with low level of tectonic deformations. Dolerite Sills and Dykes are found with thermally metamorphosed adjacent sediments. Beaufort sediments are characteristically erodible (Parwada and Van Tol 2016). In addition, there is high evidence of severe gully erosion especially along streams (Van Tol et al. 2016). The bedrock is the main constituent in the study area with some thick colluvial soil deposits covering it. Hard dolerite outcrops and subcrops in places. Alluvial sand occurs in the course of Tsitsa River and major tributary rivers and streams. Due to the steep and incised nature of the rivers, sand is mainly confined to the river channel, with few and only localized over-bank deposits (DWA 2014).

Most of the area (forests, grassland and wetlands) within the project area were identified by the Eastern Cape Biodiversity Conservation Plan (ECBCP in 2007) and the National Protected Areas Expansion Strategy (NPAES in 2008), as one of the important conservation areas due to the presence of Red Data species, endemic species and potential habitat for these species to exist (Berliner and Desmet 2007).

The natural forests within the area are small, fragmented patches and occur within the fire-prone grassland matrix. They cover altitudinal, topographical and disturbance (e.g. fire, snow and resource use) gradients. A total of 495 natural forest patches within the catchment were mapped on Google Earth Pro (Google Earth 2015), covering a total of 1570 ha (Geldenhuys et al. 2016). The majority of forest patches were less than 5 ha in area. However, the large forest patches comprise of 6.1% of the number and 46.4% of the total area. Furthermore, the mean forest patch size decreased from 7.02 ha below 1200 m asl to 0.91 ha above 2000 m asl. Fire flow patterns controls forest location pattern and limit forests to fire shadow areas within the landscape of steep slopes and gullies (Geldenhuys et al. 2016).

The presence of forest patches in the mountainous landscape of the area maintains high water quality and yield, which is critical to the rural communities' consumption and reduce soil erosion. Therefore, the management of natural forest biodiversity, use and conservation in the upper reaches of the Tsitsa River, part of the Mzimvubu River System, is essential in the socio-economic development of the proposed Ntabelanga dam in the Mzimvubu Water Project (Geldenhuys et al. 2016).

3.3 Study methodology

3.3.1 Sampling design

The mapped forest patches were used to develop a stratified random sampling design, to represent the main environmental gradients, i.e. the main macro east-west altitudinal gradient and the local topographical gradient from the foot slope to upper slope within a particular selected forest complex. Four sampling zones were marked (Figure 3.1): Zone 1 was the higher-lying areas west of road R396 (to Rhodes) in Catchments A to C; Zone 2 was the area between road R396 and road R56 between Maclear and Mount Fletcher, and mainly catchment A. Zone 3 was primarily all of Catchment D. Zone 4 was all of Catchment E. Twenty-one points in total were selected at random from the numbered points, and proportional to the number of points marked in each zone. The forest patches occurring around a selected sample point were studied on Google Earth and in the field (Figure 3.2) to select (a) forests that were accessible for sampling, (b) zones in the selected forests that would cover an altitudinal gradient, and (c) stand conditions that would represent the variation in forest condition in the selected sampling point. Parts that were too steep were excluded from sampling.

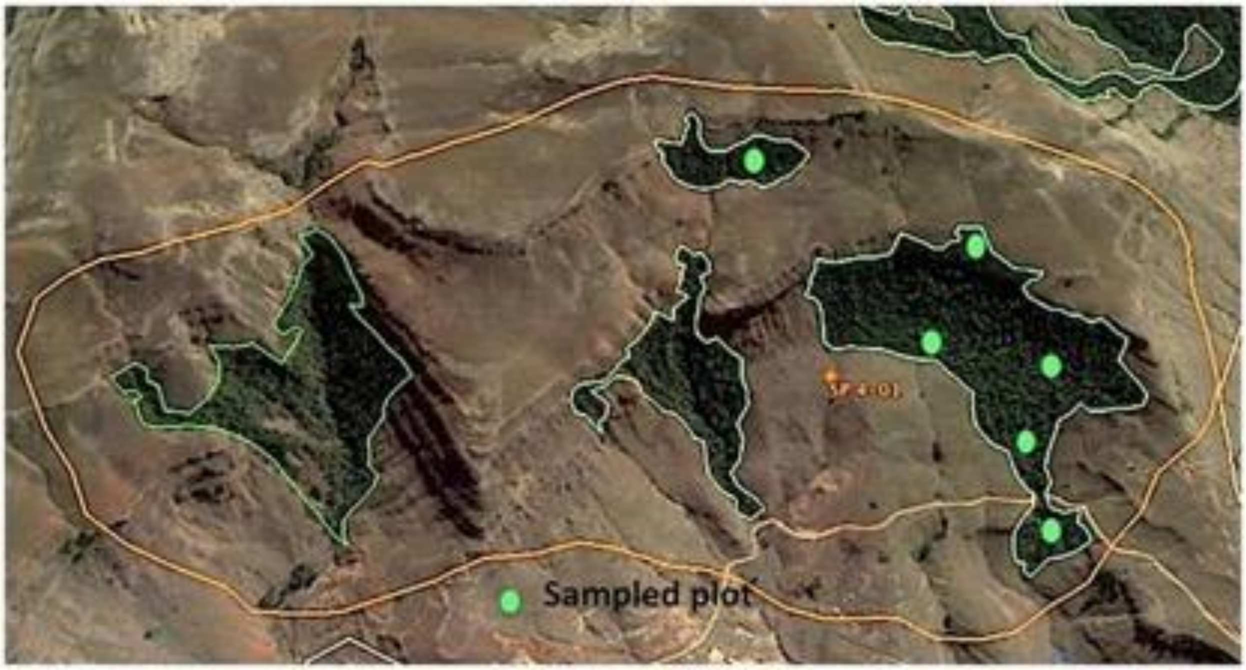


Figure 3.2: Distribution of plots sampled for floristic and structural composition of parts of the forest complex to capture mainly altitudinal variation. Note that the sampled forest had easier access to good forest over a wider area and provided a good altitudinal gradient (Geldenhuys et al. 2016).

The number of plots sampled varied between sample points, depending on the size of the area, the number of forest patches included and variation in composition and structure of the forest patches in an area. The sampling protocol followed the standard procedures used for sampling natural forests in South Africa to enable the data to be used during the improvement of the national forest type classification. Each plot was located in a relatively uniform part of the forest in a specific zone selected for sampling.

3.3.2 Data collection

A total of 56 plots were sampled. Inside the main 0.04 ha plot, all trees ≥5 cm diameter were measured at 1.3 m above ground level (breast height or DBH) and recorded by DBH and species. Individual stems of multi-stemmed or forked trees below 1.3 m height were recorded separately but given the same number to indicate that they belong to the same tree. General information recorded on a plot included: geographic coordinates using a Geographical Positioning System (GPS) for plot location, aspect, slope (level, gentle to steep), canopy conditions (smooth/ rough), presence of gaps (small/large), geomorphology (foot-slope, mid-slope, and upper slope), and substrate (deep soil, shallow soil, rocky, gully, rocky).

A field guide from the local community has assisted the field team with the identification of tree species. Plant names were recorded by local Xhosa names, or by botanical name when known. Plant material was collected for identification of unknown or uncertain plant names. However, leaves of some of the species were not accessible and this resulted in inadequate collection of samples of some species. In addition, specific notes were taken on harvested plants and their response after being harvested.

3.3.3 Data analysis

The analysis on resource use was done by getting the percentages (%) of species harvested in all the plots across forest communities and sub-communities at low and high altitude (Table 3.2).

The grain analysis used data related to canopy tree species, extracted from the total data set. This extracted data for each sampled plot were sorted into two data sets: one for the regeneration, i.e. all recorded stems of 5-15 cm DBH; and one for trees in the canopy, i.e. all recorded stems ≥20 cm DBH. Stems of 15.1 to 19.9 cm were excluded from this analysis to avoid overlap in the sizes of stems between the two categories. The input data for the Detrended Correspondence Analysis (DCA)) with the aid of vegan package software R 3.2.4 were the number of stems per species in each plot (according to the procedures used by Midgley et al., 1990 and Everard 1992). The mean ordination scores for the regeneration plots and canopy plots for each community were calculated and presented in ordination space.

The total data set from the inventory were used for the analysis of stem diameter class distributions. The data for each tree species in each sub-community were sorted into stem counts per 5 cm wide stem diameter classes and converted to stem density per ha. Histograms were used to compare the stem diameter distributions across stem diameter classes to compare across the communities in which the selected species were present.

3.4 Results

3.4.1 Observations of natural and human disturbances in the sampled areas

Field observations have shown that the main types of natural disturbances in the sampled areas were grassland fires burning into the forest edge, sometimes expanding forest edges (Figure 3.3a). Crown breaks from snow and heavy wind (Figure 3.3b) occurred on steep slopes at high altitude. This was field base evident and there was much snow and mist in the entire area during the processes of data collection. However, in some areas at low altitude, grazing and fire spotting were common. Firewood collection of both dead and alive wood were occasionally observed (Figure 3.3c), but alive poles of small stems are sometimes collected from dense stands of thin-sized trees in the understory (Figure 3.3d). Sometimes the cut stumps respond positively by sprouting, such as *Scolopia mundii* freshly cut for a pole (Figure 3.3e), sprouting on cut stems of *A. falcatus* and *Scolopia mundii* Figure 3.3f), and strong, vigorous sprouting shoots of *A. falcatus* after a stem of 12 cm diameter was cut. Sometimes the sprouting on a cut stump is browsed by cattle, as one example of a *Scolopia mundii* (Figure 3.3h). A *Podocarpus latifolius* tree of about 20 cm DBH was cut >1 m above the ground, some time ago, but did not sprout (Figure 3.3i). Most of the observed bark harvesting was old (Figure 3.3j), but occasionally some fresh harvesting was seen (Figure 3.3k). Some tree species showed no recovery after bark harvesting (such as *A. falcatus*, Figure 3.3l) but others recovered well, such as the good edge growth in *Ptaeroxylon obliquum* (Figure 3.3m).

The percentage of plots on which resource use was recorded, was higher at low altitude compared to high altitude forests (Table 3.2). At low altitude, sub-communities 1.12 and 1.22 showed a high 36% of plots with harvesting recorded, and two sub-communities with no harvesting (1.11 and 1.21). At high altitude, sub-communities 2.1 and 2.21 showed 9% of plots harvested, and no harvesting in sub-community 2.22. A relatively low percentage (2-9%) plots showed harvesting of *Afrocarpus falcatus*, *Scolopia mundii*, *S. zeyheri*, *Gymnosporia buxifolia*, *Cassine peragua*, *Vepris lanceolata* and *Olinia emarginata* in forest sub-communities 1.12 and 1.22. *Mystroxylon aethiopicum*, *Ilex mitis* and *Commiphora harveyi* were only harvested in forest sub-community 1.22. In the high-altitude forests, 3% of plots showed harvesting in forest community 2.1 for *Scolopia zeyheri* and *Diospyros whyteana*; and 5% for sub-community 2.21 for *Podocarpus* *latifolius*, *Olinia emarginata* and *Scolopia zeyheri*. Other resources harvested, other than poles, were firewood for cooking and social needs, and bark for traditional medicine.

Figure 3.3: Impact of different natural and human disturbances observed in and around natural forests in the Ntabelanga Catchment: a) Forest margin affected by fire; b) Crown branch (in yellow circle) of *Afrocarpus falcatus* tree broken by strong wind; c) Harvesting of dead and alive wood as firewood; d) Harvesting of thin poles from young dense pole-sized tree regeneration; e) *Scolopia mundii* freshly cut for a pole; f) Sprouting on cut stems of *A. falcatus* and *Scolopia mundii*; g) Strong sprouting shoots of *A. falcatus* after stem (12 cm diameter) was cut; h) Sprouting on cut stump of *Scolopia mundii* browsed by cattle; i) A *Podocarpus latifolius* tree was cut >1 m height above ground (old cut, with crown branches still on ground); j) Young tree of an unknown species freshly de-barked; k) Large tree of unknown species heavily debarked (old harvesting) and dying; l) No recovery after bark harvesting from *Afrocarpus falcatus*; m) Strong edge growth after bark harvesting from *Ptaeroxylon obliquum*.

Table 3.2: Resource uses within plots across forest communities and sub-communities

Forest communities and Sub-communities							
	Low altitude				**High altitude**		
	1.11	**1.12**	**1.21**	**1.22**	**2.1**	**2.21**	**2.22**
Number of plots sampled	**4**	**5**	**6**	**15**	**8**	**9**	**4**
Plots harvested %	25.0	80.0	0.0	26.7	12.5	11.1	0.0
Number of species recorded	17	21	0	40	28	26	0
Species harvested (%)	24.4	24.7	0	8.4	7.1	12.4	0

Most natural forests occur on steep slopes, with stands of the invasive alien Blackwattle in more accessible localities (Figure 3.4a), Much change was observed in building style, away from the traditional style with pole-mud walls and roofs of thatch on poles (Figure 3.4b). Blackwattle is used in most fence constructions (Figure 3.4c, d) and for firewood. Many modern houses are built with cement or mud-cement bricks (Figure 3.4e).

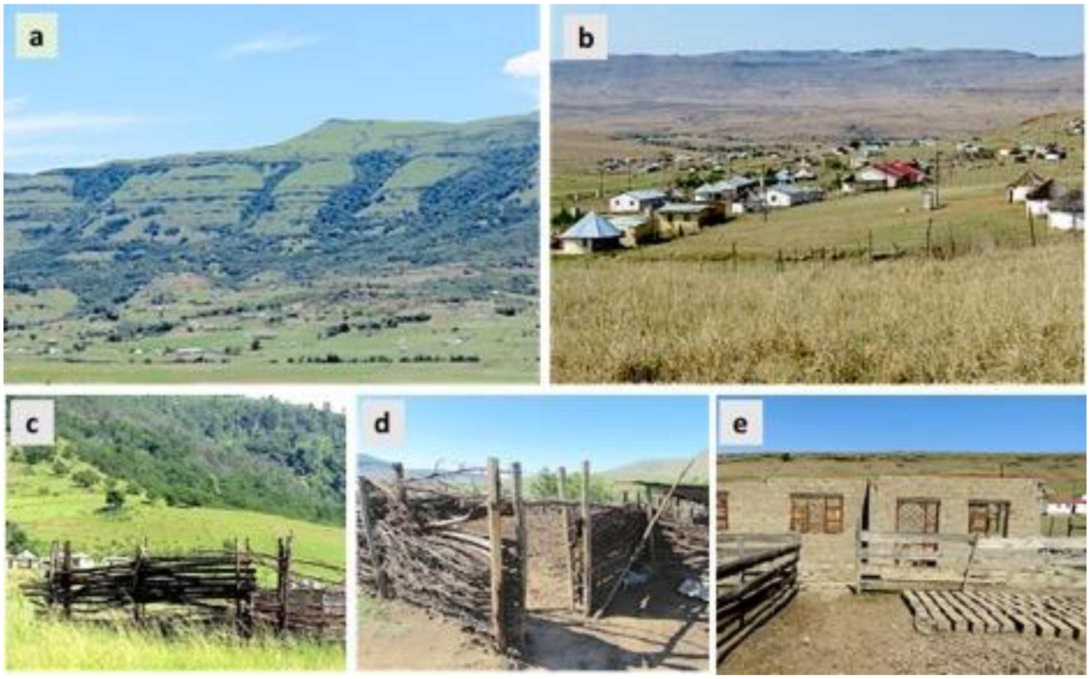


Figure 3.4. Observed changes in wood use and building style, reducing the dependency on the small natural forests in the Ntabelanga catchments. a) Natural forests in the upper steep slopes with stands of Blackwattle (*Acacia mearnsii*) at the bottom on more accessible terrain; b) The changed housing style in most houses, with some traditional houses (to the right) still used by some households; c) A wooden fence and d) a cattle enclosure entirely constructed of Blackwattle; e) A new house built from cement bricks.

The accessible forests, which may have been more intensively used in the past, do show some good stand structure of larger trees in places (Figure 3.5a), but also recovery through many dense stands of relatively young stems, often below the size of trees recorded during the forest sampling (Figure 3.5b-f), and including seedlings and saplings (Figure 3.5e,f). In some areas, small poles have been selectively harvested from such young stands (Figure 3.5f).

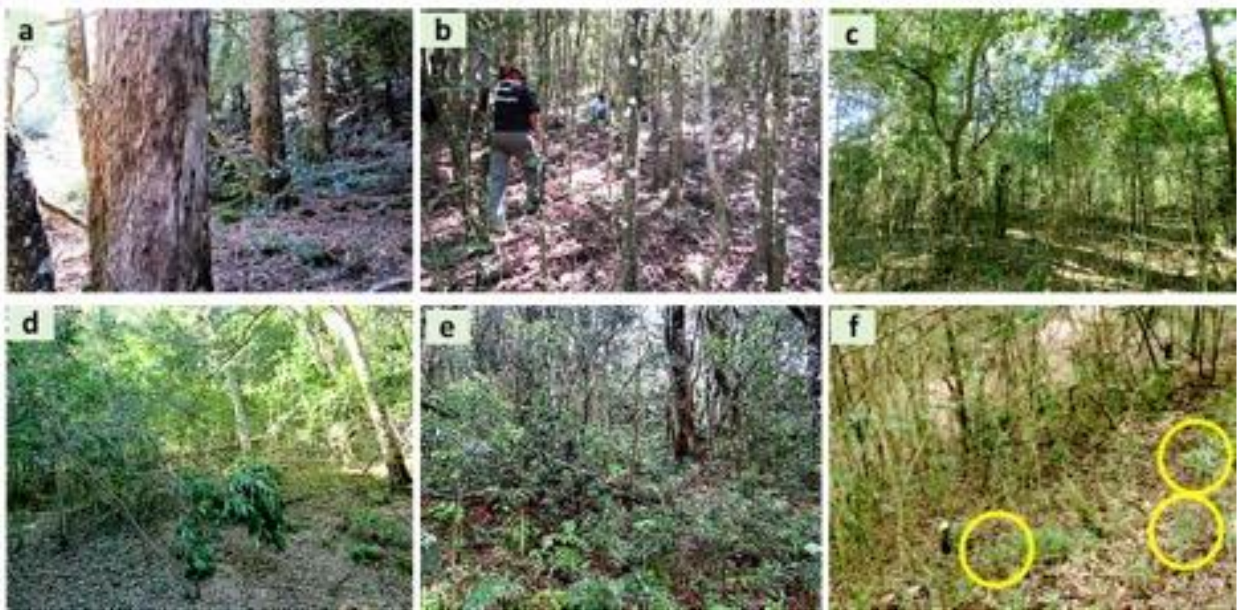


Figure 3.5. Stand structure varies from relatively open stands with large trees, to dense understory stands with good regeneration: a) *Podocarps* observed near one of the gullies at low altitude forest; b) *Diospyros whyteana* of a relatively dense stand of trees <10 cm DBH found in low altitude forests; c) A dense stand of small pole-sized trees; d) Dense regeneration of trees in a gap (on the left); e) Abundant seedlings and saplings of *Podocarpus latifolius* in a high-altitude forest; f) Small trees, with some small stems cut as poles, with well-established seedlings of *Afrocarpus falcatus* within the yellow circles in low-altitude forest.

3.4.2 Forest grain

The DCA ordination clearly separated the low-altitude forests (Community 1) from the high-altitude forests (Community 2) along Axis 1 (Figure 3.6). Within the low-altitude forests, the mean scores for composition of canopy tree species in the canopy (≥20 cm DBH) and in the regeneration (5-10 cm DBH) were very similar for sub-community 1.11 (very fine grain), relatively similar for sub-communities 1.12 and 1.22 (fine grain), but relatively far apart for sub-community 1.21 (coarser grain). Within the high-altitude forests, the mean scores for canopy and regeneration composition was relatively similar for sub-community 2.10 (fine grain), but relatively further apart for sub-communities 2.21 and 2.22 (coarse grain). The composition of the regeneration of canopy trees in the low-altitude sub-communities, and of the high-altitude sub-community 2.10 tend to be closer to the composition of the fine-grain communities closer to the center of the ordination diagram.

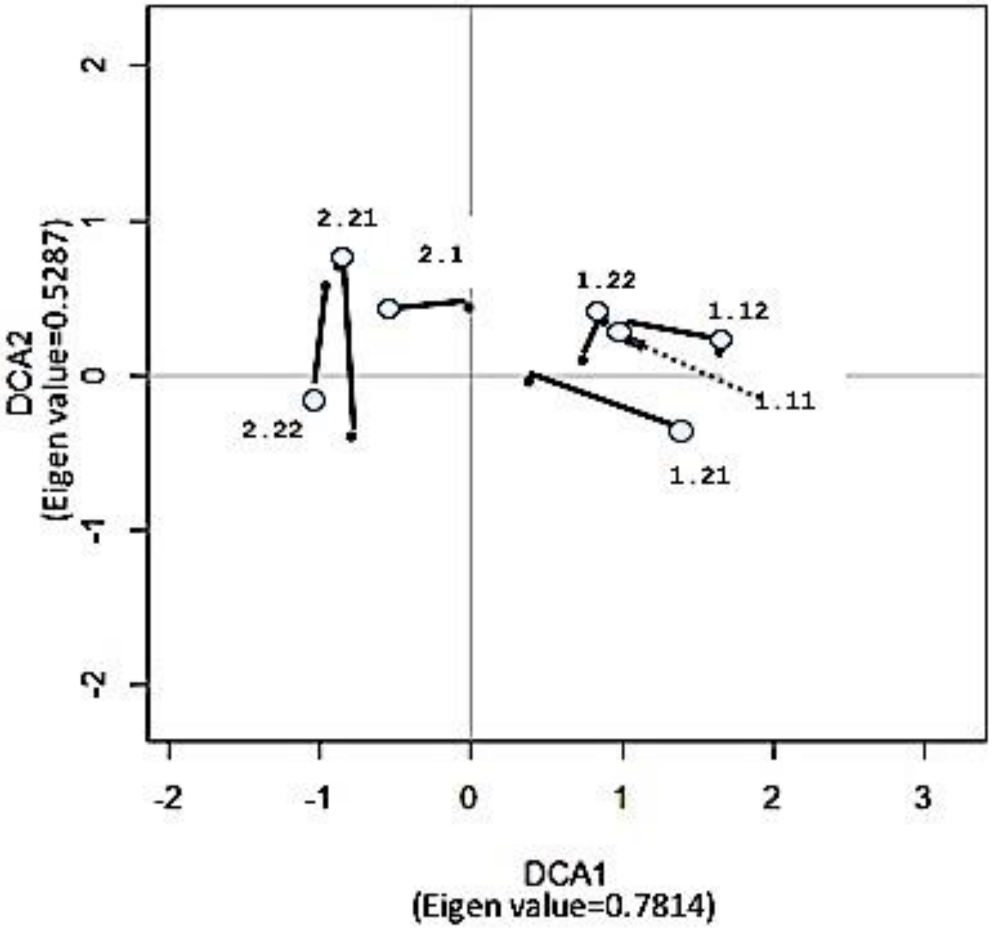


Figure 3.6. Ordination of mean scores for composition of canopy tree species in the canopy (open circle) (≥20 cm DBH) and in the regeneration (black dot) (5-10 cm DBH). The grain (relative spatial scale of canopy gaps) measures the distance (difference) in ordination space in the composition of Canopy tree species, between those in the regeneration and those in the canopy of the same stand (Midgley et al. 1990; Everard et al. 1995; Geldenhuys 1996b, 2010)

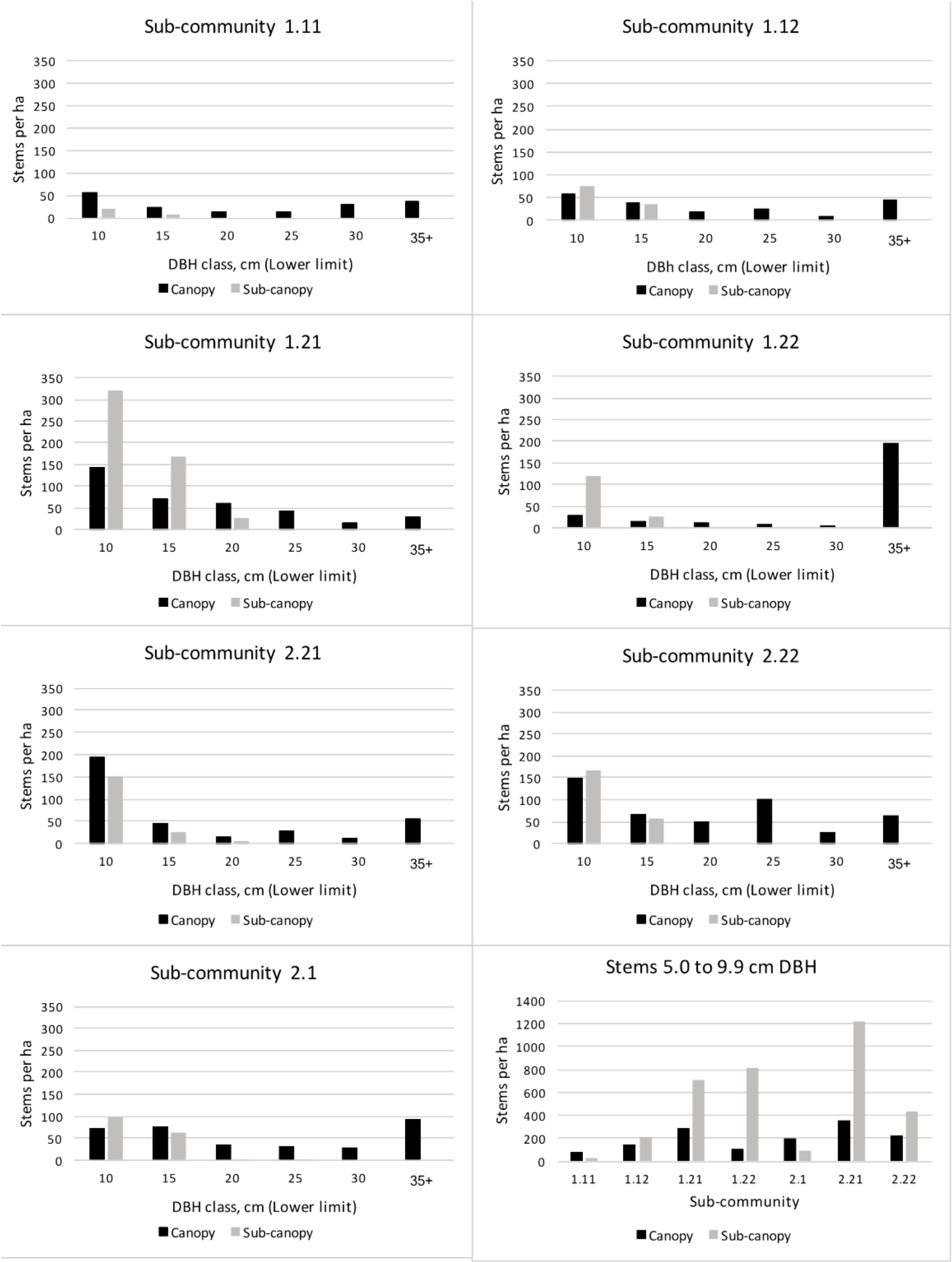
Lines connect points for the same sub-community. Axis 1 (DCA1) separated the Low-altitude forest sub-communities along the positive side and the High-altitude sub-communities along the negative side of this axis. Note that, except for sub-communities 2.2, the regeneration composition of most sub-communities tends towards similar composition towards the center of the ordination diagram.

3.4.3 Stem diameter class distributions across sub-communities and key tree species

The stem diameter class distributions have been assessed at different levels of the forests: firstly, for all canopy and sub-canopy tree species in each sub-community (Figure 3.7); secondly, for different groupings of canopy tree species (Figures 3.8 and 3.9); and thirdly, for different groupings of sub-canopy tree species (Figures 3.10 to 3.12). This showed how the population structure of different species varied in different parts of the landscape. For all histograms where canopy trees are included, the X-axis show stem diameter (DBH) classes up to 35+ cm DBH. For histograms with only sub-canopy tree species, the X-axis show DBH classes up to 25+ cm DBH. The Y-axis scales varied, depending on the maximum number of stems included in specific DBH classes. Note that the stem diameter class distributions for all species are presented in Appendix 3.1 for canopy tree species, and in Appendix 3.2 for sub-canopy tree species.

3.4.4 Canopy and sub-canopy species across sub-communities

The Y-axis scale was the same for all the sub-communities to ease the comparison of variation of stem density within DBH classes across sub-communities (Figure 3.7). The scaling up to 350 stems per ha was determined by the stem density of sub-canopy trees in the 10-14.9 cm DBH class in sub-community 1.21. The high number of stems of canopy trees in the 35+ DBH class suggest a wide range of sizes of large trees in sub-communities 1.22, 2.1, 2.21 and 2.22. Sub-community 2.22 has a relatively higher stem density in the 25-29.9 DBH class. Sub-communities 1.21, 2.21, and 2.22 show particularly high stem densities in the 10-14.9 cm DBH class for both canopy and sub-canopy tree species (and for sub-canopy tree stems in sub-community 1.22). Sub-communities 1.21, 2.1, 2.21 and 2.22 also show higher number of stems in the 15-19.9 DBH class. Sub-community 2.22 shows overall higher stem densities across all the diameter classes, more than all other sub-communities. Sub-communities 1.11 and 1.12 generally show relatively low stem densities across most DBH classes. Overall, the trend in most sub-communities is towards the inverse J-shaped DBH-class distribution for both canopy and sub-canopy trees species, although this trend is not strong in sub-communities 1.22, 2.1 and 2.22.



Sub-community 1.11

Sub-community 1.12

Sub-community 1.21

Sub-community 1.22

Sub-community 2.21

Sub-community 2.22

Sub-community 2.1

Stems 5.0 to 9.9 cm DBH

Figure 3.7 Stem diameter class distribution for the Canopy and Sub-canopy tree species across the identified forest sub-communities: 1.11 to 1.22 at lower altitude and 2.1 to 2.22 at higher altitude. The histogram in the lower, right corner shows the stem density of stems <10 cm DBH.

Stem density of canopy tree species in stems of <10 cm DBH is relatively low in sub-communities 1.11, 1.12, 1.22 and 2.1 (Figure 3.7), and the same for the sub-canopy tree species, except for sub-community 1.21. Sub-communities 1.21, 2.21 and 2.22 have higher stem densities of canopy tree species, and relatively very high stem densities of >700 stems per ha for sub-canopy tree species in this DBH class in sub-communities 1.21, 1.22, and 2.21.

3.4.5 Population structure of canopy tree species

Five canopy tree species showed good presence in both low and high-altitude forest sub-communities: *Podocarpus latifolius, Scolopia mundii, S. zeyheri, Cussonia spicata* complex, and *Ilex mitis* (Figure 3.8). All the histograms have the same scale for the Y-axis. *P. latifolius* was present in all the sub-communities, but the stem density in both DBH classes <15 cm DBH and in the 35+ cm DBH was much lower in the low-altitude sub-communities than in the high-altitude forests. *S. mundii* was well-presented in mainly the low-altitude sub-community 1.12, but with a DBH-class distribution that resembles a bell-shaped distribution, but mainly because of a lower stem density in the 10-14.9 DBH class. Sub-community 1.11 has a number of stems in the 35+ DBH class, and below 10 cm DBH. This species was present in most DBH classes of sub-communities 2.1 and 2.21 (generally poor presentation). In sub-community 2.1 it was generally well presented in all DBH classes, with a static diameter class distribution, except for stems <10 cm DBH. *S. zeyheri* generally has a better presence than *S. mundii*, in both low and high-altitude forest, but with fewer to no stems in the middle DBH classes. Its population structure in sub-community 1.21 is very different from the other sub-communities, with much higher stem numbers up to the 25-29.9 DBH class, after which there is a sharp drop in stem density in the larger DBH classes. *C. spicata* complex is present in two low-altitude and two high-altitude sub-communities, generally with few stems across most DBH classes. *Ilex mitis* is present in two low-altitude and two high-altitude sub-communities, with overall few stems, almost absent in larger stems, with higher density in stems <10 cm DBH in 1.21, and in 10-14.9 cm DBH class in 2.22.

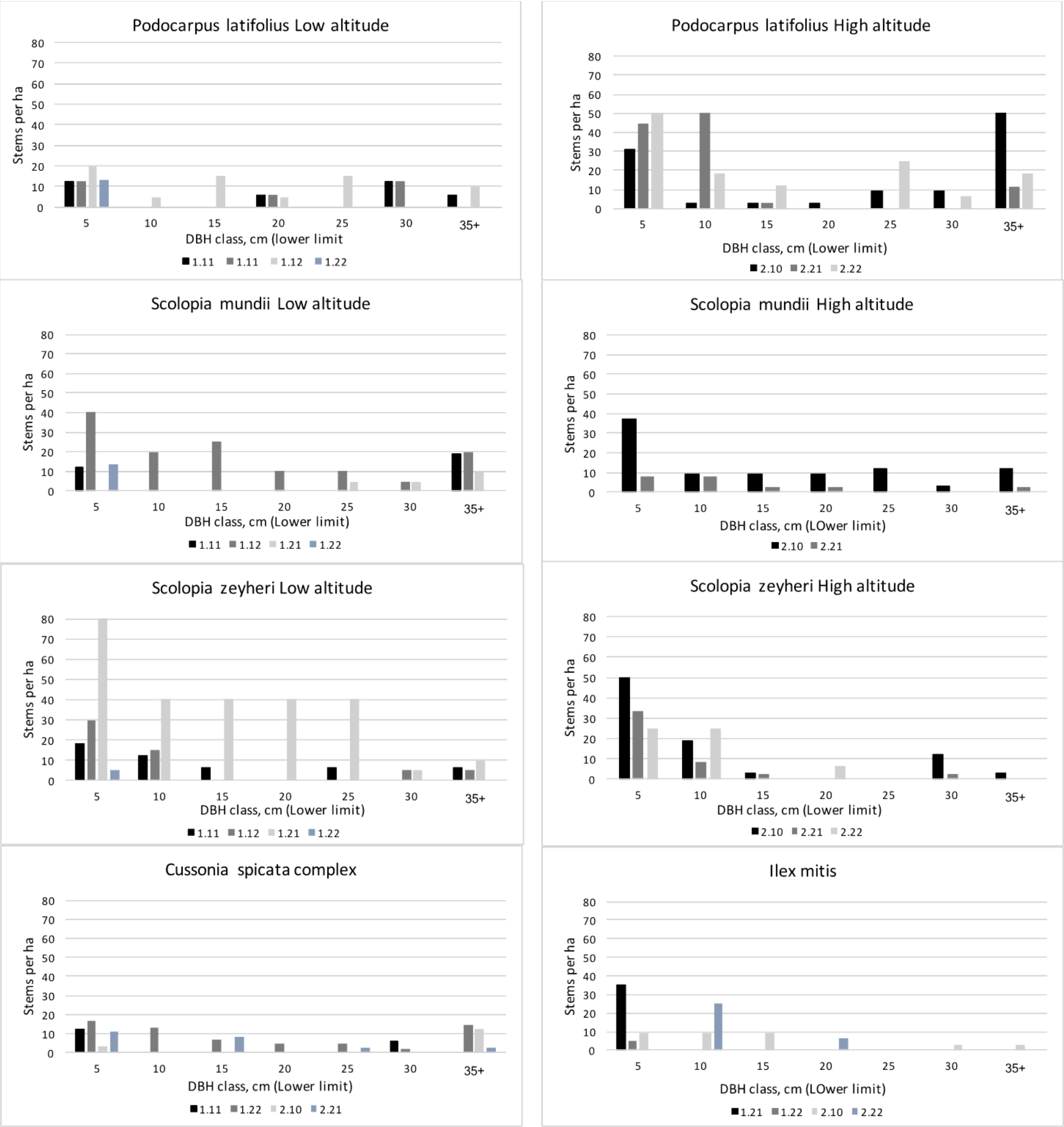


Figure 3.8. Stem diameter class distribution for the canopy tree species that are well presented in both low and high-altitude forests across identified forest sub-communities. The Y-axis scale is the same in all histograms.

Six canopy tree species are well-presented in either mainly low-altitude forests (*Afrocarpus falcatus*, *Celtis africana* and *Commiphora harveyi*) or mainly high-altitude forests (*Olinia emarginata*) or both (*Calodendrum capense* and *Ptaeroxylon obliquum*) across identified forest sub-communities (Figure 3.9). *A. falcatus* has up to 170 large stems ≥35 cm DBH in sub-community 1.22, but with no smaller stems, and has an inverse J-shaped stem diameter class distribution in sub-community 1.11 but with no trees in three of the DBH classes, and then again, a number of stems in the 35+ DBH class. *C. africana* has a few stems in some high-altitude forests but is more present in low-altitude forests. In the three sub-communities where it occurs, only some of the DBH classes have stems, even though in general the stems show an inverse J-shaped trend. *C. harveyi* has a good inverse J-shaped stem diameter class distribution in sub-community 1.22 but has stems in only two smaller DBH classes in sub-community 1.21. *C. capense* occurs in

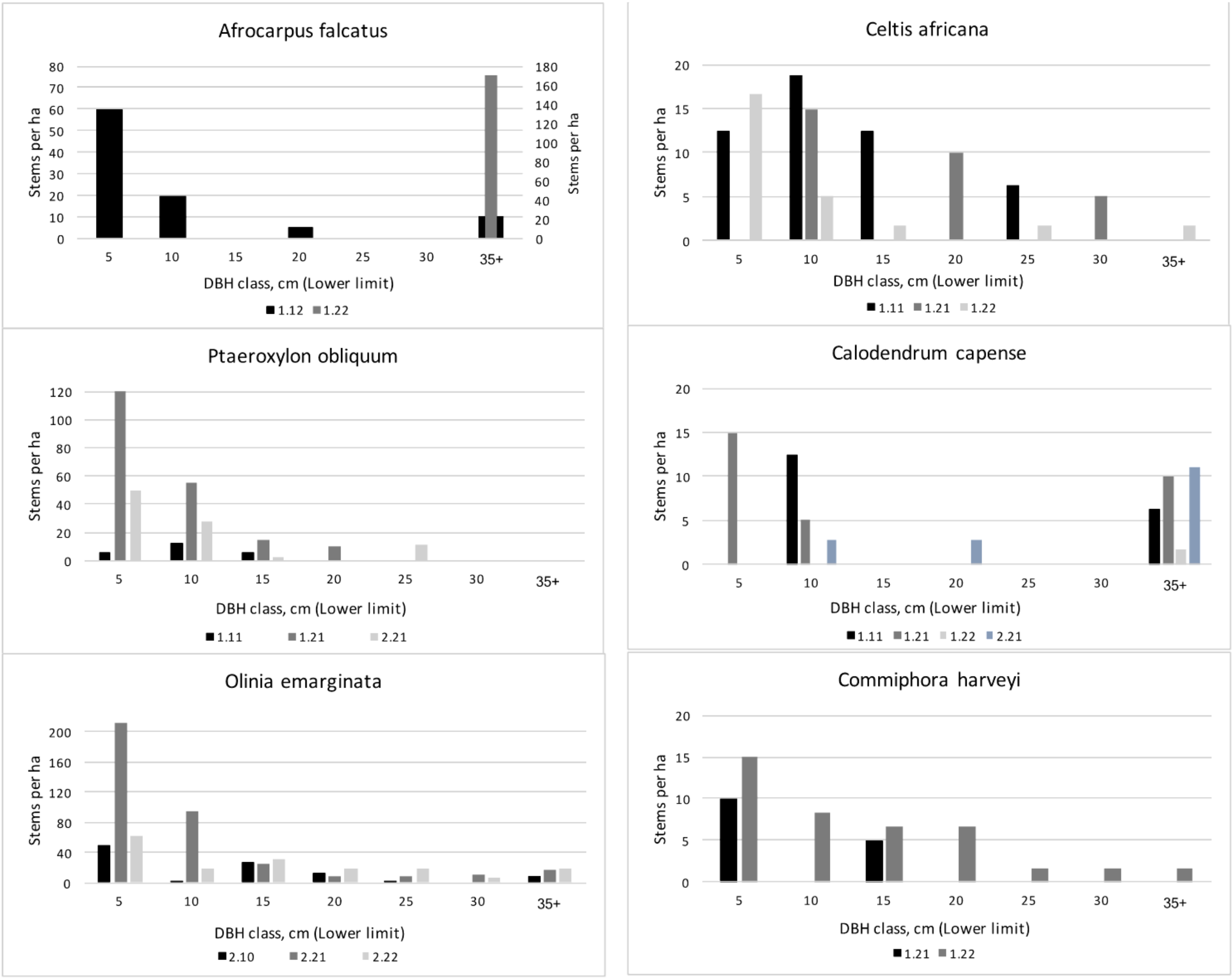


Figure 3.9. Stem diameter class distribution for six canopy tree species that are well presented in either mainly low-altitude forests or mainly high-altitude forests across identified forest sub-communities. Note that the maximum value for the Y-axis for the three species on the left, varies between 80 and 250 stems per ha (with two Y-axis scales for *A. falcatus*), but is the same but only up to 20 stems per ha for the three species on the right.

three sub-communities at low-altitude and one at high-altitude. It occurs as scattered individuals, with several trees <10 or 15 cm DBH, in 1.11 and 1.21, with several large trees in the 35+ cm DBH class in all four sub-communities. *P. obliquum* is relatively abundant in one low-altitude (1.21) and one high-altitude (2.21) sub-community, with low numbers in some DBH classes (<2]0 cm DBH). *O. emarginata* occurs in all the high-altitude forest communities, across most DBH classes. In sub-communities 2.1 and 2.22 it has a relatively lower presence, but in sub-community 2.21 it shows a strong inverse J-shaped stem diameter distribution. It is present with a few small stems in low-altitude sub-community 1.22.

3.4.6 Population structure of sub-canopy tree species

The population structure of three groups of sub-canopy tree species are presented here: firstly, three abundant species with good presence in both low and high-altitude forest sub-communities (Figure 3.10); secondly, species that are well presented in one or a few forest sub-communities with no or few stems elsewhere (Figure 3.11); and thirdly, species that are well-presented in high-altitude forest sub-communities (Figure 3.12). As shown in Figure 3.7, some sub-communities have very dense stands of sub-canopy species. Very few species have stems in the 25+ cm DBH class, and then mostly very few stems.

The three most abundant sub-canopy tree species that occur in both altitudinal zones are *Diospyros whyteana, Gymnosporia buxifolia* and *Searsia dentata* (Figure 3.10) *D. whyteana* is present in all the sub-communities presented here, is the species with the most stems recorded during this study, with most stems <10 cm DBH in both zones, with >1000 stems per ha in high-altitude sub-community 2.21. *Gymnosporia buxifolia* is much more abundant in two low-altitude sub-communities (1.12 and 1.21, with few and small stems in 1.11 and 1.22) than in the two high-altitude sub-communities (2.1 and 2.21). *S. dentata* is relatively abundant in two low-altitude sub-communities (1.21 and 1.22, with few small stems in 1.11), but with few and small stems in the three high-altitude sub-communities.

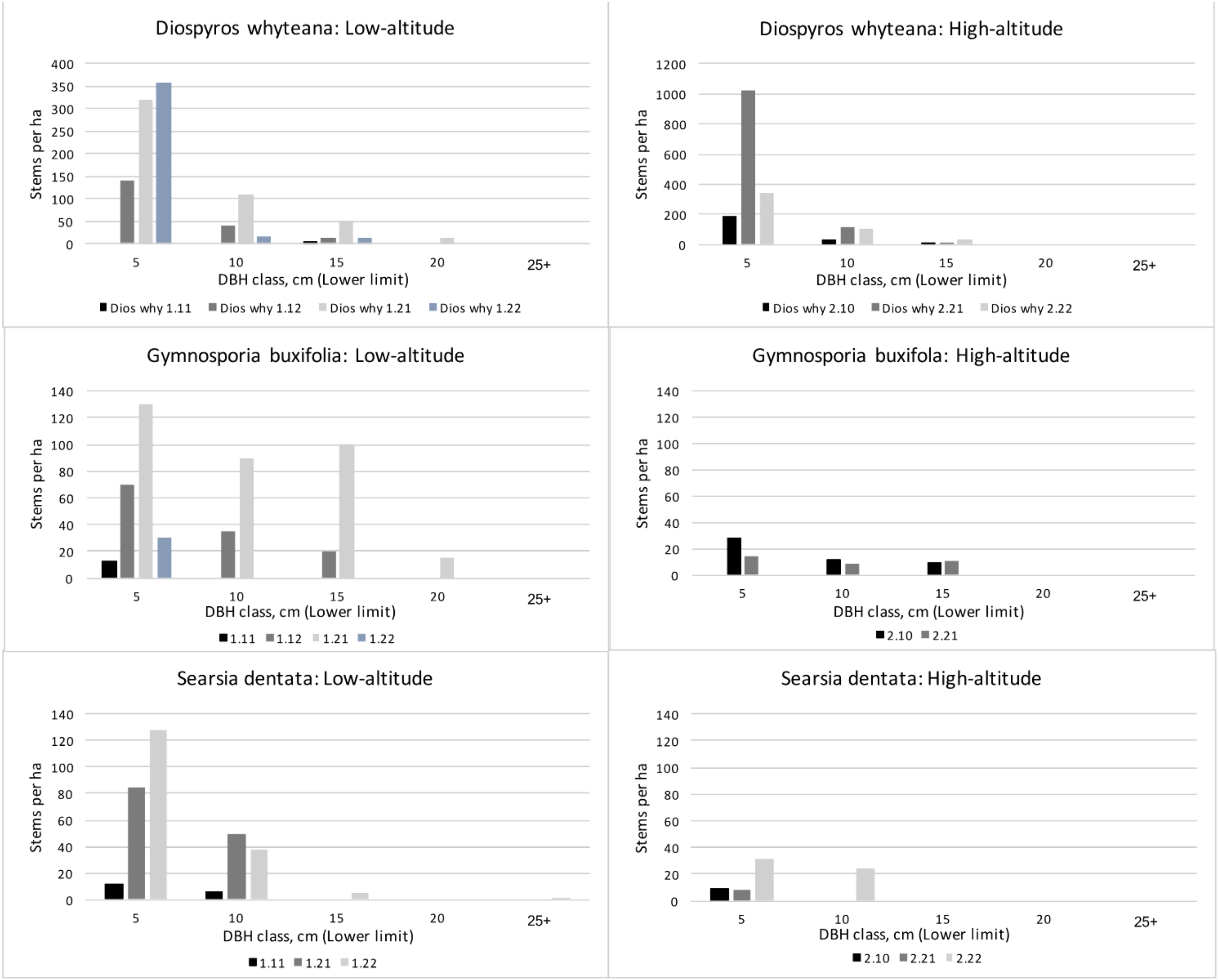


Figure 3.10 Stem diameter class distribution for the sub-canopy tree species that are well presented in both low and high-altitude forests across identified forest sub-communities. Note that the maximum value for the Y-axis for *D. whyteana* varies between 350 and 1000 stems per ha, but is the same up to 140 stems per ha for the other two species.

Four sub-canopy tree species have a good stem density in one or a few forest sub-communities, with no or a few stems elsewhere, and mostly in the low-altitude forests (Figure 3.11). *Pittosporum viridiflorum*, which sometimes does grow to stem diameters larger than what is being presented here, is showing a good stem density in stems <10 cm DBH in the three sub-communities (1.21, 1.22 and 2.22), with >30 stems per ha in the 10-14.9 cm DBH class in sub-community 1.21. The other three species (*A. decipiens*, *C. anisata* and *D. zeyheri*), are all basically low-altitude species with abundant stems in the lowest two DBH classes, mostly in sub-communities 1.21 and 1.22

(note that *C. anisata* has relatively much fewer stems, which looks abundant because of the different Y-axis scales.

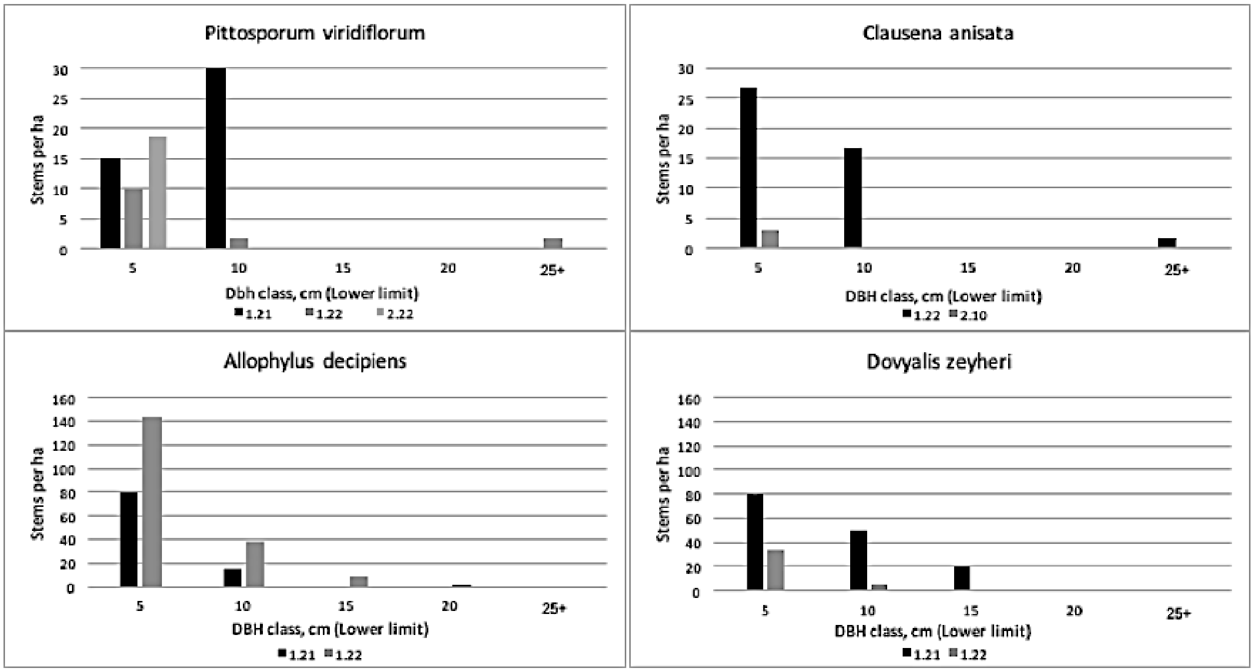


Figure 3.11. Stem diameter class distribution for the sub-canopy tree species that are well presented in mainly low-altitude forests across identified forest sub-communities. Note that the maximum value for the Y-axis varies between 30 for the upper two species and 140 stems per ha for the lower two species.

The sub-canopy tree species that sometimes can be considered as canopy species in drier forests with lower canopy, are well-presented in high-altitude forest sub-communities: *Heteromorpha arborescens*, *Cryptocarya woodii* (also in 1.22) and *Euclea undulata* (Figure 3.12). *H. arborescens* in sub-community 2.1 (the other two sub-communities have too few stems to assess the distribution trend) and *E. undulata* in sub-communities 2.1 and 2.22 tend to show a bell-shaped stem diameter class distribution, whereas *C. woodii* shows an inverse J-shaped distribution in all the sub-communities, as does *E. undulata* in 2.21. *H. arborescens* shows a wide range of stem diameters, more so than the other two species.

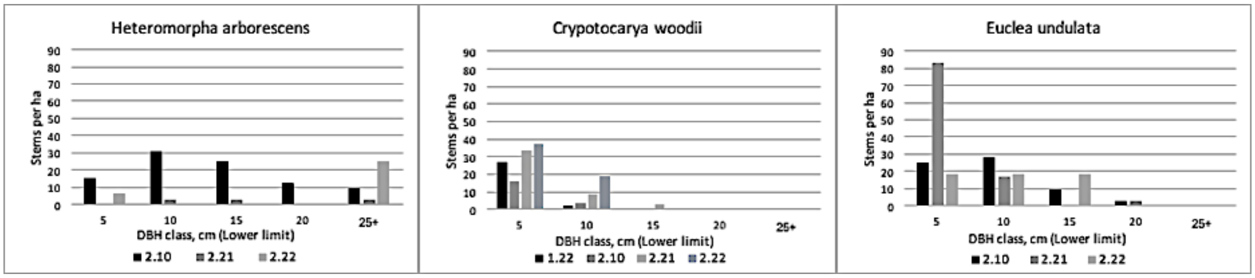


Figure 3.12. Stem diameter class distribution for the Sub-canopy tree species that are well presented in the high-altitude forests across identified forest sub-communities. Note that the same maximum value for the Y-axis is used for the three species.

3.5 Discussion

3.5.1 Observed resource use impacts

There are few resources used from the forests and at a relatively small scale but may have been higher in the past. Most resource use from the forests were observed at lower altitude, closer to where people live, with few signs of resource use at higher altitude and on steep slopes. The most popular species harvested at the low altitude forests are mainly *Afrocarpus falcatus, Scolopia mundii*, *Diospyros whyteana* and *Olinia emarginata*, preferred for poles for house and fence construction (Geldenhuys et al. 2016). However, most of the households within the Ntabelanga Catchment use wattle for firewood and construction because in most areas the natural forests are far away or not easy to access (Geldenhuys et al. 2016).

The change is probably because most of the people have shifted towards building houses made of bricks (mud, cement and/or baked bricks) and people mostly use wattle for both poles and firewood (Geldenhuys et al. 2016), even though some small poles of indigenous tree species are still being harvested from the forests. The change in building style and the shift towards the use of wattle wood could contribute to a recovery of the forests in terms of the density of trees in the lower two DBH classes.

3.5.2 Forest grain

Disturbance regimes seems to differ between the low-altitude forests, with mostly fine-grain forest communities, and high-altitude forests with mainly coarse-grain forest communities. In the low-altitude fine-grain forests, the composition of canopy tree species in the canopy (≥20 cm DBH) and in the regeneration (5-10 cm DBH) were very similar, suggesting that these forests are more stable and dominated by more shade-tolerant species in the canopy. Alternatively, the fine-grain at lower altitude could be related to disturbances such as fire-spotting from outside into the forests, crown breaks from natural causes (gusty wind and snow-fall) and from heavy resource use in the past, causing more regeneration of light-demanding canopy species and giving the impression of a fine grain forest system. However, sub-community 1.21 has a coarser grain. The canopy is dominated by deciduous tree species (*Celtis africana*, *Calodendrum capense* and *Ptaeroxylon obliquum* (Chapter 2), that are light-demanding, with relatively higher density of sub-canopy tree species below 20 cm DBH (Figure 3.7) that may constrain the regeneration of the canopy tree species. In the coarse-grain high-altitude forests (sub-community 2.2), the composition of canopy tree species was different between the canopy and regeneration. The canopy is dominated by the light-demanding canopy tree *Olinia emarginata*, and the sub-canopy is dominated by a high density of the shade-tolerant understory tree *Diospyros whyteana* (Chapter 2). By contrast, sub-community 2.10 (fine grain), is dominated by the shade-tolerant canopy tree *Podocarpus latifolius*. but relatively further apart for sub-communities 2.21 and 2.22 (coarse grain). The tendency that the composition of the regeneration of canopy tree species of the low-altitude sub-communities and of the high-altitude sub-community 2.10, aggregate towards the center of the ordination diagram, was also observed in the Southern Cape Afrotemperate forests (Geldenhuys, 1996a). This could be an indication of what the composition could be of mature forest with relatively small-scale disturbances in this landscape.

Further studies are needed to assess the role of disturbances (causing canopy gaps) such as fire-spotting from outside into the forests, crown breaks from natural causes (gusty wind and snow-fall), landslides on steep slopes, and from heavy resource use in the past, in stimulating the regeneration of light-demanding canopy tree species.

3.5.3 Canopy and sub-canopy species across sub-communities

The low stem density of tree species noted at the low altitude forests could be due to intensive resource harvesting because forest sub-communities 1.11, 1.12 and 1.22 are located near settlements. This also relates to the high percentage of harvesting noted at the low altitude forests within the catchment. However, intensive browsing by cattle could be some of the factors leading to low stem density, especially in smaller size classes. The high stem densities for the sub-canopy tree species noted in forest sub-communities 1.21 and 1.22 may be an indication that these sub-communities are in the recovery stage with high presence of *Gymnosporia buxifolia, Scolopia mundii, Scolopia zeyheri* and *Diospyros whyteana*.

Resource use at higher altitude seem to have an impact on forest community 2.1 and having less impact on 2.21. The latter is not easily accessible for resource use. Some forest patches at high altitude (e.g. 2.1) were accessible for resource use despite the fragmented nature of the landscape.

3.5.4 Population structure of canopy tree species

The harvest of species based on preferences for specific use can have an influence on their population structure especially at the smaller end of the stem diameter class distribution. This may affect the structure and composition of the targeted populations (Ticktin, 2004). A healthy population structure was considered to be one with a high ratio of juvenile to mature trees, and a spread of stems across different stem diameter classes.

The variation in the population structure of *P. latifolius*, *S. mundii* and *S. zeyheri* between the low and high altitude forests, with generally lower numbers noted at low-altitude forest except for sub-community 1.12 for *S. mundii* and sub-community 1.21 for *Scolopia zeyheri*, suggest that resource use for poles is high at the low-altitude forests. The reason for the high presence of these two species in these two sub-communities is due to the nature of the terrain in which they are located. The poor representation of *A. falcatus* in intermediate DBH classes in forest sub-communities 1.12 could be related to higher rate of harvesting of poles at low altitude. However, bark harvesting of mature *A. falcatus* were noted in some parts of the forests at low altitude. Such trees showed no edge regrowth around the debarked wounds. This could have a negative impact on tree species population structure. Population decline of species may be due to mismanagement over resource use, hence leading to harvesting of easily accessible species within the area (Moore and Hall, White, 1988). The low presence of *C. africana* at forest sub-community 1.22 in some DBH classes could be associated with its preference for yoke used in ploughing. *Podocarpus latifolius* and *Olinia emarginata* are mostly common at high altitude. These two species are highly preferred for resource use, however, they are not easily accessed due to the fragmented nature and steep terrain of the landscape in which they exit.

In Ntabelanga Natural Forests, resource harvesting was mainly for small poles (<30 cm stem diameter) mostly of mainly canopy tree species (Geldenhuys et al., 2016). In many rural areas, small-size poles are used at subsistence levels, which could be a major concern if such poles come from canopy species (Obiri et al., 2002).

3.5.5 Population structure of sub-canopy tree species

The three most abundant sub-canopy tree species (*D. whyteana*, *G. buxifolia* and *Searsia dentata*) can fit well at both low and high-altitude forest communities. However, these species can respond well to harvesting disturbances. *Diospyros whyteana* has shown good coppice regrowth after harvesting at low altitude. This could be one of the reasons why it existed at high density at low altitude despite intensive resource use.

More important, the sub-canopy species that are found only at low altitude existing at smaller DBH classes in forest sub-communities 1.21 and 1.22 could be associated with their harvesting for medicinal use. Field observations have shown that *Pittosporum viridiflorum* and *Clausena anisata* are used medicinally, but it is not clear whether the other two species (*Allophylus decipiens* and *Dovyallis zeyheri*) have local use. The relatively abundant regeneration of four species could mean that they are recovering alongside with other sub-canopy species in relation to resource use disturbances.

Some sub-canopy species that are only found at high altitude forests, such as *Heteromorpha arborescens* and *Euclea undulata*, regenerate in larger gaps caused by either tree falls or rock falls, and do not generally form dense stands but rather occur as scattered trees in high altitude forests on steep slopes and on rocky terrain. *Cryptocarya woodii* is generally a shade tolerant species that occasionally grow into slightly larger stems. It is used medicinally, but it is not clear how the local community uses this species.

Understanding the forest grain, forest composition and SCDs is a key in understanding forest dynamics, resource potential and relevant management option to be used (Geldenhuys 1993a; Geldenhuys et al. 2016).

3.6 Conclusion

The study concluded that the Ntabelanga Natural forests are in a recovery stage, after the apparent former high rate of harvesting at low altitude. This is attributed to the shift in the building style observed within the catchment. People are shifting from using poles for wall or roof construction by using baked or cement bricks and the use of poles from wattle for roofing, fencing and firewood. In addition, some forests are recovering because they are not easy to access.

In relation to forest grain, there is variation between the regeneration and canopy composition of the canopy species across forest communities. The fine grain forests are found at low altitude closer to settlements, which were attributed to canopy breaks from resource use and heavy snow falls facilitating the regeneration of more light-demanding canopy species. The coarse-grained forests are mostly found at the high-altitude forests within highly fragmented landscape. This was attributed to a dense layer of stems of sub-canopy tree species that may prevent the canopy dominant light-demanding species to regenerate, with possibly only sporadic canopy gaps. It is suggested that the role of fire-spotting from outside into the forests, crown breaks from natural causes (gusty wind and snow-fall), landslides on steep slopes, and from heavy resource use in the past, in stimulating the regeneration of light-demanding canopy tree species, need more detailed study.

The study found that stem densities are lower at low altitude due to intensive resource use, especially for the forest sub-communities near settlements, although some sub-canopy tree species, such as *Diospyros whyteana* are still present in abundance despite such use. Resource use is higher at low altitude compared to high altitude forests and that was associated with accessibility and proximity of natural forests to the settlements. However, currently the local community mostly use poles from wattle for construction and firewood. The use of such poles could be managed as a silvicultural system of stand thinning to reduce competition and improve growth of individual stems in such stands. In such a system, the sprouting ability of many of these species after cutting need to be considered to sustain resource use. The species characteristics after disturbance and its potential of a species to regenerate and coppice can be a guide to sustainable resource use within the Ntabelanga catchment.

The analyses using forest grain and the size class diameter distributions of the Ntabelanga natural forest have helped to understand the community and population dynamics of these forests, and to guide the framework for sustainable resource use management (in Chapter 4).

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Appendix 3.0

Appendix 3.1: Stems per ha of key canopy and sub-canopy tree species stem diameter classes and forest communities

Number Plots	Species	Sub-com	Stem diameter classes, lower limit, cm							Total
			5	10	15	20	25	30	35+	
Canopy tree species										
5	Afro fal	1.12	60.0	20.0	0.0	5.0	0.0	0.0	10.0	95.0
15	Afro fal	1.22	0.0	0.0	0.0	0.0	0.0	0.0	170.0	170.0
Total			60.0	20.0	0.0	5.0	0.0	0.0	180.0	
4	Calo cap	1.11	0.0	12.5	0.0	0.0	0.0	0.0	6.3	18.8
5	Calo cap	1.21	15.0	5.0	0.0	0.0	0.0	0.0	10.0	30.0
15	Calo cap	1.22	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.7
9	Calo cap	2.21	0.0	2.8	0.0	2.8	0.0	0.0	11.1	16.7
Total			15.0	20.3	0.0	2.8	0.0	0.0	29.0	
4	Celt afri	1.11	12.5	18.8	12.5	0.0	6.3	0.0	0.0	50.0
5	Celt afri	1.21	0.0	15.0	0.0	10.0	0.0	5.0	0.0	30.0
15	Celt afri	1.22	16.7	5.0	1.7	0.0	1.7	0.0	1.7	26.7
8	Celt afri	2.10	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1
9	Celt afri	2.21	0.0	0.0	0.0	0.0	2.8	0.0	0.0	2.8
Total			29.2	38.8	14.2	10.0	10.7	5.0	4.8	
5	Comm har	1.21	10.0	0.0	5.0	0.0	0.0	0.0	0.0	15.0
15	Comm har	1.22	15.0	8.3	6.7	6.7	1.7	1.7	1.7	41.7
Total			25.0	8.3	11.7	6.7	1.7	1.7	1.7	
4	Cuss spi	1.11	12.5	0.0	0.0	0.0	0.0	6.3	0.0	18.8
15	Cuss spi	1.22	16.7	13.3	6.7	5.0	5.0	1.7	15.0	63.3
8	Cuss spi	2.10	3.1	0.0	0.0	0.0	0.0	0.0	12.5	15.6
9	Cuss spi	2.21	11.1	0.0	8.3	0.0	2.8	0.0	2.8	25.0
Total			43.4	13.3	15.0	5.0	7.8	7.9	30.3	
8	Hete arb	2.10	15.6	31.3	25.0	12.5	9.4	0.0	0.0	93.8
9	Hete arb	2.21	0.0	2.8	2.8	0.0	2.8	0.0	0.0	8.3
4	Hete arb	2.22	6.3	0.0	0.0	0.0	25.0	0.0	0.0	31.3
Total			21.9	34.0	27.8	12.5	37.2	0.0	0.0	
5	Ilex mit	1.21	35.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0
15	Ilex mit	1.22	5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
8	Ilex mit	2.10	9.4	9.4	9.4	0.0	0.0	3.1	3.1	34.4
4	Ilex mit	2.22	0.0	25.0	0.0	6.3	0.0	0.0	0.0	31.3
Total			49.4	34.4	9.4	6.3	0.0	3.1	3.1	
5	Myst aet	1.21	0.0	0.0	10.0	0.0	0.0	0.0	0.0	10.0
15	Myst aet	1.22	1.7	0.0	0.0	0.0	0.0	1.7	0.0	3.3
Total			1.7	0.0	10.0	0.0	0.0	1.7	0.0	
15	Olin ema	1.22	6.7	0.0	0.0	0.0	0.0	0.0	0.0	6.7
8	Olin ema	2.10	50.0	3.1	28.1	12.5	3.1	0.0	9.4	106.3
9	Olin ema	2.21	211.1	94.4	25.0	8.3	8.3	11.1	16.7	375.0

Number Plots	Species	Sub-com	Stem diameter classes, lower limit, cm							Total
			5	10	15	20	25	30	35+	
4	Olin ema	2.22	62.5	18.8	31.3	18.8	18.8	6.3	18.8	175.0
Total			330.3	116.3	84.4	39.6	30.2	17.4	44.8	
5	Pitt viri	1.21	15.0	30.0	0.0	0.0	0.0	0.0	0.0	45.0
15	Pitt viri	1.22	10.0	1.7	0.0	0.0	1.7	0.0	0.0	13.3
4	Pitt viri	2.22	18.8	0.0	0.0	0.0	0.0	0.0	0.0	18.8
Total			43.8	31.7	0.0	0.0	1.7	0.0	0.0	
4	Plue cap	2.22	62.5	62.5	18.8	18.8	31.3	6.3	25.0	225.0
4	Podo lat	1.11	12.5	0.0	0.0	6.3	0.0	12.5	6.3	37.5
4	Podo lat	1.11	12.5	0.0	0.0	6.3	0.0	12.5	0.0	31.3
5	Podo lat	1.12	20.0	5.0	15.0	5.0	15.0	0.0	10.0	70.0
15	Podo lat	1.22	13.3	0.0	0.0	0.0	0.0	0.0	0.0	13.3
8	Podo lat	2.10	31.3	3.1	3.1	3.1	9.4	9.4	50.0	109.4
9	Podo lat	2.21	44.4	50.0	2.8	0.0	0.0	0.0	11.1	108.3
4	Podo lat	2.22	50.0	18.8	12.5	0.0	25.0	6.3	18.8	131.3
Total			184.0	76.9	33.4	20.6	49.4	40.6	96.1	
4	Ptae obl	1.11	6.3	12.5	6.3	0.0	0.0	0.0	0.0	25.0
5	Ptae obli	1.21	120.0	55.0	15.0	10.0	0.0	0.0	0.0	200.0
9	Ptae obli	2.21	50.0	27.8	2.8	0.0	11.1	0.0	0.0	91.7
Total			176.3	95.3	24.0	10.0	11.1	0.0	0.0	
9	Rapa mel	2.21	0.0	0.0	0.0	2.8	0.0	0.0	0.0	2.8
4	Rapa mel	2.22	0.0	0.0	6.3	0.0	0.0	6.3	0.0	12.5
Total			0.0	0.0	6.3	2.8	0.0	6.3	0.0	
4	Scol mun	1.11	12.5	0.0	0.0	0.0	0.0	0.0	18.8	31.3
5	Scol mun	1.12	40.0	20.0	25.0	10.0	10.0	5.0	20.0	130.0
5	Scol mun	1.21	0.0	0.0	0.0	0.0	5.0	5.0	10.0	20.0
15	Scol mun	1.22	13.3	0.0	0.0	0.0	0.0	0.0	0.0	13.3
8	Scol mun	2.10	37.5	9.4	9.4	9.4	12.5	3.1	12.5	93.8
9	Scol mun	2.21	8.3	8.3	2.8	2.8	0.0	0.0	2.8	25.0
Total			111.7	37.7	37.2	22.2	27.5	13.1	64.0	
4	Scol zey	1.11	18.8	12.5	6.3	0.0	6.3	0.0	6.3	50.0
5	Scol zey	1.12	30.0	15.0	0.0	0.0	0.0	5.0	5.0	55.0
5	Scol zey	1.21	85.0	40.0	40.0	40.0	40.0	5.0	10.0	260.0
15	Scol zey	1.22	5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
8	Scol zey	2.10	50.0	18.8	3.1	0.0	0.0	12.5	3.1	87.5
9	Scol zey	2.21	33.3	8.3	2.8	0.0	0.0	2.8	0.0	47.2
4	Scol zey	2.22	25.0	25.0	0.0	6.3	0.0	0.0	0.0	56.3
Total			247.1	119.6	52.2	46.3	46.3	25.3	24.4	
5	Vepr lan	1.21	5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
15	Vepr lan	1.22	1.7	1.7	0.0	0.0	0.0	0.0	6.7	10.0
9	Vepr lan	2.21	0.0	0.0	0.0	0.0	0.0	0.0	11.1	11.1
Total			6.7	1.7	0.0	0.0	0.0	0.0	17.8	
5	Xyma mon	1.21	5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
15	Xyma mon	1.22	6.7	0.0	0.0	0.0	0.0	1.7	0.0	8.3

Number Plots	Species	Sub-com	Stem diameter classes, lower limit, cm							Total
			5	10	15	20	25	30	35+	
Total			11.7	0.0	0.0	0.0	0.0	1.7	0.0	
Sub-canopy tree species										
5	Allo dec	1.21	80.0	15.0	0.0	0.0	0.0	0.0	0.0	95.0
15	Allo dec	1.22	143.3	38.3	8.3	1.7	0.0	0.0	0.0	191.7
Total			223.3	53.3	8.3	1.7	0.0	0.0	0.0	
8	Cant cil	2.10	28.1	12.5	9.4	0.0	0.0	0.0	0.0	50.0
15	Cass ili	1.22	30.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
8	Cass ili	2.10	78.1	0.0	0.0	0.0	0.0	0.0	0.0	78.1
9	Cass ili	2.21	55.6	2.8	0.0	2.8	0.0	0.0	0.0	61.1
Total			163.7	2.8	0.0	2.8	0.0	0.0	0.0	
15	Clau ani	1.22	26.7	16.7	0.0	0.0	1.7	0.0	0.0	45.0
8	Clau ani	2.10	3.1	0.0	0.0	0.0	0.0	0.0	0.0	3.1
Total			29.8	16.7	0.0	0.0	1.7	0.0	0.0	
15	Cryp woo	1.22	26.7	1.7	0.0	0.0	0.0	0.0	0.0	28.3
8	Cryp woo	2.10	15.6	3.1	0.0	0.0	0.0	0.0	0.0	18.8
9	Cryp woo	2.21	33.3	8.3	2.8	0.0	0.0	0.0	0.0	44.4
4	Cryp woo	2.22	37.5	18.8	0.0	0.0	0.0	0.0	0.0	56.3
Total			113.1	31.9	2.8	0.0	0.0	0.0	0.0	
15	Dios lyc	1.22	1.7	0.0	0.0	0.0	0.0	0.0	0.0	1.7
4	Dios why	1.11	0.0	0.0	6.3	0.0	0.0	0.0	0.0	6.3
5	Dios why	1.12	140.0	40.0	15.0	0.0	0.0	0.0	0.0	195.0
5	Dios why	1.21	320.0	110.0	50.0	15.0	0.0	0.0	0.0	495.0
15	Dios why	1.22	358.3	16.7	13.3	0.0	0.0	0.0	0.0	388.3
8	Dios why	2.10	184.4	31.3	15.6	0.0	0.0	0.0	0.0	231.3
9	Dios why	2.21	1027.8	119.4	13.9	0.0	0.0	0.0	0.0	1161.1
4	Dios why	2.22	343.8	106.3	37.5	0.0	0.0	0.0	0.0	487.5
Total			2374.2	423.6	151.6	15.0	0.0	0.0	0.0	
5	Dovy zey	1.21	80.0	50.0	20.0	0.0	0.0	0.0	0.0	150.0
15	Dovy zey	1.22	33.3	5.0	0.0	0.0	0.0	0.0	0.0	38.3
Total			113.3	55.0	20.0	0.0	0.0	0.0	0.0	
8	Eucl und	2.10	25.0	28.1	9.4	3.1	0.0	0.0	0.0	65.6
9	Eucl und	2.21	83.3	16.7	0.0	2.8	0.0	0.0	0.0	102.8
4	Eucl und	2.22	18.8	18.8	18.8	0.0	0.0	0.0	0.0	56.3
Total			127.1	63.5	28.1	5.9	0.0	0.0	0.0	
4	Gymn bux	1.11	12.5	0.0	0.0	0.0	0.0	0.0	0.0	12.5
5	Gymn bux	1.12	70.0	35.0	20.0	0.0	0.0	0.0	0.0	125.0
5	Gymn bux	1.21	130.0	90.0	100.0	15.0	0.0	0.0	0.0	335.0
15	Gymn bux	1.22	30.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
8	Gymn bux	2.10	28.1	12.5	9.4	0.0	0.0	0.0	0.0	50.0
9	Gymn bux	2.21	13.9	8.3	11.1	0.0	0.0	0.0	0.0	33.3
Total			284.5	145.8	140.5	15.0	0.0	0.0	0.0	
4	Hall luc	1.11	0.0	12.5	0.0	0.0	0.0	0.0	0.0	h12.5

Number Plots	**Species**	**Sub-com**	**Stem diameter classes, lower limit, cm**							**Total**
			5	**10**	**15**	**20**	**25**	**30**	**35+**	
15	Hall luc	1.22	6.7	0.0	0.0	0.0	0.0	0.0	0.0	6.7
8	Hall luc	2.10	25.0	9.4	18.8	0.0	3.1	0.0	0.0	56.3
9	Hall luc	2.21	2.8	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Total			34.4	21.9	18.8	0.0	3.1	0.0	0.0	
15	Ilat spp	1.22	5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
15	Ilot han	1.22	1.7	0.0	0.0	0.0	0.0	0.0	0.0	1.7
5	Lusi tsh	1.21	5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
4	Sear den	1.11	12.5	6.3	0.0	0.0	0.0	0.0	0.0	18.8
5	Sear den	1.21	85.0	50.0	0.0	0.0	0.0	0.0	0.0	135.0
15	Sear den	1.22	128.3	38.3	5.0	0.0	0.0	0.0	1.7	173.3
8	Sear den	2.10	9.4	0.0	0.0	0.0	0.0	0.0	0.0	9.4
9	Sear den	2.21	8.3	0.0	0.0	0.0	0.0	0.0	0.0	8.3
4	Sear den	2.22	31.3	25.0	0.0	0.0	0.0	0.0	0.0	56.3
Total			274.8	119.6	5.0	0.0	0.0	0.0	1.7	
4	Zant cap	1.11	6.3	0.0	0.0	0.0	0.0	0.0	0.0	6.3
5	Zant cap	1.21	5.0	5.0	0.0	0.0	0.0	0.0	0.0	10.0
15	Zant cap	1.22	16.7	5.0	0.0	0.0	1.7	0.0	0.0	23.3
Total			27.9	10.0	0.0	0.0	1.7	0.0	0.0	

Chapter 4: Composition and stand dynamics of Ntabelanga natural forests: Synthesis and management frame guidelines

4.1 Introduction

In the natural forests in the Ntabelanga catchments in the Maclear area in the Eastern Cape, South Africa, it was important to know how these fragmented forest patches are affected by the use of various products in relation to resource use from invader plant stands that are to be cleared from the area. The most important question raised was whether the clearance of invader plant stands within the catchment would revert pressure on the natural forests from the rural society using products they need from the natural forests.

A knowledge and understanding of the floristic and structural composition of forests are important to achieve sustainable management of forests (Geldenhuys andv Murray 1993; Pappoe et al. 2010; Farhadi et al. 2013). This helps to relate the specific forests to other forests (Von Maltitz et al. 2003) and to identify ecologically and economically important plant species (Addo-Fordjour et al. 2009). Such information is critical for the development of sustained use of the forest resources. Forests provide a wide range of ecosystem services, including species conservation, erosion control and habitat for both flora and fauna (Armenteras et al. 2009). They also act as a safety net for the livelihoods of people in both the rural and urban areas (Emanuel et al. 2005). The misuse of forest resources may result in major environmental and economic problems globally (Mani and Parthasarathy 2006). Their varied use over time and space (Taylor et al. 2008) has varied impacts on forests (Thapa and Chapman 2010), resulting in an ecological change in structure and composition of forest ecosystems, affecting the survival rate, growth and reproduction of harvested species (Denslow 1995).

Previous studies indicated that unsustainable resource use, especially by rural communities (Willis 2004), has serious impacts on natural forests in South Africa. The subsistence use of wood and non-wood products (e.g. laths, poles, bark and fuelwood) is one of the major disturbances facing the natural forests (Obiri et al. 2002). This may create gaps which may influence forest structure (Scoot and Steenkamp, 1996). However, studies have also shown that forest response to disturbance is associated with the ecology of that specific forest type and its grain (i.e. the regeneration status related to the relative shade tolerance of canopy tree species) (Midgley et al. 1990; Everard et al. 1995; Geldenhuys 1996).

Studies have shown that there is a gap in understanding the natural ecological processes in natural forests that may result in insufficient and costly management approaches (Geldenhuys 1997). The general practice in invader plant control is to clear the invader plants because the natural vegetation and invader plant stands have the same ecological requirements (they are adapted to large-scale disturbances and are intolerant of shade), causing direct competition for the same site. This practice is therefore successful in the fynbos and grassland biomes (Richardson and Van Wilgen 2004). Geldenhuys and Bezuidenhout (2011) indicated such clearance of invasive alien plants to recover natural forests, as many people perceive to be the best practice, may lead to fast recovery of invasive alien plant stands at high density, which would cause high clearing costs. In the forest biome, this practice is inadequate because major disturbances created by the clearance of invader plants tend to stimulate massive recruitment of the light-demanding invader plants. This was shown in a study at Buffeljagsrivier, Western Cape Province (Atsame-Edda 2014; Geldenhuys et al. 2016). Indigenous forest species were spreading into the invading wattle stands developing on the abandoned agricultural land along the riverine terraces. Other studies have shown that invasive species emerged in several disturbed forest ecosystems, reducing ecosystem services (Cannon et al. 1998). It is necessary to understand human-related disturbances and how they affect biodiversity and forest vegetation structure to help conservationists to suggest best forest management practices (Pinard et al. 2000). The Ntabelanga study (Geldenhuys et al. 2016) has highlighted the need for implementing sustainable resource use through relevant institutional structures, practical guidelines for sustainable resource use and control of wattle invasion within the Ntabelanga catchment.

The main objective of this study was to assess the floristic-structural composition and stand dynamics of natural forests within the Ntabelanga catchments around Maclear, Eastern Capes, in relation to site and disturbances factors, as basis for a resource management framework. The study pursued two specific objectives.

4.1.1 Specific objective 1

To assess how the floristiccomposition of natural forests vary along the main altitudinal, topographical and disturbance gradients within the Ntabelanga catchments as a basis for the development of sustainable forest management strategies. The study tried to answer the following research questions:

1. What is the relationship in terms of species composition of the Ntabelanga forest communities with the national forest types of South Africa?
2. How does the floristic composition of the forests vary along the macro and local altitudinal gradients within the catchments?
3. How do altitude, aspect and slope affect the floristic and structural composition of the forest communities?

4.1.2 Specific objective 2

To determine the scale of disturbances that influence the composition of the forests and their regeneration status at community and population levels. The study tried to answer the following research questions:

1. What are the main natural and human disturbances (e.g. snow, fire, tree falls and resource use) impacting on the forests and species in the Ntabelanga forests?
2. What is the relationship between the composition of the canopy species in a stand in the regeneration and canopy of the same stand within the different forest communities?
3. What are the characteristic stem diameter class distributions (population structure) of key ecologically and used tree species across different identified communities in the Ntabelanga Forests, how can they be used to guide the development of silvicultural management systems for sustainable resource use in different forest communities?

This chapter elaborates the synthesis of the main findings in this study (Chapters 2 and 3) and provides a guiding management plan framework on how to manage the natural forests within the Ntabelanga catchment.

4.2 Study conceptual framework

The conceptual framework highlights the overall and specific objectives of the study needed to address the components of the study (Figure 4.1). It was developed based on composition, biogeography and structure of natural forests in Ntabelanga area in relation to type and scale of disturbances and its relation to the national forest types in the surrounding areas. This would pave a way towards sustainable resource use from the forest for better conserving its products, values and services.

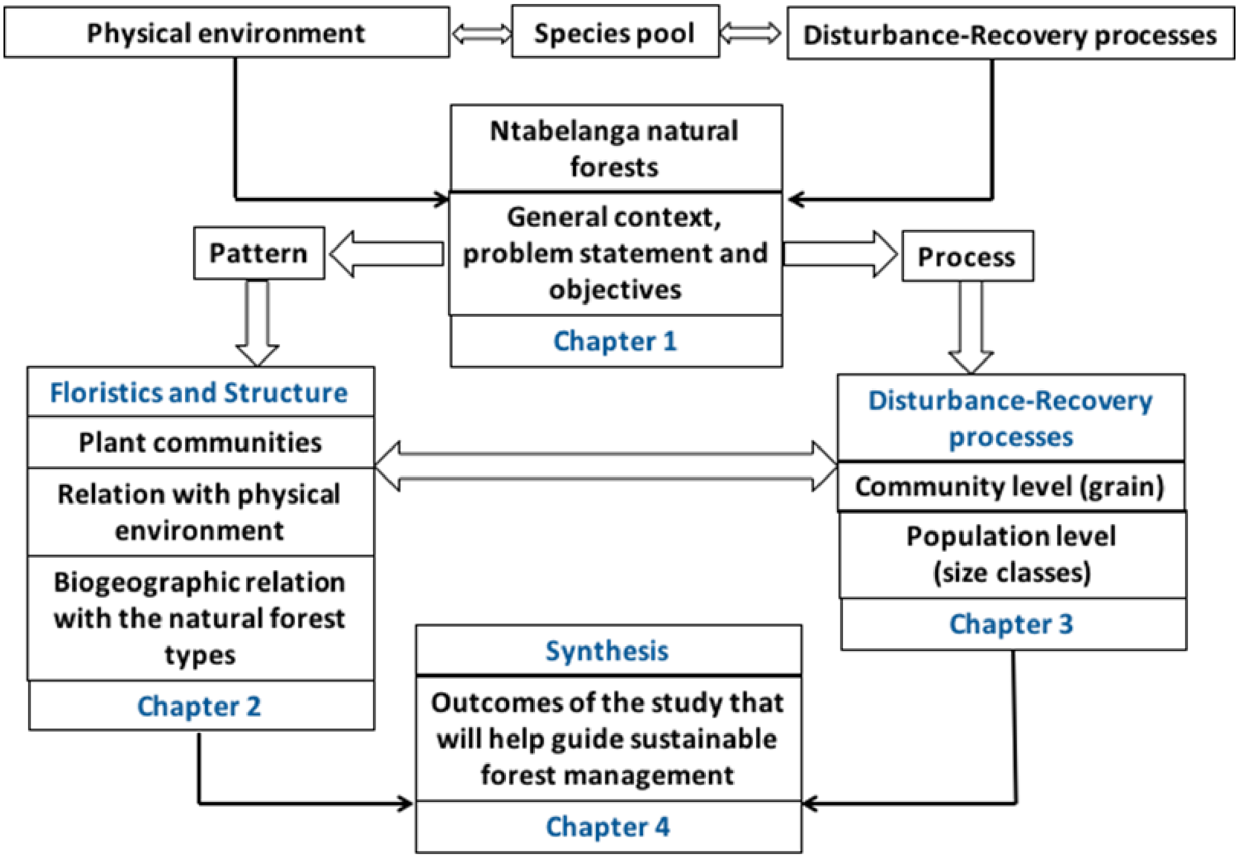

Figure 4.1: Conceptual framework for the study of Ntabelanga natural forests to guide sustainable use of the products, values and services provided by the forests.

4.3 Summary and main findings

4.3.1 Chapter 2

Specific objective 1 was achieved, and all the related questions were answered successfully. The study recorded 63 species of trees and large shrubs from 56 plots, of which only 55 were positively identified by their botanical names. These species representat 49 genera in 30 families. The Celastraceae and Rutaceae families included high number of species (8 and 6 species respectively). Several families had only one species present: Araliaceae, Aquifoliaceae, Apocynaceae, Apiaceae, Burseraceae, Celtidaceae, Hamamelidaceae, Lauraceae, Monimiaceae, Oliniaceae, Ptaeroxylaceae, Pittosposraceae, Scrophulariaceae and Solanaceae.

The species sampled represented 40% canopy tree species, 36% sub-canopy tree species, 12% shrub species and 12% other species (scramblers, lianas and ferns). Most tree species were evergreen (71%), with 19% deciduous and 10% semi-deciduous.

The highest number of woody species (49) was found at low altitude compared to the 28 species at higher altitude forests. These species were used to compare the biogeographic relationships with the three nearby South African National Forests Types. The results suggested that both the low- and high-altitude Ntabelanga natural forests occupied an intermediate, linking position (36.7%) between the national forest types. The sharing of the Ntabelanga woody forest species between the three nearby national forest types is high (73.5% to 85.3%). Species composition showed a strong similarity with both the Eastern Mistbelt and Drakensberg Montane Forests (respectively 63.3% and 65.3% for the Ntabelanga low-altitude forests, and 85.3% and 73.5% for Ntabelanga high-altitude forests). The similarity was lower with the Transkei Mistbelt Forests (respectively 57.1% and 71.4%).

Some species were noted to be confined only to the nearby national forest types (*Capparis sepiaria* var. *citrifolia, Capparis tomentosa, Commiphora harveyi, Diospyros lycioides* subsp. *lycioides, Euclea undulata, Morella serrata, Mystroxylon aethiopicum* subsp. *aethiopicum* and *Zanthoxylum capense*) Other species were confined only to the Ntabelanga high altitude forests (*Canthium inerme, Canthium kuntzeanum, Cassinopsis ilicifolia, Maytenus acuminata and Maytenus undata)*.

The TWINSPAN classification produced four communities and six sub-communities (see their description in Section 4.4).

4.3.3 Chapter 3

Specific objective 2 was achieved, and all the related questions were answered.

4.3.3.1 Common types of disturbances

The most common types of disturbances noted in the sampled areas were grassland fires burning into forest edges; sometimes destroying expanding forest edges (Figure 3.3a). Crown breaks from snow and heavy wind were common at high altitude on steep slopes (Figure 3.3b). Firewood collection of both dead and alive wood were occasionally observed (Figure 3.3c), but alive poles of small stems were sometimes collected from dense stands of thin-sized trees in the understory (Figure 3.3d). Some cut stumps responded positively by sprouting such as a *Scolopia mundii* tree freshly cut for a pole (Figure 3.3e), sprouting on cut stems of *Afrocarpus falcatus* and *Scolopia mundii* (Figure 3.3f), and strong, vigorous sprouting shoots of *A. falcatus* after stem (12 cm diameter) was cut. Sometimes the sprouting on a cut stump is browsed by cattle, as one example of a *Scolopia mundii* (Figure 3.3h). A tree of *Podocarpus latifolius* with about 20 cm DBH was cut >1 m above the ground, some time ago, but did not sprout (Figure 3.3i). Most of the observed bark harvesting was old (Figure 3.3j), but occasionally some fresh harvesting was seen (Figure 3.3k). Some tree species showed no recovery after bark harvesting (such as *A. falcatus*; Figure 3.3l) but others recovered well, such as the good edge growth in *Ptaeroxylon obliquum* (Figure 3.3m).

More plots showed resource use at low altitude (33 %) when compared to high altitude forests (8%; Table 3.2). At low altitude, 36% of plots in sub-communities 1.12 and 1.22 recorded harvesting, but no harvesting was recorded in sub-communities 1.11 and 1.21. At high altitude, harvesting was recorded in 9% of plots in sub-communities 2.1 and 2.21, but no harvesting in sub-community 2.22. A relatively high percentage (2-9%) plots showed harvesting of *Afrocarpus falcatus*, *Scolopia mundii*, *S. zeyheri*, *Gymnosporia buxifolia*, *Cassine peragua*, *Vepris lanceolata* and *Olinia emarginata* in forest sub-communities 1.12 and 1.22. *Mystroxylon aethiopicum, Ilex mitis* and *Commiphora harveyi* were only harvested in forest sub-community 1.22. In the high-altitude forests, 3% of plots showed harvesting in forest community 2.1 for *Scolopia zeyheri* and

Diospyros whyteana; and 5% for sub-community 2.21 for *Podocarpus latifolius, Olinia emarginata* and *Scolopia zeyheri*. Other resources harvested, other than poles, were firewood for cooking and social needs, and bark for traditional medicine.

4.3.3.2 Grain analyses

The grain analysis DCA ordination clearly separated the low-altitude forests (Community 1) from the high-altitude forests (Community 2) along Axis 1 (Figure 3.6). The mean scores for composition of canopy tree species in the canopy (≥20 cm DBH) and in the regeneration (5-10 cm DBH) within low-altitude forests were very similar for sub-community 1.11 (very fine grain), relatively similar for sub-communities 1.12 and 1.22 (fine grain), but relatively far apart for sub-community 1.21 (coarser grain). Within the high-altitude forests, the mean scores were relatively similar for sub-community 2.10 (fine grain), but relatively further apart for sub-communities 2.21 and 2.22 (coarse grain). The composition of the regeneration of canopy trees in the low-altitude sub-communities, and of the high-altitude sub-community 2.10 tend to be closer to the composition of the fine-grain communities closer to the center of the ordination diagram. It was suggested that the observed patterns could relate to larger forest gaps caused by snowfall, strong wind on steep slopes that would cause good regeneration even of more shade-intolerant species, even in relatively fine-grain forest.

4.3.4 Stem diameter class distributions across sub-communities and key tree species

The stem diameter class distributions have been assessed at different levels of the forests: firstly, for all canopy and sub-canopy species in each sub-community (Figure 3.7); secondly, for different groupings of canopy species (Figures 3.8 and 3.9); and thirdly, for different groupings of sub-canopy species (Figures 3.10 to 3.12), and in table format for all species (Appendices 3.1 and 3.2). This showed how the population structure of different canopy and sub-canopy species varied in different parts of the landscape, and under different resource use pressures. Resource use focused on the smaller stems, but several species showed the ability to recover through stem sprouting. The relatively high density of stems in the smaller stem diameter classes of several species showed that the forests were in a state of recovery after former heavy resource use; current levels of resource use from the forests are relatively low.

The high number of stems of canopy trees in the 35+ DBH class suggest a wide range of sizes of large trees in sub-communities 1.22, 2.1, 2.21 and 2.22. Sub-community 2.22 has a relatively higher stem density in the 25-29.9 DBH class. Sub-communities 1.21, 2.21, and 2.22 show particularly high stem densities in the 10-14.9 cm DBH class for both canopy and sub-canopy tree species (and for sub-canopy tree stems in sub-community 1.22). Sub-communities 1.21, 2.1, 2.21 and 2.22 also show higher number of stems in the 15-19.9 DBH class. Sub-community 2.22 shows overall higher stem densities across all the diameter classes, more than all other sub-communities. Sub-communities 1.11 and 1.12 generally show relatively low stem densities across most DBH classes. Overall, the trend in most sub-communities is towards the inverse J-shaped DBH-class distribution for both canopy and sub-canopy trees species, although this trend is not strong in sub-communities 2.1 and 2.22.

Some sub-communities show relatively low stem density of canopy tree species in stems <10 cm DBH (1.11, 1.12, 1.22, 2.1; Figure 3.7), and for sub-canopy tree species, except for sub-community 1.21. By contrast, some sub-communities 1.21, 2.21 and 2.22 have higher stem densities of canopy tree species (1.21, 2.21,2.22), and relatively very high stem densities of >700 stems per ha for sub-canopy tree species in this DBH class (in 1.21, 1.22, and 2.21). These forest communities are situated near settlements, especially at lower altitude, except for forest sub-community 2.21. Resource use in these areas is relatively higher, causing mainly light demanding species to recover. However, some species can positively respond to harvesting by sprouting or coppicing faster than others. The high number of stems in forest sub-community 2.21 could be associated with snow damage at high altitude, meaning that the stand might be in a recovery stage since human disturbance is at minimum level.

4.4 Description of Ntabelanga natural forest communities

The floristic-structural composition and stand dynamics of forest types and population characteristics of their important species form the basis of sustainable forest management. Such information is particularly relevant for zoning the area into management classes (resource use, protecction, nature reserve, recreation and research) and to guide decisions on managing important, rare or threatened plant communities (Geldenhuys and Venter 2002).

The Ntabelanga natural forest communities are described based on floristic composition, diagnostic species and their location on the landscape ((Table 4.1; Figure 4.2). Two stand types were not included into the classification because they were composed of only one species each. *Leucosidea sericea* stands grow as scrub or scrub-forest at high altitude. *Hippobromus pauciflorus* stands grow as regrowing scrub-forest at both low and high altitude.

4.5 Discussion and guiding framework for the management of Ntabelanga natural forests

Studies have shown that wattle is an important wood resource in rural communities, highly used for firewood and house construction, but the society also needs the spread of wattle to be controlled. Field observations have shown that most of the rural community use wood and non-wood products from both natural forests and wattle stands for poles, laths and firewood, especially during their very cold winter season (Geldenhuys et al. 2016). The resource use plan should be based on the needs and priorities of the management institution and beneficiaries at large.

4.5.1 Resource use management system

The management system should be based on the forest communities, the population structure of key species and how species respond to resource harvesting, within the catchment. Resource use from wattle stands should be confined within grasslands. Such areas need to be identified by the rural community (Village Forest Management Committee) and managing institutions (Forestry, Nature Conservation and Working for Water), and the zoning should consider the resource needs for poles, firewood, laths, etc. and the need for grazing areas for livestock. Wattle stands along the streams should all be cleared to reduce their negative impacts on water consumption and stream flow. These processes should involve the local resource users and the managing institutions. However, such collaborative implementation of sustainable resource use practices within Ntabelanga catchment requires practical guidelines and training of personnel from different institutions and local communities on sustainable use of forest resources (Geldenhuys et al. 2016).

Table 4.1 Description of forest sub-communities in the Ntabelanga catchments

Forest Sub-communities	Diagnostic species	Other important species	General notes
Plant community 1: Scolopia zeyheri - Celtis africana low-altitude forest Growing from 956 to 1223 m asl, confined to zones 3 and 4 in catchment T35E (Figure 3.1), with four sub-communities. The indicator species are *Scolopia zeyheri* and *Celtis africana* (existing across all sub-communities), *Cussonia spicata* complex, *Afrocarpus falcatus, Dovyalis zeyheri* and *Allophylus decipiens*.			
1.11	*Scolopia* zeyheri - *Cussonia* spicata regrowth forest	*C. africana, Scolopia mundii, Podocarpus latifolius, S. zeyheri* and *Searsia dentata*	Occurs near settlements with higher resource use. *S. zeyheri* grows within and at forest margins. *C. spicata* occurs scattered within the forest.
1.12	*Scolopia* zeyheri – *Celtis africana - Afrocarpus falcatus* - Elaeodendron *croceum* high forest		Historically there were many trees of *A. falcatus* but they were heavily harvested. Currently this species shows abundant regeneration but with high scattered harvesting of poles, and cut stems showing good coppicing.
1.21	*Dovyalis zeyheri - Allophylus* decipiens - Calodendrum *capense* disturbed forest	*Ptaeroxylon obliquum*	Grows near settlements with resource use disturbance
1.22	*Cussonia spicata - Commiphora harveyi* scrub-forest	*Diospyros whyteana, S. mundii, Gymnosporia buxifolia* and *S. zeyheri*	Occurs in rocky areas
Forest community 2: Scolopia zeyheri-Celtis africana-Podocarpus latifolius-Olinia emarginata high-altitude forest Growing above 1236 m asl, in zone 1, all of zone 2 and parts of zone 4 in catchments T35A-C and E (Figure 3.1), sometimes on steep slopes and dissected landscapes. The good presence of *Podocarpus latifolius* and *Olinia emarginata* differentiates it from low-altitude forest. Frost and fire affect forest margins, preventing forest expansion in places. Difficult terrain makes most forest patches inaccessible for resource harvesting.			
2.1	*Podocarpus* latifolius - Halleria lucida - Olinia *emarginata* high forest	*D. whyteana, Heteromorpha arborescens, P. latifolius, O. emarginata* and *S. zeyheri*	Mature forest on steep slopes with tall large trees of *P. latifolius* and *O. emarginata.*
2.21	*Olinia* emarginata - Euclea undullata - Cryptocarya *woodii* regrowth forest	*S. zeyheri* and *C. africana*	Species show good coppice regrowth; in recovery stage
2.22	*Podocarpus latifolius - Olinia* emarginata - Pleurostylia *capensis* regrowth forest	*D. whyteana* and *Scutia myrtina*	Growing on steep slopes with abundant *D. whyteana* and *S. myrtina* in understory.

Figure 4.2: Forest communities of Ntabelanga catchment: (a) Ouhout (*Leucosidea sericea*) scrub-forest and scrub above 1700 m asl; (b) Inside a mature stand of Ouhout forest; (c) & (d) Mixed higher altitude forest at 1240 to 1640 m asl, with variable understory but good regeneration in places, such as dense regeneration of *Podocarpus latifolius* in (d); (e) & (f) Mixed lower altitude forest below 1230 m asl, with large trees of *Podocarpus latifolius* in (e), and dense pole-sized regeneration of various tree species in (f) (Geldenhuys et al., 2016)

Figure 4.3 The main wood products used in the rural households: (a) & (b) Firewood of different dimensions but almost totally obtained from wattle; (c) A sledge used to transport various goods, and made of wattle and some indigenous tree species; (d) Garden fence covering a large area; (e) to (h): Livestock fences of different kind; (i) Discussions with the household leader on the use of various other non-wood forest products (Geldenhuys et al., 2016).

The primary resource use management practices will be determined by the demography and ecology of the dominant and the targeted species. Harvesting should focus on species with high potential to regenerate especially after harvesting. The management guidelines should be simple and practical to ensure that local resource users can practice it. Resource use from wattle stands, for example, should be done in a way to facilitate their conversion towards natural forest, in the forest environment, such as along streams, along the forest margin, and in large forest gaps (Geldenhuys et al. 2017). However, this may take time, since succession is a process. Field observations in some areas where wattle stands were selectively harvested or burnt during wildfires (Figure 4.4), showed that natural forest species were establishing. In such areas, with effective management of fire, natural forest species may establish successfully.

Figure 4.4: Natural forest establishing within wattle stands at the foot slope of the mountain. A fire burnt the wattle stand and the regeneration is a mixture of wattle and forest species.

The following steps need to be followed for the sustainable resource use practices within the Ntabelanga natural forests (Figure 4.5, adapted from DWAF 2005):

Step 1

The interests and needs for products and services of the local forest users should be identified and the resource use status of the forest should be assessed, as was done in the overall study (Geldenhuys et al., 2016). This can be achieved by exploring, mapping and zonation of the area for different management focus (e.g. poles, firewood, bark harvesting, etc.) and implementing a resource inventory.

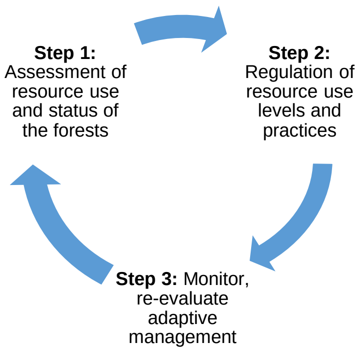

Figure 4.5 The process for the development of sustainable resource use (adapted from DWAF 2005).

Step 2

The use level and resource use practices should be regulated by assessing the mode of species response after harvesting, and the growth rate, and by developing appropriate guidelines for resource use practices. The area under management should be controlled and guided by the resource use management plan. Field observations have shown that some species within the Ntabelanga catchment such as *Diospyros whyteana*, *Scolopia zeyheri* and *Afrocarpus falcatus* have good coppicing potential after harvesting. Such characteristics should form part of the guidelines for sustainable resource.

Step 3

Monitoring resource use impacts on the species, assessing such impact and developing an adaptive management strategy (i.e. action research or learning by doing) would generate knowledge, a clear understanding and confidence among different stakeholders involved in the management of the natural forests. The process to manage the use and conversion of wattle stands is shown diagrammatically in Figure 4.6.

Some types of resources, such as fruit, traditional medicine and other minor forest products, cannot be obtained from the wattle stands. Their harvesting from the natural forests should be done in a sustainable manner and should not affect the targeted species negatively and should not cause wattle invasion.

In areas where wattle stands exist close to the forest margin, and where the focus would be to encourage expansion of forest margins, selective cutting of wattle trees for poles and laths is recommended to facilitate natural forest species invasion and establishment (Geldenhuys et al. 2017). Minimum disturbance should be maintained to facilitate the establishment of light demanding natural forest species and to minimize the re-establishment of wattle.

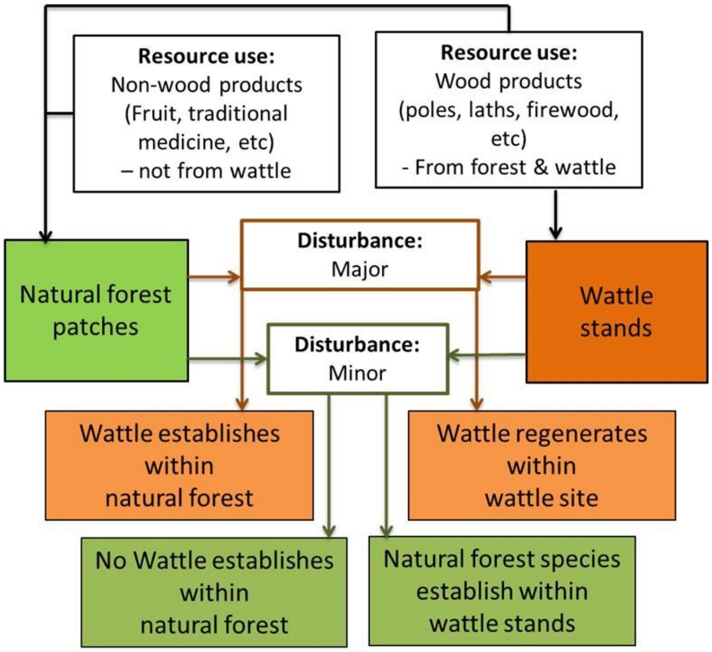

Figure 4.6 Schematic illustration on how to manage the use of wattle in Ntabelanga catchment.

Some sampled stands showed a high density of stems <5 cm and 5-15 cm DBH, of species that are harvested for poles. Such stands could be silviculturally managed by stem thinning. Rural communities should be allowed, with relevant training, to use them for sticks and poles (Figure 4.7 & 4.8). The regeneration dynamics of species after harvesting is important because this will help to guide the management approach on specific targeted species (DWAF 2005). Species such as the canopy tree species *Scolopia zeyheri* and *Scolopia mundii* and subcanopy tree species *Diospyros whyteana* have a high regeneration potential, both from seed and from coppicing. Some species have shown good regeneration in certain areas but poor or no regeneration in other areas. This could be attributed to their ecological requirements, such as being unable to regenerate beneath the closed forest canopy, or mother trees (Lubbe & Geldenhuys 1991) or irregular seed production. Such species may need gap disturbance to allow the species to regenerate. Such information on ecological requirements of target species need to be included in the resource use guidelines. Resource users need to be trained on how to harvest poles at a suitable stump height to enable effective coppicing, with early rooting of coppicing shoots to provide for stable growth into trees. Cutting of poles too high above the ground may result in poor coppicing, as observed in Ntabelanga natural forests (Figure 4.7). However, Handavu et al. (2011) noted that in woodland clearing that cutting stems at an increased stump height facilitates stump survival and coppicing, with some species such as *Brachystegia longifolia*, *B. spiciformis* and *Isoberlinia angolensis* showing high coppicing ability in the 15 to 35 cm stem diameter range.

Guideline development should consider the following questions to ensure the implementation of sustainable resource use practices (DAFF 2005):

1. Does the species produce seed regularly, occasionally or sporadically?
2. What type of fruit (capsule, pod, fleshy) or seed does it produce?
3. What is the dispersal mechanism (e.g. by wind, water, birds or mammals)?
4. Does any of the mechanisms affect the recruitment of the species?
5. Does the species coppice effectively or regenerate after harvest or disturbance (e.g. fire, browsing)?

Figure 4.7. Cutting of *Diospyros whyteana* trees at about 50 cm above ground level within one of the sampled plots, which could be considered as improper harvesting.

Guidelines had been developed for sustainable bark harvesting, associated with training of bark harvester groups (Geldenhuys 2004; Vermeulen et al. 2011, 2012). It involves either harvesting of small amounts of bark in vertical strips (no ring-barking) or the selective cutting of fewer trees, harvesting of all the bark of the few cut trees, using the timber, and taking care of the coppice regrowth that it is not browsed by livestock or wildlife. Ring barking of trees should be avoided. Preferably, harvesting of bark from smaller stems should be avoided unless such bark is taken from thinned stems as part of silvicultural management (Figure 4.8a-b). Root harvesting is also risky; it may lead to the death of the whole tree (Figure 4.8c).

Figure 4.7: The main wood products used in the rural households

a) & (b) Firewood of different dimensions but almost totally obtained from wattle; (c) A sledge used to transport various goods, and made of wattle and some indigenous tree species; (d) Garden fence covering a large area; (e) to (h): Livestock fences of different kind; (i) Discussions with the household leader on the use of various other non-wood forest products (Geldenhuys et al. 2016).

Figure 4.8: Resource harvesting within some of the Ntabelanga forests: (a) Dry pieces of wood collected for firewood; (b) Small poles of <10 cm stem diameter of various species along a footpath through the forest; (c) A tree of *Podocarpus latifolius* cut at about 1.3 m above ground level, but most of the branches above the main stem were left at the site; (d) Stumps of harvested poles of *Podocarpus falcatus* and *Diospyros whyteana* are sprouting; (e) A sprouting stem of *P. falcatus* that was cut at 1 m above ground level; (f) Shoots from a cut stem of *P. falcatus* developed into three fast-growing pole-sized stems and could be selectively thinned to produce a main stem of good form; (g) An old debarked wound on *P. falcatus* tree that showed no bark recovery; (h) Medium-sized debarking of a large tree in the forest; (i) A large relatively recent debarking of a tree in the forest (species unknown).

4.5.2 Control of wattle invasion through sustainable resource use practices

The resource use management for the livelihood of the rural people within the Ntabelanga catchment area need to consider the conversion management of wattle. Wattle should be utilized in a way that would gradually convert the wattle stand to re-growing natural forest (Geldenhuys & Bezuidenhout 2011; Geldenhuys 2013; Geldenhuys et al. 2017). The rural people within the catchment who use poles for construction and firewood should be allowed to use the wattle as a conversion process in areas identified to facilitate forest recovery (in consultation with community leaders and groups) using poles, firewood and traditional medicine. Effective conversion management requires that the identified areas be zoned into stand development stages (Figure 4.9).

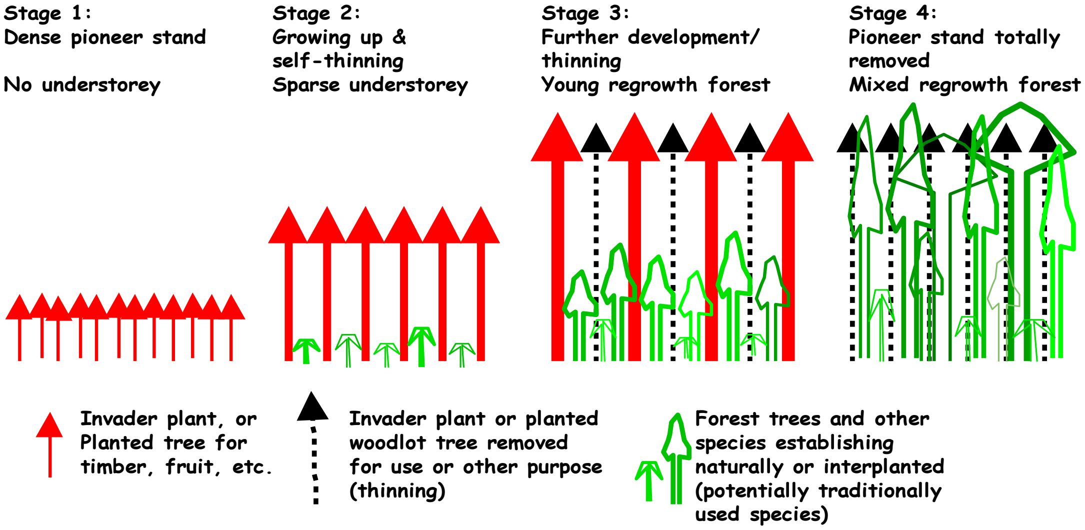

Figure 4.9. Developmental stages during the succession of invader plant stands, such as dense wattle, towards mixed evergreen natural forests (Geldenhuys & Bezuidenhout, 2011; Geldenhuys et al. 2017).

Stage 1: Dense young and pure wattle stands. Such areas can be thinned to use the stems of small diameter as laths, depending on the needs of resource users. In areas not identified for conversion to natural forest, wattle clearance should be confined to areas along streams, in grassland (toprotect grazing areas), near households where it could overtake gardens, along footpaths between villages to minimize crime, and along fire pathways.

Stage 2: Young wattle stands of 1 to 3 m height, with sparse to no regeneration of forest species. Such areas can be selectively thinned for small (thin) poles in micro sites where natural forest species are establishing. This will provide space for the indigenous forest species (e.g. shade tolerant) to grow faster.

Stage 3: Taller young wattle stands with pole-sized stems (5 to 15 cm stem diameter) and more established natural forest stems. Harvesting should focus on selective thinning of wattle stems in clusters of dense regeneration of forest species, with care not to create large gaps that would allow wattle to regenerate.

Stage 4: Areas with few larger wattle trees and well-established regeneration of forest species. All wattle trees should gradually be removed to enable the forest species to grow into larger sizes, faster.

Field observations within the Ntabelanga catchments have shown that indigenous forest species are establishing within wattle stands where minor disturbances such as selective cutting of poles and firewood have occurred (Figure 4.10).

Figure 4.10: Conversion of wattle to regrowth natural forest: (a) A small cluster of several indigenous species surrounded by young wattle stems; (b) Young wattle stems have been cut at ground level to facilitate the better growth of the natural forest species; (c) & (d) Dead wattle trees with developing natural forest regeneration.

Concerns were raised on how the clearance of the invasive wattle stands would impact on the conservation of natural forests in the Ntabelanga catchment and how the use of products by the rural communities revert to the natural forests. Geldenhuys and Beuidenhout (2006) showed that clear-felling of wattle stands exposes the wattle seedbanks to regenerate aggressively. This implies that sustainable resource use from the natural forests within Ntabelanga is linked with the management of the invasive wattle stands. This has an impact on the livelihoods of the local communities since the entire village rely on wood and non-wood resources (Geldenhuys et al. 2016). Management of this processes requires that ecological, social and economic concerns be considered in the management plan framework to guide resource use within the catchment.

4.6 Conclusion and recommendations

This study has shown that floristically the Ntabelanga Low and High-altitude Forests occupy an intermediate position between three National Forest Types, i.e. the Eastern Mistbelt and Drakensberg Montane Forests, and to a lesser extent the Transkei Mistbelt Forests. Floristic-structural differentiation of species associations was strongly influenced by gradients in macro and local altitudinal landscape features and natural and local disturbance gradients, with a major differentiation into Low-altitude Forests with four sub-communities, and High-altitude forest, with three sub-communities.

The main natural disturbances were grassland fires affecting forest margins, and some fire spotting into the forest interior, crown breaks caused by snow fall and strong wind. Resource harvesting for timber, poles, firewood and traditional medicine may have been more severe in the past but is relatively low at present. This is attributed to the change in building style towards better houses built with bricks of different kind, and that >90% of construction poles and firewood are harvested from the many stands of the invasive Black wattle. Wattle remains the main source of wood and non-wood products for rural communities within the Ntabelanga catchment, implying that sustainable resource use is linked to wattle management.

The high densities of stems below 10 cm DBH in the Low-altitude forest were in forests around settlements with higher resource harvesting impacts. In some forest communities at high altitude, high densities of small-sized poles in the High-altitude forest were related to disturbances from snow or fires. The indication in both altitudinal zones is that these forests are in a recovery stage. This influenced the results of the grain analysis which showed that the Low-altitude forests have fine to coarse grain characteristics in the canopy tree species, whereas the high-altitude forest were mostly coarse-grained.

Sustainable management of forest resource use within the Ntabelanga catchments requires guidelines that are easy to use by the Village Management Committee, resource user groups, and relevant institutions. This will require zonation of the areas based on resource needs (e.g. poles, laths, firewood and traditional medicine). The following zonation categories should be adopted for effective management of natural forests within the Ntabelanga Catchment (Geldenhuys et al. 2016; Figure 11):

1. Areas with no wattle, except single to few trees in small groups – to be cleared before they develop a seed bank or spread more. This would include areas as shown in Figure 4.11a above the burnt wattle stand.
2. Areas where there is wattle in various densities around natural forests, including riverine areas (Figure 4.11b, f). Wattle outside the fire zone should be managed to convert the wattle stands gradually towards natural forest through stand manipulation while utilizing the wattle wood for poles and firewood.
3. Wattle in areas that should be grassland (Figure 4.9 c-e), but zonation should consider the needs expressed in the resource use assessment of what wattle areas should be removed: (a) near households where wattle takes over the gardens; (ii) along the foot paths between villages (making it not safe to travel from one village to another because criminals may hide there), and (iii) on the grasslands (taking over the grazing lands and crop fields). This zonation should also consider areas of wattle that should be retained as sources of poles and firewood.

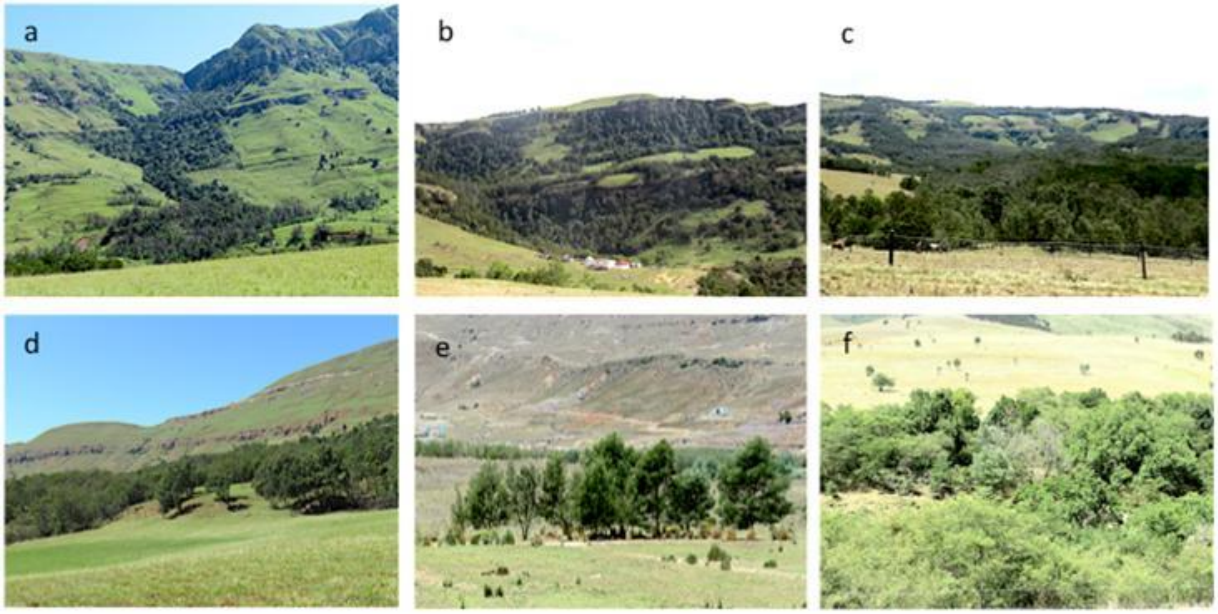

Figure 4.11. Wattle invasions in different localities that should be managed differently: (a) Wattle in the valley (fire zone) with no wattle above the zone (natural forest and grassland without wattle); (b) Mixture of wattle, natural forests and areas that should be grassland; (c) Extensive areas of wattle stands of different age (height and tree size) in what should be grassland; (d) Extensive stands of mature wattle in grassland; (e) Scattered stands of young developing wattle stands; (f) wattle within stands of indigenous tree species along streams and rivers.

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