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A phytosociological study of peat swamp forests in the Kosi Bay lake system, Maputaland, South Africa

by

Lourens Erasmus Retief Grobler

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Faculty of Natural and Agricultural Sciences
University of Pretoria
Pretoria

Supervisor: Prof Dr GJ Bredenkamp
Co-supervisor: Dr J Sliva

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Declaration

I, **Lourens Erasmus Retief Grobler**, declare that the thesis which I hereby submit for the degree Magister Scientiae at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at this or any other tertiary institution.

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ABSTRACT

This study investigates patterns and processes in transformed and uncultivated Peat Swamp Forests (PSF) situated within the Kosi Bay Lake System Catchment (KBLSC) in north-eastern Maputaland, South Africa. Phytosociological investigations were performed to identify and describe the influence of recorded environmental factors and land use cultivation practices on PSF vegetation patterns (gradients and associations). PSF habitat were grouped into four mutually exclusive classes in the form of pristine, long-time recovering, recently disturbed and active gardening sites. Plant species were recorded separately in different forest strata, while peat profiles were sampled and described in selected Peat Swamp Forest valley bottom cross-sections during fieldwork surveys in May and September of 2003.

Multivariate analysis in the form of Agglomerative cluster analysis, Detrended correspondence analysis (DCA), Non-metric multidimensional scaling (NMDS) ordinations, and Indicator species analysis were used to identify and describe 5 Peat Swamp Forest communities associated with uncultivated and long-time recovering conditions (38 sampling plots), while 9 PSF communities were identified and described from the combined (four) PSF classes (65 sampling plots).

Peat Swamp Forests were associated with channeled valley bottom and hillslope seepage inter–dune landscape settings that are connected to other watercourses within the Kosi Bay Lake System Catchment. The study found that Peat Swamp Forests are consistent with the definition of a phreatic (groundwater dependant) ecosystem, as they displayed indicators of prolonged groundwater-derived saturation, including peat development on slopes located above the active channel. Cultivation practices modified the structure and species composition of PSF, while their recovery after gardening abandonment appeared to be related to the wetness regime and the remaining peat body.

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CHAPTER ONE: INTRODUCTION

1.1 Motivation for the study

Why should Peat Swamp Forests be investigated in northern Kwa-Zulu Natal?

Peat Swamp Forests are freshwater forested wetlands that are established on peat soils (histosols). Coastal Peat Swamp Forests is a term that has recently been used to refer to Peat Swamp Forests that occur in close proximity to the coastline, but remains distinct from mangroves which are affected by tidal interaction (Sliva *et al.* 2004). Rodgers (1995) classifies Swamp Forests as riparian wetlands that experience a high flux of energy and nutrients located between aquatic and terrestrial ecosystems. Wetlands are regarded as the third most important life support ecosystem on earth and receive international protection through intergovernmental treaties, conventions and laws (Ramsar Convention Secretariat 2004). It has been estimated that at least half of South Africa's wetlands have already been destroyed, while remaining wetlands continue to be under pressure from urbanisation, expanding mining activities, agriculture, and climate change (Grundling & Grobler 2005; DWAF 2006). Begg (1980) mentions that wetlands represent some of the most threatened natural areas in existence, which highlights the need for their conservation prioritisation and protection. Wetlands are of value to society as different types of wetlands provide different functions (ecosystem services) that can include improvements to water quality; attenuation of flooding events; augmentation of stream flow; sequestration of carbon, the supply of harvestable natural resources; and the provision of breeding, foraging, and dispersal habitat for wetland dependant and independent fauna species (Kotze *et al.,* 2005).

The presence of wetlands in South Africa is limited by dominating dry climatic conditions with a mean annual rainfall of only 497mm in comparison to a world average of 860mm (DWAF 2003). The eastern half of South Africa with an above average annual rainfall supports a higher density of wetlands, although the area is characterised by a generally steep topography and escarpment that restricts the presence of flat expanses of landmass to support low energy environments and wide wetland systems. The Maputaland Coastal Plain in northern Kwa-Zulu Natal is however an exception with its undulating topography and high annual rainfall near the eastern Indian Ocean seaboard (Begg 1980).

In an international context wetland systems with a peat-covered area of at least 0.3m deep are referred to as peatlands (Joosten & Clarke 2002; Rydin & Jeglum 2006). Peatlands are considered as unique and rare wetland types in South Africa, with the majority of peatlands being concentrated in the Maputaland Coastal Plain (Grundling *et al*., 1998; Grundling & Grobler 2005). Maputaland's peat resources were investigated in the 1990's as a potential commercial energy resource (Smuts & Kirstein 1995), but peat mining to this end has not yet occurred in the area. Local slash-and-burn farming practices are however a major anthropogenic factor affecting peatland systems in Maputaland (Grundling, 1996; Grobler 2004). A variety of crops are cultivated in created gardens that displace the natural vegetation and modify the peat substrate through the creation of drainage ditches (Grobler 2004; Sliva *et al.,* 2004). Peat Swamp Forest areas located in linear drainage lines are specifically targeted for the establishment of cultivated gardens (Grundling & Grobler 2005).

Peat Swamp Forests are more commonly referred to in literature as Swamp Forests, without the connotation to their organic rich soils (Moll 1980; Lubbe 1997; & Wessels 1997). They are threatened vegetation types in South Africa, being the second rarest forest type in the country and only occur in isolated patches from the Mozambique border to just south of the Msikaba River in the Eastern Cape (Moll 1980; Wessels 1997). In 1997 approximately 3986ha of Swamp Forest habitat was recorded within northern Kwa-Zulu Natal, with additional areas not being incorporated due to mapping classification constrains associated with the remoteness and inaccessibility of these systems (Wessels 1997). Swamp Forests on the Maputaland Coastal Plain form 75% of all Swamp Forest areas present within South Africa (Lubbe 1997). Such a high concentration of a threatened habitat type that constitutes wetland, peatland and forest features in a single entity highlight the conservation value of Maputaland's PSF. Information regarding these forested peatlands are scarce in South Africa when compared to international research, but even on a worldwide scale tropical Peat Swamp Forest ecosystems have received little attention in the recent past and their ecological functioning remains something of an enigma (Page *et al.,* 1999). It is however expected that PSF are becoming of increasing relevance in a carbon emission sensitive world, as a result of their ability to sequestrate carbon via peat accumulation or release carbon via drainage and burning. Further scientific investigations to improve our understanding of these systems are therefore much needed.

Problem statement

What are the aspects affecting Peat Swamp Forests in northern Kwa-Zulu Natal?

The following paragraphs include an introduction to three selected aspects that pertain to Peat Swamp Forests in Maputaland:

1.2.1 Biophysical aspects

The largest stand of intact Peat Swamp Forests (PSF) in South Africa is located along the banks of the Syadla River, which forms the main source of freshwater surface flow into the Kosi Bay Lake System (KBLS) in north-eastern Maputaland (Wessels 1997). PSF are present throughout the lake system's catchment in a landscape that is still largely undeveloped and located in tribal land that is characterised by natural vegetation (Lubbe 1997; Grobler 2004). The Kosi Bay Lake System Catchment (KBLSC) was selected as the main study area in order to focus the investigation in one specific drainage basin with similar abiotic parameters such geology and climatic conditions, as well as similar cultural land uses and community values associated with PSF. A large portion of the KBLSC falls within the iSimangaliso Wetland Park (iSimangaliso), previously known as the Greater St Lucia Wetland Park. This results in areas of PSF being protected inside the reserve and portions that remain unprotected outside the park.

In situ agricultural practices inside PSF areas are currently regarded as the main land use threatening these ecosystems in Maputaland, with estimated values indicating that between 60-80% of PSF containing crop species (Grundling & Grobler, 2005). Farming practices target wetland systems with more fertile soils such as PSF as suitable sites to cultivate crops that include *Musa ×paradisiaca* (bananas) in particular, as well as other species such as *Colocasia esculenta* (madumbes, also known as taros or coco yams), and *Ipomoea batatas* (sweet potatoes), (Grobler 2004, Sliva *et al.* 2004). The transformation of Swamp Forest vegetation to make way for cultivation areas, commonly referred to as gardens, occur on an extensive scale. Venter (1972) mentions the rapid conversion of *Ficus trichopoda* (previously *F. hippopotami*) dominated Swamp Forests into crop lands around Richards Bay being driven by a relative small group of people aided by bush knives (machetes) and fire, while Lubbe (1997) states that little PSF remain outside of protected areas around the KBLS.

PSF are the most favoured natural vegetation types targeted by rural agriculturalists, because of the richer nutrient content of the peat soils versus the surrounding leached sands, as well as the relative ease of draining peat soils situated on a slope compared to peatlands located in depressions or flats (Grobler 2004). The presence of water and nutrients and ease of working the soft peat soils without advanced farming implements, render these ecosystems as the most viable land type suitable for the subsistence cultivation of tropical staple crops, such as *Musa ×paradisiaca* and *Colocasia esculenta* (Grobler 2004).

1.2.2 Legislative aspects

National legislation

Prior to 1983 wetlands were poorly protected by South Africa law and regarded as “wastelands” only suitable as pest breeding habitat that should either be destroyed or transformed through drainage and/or infilling into arable land (Lizamore 2005). From 1983 up to 1997 the Conservation of Agricultural Resources Act (CARA, Act No. 43 of 1983) was the deciding statute on wetland utilisation and was only applicable to agricultural land outside official town planning schemes. From 1997 onwards, additional legislation protecting wetlands has been drafted, but no single act is solely dedicated to wetlands. Despite the lack of one specific act addressing wetland aspects their inherent importance and value to society is officially recognised and protected through several pieces of South African legislation, in particular the National Water Act (NWA, Act No. 36 of 1998).

The authoritive legislation that list impacts and activities on wetland and riparian areas requiring authorisation, are:

- Conservation of Agriculture Resources Act No. 43 of 1983 (CARA, 1983).
- National Water Act No. 36 of 1998 (NWA, 1998).
- National Environmental Management Act No. 107 of 1998 (NEMA).
- National Environmental Management Biodiversity Act, 2004 (NEMBA), Act No. 10 of 2004.

These pieces of legislature, in particular CARA (Act No. 43 of 1983) and the NWA (Act No. 36 of 1998) indicate illegal contraventions associated with agricultural practices inside Peat Swamp Forests or other wetlands that have not been approve. This is of particular importance in cases where newly created cultivated areas (gardens) were established after the legislation came into effect, which with reference to CARA (Act No. 43 of 1983) refers back to 1983. Subsistence farmers have however traditionally been treated with more leeway compared to commercial farmers, but local farmers are known to have been arrested by park authorities (rangers) when caught cutting down Swamp Forest trees.

International treaties

On a larger scale the international community recognises wetlands as areas of economical, cultural, scientific and aesthetical importance and formed the Ramsar Convention in 1971 in Ramsar, Iran (Ramsar Convention Secretariat 2004). Cowan (1994) defines the aims of the convention as to "*commit member nations to reduce the increasing loss of wetlands by promoting wise use of wetlands, give special protection to selected wetlands and undertake the obligation of training all parties concerned so as to result in wetland conservation.*"

South Africa was one of the pioneering nations to accept the Convention and became the fifth member on 12 March 1975, while simultaneously introducing two wetlands on the List of Wetlands of International Importance. The Kosi Bay System was added to the list in 1991 and subsequently gained international acknowledgement and protection (Cowan, 1994). The Ramsar Convention does not exclude the usage of wetlands for non-conservation orientated purposes, but do emphasise that signatories of the treaty commit themselves to implement and promote "*the wise use of wetlands in their territory*" as far as possible (Article 3.1 of the treaty). Approved guidelines as well as additional guidelines have been made available to contracting parties on how to attain "*wise use*" within wetlands, with "*wise use*" interpreted as being synonymous with "*sustainable use*" (Ramsar Convention Secretariat 2004). It is suspected/believed that no "*wise use*" practices for agricultural practices within Peat Swamp Forests have yet been implemented and that existing practices are unlikely to be sustainable.

1.2.3 Social aspects

Anthropogenic pressures have had a pronounced effect on Peat Swamp Forest distribution and conservation as the human population of KwaZulu-Natal has significantly increased during the last 100-200 years (Eeley *et al.,* 1999). The rural areas of KwaZulu-Natal are some of the most densely populated rural areas in Africa, with several parts possessing a population density of well over a 100 people per km^2 (Van Wyk, 1994). As a result large expanses of suitable and existing peat swamp forest habitat have been converted into forestry, agriculture (on subsistence and commercial scale) and human settlement areas that act as barriers to potential future movement of species (Eeley *et al.,* 1999).

The entire Kosi Bay Lake System was included into a single reserve in 1988-1987 (Lubbe 1997), known as the Kosi Bay Coastal Forest Reserve by the KwaZulu Department of Nature Conservation in order to protect the lake system as one intact functioning ecosystem (Lubbe 1997). Since then the Kosi Bay Coastal Forest Reserve became part of the Greater St Lucia Wetland Park in 2000, and has again been renamed as the iSimangaliso Wetland Park in 2007. Portions of Peat Swamp Forests associated with the Kosi Bay Lake System Catchment located outside the iSimangaliso Wetland Park are primarily regulated by the local Tembe tribal authority with regards to land tenure and the use of natural resources. Unfortunately the tribal authority appears to have little restraining effect on the transformation of Peat Swamp Forest habitat as pressure for agricultural land has increased over time (Lubbe 1997).

Herrington (2003) provided several reasons why the pressure for additional crops, mainly derived from peat Swamp Forests, has been increasing over recent years in the Kosi Bay area:

- Population growth has generally increased as health services and infrastructure have improved over the last few decades.
- During the same time many miners have been retrenched and relocated back to the area as mines closed in Gauteng, North West and the Free State. This led to increased local unemployment and poverty with access to secure food sources becoming more uncertain.
- Portuguese and Tonga (also spelled Thonga) speaking illegal immigrants continue to move into the area, while the local Tembe (also spelled Thembe) people do not treat them, especially fellow Tongas, with antagonism, but rather feel obligated to help them, leading to yet a greater need for reliable sources of nutrition.
- HIV/Aids are another factor causing yet more poverty as the breadwinners are commonly those most at risk to the disease. As the disease proliferates it creates the need for yet more nutrient supplements to stay healthy for longer. One way of obtaining additional nutrient sources in a self supportive manner is to establish a garden plot in Peat Swamp Forest habitat.

The majority of the local Tembe community whom as a people have been inhabiting this land for centuries were forced to leave the protected area with the proclamation of the reserve in 1988 and were poorly compensated for their cooperation (Herrington 2003). Peat Swamp Forest areas around the Kosi Bay Lake System have consequently been a conflict zone between traditional land users and nature conservation authorities since 1988, with fences around the wetland park being removed and gardens being established within the reserve in Swamp Forest areas (Herrington 2003). Lubbe (1997) also mentions that fences were removed by the local community in order to gain access into the Mambas Tribal Game Reserve, situated south of the Kosi Bay Lake System Catchment at Lake Siberia.

Historically this is no unique situation in southern Africa as the establishment of nature reserves have oftentimes been associated with the relocation of local people from these areas (Kloppers 2001). Nature conservation measures applied in Africa during the twentieth century have been largely based on European and North American conservation philosophies in the form of 'preservationist', which aimed to exclude people as far as possible from conservation areas (Kloppers 2001). This conservation practice however failed to recognise and incorporate the age-old interconnectedness between people and their natural environments and moved them outside the boundaries of new conservation areas (Kloppers 2001). In effect the former land users are denied access to the natural resources that they previously depended upon for their livelihoods, and are left with little option but to continue their traditional way of live under typically less ideal circumstances (Adams & McShane 1992; Bell 1987). Most commonly relocated people derive little to no advantages from new conservation areas and in many cases do not even understand why these areas where created in the first place (Kloppers 2001). Consequently most displaced people feel disinherited and generally do not support the existence of conservation areas in places where they previously obtained livelihood-related benefits from (Adams & McShane 1992).

Hypothesis

It is accepted that any ecosystem is driven by a complex set of environmental (abiotic) variables coupled with biotic interactions and adaptations with regards to competition, life history strategies and anthropogenic influences. Several knowledge gaps continue to persist especially when the ecosystem under investigation has not been extensively studied under local (South African) conditions, as is the case with Peat Swamp Forests. This investigation is consequently not intended as an exhaustive study of every component influencing Peat Swamp Forest dynamics, but focuses on a selected set off variables that in effect ignores or only marginally include several other abiotic and biotic components. The investigation is also strongly orientated towards a descriptive approach with the main focus on Peat Swamp Forest vegetation community characteristics and change in response to the presence and absence of anthropogenic impacts in the form of traditional agricultural practices. The hypothesis guiding the study can be formulated as:

It is postulated that traditional agricultural practices within inter-dune Peat Swamp Forests modify these ecosystems in terms of their vegetation structure and species composition. In addition it is proposed that peat properties and land use have a bearing on Peat Swamp Forest vegetation patterns.

Problem solution

This investigation addresses a limited section of the multi-component problem statement, by focussing on the general biophysical properties of Peat Swamp Forests, and in particular their phytosociological aspects. The effect of long-term climate change is not taken into specific consideration nor are detailed hydrological changes related to groundwater table fluctuations over time. Several PSF related biotic aspects also remain unaddressed such as intra and inter-specific plant competition, seed bank dynamics, population dynamics and faunal interactions. The nature and properties of the peat substrate is addressed in part, although peat decomposition as a result of cultivation practices and peat accumulation in untransformed PSF are not presented in a quantifiable manner. However, scientific literature was investigated to illustrate the effect of agriculture practices on peat in tropical PSF. A previous pilot study in the Kosi Bay area as well as existing international literature indicated that traditional agriculture practices have a detrimental effect on PSF vegetation (Grobler 2004). This has yet to be investigated in more detail in order to improve our understanding of how local PSF respond to agricultural impacts and how impacted areas differ from undisturbed PSF.

This thesis investigates PSF vegetation patterns in response to agriculture activities by incorporating a larger dataset and a different analysis methodology than that used by Grobler in 2004. In addition, investigations into peat stratigraphy and PSF vegetation gradients across valley bottom landscape positions are included, while community uses and perspectives of PSF are also incorporated. The latter is deemed necessary (albeit on a limited scope) based on the stated hypothesis, which considers anthropological driving forces as a key factor in PSF change. Investigated PSF were primarily associated with linear watercourses situated within inter-dune landscape positions, as opposed to PSF associated with littoral zones around lakes. Valley bottom PSF habitats appear to be the most common habitat for PSF occurrence in the Kosi Bay Lake System Catchment (Sliva *et al*. 2004). *Raphia australis* PSF habitat on the western shore of Lake Amanzimnyama is however an exception, but was not investigated to the same level of detail due to little to no farming activities being observed within this area (Grobler 2004).

Thesis organisation and structure

This thesis investigates Peat Swamp Forest changes in response to traditional agriculture activities in the Kosi Bay Lake System Catchment. The motivation for the thesis including specific problem statements, followed by a review of existing literature and a description of the applied methodology are presented in chapters 1 to 3.Chapters 4 to 6 include results and relevant discussions regarding each individual chapter, while Chapter 7 provides a conclusion of the overall thesis and suggestions for a way forward.

CHAPTER ONE: INTRODUCTION

Chapter 1 serves as an introduction to the thesis and provides information to set the context of the study, as well as the postulated hypothesis and proposed problem solution.

CHAPTER TWO: STUDY AREA

National and international literature is referred to regarding a description of the study area, as well as selected PSF aspects.

CHAPTER THREE: METHODS

Chapter 3 describes the field and analytic methods related to the thesis, which include the selection of sites, environmental parameters and data gathering techniques, as well as the applied computer aided analysis methodologies and rationales.

CHAPTER FOUR: PEAT SWAMP FOREST COMMUNITY PHYTOSOCIOLOGY

Variation in PSF vegetation, determination of vegetation groups (plant communities), and the identification of dominant environmental variables are described from different groupings and related multivariate analysis of sampling plots located throughout the Kosi Bay Lake System Catchment.

CHAPTER FIVE: PEAT PROFILES AND VEGETATION GRADIENTS IN INTER-DUNE SWAMP FOREST SYSTEMS

Chapter 5 investigates peat profiles and its associated groundwater table, as well as lateral vegetation gradients across Peat Swamp Forests inter-dune systems at six transects located throughout the study area.

CHAPTER SIX: CONCLUSION

Chapter 6 draws conclusions from the results and discussion, and provide suggestions for future research initiatives.

CHAPTER 2: STUDY AREA

2.1 Maputaland

2.1.1 Location and landscape features

Maputaland is located in the north-eastern corner of KwaZulu-Natal and is confined by the RSA-Mozambique border to the north, the Indian Ocean to the east, the Lebombo Mountains and Swaziland to the west and the Mkuzi River and Lake St. Lucia to the south (Moll 1977; Figure 2.1). Maputaland forms part of the Mozambique coastal plain and comprises a broad, flat to undulating, cretaceously uplifted, sandy region about 60 km in width (Lubbe 1997; Figure 2.2). The area is situated within the Indian Ocean Coastal Belt and the Savanna Biome (Mucina & Rutherford 2006). Several plant and animal species reach their southernmost distribution limit here, which indicates that Maputaland can be referred to as the southern end of the tropics in Africa (Van Wyk 1994), but tropical influences in the flora composition continues further south, far as the Alexandria Forest between Port Elizabeth and East London in the Eastern Cape (Meadows 1985).

The boundaries of the Maputaland Centre are biogeographically well defined, except in the north, where the line is arbitrary (Van Wyk 1994). Biogeographically Maputaland is to a large extend part of the Maputaland coastal forest mosaic (WWF 2001), which also extends far into Mozambique (up to Xai Xai in the north) while phytogeographically, it is part of the Indian Ocean Coastal Belt (Moll & White 1978). The seaboard side of Maputaland consists of large windblown sandy depositions that are infertile and orientated in a series of north–south aligned dunes, parallel to the coastline, stretching several kilometres inland (Maud 1980).

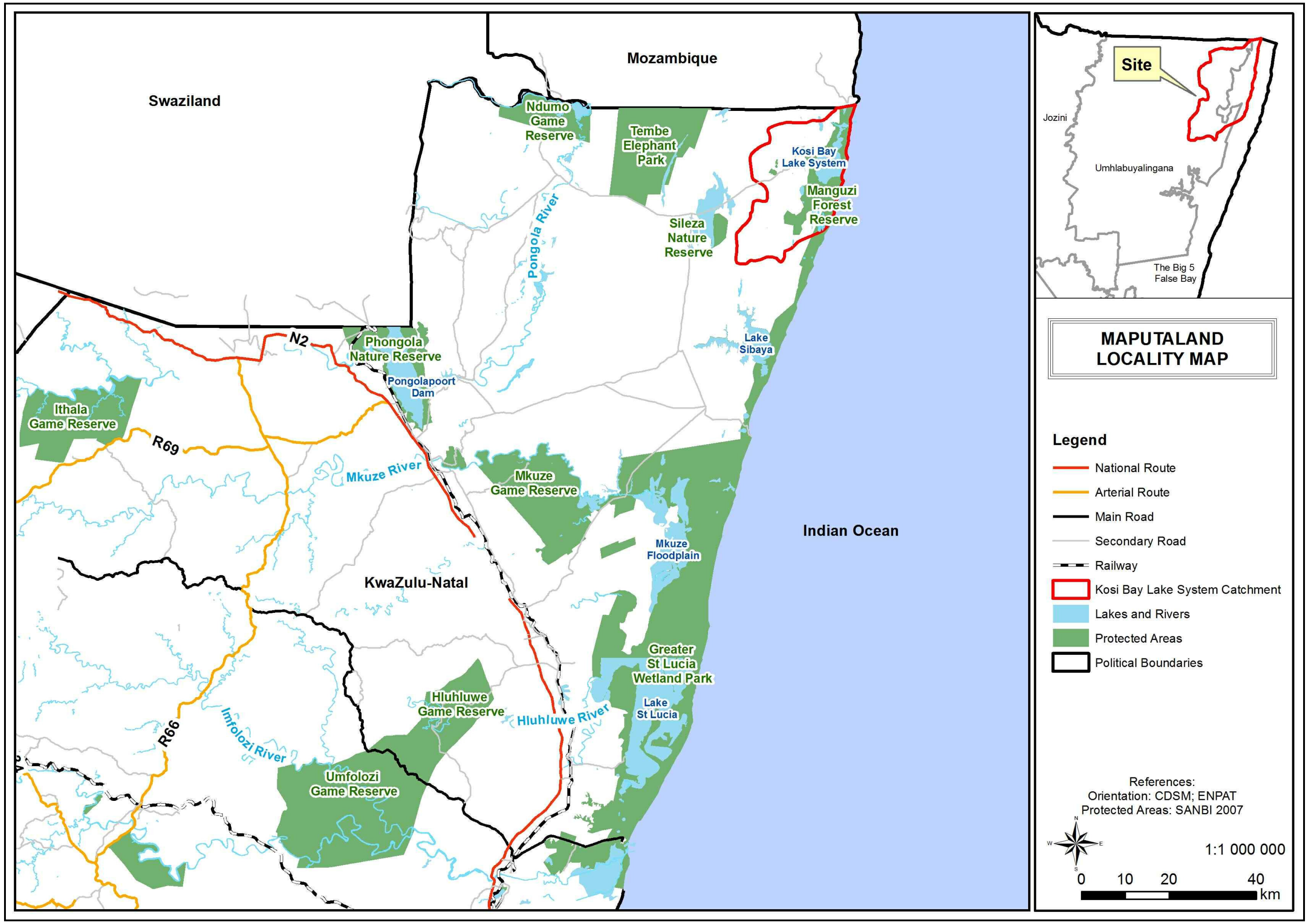

Figure 2.1 Locality map of Maputaland.

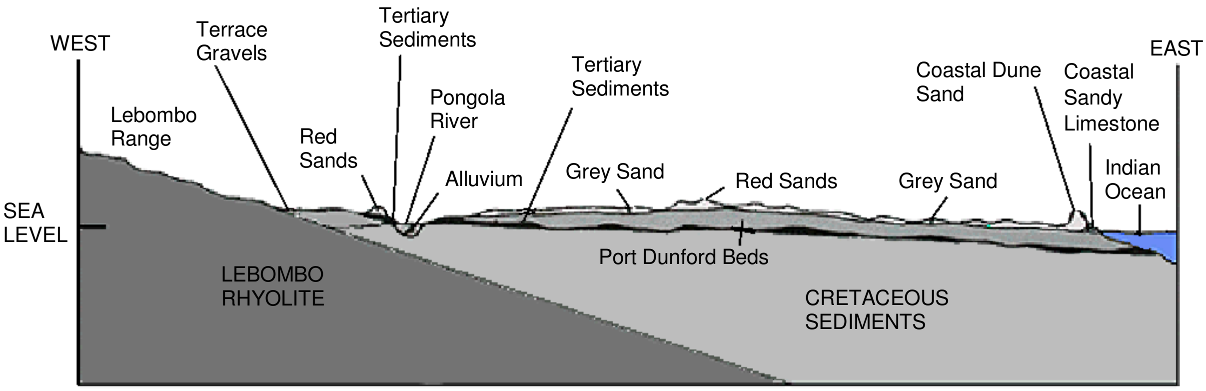

Figure 2.2 Schematic cross-section of the geological strata of Maputaland (not to scale), (Bruton & Cooper 1980).

Geological formations known as the Port Durnford Beds are located underneath the surface sands and consist of sands, clayey limestones and diatomites deposited under marine shallow-water, terrestrial and freshwater lacustrine conditions (Maud 1980; Figure 2.2) These beds are impermeable and may therefore form aquitards associated with an overlying aquifer that results in a shallow groundwater table at or near the surface in lower-lying landscape positions.

2.1.2 Biogeography

Maputaland is characterized by a high species richness, e.g. 2 500 plant species/ interspecific taxa (Van Wyk & Smith 2001); 470 bird species including five endemics (Harisson *et al*. 1997), as well as a high proportion of endemic plant (9.2% of vascular plant species) and animal species (Moll 1980, Stattersfield *et al*. 1998, WWF 2001). Moll (1980) classified the vegetation of Maputaland into 15 major types, ranging from the coast with Coastal Grassland and Dune Forest through to Sand Forests, Swamp Forests, and Swamps (freshwater marshes), up to forests associated with the Lebombo Mountain Range.

The area has recognised floristics links with the Pondaland Centre of Endemism and is hence also referred to as the Tongaland-Pondaland Regional Mosaic (Meadows 1985), a region which displays at least three foci of high floristic endemism, namely the Maputaland Centre in the north and the Pondoland Centre and Albany Centre to the south (Van Wyk 1994; Van Wyk & Smith 2001). For its size, (approximately 26734 km²), the Maputaland Centre of

Endemism is one of the most remarkable areas of biodiversity in Africa (Van Wyk & Smith 2001).

The varieties in vegetation types are generally diverse in addition to the presence of high numbers of endemic plant species. This is partially attributed to existing landscape heterogeneity in the form of high coastal dunes parallel to the eastern seaboard, an adjacent flat undulating plain towards the west, a sudden topography change associated with the Lebombo Mountain Range, and the presence of connected and isolated watercourses that include large perennial rivers, ephemeral streams, pans, and coastal lakes (Figure 2.3). A rainfall gradient that decreases from east to west further contributes to the variation in environmental conditions (Figure 2.4), while a climatic ecotone between subtropical and tropical conditions is also present (Maud 1980). Evidence of climatic changes and associated vegetation responses from the past are vague, but do indicate warmer wetter conditions resulting in forest expansion as well as cooler drier climates leading to forest reduction (Eeley *et al.* 1999).

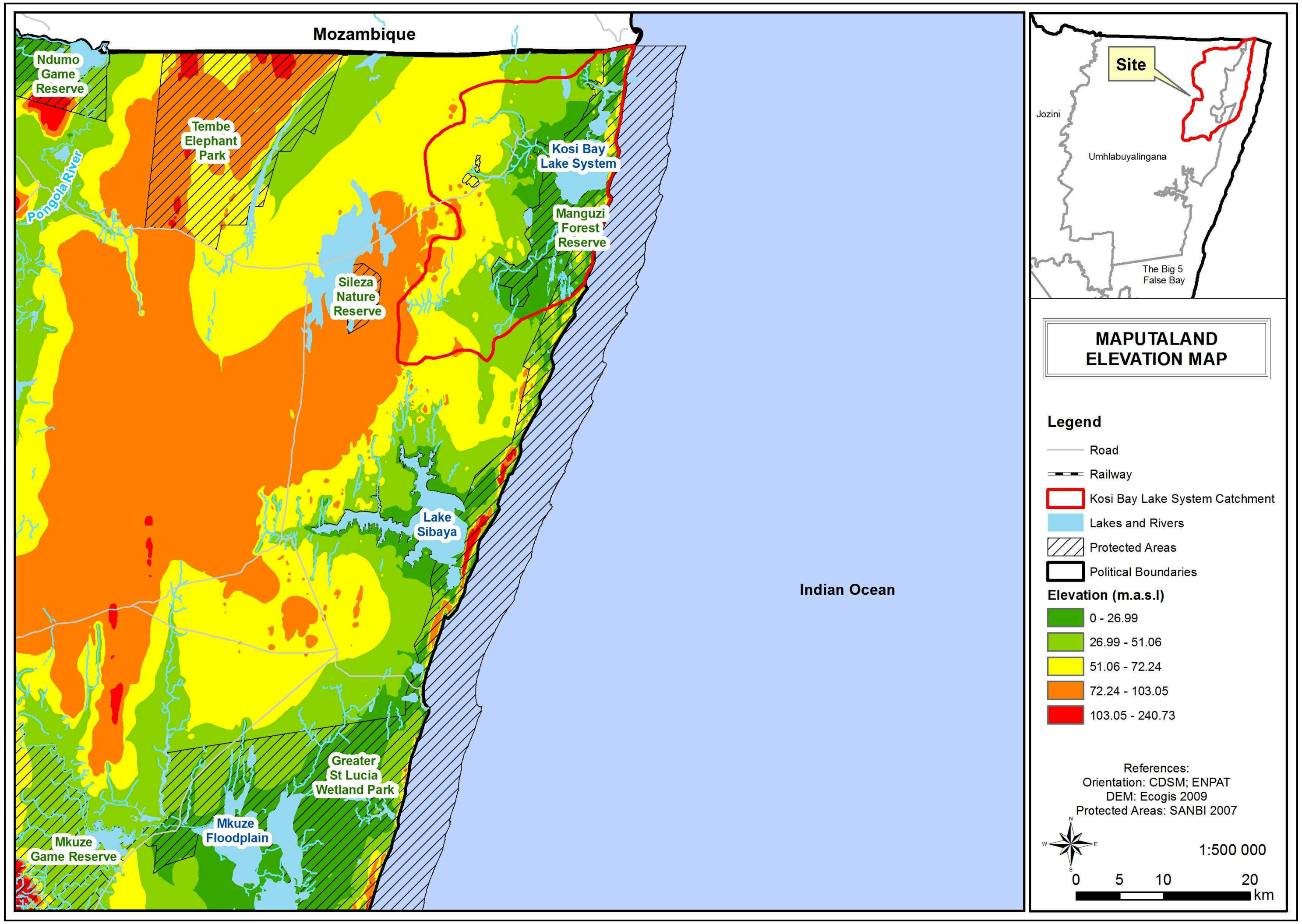

Figure 2.3 Changes in topography (elevation) within Maputaland, excluding the Lebombo Mountain Range.

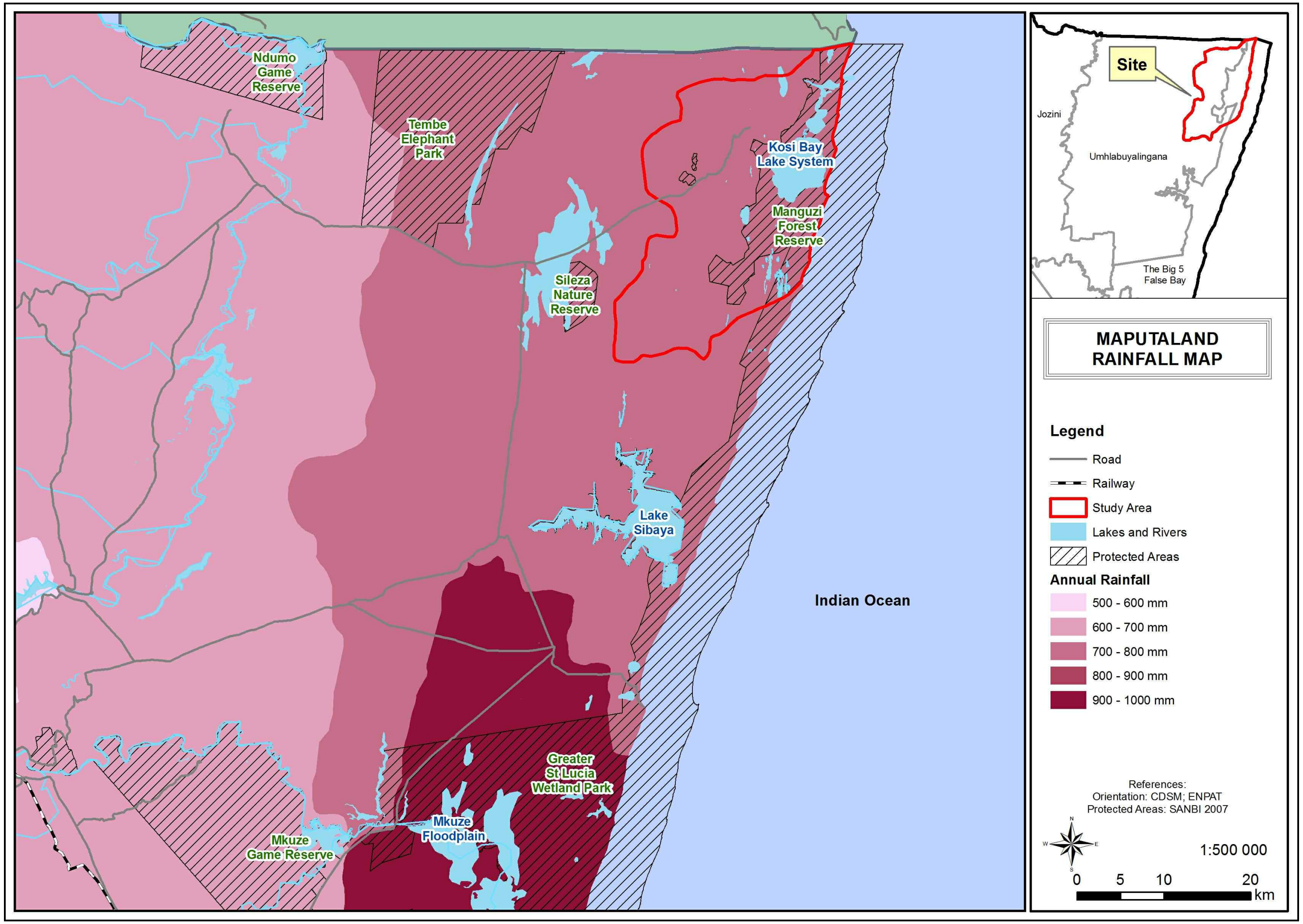

Figure 2.4 Rainfall variations within Maputaland.

2.1.3 Peatlands and Peat Swamp Forests as unique wetlands

Peat is the result of organic material that accumulates under predominately water saturated conditions where decomposition and chemical change are much slower (Rydin & Jeglum 2006). Peat can be more clearly defined as a substrate with an organic content of greater than 50 % with over 20 % being "organic soil" and less than 35 % consists of unburnable inorganic matter (Clymo 1983, Thompson & Hamilton 1983). Peat is therefore not a single homogenous substance, but undergoes several changes collectively known as humification, decay, decomposition, and breakdown that starts fast at first and becomes slower over time (Clymo 1983). These changes are governed by numerous biotic and abiotic mechanisms that end up converting dead plant material to a new chemical state with a loss of physical structure and a loss of organic matter (Clymo 1983).

Mires are considered as wetlands that contain some peat and are dominated by living peat forming plants, while a peatland refers to a peat covered terrain that need not be covered by living peat forming plants, but should posses a minimum peat depth of between 30–40 cm depending on the applied definition (Rydin & Jeglum 2006). The 266 known peatlands in Maputaland have peat depths that vary between 0.5 and 10 m, which contributes to an estimated 60% of South Africa's peat resources (Grundling *et al.* 1998). This area with its diverse array of peat producing vegetation types arguably contains the most diverse peat types in South Africa.

Tropical peatlands occur in a relative broad band centred around the equator all around the globe, but only in those localities that receive a high rainfall and have a topography which facilitates poor drainage, permanent water-logging, and substrate acidification (Page *et al.* 1999). Tropical peat is typically characterized as fibrous with low ash and mineral contents, being derived predominantly from yet distinguishable but decomposed trunks, branches and roots of trees surrounded in a matrix of virtually structureless organic material that also originates from swamp forest trees in particular (Page *et al.* 1999; Figure 2.5). Tropical peat can be either topogenous or ombrogenous with the latter referring to peat that receives water and nutrient supplies entirely derived from aerial deposition, including rain, aerosols, and dust (Page *et al.* 1999). Peat Swamp Forests in the Kosi Bay Lake System are typically associated with flowing surface water and receives water and nutrients from intermitted flow and surface runoff as well (Sliva *et al.* 2004), which by definition categorizes it as topogenous peat.

Figure 2.5 Peat and Peat Swamp Forests in Maputaland: a. Fibrous peat with woody remnants that is consistent with tropical peat features in Peat Swamp Forest habitat; b. Intact Peat Swamp Forest adjacent to the Syadla River; c. Peat Swamp Forest clearing and drainage for banana cultivation; d. Large scale cultivation of bananas recorded in transformed Peat Swamp Forest habitat in 2004.

Peat Swamp Forests (PSF) can be divided into two main, but mutually dependant parts that are in dynamic equilibrium with one another: Forest vegetation and tropical peat (Page *et al.* 1999). PSF can therefore be considered as a dual ecosystem and conservation strategies therefore need to make provision for both components. The hydrological conductivity of the acrotelm of tropical peat seems to be significantly higher than that of temperate peat, which means the water-table can drop at a faster rate, resulting in water-level fluctuation to be more common (Page *et al.* 1999). As a result PSF vegetation needs to be adapted to cope with a wider range of changing water regimes and oxygen availability.

Tropical peat comprises approximately 12% of the total global peatland resource (Page *et al.* 1999). This is a significant enough fraction to justify conservation action and sustainable management practices, especially in light of the mounting pressures that threaten their future existence. It is furthermore estimated that between 30 and 45 million hectares of undeveloped tropical peat remains intact, half of which occurs in Indonesia (Page *et al.* 1999), which makes it a precious resource to Africa and South Africa.

Swamps Forests (referred to as Peat Swamp Forests when peat soils are present) are highly threatened ecosystems in South Africa, being the second rarest forest type in the country and is only found in isolated patches from the Mozambique border to just south of the Msikaba River in the Eastern Cape (Moll 1980, Wessels 1997). Roughly 3986 ha of Swamp Forest occur in Maputaland of which a great deal is still unclassified due to their remoteness and inaccessibility, the Swamp Forests on the flat coastal plain of Maputaland form 75 % of all Swamp Forest found in South Africa, which makes it a valuable entity for future conservation (Lubbe 1997). In Maputaland the largest sections of Swamp Forests, supporting approximately 59 % of all South African Swamp Forests, are protected inside the iSimangaliso Wetland Park (previously the Greater St. Lucia Wetland Park), (Wessels 1997). The largest intact individual Swamp Forest system in South Africa is located on either side of the Syadla River, which is the main source of fresh surface-water inflow into the Kosi Bay Lake System (Wessels 1997; Figure 2.5).

2.1.4 Early humans and selected socio-economic aspects

Humans have occupied Maputaland since the early Stone Age, with three known occupation sites on the Acheulian (between 500 000 and one million years B.P.) located within the iSimangaliso Wetland Park (Avery 1980). Evidence suggests that people of Middle and Late Stone Age cultures inhabited the Maputaland area since the last Interglacial and probably for as long as 1.1 million years (Bruton & Cooper 1980). The Maputaland plain was widely settled by agriculturists in the early (250–100 AD) and late (1000–1840 AD) Iron periods. It is believed that these people occupied sites along the coastline as early as 1600 years ago and cut their fields and lived in the coastal forest (Bruton & Cooper 1980). Due to the prevalence of malaria and the cattle disease trypanosomiasis carried out by the tsetse fly, extensive areas of Maputaland were uninhabited (Bruton & Cooper 1980). The Tembe community is part of the old Tonga tribe with its own language (Tonga) and were conquered by the king Shaka in the nineteenth century and assimilated into the Zulu kingdom (Bryant 1949). Originally they lived as a single community on both sides of the border between South Africa and Mozambique.

The Tembe community as a land user, and Ezemvelo KZN Nature Conservation and the iSimangaliso Wetland Authority as conservation institutions are often in conflict situations as a result of diverging objectives with regards to the use and management of natural resources within the Kosi Bay Lake System Catchment (KBLSC). This has resulted in the local community removing fences around the park and cultivating gardens, especially banana (*Musa* x*paradisiaca*) gardens inside the reserve in Peat Swamp Forest areas. Improved access to offset markets have also resulted in cultivation operations expanding from subsistence based crop production as a means of food security and augmentative dietary supplements to commercial based ventures focussed on capital gain of individual farmers (Sliva *et al.* 2004).

2.1.5 Industries and infrastructure development

Today Maputaland is an underdeveloped area as far as the utilisation of mining and agricultural resources are concerned. The limited occurrence of mineral-rich ore bodies and other mining resources (apart from peat) have restricted opportunities for infrastructure development (Watkeys *et al.* 1993). However, dunes near the coast consist of pure quartz sand with local concentrations of heavy minerals such as ilmenite, rutile, zircon and magnetite (Hobday 1979).

These mineral deposits are currently mined near Richards Bay and similar resources are known to be present around the St. Lucia Estuary.

Available arable land is also limited due to the extensive distribution of sandy soils that are inherently nutrient poor and prone to leaching. However, these limitations from an agricultural consideration have contributed to the preservation of large areas of intact natural ecosystems that are currently protected in nature reserves. There are exceptions, but these pertain primarily to cultivation practices within wetland associated soils, such as extensive modifications of wetland areas into sugarcane fields in the tributaries of the Umfolozi River. Several reserves have been incorporated within the iSimangaliso Wetland Park (previously known as the Greater St. Lucia Wetland Park), while a few smaller reserves still remain present such as the Tembe Elephant Park and Ndumo Nature Reserve (Figure 2.1).

2.2 Kosi Bay Lake System and surroundings

2.2.1 Location

The Kosi Bay Lake System (KBLS) is situated in the north-eastern corner of Maputaland; it forms a unique estuary and freshwater wetland system of international importance, having been designated as a Ramsar site (Cowan & Van Riet 1998). The KBLS currently forms part of the iSimangaliso Wetland Park. The lake system consists of 4 interconnecting lakes that are orientated parallel to the coastline (Begg 1980). Two main rivers drain into the KBLS, the Syadla River (also referred to as the Siyadla and Syhadla River), which is the largest, and the Tswamanzi River. The Syadla River flows into Lake Amanzimnyama and the Tswamanzi River into Lake Nhlange (Lake Kosi). The Kosi Bay Lake System Catchment (KBLSC) forms the core study area of this investigation, but the accurate demarcation of catchment areas in coastal plain areas are complicated by the contribution of groundwater discharge in these landscape settings (Kotze *et al.* 2005). Hence, the represented KBLSC is expected to only provide an approximation of the actual catchment area based on the interpretation of available 20m contour lines (Figure 2.1 & 2.6).

2.2.2 Hydrology

The Kosi Bay Lake System (KBLS) possesses a single outlet towards the ocean with the rest of the lake system secluded from the sea by high dunes on its eastern border. Freshwater enters the KBLS through rivers and smaller streams at several locations around the lakes, while salt water enters through Kosi Mouth. The result is a diverse but consistent gradient of saline to freshwater conditions from Kosi Mouth in the north to Lake Amanzimnyama in the south.

All the rivers, streams and inlets that drain into the lake system have their origin no further than 30km from the closest lake at anytime (Begg 1980), indicating that the lake system's entire catchment area is quite small (approximately 52437.63 ha) and therefore sensitive to disturbances (Figure 2.6). The Syadla River is a nutrient poor river as many of its tributaries and the large portions of the river itself contains peat soils associated with Swamp Forests vegetation (Begg 1980; Grobler 2004). Peat possesses a small cation exchange capacity (CEC), which enables the adsorption of cations (Clymo 1983), while it also releases organic compounds such as humic and fluvic acids that are dark in colour and stains the water to create the characteristic "tea water" colour associated with Lake Amanzimnyama.

2.2.3 Land cover

Table 2.1 and Figure 2.6 represent different land cover categories present within the Kosi Bay Lake System Catchment. The study area is characterised by the near absence of Urban areas, but transformed land is common in the form of Degraded grassland and Cultivated land. The combined contribution of waterbodies and wetlands is greater than 10%, which is considered to be high.

Table 2.1 The extent and percentage of different land cover categories present within the Kosi Bay Lake System Catchment, as derived from the 2005 Ezemvelo KZN spatial dataset (Figure 2.5)

Land Cover Categories	Hectares	Percentage
Barren rock	135.15	0.26
Cultivated land	6054.10	11.55
Degraded forest, woodland and bushland	2667.18	5.09
Degraded grassland	28246.37	53.87
Forest and Woodland	7532.72	14.37
Plantations	1825.23	3.48
Thicket & bushland	405.75	0.77
Urban areas	17.28	0.03
Waterbodies	4287.40	8.18
Wetlands	1266.45	2.42
Total	52437.63	100.00

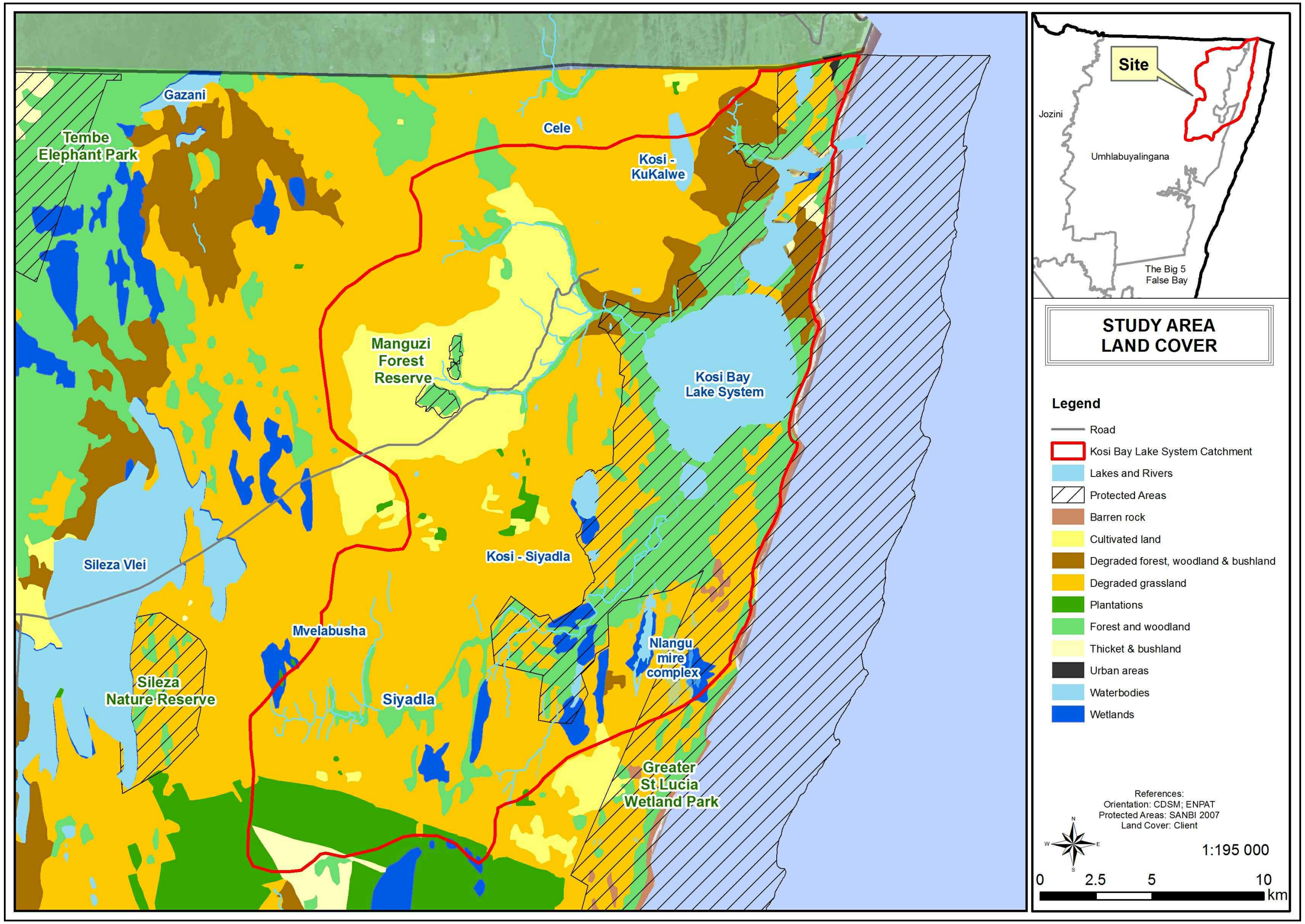

Figure 2.6 Land cover from the 2005 Ezemvelo KZN dataset for the Kosi Bay Lake System Catchment.

2.2.4 Climate

The Kosi Bay Lake System Catchment is located within the transitional zone between the tropics to the north and subtropical coastal conditions to the south, more so than the rest of the Maputaland (South African section) as it is located on the northern-eastern national border (De La Rüe 1958). The climate can in general be described as warm to hot in summer (mean daily January maximum is 28°C) and mild to warm in the winter (22°C), as well as humid and subtropical (Meadows 1985, Lubbe 1997; Figure 2.7). The Mozambique Current from the warmer tropical water to the north exerts a significant warming influence on the area, with a resultant mean annual temperature that exceeds 22°C and also provides year round rain (Schulze 1982). The predominant subtropical to tropical climate can be regarded as providing an almost all year round growing season, while frost events are highly unlikely (Meadows 1985).

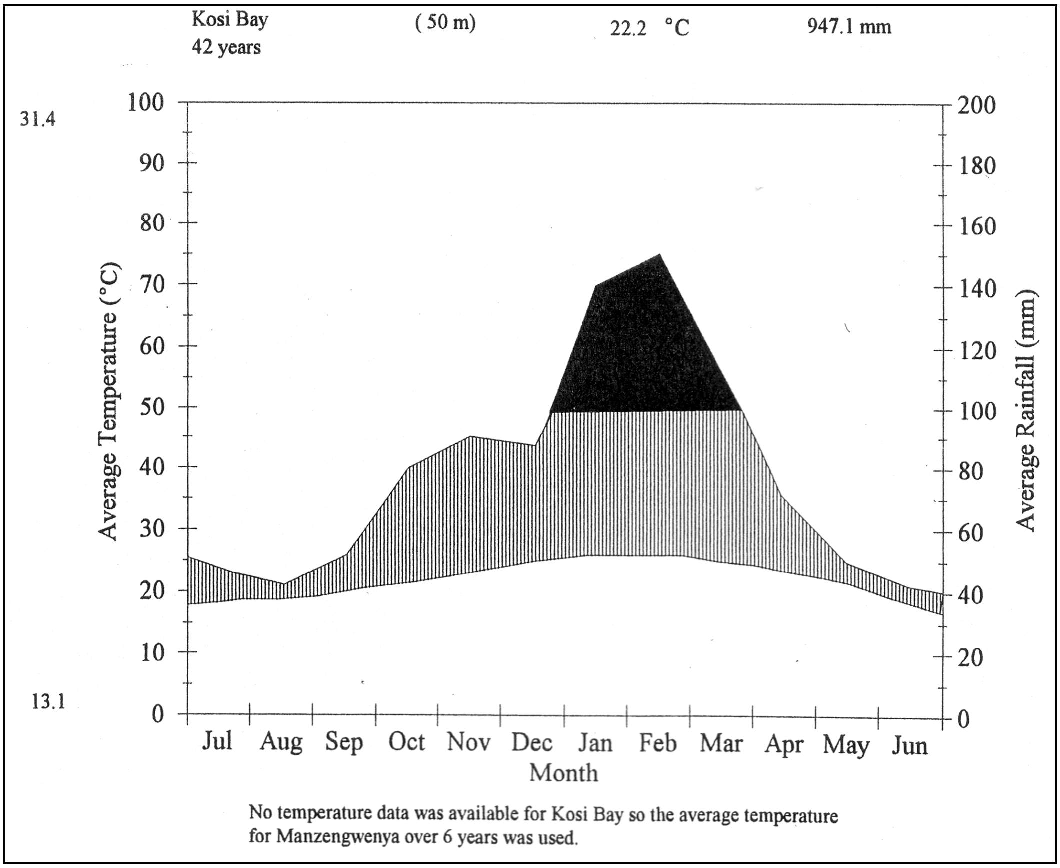

Figure 2.7 Average temperature and rainfall for Kosi Bay, which is inferred from the Manzengwenya area in the southern portion of the Kosi Bay Lake System Catchment (Lubbe 1997).

2.2.5 Vegetation

Swamp Forests are predominately located in the tropics and to a lesser extend in the subtropics, but also occur in the temperate areas of North America and Europe (Wessels 1997). In Africa there are several types of Peat Swamp Forests (PSF). In Nigeria for example, they are characterized by species such as *Cleistopholis patens, Ficus congensis, Syzygium guineense* and *Voacanga obtusa,* while many parts of West Africa and the Central basin of Congo are characterized by locally dominating stands of the palm *Raphia farinifera* (Thompson & Hamilton 1983). In South-eastern Africa *Raphia farinifera* is replaced by another palm, *Raphia australis*, which forms locally dominating stands in the Kosi Bay Lake System Catchment (KBLSC). The western shore of Lake Amanzimnyama supports the largest known stand of this Maputaland endemic palm tree (Lubbe 1997). The KBLSC also represents the southern-most natural distribution range or *Raphia australis* (*R. australis* located further south at Mtunzini were introduced in 1916), (Mattson & Uken 2007).

The KBLSC supports a high diversity of vegetation types that include a continuum of upland (terrestrial) forests such as Northern Coastal Forest, to azonal freshwater Swamp Forest, and saline Mangroves Forest around Kosi Mouth (Mucina & Rutherford 2006; Figure 2.8). The Mangrove Forests at Kosi Mouth includes all 6 mangrove species present in southern Africa (Lubbe 1997). Open swamps along lake margins are dominated by *Phragmites australis*, while coastal grasslands and forests on the high sand dunes separate the lake system from the sea (Bruton &Cooper 1980).

Based on existing knowledge Swamp Forests are characterized by a high canopy dominated by a variety of trees such as: *Ficus trichopoda*, *Voaganga thouarsii, Syzegium cordatum* and *Barringtonia racemosa.* (Lubbe 1997, Mucina & Rutherford 2006). The understory shrub layer is more sparsely vegetated and characterized by plant species such as the shrub *Keetia gueinzii* and the smallish tree *Rapanea melanophloes* (Lubbe 1997). The herbaceous layer is characterised by fern species such as *Nephrolepis biserrata, Stenochlaena tenuifolia* and *Lygodium microphyllum*, as well as climbers such as *Dhalbergia armata* and *Smilax anceps* (Lubbe 1997). Swamp Forests around the Kosi Bay Lake System Catchment (KBLSC) also contain the endemic tree species *Podocarpus falcatus* (Maputaland center form), (Lubbe 1997).

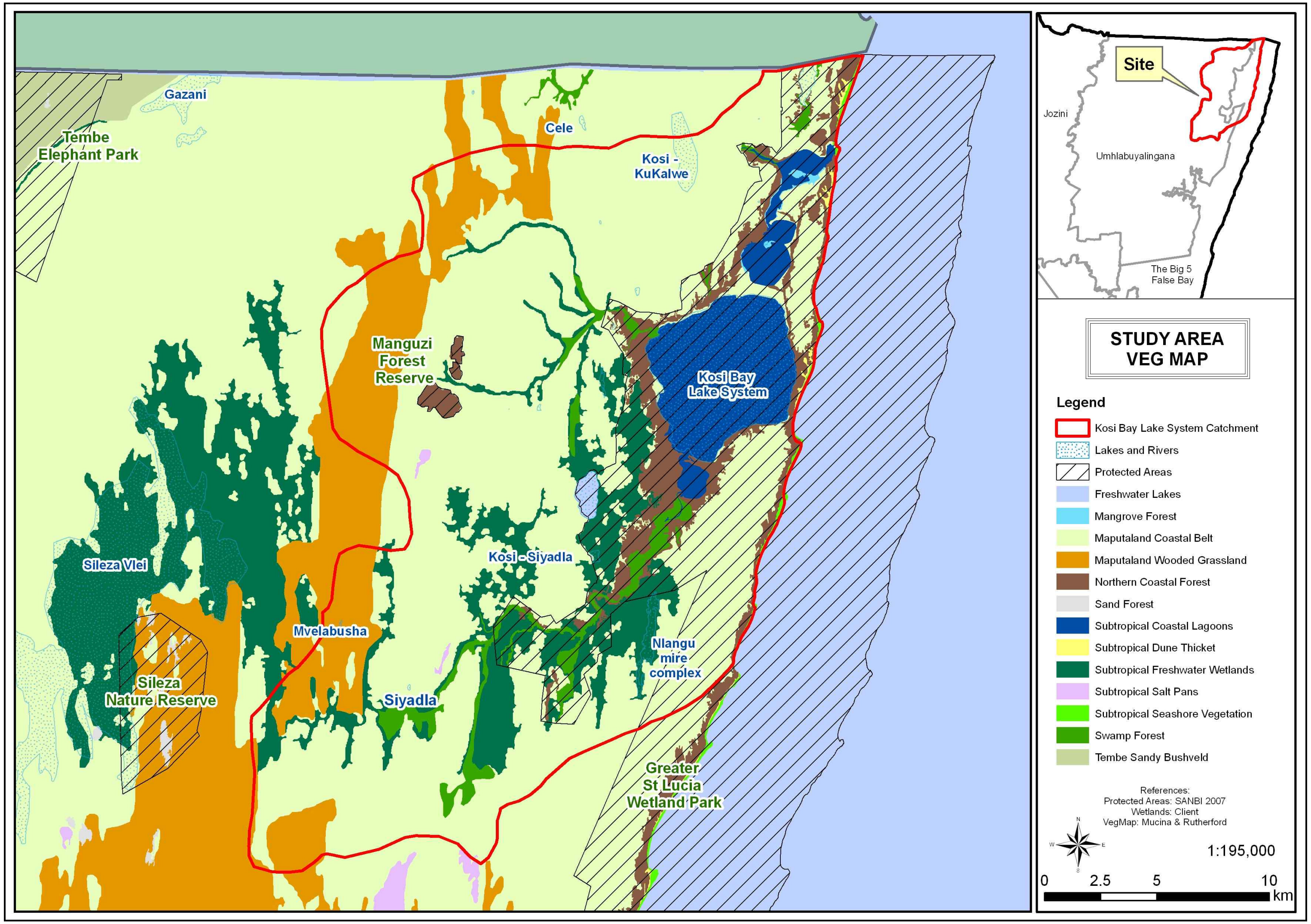

Figure 2.8 Vegetation types described by Mucina & Rutherford (2006) present within the Kosi Bay Lake System Catchment.

Mucina & Rutherford (2006) describe the conservation status of Swamp Forests as Critically Endangered, with a conservation target of 100%, while approximately 66% is currently located within nature reserves such as the iSimangaliso Wetland Park. Unknown sections of these systems have however been modified by development (e.g. around Richards Bay), plantations and agriculture, with Swamp Forest areas around the Kosi Bay Lake System being especially impacted by local farmers (Grundling *et al.* 1998, Mucina & Rutherford 2006).

2.2.6 Bananas and Peat Swamp Forests cultivation

Bananas (*Musa* x*paradisiaca*) are not native to Africa, but have been here for a long period of time and contributed to improved human population dynamics due to their high yields with minimal labour input requirements (Reader 1997). They were introduced to Africa from Southeast Asia, their cradle of origin and land of cultivation, approximately 2000 years ago and became an integral part of the local food supply (Reader, 1997). This is clearly reflected in the 250 kg of bananas that a present day average African consumes annually in the tropical and subtropical parts of the continent where it has been a very important staple food source for centuries (Anon 1991).

Bananas are an excellent energy food source, second only to cassava in calorie yield and two to three times more productive than cereals. They have high concentrations of vitamin C and potassium, but are unfortunately low in iron, calcium, and contains virtually no proteins or fats (Reader 1997). It is however not only the nutrient requirements that make bananas so popular but also their ease of cultivation and the large quantities produced in return that makes them a very attractive investment for local farmers. A well maintained banana garden in favorable conditions that may or may not be cultivated on peat are known to produce good crops for thirty years or more (Reader 1997) if it remains free of pathogens such as Panama disease. Such ease of cultivation has allowed many African farmers and their families to rely on bananas on plots typically smaller than 1 hectare (Reader 1997). In order for bananas to be grown throughout the whole year they require a more or less continuous rainfall and temperatures always relatively high. Swamp Forest habitat on peat soils therefore provide ideal environments for banana cultivation in the Kosi Bay Lake System Catchment. This area is more nutrient-rich compared to the surrounding infertile sandy soils and soil moisture conditions can be manipulated via drainage ditches in wet peat (Figure 2.5).

CHAPTHER THREE: METHODS

3.1 Introduction

This thesis focuses on Peat Swamp Forest transformation in response to anthropogenic induced disturbances in the form of local agricultural practices. Identifying and describing plant communities typical of undisturbed and actively disturbed PSF, as well as the range of possible stages in between form integral components thereof. PSF associated with linear drainage lines in valley bottom landscape positions form the geomorphic setting of the investigation, which by implication ignores or under emphasise other areas of PSF habitats such as lake margins (littoral zones). Pollen profile studies and autogenic drivers such as plant competition and life history strategies are also excluded from the investigation. However, PSF vegetation patterns are investigated in a range of undisturbed to actively cultivated localities throughout the Kosi Bay Lake System Catchment. These are augmented with descriptions of PSF properties illustrated by historic aerial photographs and the underlying peat stratigraphy, as well as vegetation change across PSF systems at surveyed transects. By implication the thesis has a strong descriptive approach.

All of these aspects are aimed to obtain an improved understanding of undisturbed Peat Swamp Forests (PSF), as well as the effects and responses of traditional farming practices on PSF communities in accordance with the postulated hypothesis. Work presented in this thesis forms one of the components of a larger Wetlands International funded PSF project that consisted of several overlapping focus areas managed by different institutions and researchers. Christoph Moning from the Technische Universitaet Muenchen (Germany) worked in close association on this particular component of the study and jointly conducted the fieldwork and some of the analysis. Christoph was of particular help with the creation of cross-section profile images that display the peat stratigraphy and surface topography of individual PSF cross-sections

3.2 Data Collection Phase

3.2.1 Selection of investigated sites

The study area incorporates the Kosi Bay Lake System Catchment (KBLSC), with its largely homogenous climate and geology, and gentle variation in topography from east to west. One sampling area (Cele) is located outside of the KBLSC, in close proximity to the catchment divide (Figure 3.1). The Cele area was still included as part of the sampling dataset due to its nearby location to the study area and comparable conditions.

A literature review based on existing information related to the study area and its people, as well as publications concerning tropical peatland ecosystems, Peat Swamp Forests (PES), tropical agriculture, and national and international wetland legislation and treaties were conducted as an initial step of the investigation (Chapter 2). The purpose thereof was to provide background information and highlight important concepts pertaining to PSF and their conservation.

Field surveys were considered to be more effective by focussing sampling efforts in a single drainage basin, as opposed to collecting data from different catchments across diverse rainfall conditions within the Maputaland Coastal Plain. This approach has the benefit that a single hydrological unit (at catchment scale) could be investigated more thoroughly in an environment where travelling is logistically constrained by informal roads and difficult driving conditions (Felgate 1982; Grobler 2004). In additional, similar cultural values and uses are likely to be associated with PSF ecosystems located within a single tribal community area.

Field surveys were conducted in May and September 2003, with a combined total of 41 field days, 16 sampled sites and 65 sampling plots (Figure 3.1). Potential PSF were identified from 1:50000 topographical maps, aerial photographs, a Landsat satellite image, and indigenous knowledge obtained from local guides, community members and Ezemvelo KZN Nature Conservation personnel. The available range of PSF habitats present within valley bottom drainage lines were sought throughout the KBLSC, so as to investigate the whole spectrum of cultivation-related disturbances inside these ecosystems.

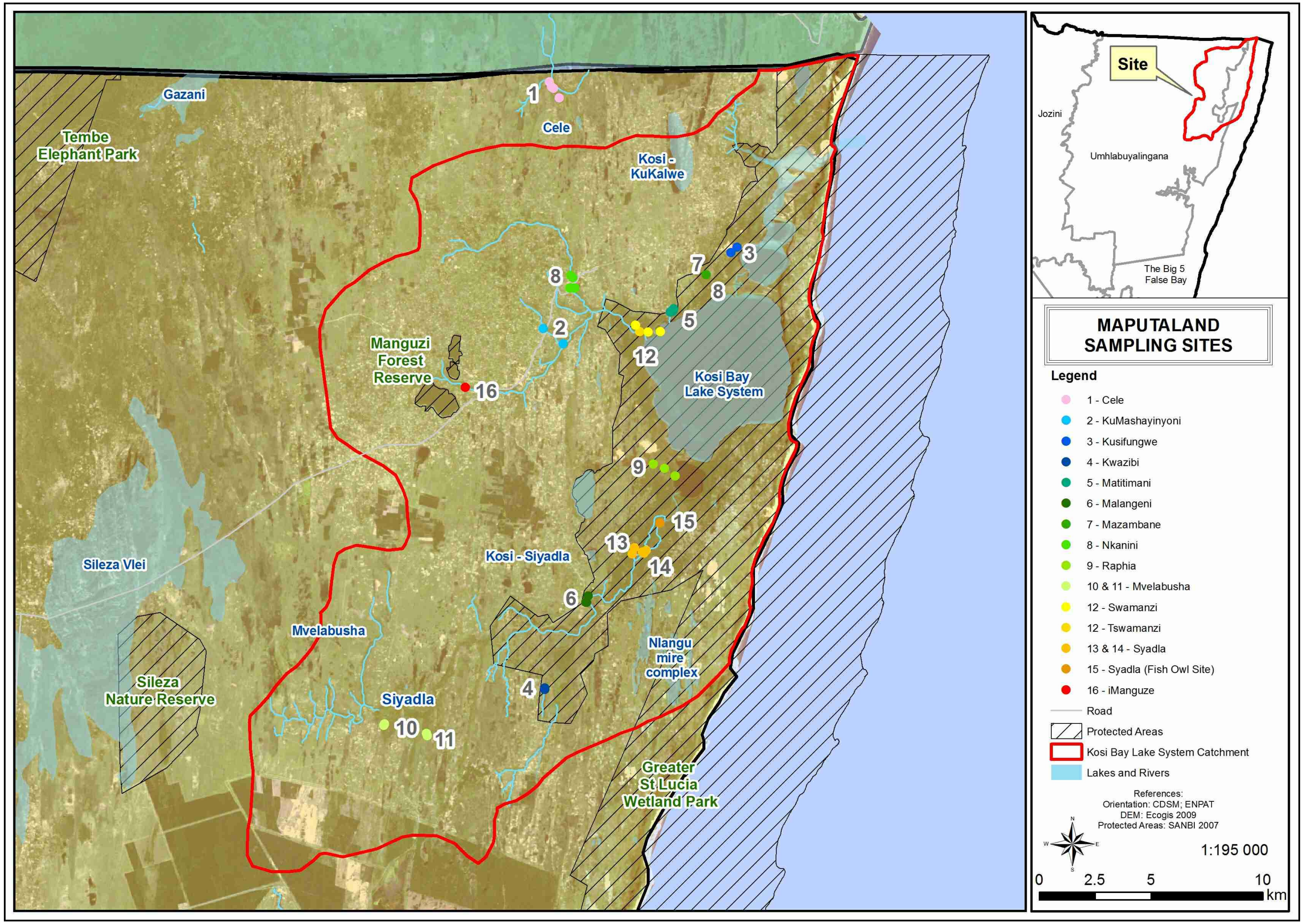

Figure 3.1. Sampling sites located within the study area (Kosi Bay Lake System Catchment), with the Cele site being the only exception.

Selected Peat Swamp Forest (PSF) areas were categorised into four mutually exclusive classes in the field based on the degree of disturbance and time elapsed since the disturbance. Disturbances had to be specifically related to agricultural practices. The classes were identified based on set criteria that made use of indigenous knowledge and visible indicators (Table 3.1). In most cases the PSF class was apparent from visible indicators, but information obtained from the guides, local land users, and inhabitants proved to be useful to verify specific classes, especially *Long-time recovering PSF*, *Pristine PSF*, and highly modified *Active gardening PSF*.

Table 3.1 Four classes of PSF and their respective properties associated with different stages of cultivation-related disturbances.

PSF class	Class description	Time elapse since disturbance	Selected visible indicators
Pristine PSF	Undisturbed natural vegetation	Never or long enough for disturbance indicators to have disappeared	Lack of drainage ditches; tree cuttings and clearing signs; and absence of burning events
Long-time recovering PSF	Marginally disturbed natural vegetation, forest vegetation has been recovering from previous cultivation activities	Several years or even decades ago, but not long enough for disturbance indicators to have disappeared	Recovering tree and shrub layer; visible resprouting from cut trunks and branches; absence of cultivated crops (except naturalised spp.); presence of old drainage ditches and burn marks on trunks.
Recently disturbed PSF	Area prepared for cultivation	Recently disturbed	Disturbance indicators (cleared vegetation and cut drains) are new with little resprouting; however no crops have yet been planted
Active gardening PSF	Area used for cultivating crops	Currently disturbed	Disturbance indicators (cleared vegetation and cut drains) are new and crops are cultivated

Each selected site had to be positioned in a linear watercourse that is connected to the drainage network and support or supported Peat Swamp Forests (PES) at sometime in the past irrespective of how it looked at the time of the field survey. An additional requirement for each site was that it still had to contain a distinguishable peat layer or at least a high organic content in the A horizon that differed from upslope soils. Notes on the nature of any visual disturbances were also recorded and included remarks on cutting and clearing, fire, presence of drainage ditches, and active cultivation (gardening), (Table 3.1). All selected sites were recorded with a global positioning system handheld device (Garmin GPS 12), which had a limited accuracy under dense canopy conditions.

During the second field survey transect lines were cut and sampled through linear PSF systems at six of the sixteen selected sites, which represented different locations of PSF in the catchment (Figure 3.1). It must be emphasised that the selection of sampling plots were not ideal to record PSF succession, as the positioning of different plots in different stages of recovery from cultivation do not all occur on the same slope, aspect, wetness regime or peat substrate. Hence the selected plots are located across environmental gradients that are likely to have their own effects on vegetation regeneration. Time and funding constrains prevented the possibility of repeated sampling of fixed plots to observe vegetation change over time, as well as the selection of more plots along additional transect lines. The latter would have served to increase the sampling size so that more plots in the same stage of recovery and in the same transect position with similar environmental factors could be used for comparable data analysis.

3.2.2 Vegetation surveys and recorded environmental variables

A few days were set aside with the onset of the vegetation survey to become familiarised with the variation in Peat Swamp Forest vegetation within the study area. PSF vegetation was sampled in quadrants (sampling plots) with an area size of 10 x 10 m ($100m^2$) that were located in different PSF classes and characterized by a uniform assemblage of species. Plant taxa information in the form of estimated cover abundance data for each species was recorded in individual sampling plots (releves). A releve therefore represents a sub-sample of vegetation stands or communities, which "*bounds and compartmentalises variation in species composition in space and time*" (McCune & Grace 2002). All plant taxa present were identified to species level where possible; scientific names follow Germishuizen & Meyer (2003).

Sample plots had to be large enough to incorporate a representative sample of a particular homogenous vegetation habitat, yet remain confined to the same vegetation type that could typically differ sharply over short distances due to selective farming-related disturbances. The sampling method incorporated cover-abundance classes of individual species as defined by Braun-Blanquet (Mueller-Dombois & Ellenberg 1974; Table 3.2).

The average Braun-Blanquet cover abundance class value for each plant species was assessed separately in one of the four identified vegetation strata: tree (T), shrub (S), herb (H), and liana (L) layer in all of the sample plots (Table 3.2). The height and presence of vegetation strata were decided upon based on the physiognomy of each individual sample plot. Consequently, if the same species occurred in all of the vegetation strata present within a sample plot, it would be recorded with independent cover abundance values in each of the vegetation layers.

Table 3.2 Braun-Blanquet Cover classes (Mueller-Dombois & Ellenberg 1974)

Class	Range of cover (%)	Mean
5	75-100	87.5
4	50-75	62.5
3	25-50	37.5
2	5-25	15.0
1	1-5	2.5
+	<1	0.5
r	<<1	0.1

During the first field campaign (May 2003) 35 sampling plots were setout in different Peat Swamp Forest localities throughout the Kosi Bay Lake System Catchment based on a placement pattern that can best be described as "*arbitrary but without preconceived bias*", (McCune & Grace 2002). Potential PSF areas were identified from maps, satellite images, aerial photographs and local knowledge.

In the second field campaign (September 2003) 26 sampling plots were set out along transect lines bisecting selected PSF areas that were previously identified (May 2003), while a further four plots were located in new PSF areas. The first field survey was done to obtain a general impression of the study area and identify representative sites throughout the catchment for further investigation. The second field survey investigated these selected sites in more detail to include measurements, such as water depth, and pH and electro-conductivity (EC) values of groundwater.

The following data fields were recorded on plot sheets at each of the 65 sampled plots (including both field surveys): survey date, site name and abbreviation, location and coordinates, and categories of biotic effects (e.g. evidence of coppicing after cutting). Plot characteristics such as evidence of fire disturbances, hydrology, pH, EC, presence of drain ditches, peat depth, signs of cutting (slashing), and percentage cover values for tree, shrub, herb and litter layers were noted when present. Data on PSF environmental variables were also noted and included a subjective categorical classification of the hydrology of the peat surface, as either: flooded, wet, moist, or dry. Detailed peat coring, profile description, and groundwater measurements formed part of the September 2003 transect survey.

3.2.3 Peat Swamp Forest cross-section profiles, peat stratigraphy, and hydrology measurements

During the September 2003 field survey six sites were furthered sampled at locations regarded to represent different areas of Peat Swamp Forest habitat within the Kosi Bay Lake System Catchment. The Cele site was again included as an exception, as it was regarded as comparable to the other locations and useful due to its close proximity to the catchment divide and the presence of upper drainage line PSF habitat. The six transect sites therefore include: Cele, Matitimani, Mvelabusha, Nkanini, Syadla, and Tswamanzi (Figure 3.2).

At each of the six locations coring of the entire peat body was systematically done with the aid of a Russian Peat Sampler and extensions along a cross-section of the Peat Swamp Forest System. This device allows the collection of moderately undisturbed samples from top to bottom in a peat profile, with an associated accuracy in the order of a decimeter. Cored increments were analysed in the field and sub-sampled where necessary. All of the samples were therefore described in the field according to their perceived colour, moisture content, and the presence of woody peat remnants. In addition, each sampled increment was also classified into one the appropriated categories represented in the Von Post humification scale that range from H1 to H10 (Table 3.3). Simultaneously the cross-sectional profiles of the respective valley bottom settings were measured with the aid of a bush cleared path, a tripod-mounted theodolite, a height pole with increments in centimeters, and a 50 m-measuring tape.

Through this process the stratigraphy of the peat bodies at each of the six transect sites could be constructed and represented graphically along with distance and height scales in meter. The approach also enabled the representation of geomorphological important features such as the location of channels within the cross-section. Hydrological measurements aimed at determining and sampling the groundwater levels were also made along all of the cross-section profiles at intervals ranging between 10–20 m. Perforated PVC pipes where inserted at depths up to 2 m in the peat body and left for a minimum of 24 hours before sampling occurred. In situ sampling along the transects included vegetation sampling in plots of 10 x 10 m in areas with perceived homogenous vegetation, water depth, pH, electrical conductivity (EC) and temperature. Hand held pH, EC, and temperature devices were used in the process, while the vegetation sampling followed the same approach outlined as part of the May 2003 field survey.

Table 3.3 The ten-point Von Post peat humification scale (Von Post & Granlund 1926).

Symbol	Plant Structure in peat	When squeezed there escapes between the fingers	Residue after squeezing
H1	Clearly evident	Colourless, clear water	Not pulpy
H2	Clearly evident	Faintly yellowish-brown, almost clear water	Not pulpy
H3	Clearly evident	Brown, quite turbid water	Not pulpy
H4	Clearly evident	Brown, very turbid water	Not pulpy
H5	Clearly evident	Very turbid water, also some peat substance	Slightly pulpy
H6	Evident	Up to 1/3 of the peat substance	Very pulpy
H7	Still barely recognizable	About 1/2 of the peat substance	Plant structures more recognizable than before
H8	Very unclear	About 2/3 of the peat substance	Mainly resistant residuals,
H9	Almost no longer recognizable	Almost all of the peat substance	e.g. wood and fibres
H10	No longer recognizable	All of the peat substance	No residue

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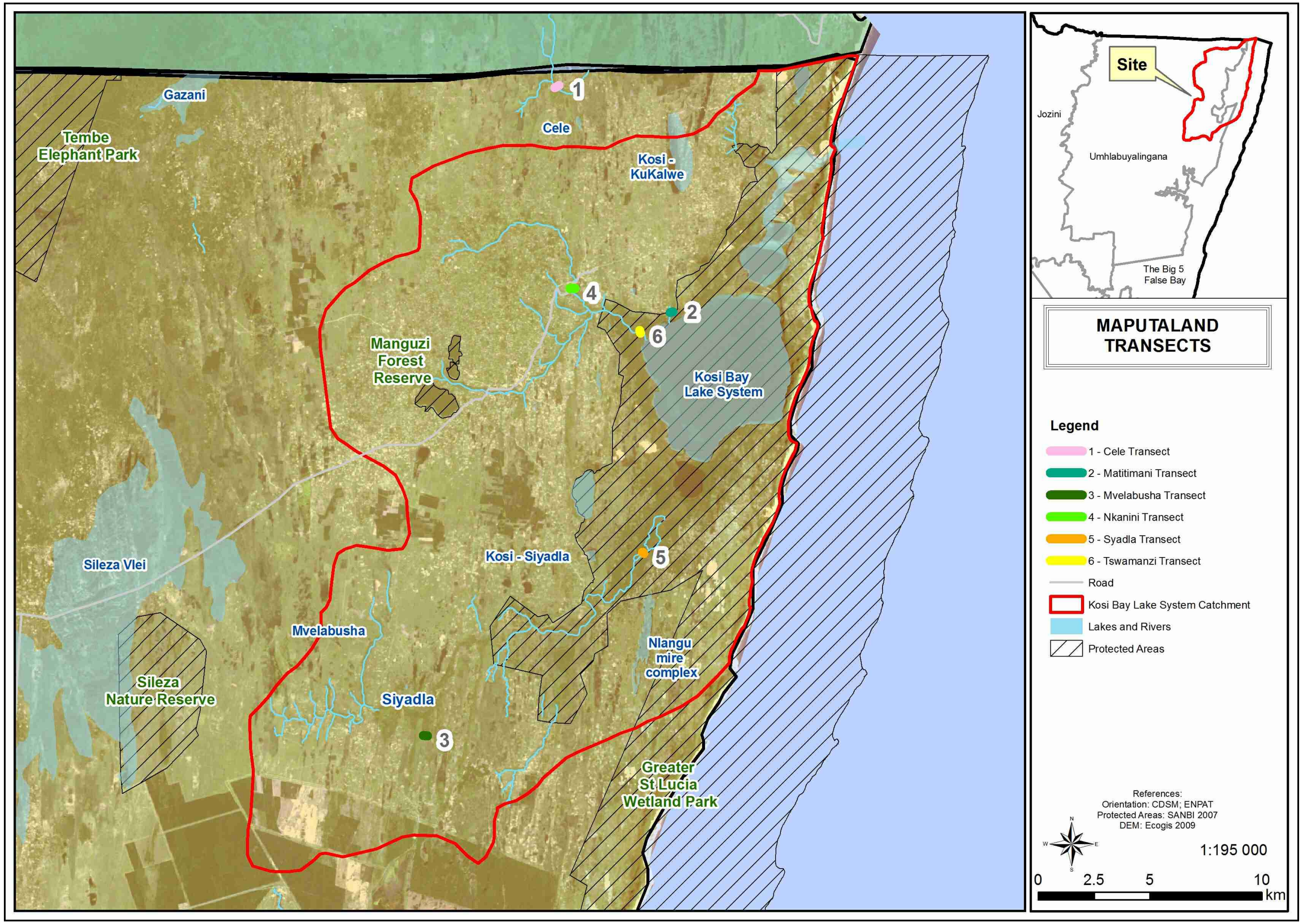


Figure3.2 The location of sampled cross-section profiles throughout the Kosi Bay Lake System Catchment, with the Cele site being the only exception.

3.2.4 Socio aspects

A minor yet important focus was placed on actively engaging with the local land users that utilise some form of natural and/or introduced resource associated with Peat Swamp Forest habitat, specifically farmers cultivating crops within these systems. In this context the two local guides were an indispensable help due to their detailed local knowledge and ability to facilitate communication and cooperation. It was frequently necessary to interact with land users at different sites, in order to gain permission to work in their gardens and/or land, and to inform them about our project, as well as enquiring about their land use practices. Information was hence generated through participant observation via informal and unstructured interviews that differed from area to area based on the presence/availability of the land users and their willingness to engage in conversation.

3.3 Computer-Based Data Analysis and Related Statistics

Multivariate statistical analyses were carried out as part of the study, specifically aimed to identify and describe the influence of recorded environmental factors and land use cultivation impacts on Peat Swamp Forest vegetation patterns (gradients and associations). Consequently, an array of defensible and traditionally used multivariate statistical techniques was selected to investigate sampled species cover abundance data and environmental variables through the PC-ORD version 5.10 software package (McCune & Mefford 2006).

3.3.1 Data set selection, data transformation and diversity indices

Different portions of the data set were selected for multivariate analysis in order to investigate the combined Peat Swamp Forests data set that includes releves from all four PSF classes, and a PSF data set of undisturbed to limited transformed PSF classes (Pristine and Long-time recovering PSF classes), (Table 3.1). Through this approach PSF vegetation patterns and their recorded environmental variables could potentially be differentiated into groupings of natural and cultivation-affected PSF patterns and environmental factors. All cultivated crops were excluded from the data sets used for statistical analyses, as these were selectively planted and maintained and would therefore not result in an objective interpretation of vegetation patterns.

In both data set selections rare species, regarded as uninformative species from a phytosociological consideration, and outlier releves were excluded in an attempt to eliminate noise and skewness within the respective data sets. Rare species were defined as species that occur less than once within a releve with a combined mean cover abundance value smaller than 0.5. The resultant species abundance data matrixes prepared for multivariate analysis also underwent a square root transformation in order to improve assumptions of normality, linearity and homogeneity of variance, as well as to emphasise informative species at the expense of uninformative species (McCune & Grace 2002). For the purpose of species diversity analysis, including alpha, beta and gamma diversity measures no species were excluded from either data set.

3.3.2 Classification – Identification of species-determined groups (communities) in the data

Plant communities are regarded as "concrete communities" as part of the community concept in this study, which in simple terms defines a plant community as the collection of plant species present at a specific area and period in time (McCune & Grace 2003). Concepts such as vegetation units are used as synonyms to plant communities, while sub-communities are regarded as sub-components of a community that are not readily identifiable in the field, and therefore represent a heterogeneous variant or patchiness of a larger community.

Agglomerative cluster analysis

As part of the multivariate analysis hierarchical agglomerative cluster analyses were performed for each of the two Peat Swamp Forest data sets. Through this approach it was possible to objectively define groups from the sampled species cover-abundance data by sorting releves into clusters based on the differences and similarities in their species cover-abundance values. According to this method groups are composed of subgroups (groups are nested within groups) based on an algorithm created by Post & Sheperd (1974) and adapted by McCune & Mefford (2006), with the results represented in a dendogram. The final division typically results in a grouping of releves that can be ecologically interpreted with specific associated environmental variables. These clustered releves therefore define the plant communities (vegetation units) present within the study area

This statistical technique consequently reveals the hierarchical structure and relationships between different groups present within the species abundance data set. Relative Euclidean distance measure (sorting strategy) was used in combination with Ward's method as a space-conserving linkage method to form groups via fusion from the bottom up (McCune & Grace 2002). The selection of a space-conserving linkage method with a compatible distance measure, specifically Ward's method with Relative Euclidean distance, increased the defensibility and reduced the risk of distortion in the results (McCune & Grace 2002).

Indicator species analysis

An Indicator species analysis (Dufrene & Legendre 1997) was performed in order to determine and describe the value of individual species to a particular group and its associated environmental conditions (in this case the generated cluster analysis). The technique combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group. Generated indicator values for each species were tested for statistical significance via a randomisation method (Monte Carlo test), (McCune & Grace 2002).

Indicator species analysis can also be performed on other types of groups that contain species with particular species cover-abundance values. Based on this principle, the technique was also used in an attempt to identify Peat Swamp Forest associated indicator species in different geographical positions across a transect of the system. This grouping is technically speaking based on subjectively defining boundaries at different positions along a gradient. The geographical position is therefore used as the group denominator, with the PSF being divided into four different mutually-exclusive zones in a cross-section profile orientation that can include:

- Outer valley bottom zone– higher lying areas near the transition with drier terrestrial areas.
- Intermediate valley bottom zone - located on a slope between the outer and centre valley bottom zones.
- Centre valley bottom zone– the section situated on the middle point of the valley bottom.
- Channel – referring to the channel position need not be located in the centre of the valley bottom.

Based on the influence of water on species composition (Mucina & Rutherford 2006), the influence of a channel with flowing water is regarded as more important than that of the remaining three zones, and is hence selected firstly and foremost should a releve overlap with an active channel on any of the three zones.

Phytosociological table

Information obtained from the agglomerative cluster analysis derived releve groups and Indicators species analysis values of individual species of each data set were respectively combined and represented in a phytosociological table. This table is similar in nature to the traditional Braun-Blanquet derived phytosociological table commonly used in phytosociological investigations in South Africa (Du Plessis 2001). However, the arrangement of community data in phytosociological tables that formed part of this study involved the fixed grouping of releves according to their assigned cluster group (based on the cluster analysis results). Species were arranged in species groups that were sorted in descending order according to their highest Indicator species value associated with a specific cluster of releves, while statistically significant ($p<0.005$) associations of a species with a particular cluster was also included.

3.3.3 Ordination – Identification of species-determined gradients in the data

Ordination techniques enable the differentiation of important patterns in the community data from weaker (less important) ones, while both expected and unforeseen patterns are represented. The distances between points (releves and/or individual species) in the ordination space are approximately proportional to the dissimilarities between these point entities (McCune & Grace 2002).

The influence (relationship) of environmental variables (categorical and/or quantitative) and ordination scores were indicated by biplots. Biplots represent environmental variables as vectors with a specific angle (direction) and length that is proportional to the strength of their relationship with the ordination scores (McCune & Grace 2002). Releves and/or species are typically represented along with strong biplot associated environmental variables. These biplot vectors can then be used as indicators of recorded environmental drivers and as reference lines for describing associations between different releves and/or species patterns in the ordination space. Ordination analyses were applied to the two main datasets (releves from all four PSF classes and a PSF data set of undisturbed to limited transformed PSF classes).

Two types of ordination techniques were used in association with the grouping technique (agglomerative cluster analyses) and phytosociological tables. The investigation of vegetation community data that incorporates ordination with Braun-Blanquet or Zürich-Montpellier derived phytosociological tables (Mueller-Dombois & Ellenberg 1974) has traditionally been used and popularised in South Africa by Werger (1973), Bredenkamp (1982), Bredenkamp & Bezuidenhout (1995) and others. This subsequently led to a specific phytosociological school of thought developed at the University of Pretoria. The combination of these multivariate analysis techniques in this particular study differs somewhat from the traditional approach, specifically in the use of the following:

- Grouping techniques (Agglomerative cluster analysis versus Two-way indicator species analysis).
- The inclusion of indicator species analysis with p-values.
- The representation and use of generated information in phytosociological tables.
- The selection of ordination techniques (Non-metric multidimensional scaling and Detrended correspondence analysis versus Detrended correspondence analysis alone).

Non-Metric Multidimensional Scaling (NMS)

Patterns and relationships between the releves were graphically presented and described through a nonmetric multidimensional scaling (NMDS or NMS) ordination technique based on species composition data recorded in each releve. McCune and Grace (2002) regard the NMDS method as the generally most effective ordination technique for ecological community data interpretation. The authors also state that NMDS ordination is one of the most defensible ordination techniques due to its increasing use in peer reviewed articles and lack of constrains and assumptions (e.g. it avoids assumptions of linear relationships among variables and does not produce the “zero truncation problem” inherit to several other ordination techniques).

Statistical parameters used in the NMDS ordination included a Bray-Curtis distance measure, while the algorithm followed Mather (1976) and Kruskal (1964). Random starting configurations were used based on 250 real and random runs of the data.

Detrended Correspondence Analysis

Detrended correspondence analysis (DECORANA or DCA), (Hill, 1979) has traditionally been extensively used in South Africa for phytosociological investigations (Bredenkamp & Deutschländer 1995, Du Plessis 2001). The technique has been criticized in recent years due to its rescaling and detrending processes, although it has remained quite popular in ecological studies (McCune & Grace 2002). The criticism is chiefly related to the incorporation of assumptions regarding spatial distributions of releves and species inherent to the technique's operation, which includes changes in the DCA scores that depend on the sequence of releves in the data set (McCune & Grace 2002).

The common use of DECORANA ordinations in South African phytosociological investigations was used as motivation for its inclusion in this study, along with NMDS ordinations for the same data sets. However, the PC-ORD multivariate statistical software package used in this study make use of corrections that improve the original stability of the solutions and incorporate an improve DECORANA smoothing algorithm (McCune & Grace 2002).

CHAPTHER FOUR: PHYTOSOCIOLOGY OF PEAT SWAMP FORESTS

4.1 Phytosociology of uncultivated (pristine) and long-time recovering Peat Swamp Forests

4.1.1 Introduction

A phytosociology analysis was performed on all releves that showed no evidence of recent disturbances, but were perceived to be pristine or have been in a process of recovering for a long period of time, up to the point where they were structurally similar to pristine Peat Swamp Forest sites. Associations in species combinations and environmental factors related to sampling plots from Pristine and Long-term recovering PSF classes are investigated in order to identify, order, and describe different plant communities from uncultivated and historically disturbed PSF habitats. Plant community analysis will contribute to a better understanding of the structure of undisturbed and limited transformed PSF vegetation groups (in terms of cultivation related impacts) and their relationships to the surrounding environment.

This process is facilitated by an array of multivariate analysis techniques aimed at the identification of groups and their similarity/dissimilarity to each other through agglomerative cluster analysis (Van Tongeren 1995), as well as the presence of indicator plant species as characteristic group features (Dufrene & Legendre 1997). Information obtained through these techniques are then represented in a phytosociological table for comparative and descriptive purposes. Finally ordinations in the form of detrended correspondence analysis (DCA) and nonmetric multidimensional scaling (NMDS) are performed to identify relationships between releves, and between releves and/or releve groups (communities) and environment variables (Ter Braak 1995). The locations and names of the sampling plots used as part of the phytosociological assessment is illustrated in Figure 3.1.

4.1.2 Agglomerative cluster analysis

A division of five releve clusters provided the most suitable or best possible fit of groupings in terms of ecological interpretation from the sampled dataset (Figure 4.1). Ecological interpretation refers to the identification of statistically derived information (in this case groups) in the natural environment, with the statistical group information related to expected uncultivated and historically disturbed PSF plant communities. The hierarchical structure of these plant communities are represented in two dendrograms, as derived from a cluster analysis and an indicator species analysis, performed at each of the five group membership levels (Figure 4.1 & 4.2).

Statistically significant ($p<0.05$) indicator species were also used in the naming of each of the five groups (plant communities). The *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L) vegetation unit (plant community 4) is the most distinct of all the uncultivated to long-term recovering plant communities and splits off first, followed by the *Scleria angusta* (H) – *Nephrolepis biserrata* (H) and *Raphia australis* (T) – *Raphia australis* (H) vegetation units (plant community 1 and 2) respectively (Figure 4.1 & 4.2). Plant communities 4 and 2 have the longest "stems" in the dendrogram, which indicates smaller intra-specific group variation (Figure 4.1). This implies a greater physiognomical consistency within these two communities and therefore easier recognisable community features in the environment. The *Raphia australis* (T) – *Raphia australis* (H) community is characterised by only two releves, which is considered too few (a minimum of three releves can form a community), hence a lower confidence is associated with this particular group and its status as a community is applied in an informal sense only. Communities 1 and 7 have an average level of intra-specific group variation and therefore an average degree of physiognomical consistency in the environment, while community 3 is the most heterogeneous and least recognisable (Figure 4.1).

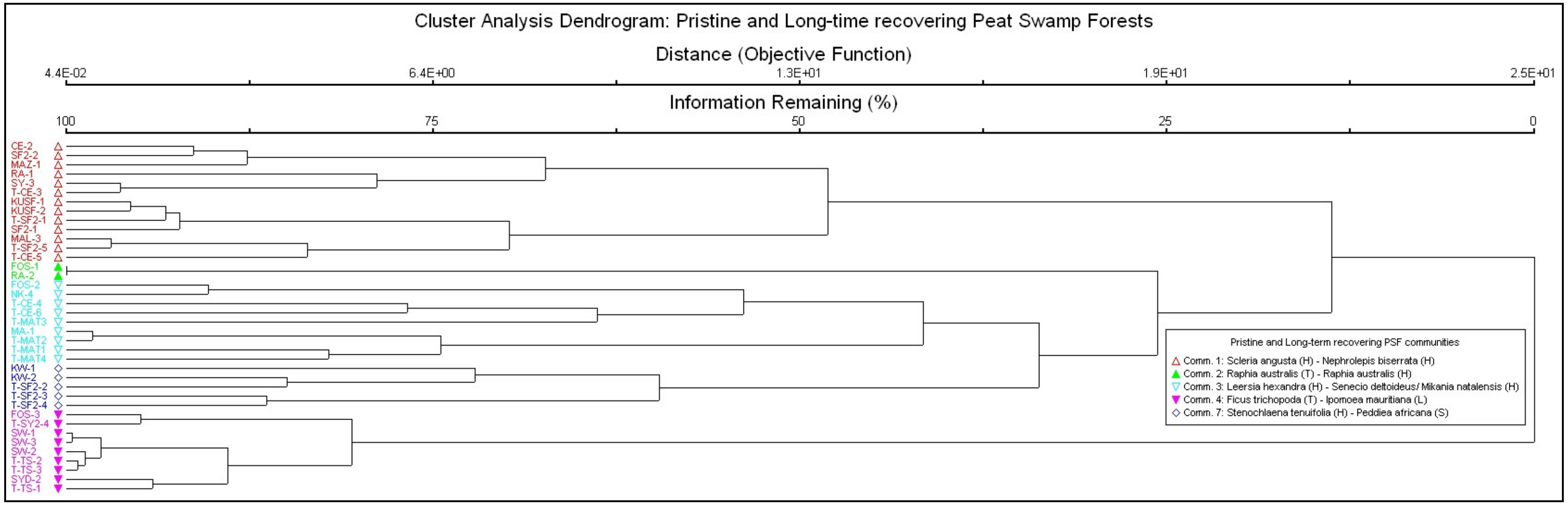


Figure 4.1 A dendrogram of Pristine and Long-time recovering Peat Swamp Forest classes that illustrates different levels of releve divisions based on the similarity/dissimilarity in species composition at each division level of the agglomerative cluster analysis; the five identified releve clusters represent plant communities present within the dataset.

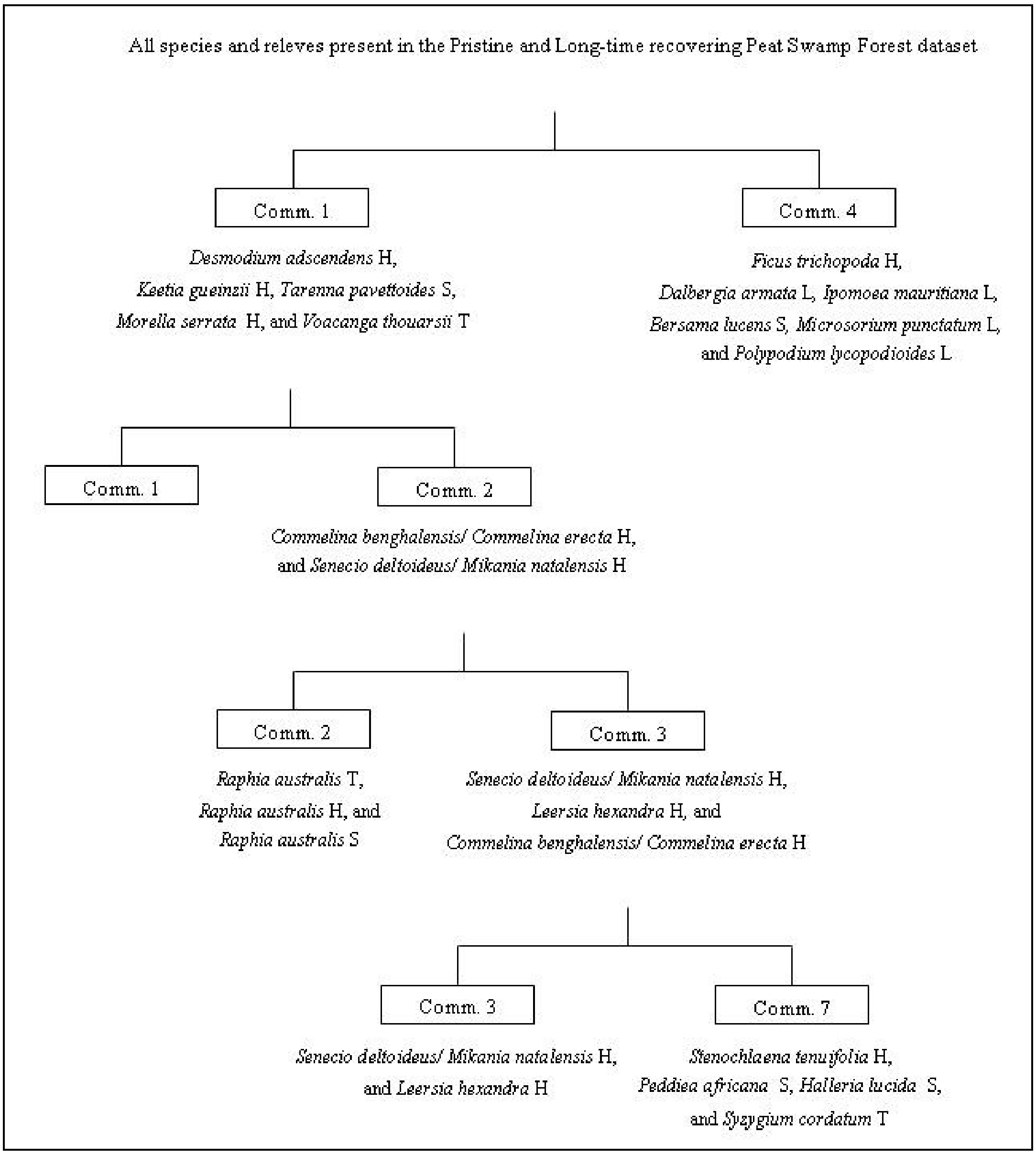


Figure 4.2 A dendrogram of Pristine and Long-term recovering Peat Swamp Forest classes that illustrates the division hierarchy, including indicator species present at each division level and the five plant communities (divisions not according to scale).

4.1.3 Community description

Species diversity measures related to the identified five groups (clusters/ plant communities) are represented through alpha, beta and gamma diversity. Whitaker (1972) defined these three diversity measures as:

- Alpha diversity as the average species richness per releve.
- Beta diversity (Whitaker's beta diversity = $ß_w$) is a measure of heterogeneity in the data, which is calculated as the total number of species divided by the average number of species (gamma over alpha diversity) minus one.
- Gamma diversity is the landscape-level diversity, estimated as the total number of species across releves (McCune *et al.* 1997), (Table 4.1).

Species information used as part of the species diversity calculations were solely based on the presence of a species per releve and were hence not recorded separately in each of the vegetation strata, as used in the multivariate analysis (cluster analysis, phytosociolgical tables and ordinations), (Appendix A & B).

Table 4.1 Species diversity measures related to the five uncultivated and long-term recovering plant communities.

		Diversity measure		
Community name	**n**	**alpha**	**beta ($ß_w$)**	**gamma**
Community 1: *Scleria angusta* (H) – *Nephrolepis biserrata* (H)	13	20.46	2.08	63
Community 2: *Raphia australis* (T) – *Raphia australis* (H)	2	7.50	0.60	12
Community 3: *Leersia hexandra* (H) – *Senecio deltoideus/ Mikania natalensis* (H)	9	18.33	1.73	50
Community 7: *Stenochlaena tenuifolia* (H) – *Peddiea africana* (S)	5	19	1.21	42
Community 4: *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L)	9	19.44	2.14	61

The Cluster analysis classification performed on the vegetation data of all the pristine and long-time recovering releves resulted in five vegetation communities with nine species groups as represented in the phytosociological table (Table 4.2). The simultaneous use of species diversity measures, classification results, and statistics on vegetation strata height and percentage species contributions per stratum are applied to describe the five vegetation communities as follow:

Community 1: *Scleria angusta* (H) – *Nephrolepis biserrata* (H)

This community is the largest of the five Peat Swamp Forest communities and consists of 13 releves: CE-2, MAZ-1, RA-1, SF2-2, SY-3, T-CE-3, KUSIF-1, KUSIF-2, MAL-3, SF2-1, T-CE-5, T-SF2-1 and T-SF2-5. The community is made up of eight long-time recovering and five pristine Peat Swamp Forest sites, and is therefore considered as an example of a long-term recovering PSF community that is in the process of recovering to an uncultivated PSF system. The community is characterized by species group AA, while the general (shared) species groups AD and AF also overlaps with the community (Table 4.2). The sedge *Scleria angusta* and the fern *Nephrolepis biserrata* characterise the community as the only two statistically significant indicator plant species present (Table 4.2). Other diagnostic species include the trees *Apodytes dimidiata, Schefflera umbellifera,* and *Cassonia sphaerocephala,* while the tree *Voacanga thouarsii* is also very dominant but not diagnostic to the community (Table 4.2).

The plant community is for the most part located on a well developed peat body between the outer boundary of the valley bottom peatland and the active channel, with a wet to moderately wet hydrological regime that results in saturated conditions at or near the surface. Drainage furrows are typically absent even from the long-term recovering releves, with the exception of releve T-SF2-5. From a structural perspective the community is quite homogenous with a distinct tree, shrub and herbaceous (herb) strata, including a litter layer on the surface. The average tree stratum height is 12.62 m (SD = ±1.85), shrub stratum height = 6 m (SD = ±0.71), and herb stratum height = 1.50 m (SD = ±0.24). The herbaceous layer has the most dense average spatial cover of all five communities with a value of 81.92 % (SD = ±14.94) compared to the overall average value of 68.05 % (SD = ±24.02).

The community has a total of 63 species, with a average species richness of 20.46 (SD = 4.91), making it the richest community in terms of plant diversity (Table 4.1). The large number of releves and plant species present within the community indicates a wide ecological amplitude. Hence, various untransformed or recovering peat soil slopes with a wet to moderately wet hydrological regime are expected to be covered by this particular PSF community.

Community 2: *Raphia australis* (T) – *Raphia australis* (H)

This particular group is dominated by the presence of the Giant Raphia Palm (*Raphia australis*) in the tree and shrub layer next to the western shore of Lake Amanzamnyama and around the Syadla River Mouth (Figure 4.3; Table 4.2). The community is the smallest of the five Peat Swamp Forest communites and should strictly speaking not be treated as a community due to the presence of only two releves (FOS-1 and RA-2). However, the group was regarded as a proper plant community that was under-sampled during the field survey. Justification for the treatment of the group as a distinct plant community is based on previous descriptions of this palm to form a "magnificent grove" next to the western shore of Lake Amanzamnyama (Mattson & Uken, 2007). In addition, its presence is also indicated at the same position on topographical 1:50000 map 2732 BB as *Giant Raphia Palms*, where it is locally abundant but regionally scarce.

The community is characterized by species group AB, with *Raphia australis* (tree) and *Raphia australis* (herb) as the only statistically significant indicator species in the community (Table 4.2). The vegetation unit is regarded as a pristine *Raphia australis* Peat Swamp Forest community with the most dense tree canopy of all five Pristine to long-term recovering plant communities (average tree canopy density = 92.50 %; SD = ±3.54). The community has a total of 12 species with an average species richness of 7.50 (SD = ±2.12), (Table 4.1), while average strata heights include a tree layer of 13 m (SD = ±4.24), shrub layer of 2.75 m (SD = ±1.77), and a herb layer of 0.65 m (SD = ±0.21). The average shrub and herb layers are the shortest with the sparsest cover of all the respective shrub and herbaceous strata sampling plots that form part of the five communities. No species were recorded in the liana stratum, but additional sampling plots would be required to verify this pattern as well as others with a greater measure of confidence.

Figure 4.3 Pristine and Long-time recovering Peat Swamp Forests: a. An active channel draining through a *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L) plant community; b. Prop roots as an adaptation of *Ficus trichopoda* trees to grow in saturated peat soils; c. Dense undergrowth of *Cyperus textiles* with *Voacanga thouarsii* and *Ficus trichopoda* trees in the *Leersia hexandra* (H) – *Senecio deltoideus/ Mikania natalensis* (H) plant community; d. The forest edge of the *Raphia australis* (T) – *Raphia australis* (H) community upslope of the western shore of Lake Amanzamnyama.

Community 3: ***Leersia hexandra*** **(H) –** ***Senecio deltoideus/ Mikania natalensis*** **(H)**

The community is characterised by species group AC and overlaps partially with the shared species groups AD and AF (Table 4.2) It is composed of nine reléves: FOS-3, NK-4, T-CE-4, T-CE-6, T-MAT-3, MA-1, T-MAT-1, T-MAT-2 and T-MAT-4, and is considered a recovering Peat Swamp Forest that has been more recently disturbed compared to the other communities. The community consistently contained saturated peat soils with surface water often present. The historic disturbances are not expected to be directly related to active cultivation activities, as only one releve (NK-4) contains drainage furrows. However, the system has been subjected to vegetation clearing, especially in the tree layer, as the community contains the smallest species contribution (9 %) in the tree stratum compared to the three other strata (shrub, herb and liana layers) of all five communities. The tree stratum appears to be in a stage of recovery, but its average height (9.89 m; SD = ±5.06) remains lower than the overall average tree layer height from the five communities (12.24 m; SD = ±3.79), while its percentage tree canopy cover is the second lowest of the five communities (44.44 %; SD = ±24.55). No tree species were identified as reliable indicator species in the community. The forb species complex *Senecio deltoideus/ Mikania natalensis* and the grass *Leersia hexandra* were the only two statistically significant indicator species and remained confined to the herbaceous layer (Table 4.2). Other important diagnostic species include the fern *Thelypteris interrupta,* and the sedges *Cyperus prolifera, Typha capensis,* and *Cyperus textilis* that indicate wet and open conditions. Important non-diagnostic tree species in the community that form part of species group AF are *Voacanga thouarsii* and *Ficus trichopoda* (Figure 4.3; Table 4.2).

The average height of the shrub and herb strata were comparable to the average heights from the five communities with values of 4.06 m (SD = ±1.04) and 1.51 m (SD = ±0.34) compared to 4.62 m (SD = ±1.34) and 1.54 m (SD = ±0.36) respectively. The community has a total of 50 species with an average species richness of 18.33 (SD = ±3.12) per releve, which is comparable to the other three well defined uncultivated and long-term recovering Peat Swamp Forest communities (excluding community 2), (Table 4.1).

Community 7: ***Stenochlaena tenuifolia*** **(H) –** ***Peddiea africana*** **(S)**

This community is considered as a dry long-term recovering Peat Swamp Forest vegetation unit that consists entirely of long-term recovering PSF sampling plots with five reléves in total: KW-1, KW-2, T-SF2-2, T-SF2-3 and T-SF2-4. The community is characterised by species group AE and overlaps partially with the shared species group AF and AH; statistically significant indicator species include the climbing fern *Stenochlaena tenuifolia,* the shrubs *Peddiea africana*, and *Halleria lucida* (Table 4.2). Other important diagnostic species include: the trees *Syzygium cordatum* and *Rauvolfia caffra,* the shrub *Keetia gueinzii,* the grasses *Panicum parvifolium* and *Oplismenus hirtellus,* as well as the forb *Smilax anceps* (Table 4.2). The community has 42 species in total with an average species richness of 19 (SD = ±5.20).

The community is associated with drier Peat Swamp Forest habitat with shallow peat profiles that are more typical of headwater PSF watercourses such as the sampled plots at Mvelabusha (Figure 3.1). The average tree strata height (10 m; SD = ±3.16) and canopy cover (34 %; SD = ±22.19) are below the average values for the five communities as whole. While the shrub layer is well developed with an average height of 4.90 m (SD = ±1.67) and an average cover of 40% (SD = ±22.64), which are both greater than the average values of the five communities. The shrub layer is expected to benefit from increased sunlight for photosynthesis and increased productivity, as a result of the sparser and shorter tree layer compared to the majority of the other uncultivated and long-term recovering PSF plant communities.

Community 4: *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L)

The community is the most distinct in terms of the cluster analysis classification, as derived from similarities and dissimilarities in the species composition of individual releves (Figure 4.1 & 4.2). A total of nine releves (FOS-3, SW-1, SW-2, SW-3, SYD-2, T-SY2-4, T-TSW-1, T-TSW-2 and T-TSW-3) form part of this plant communityt; with the majority of them being classified as uncultivated Peat Swamp Forest sites (releve SW-2 is the only exception as a long-term recovering site). Species group AG characterises the community, while species group AH is shared among all five identified communities. Statistically significant indicator plant species include *Ficus trichopoda* in the tree stratum, the woody climber *Dalbergia armata* in the liana layer and an unidentified Asteraceae forb species (pseudonym: White Asteracea) in the herb layer (Table 4.2). Other important diagnostic species include: *Bersama lucens* (tree and shrub strata) and the lianas *Ipomoea mauritiana, Asparagus falcatus,* and *Petopentia natalensis.* Epiphytic ferns that grow in the liana layer are *Microsorium punctatum* and *Polypodium lycopodioides. Scleria angusta,* though not a diagnostic species to the community, is also very common and contribute to an average percentage cover in the herbaceous layer of 56.11 % (SD = ±14.74), (Table 4.2). The percentage cover of the herbaceous stratum is the second lowest of all five PSF communities and well below the average cover value of 68.05 % (SD = ±24.02).

Field observations indicated that the community is associated with a nearby channel with flowing water in a valley bottom setting (Figure 4.3). The associated peat soils are deep and saturated with surface ponding, while peat profiles on the higher-lying outer margins are shallower. Dense stands of full grown *Ficus trichopoda* trees are clumped around the active channel to create a distinct physiognomical structure with their prop and buttress roots (Figure 4.3). Another distinct feature related to the physiognomy of the community is the presence of several species in the liana stratum. 19% of the total species contribution in the four vegetation strata is represented within the liana layer, the largest contribution in all five PSF communities. An average tree stratum height of 15.11 m (SD = ±3.06) is the highest of the five plant communities, while the average shrub and herb strata heights (4.89 m; SD = ±1.76 and 1.58 m; SD = ±0.13) is similar to the average values from the combined communities. The community has a total of 61 species, with an average species richness of 19.44 (SD = ±5.96) species per releve (Table 4.1).

4.1.4 Ordinations

Figure 4.4 & 4.5 represent the first and second axes of a Detrended Correspondence Analysis (DCA) and a Nonmetric Multidimensional Scaling (NMDS) ordination respectively, of all 38 releves associated with uncultivated and long-time recovering Peat Swamp Forest releves. A DCA ordination is included despite criticism against the use of the technique to interpret ecological community data (Legendre & Legendre 1999), as the technique has been widely used in South Africa with a general familiarisation and acceptance thereof. Axes one and two of the DCA represent 26.3% and 14.4% of the variance in the PSF communities (cumulative variance = 40.8%), with eigenvalues of 0.67 (gradient length = 4.45) and 0.42 (gradient length = 3.48).

Spatial cover of the herbaceous and tree strata form the two strongest environmental variables correlated to the first axis in the form of biplot vectors in the DCA ordination (Pearson and Kendall's r-values of 0.58 and -0.52 respectively), (Figure 4.4). The first axis provides and indication of the physiognomical heterogeneity between the PSF communities, with the *Leersia hexandra* (H) – *Senecio deltoideus/ Mikania natalensis* (H) community displaying the most variation along this gradient as the community is in more diverse stages of recovery from disturbances to its tree layer (Figure 4.4). On a finer scale releve RA-1 is a distinct outlier of community 1 and appears to be more closely associated with community 2 (Figure 4.4).

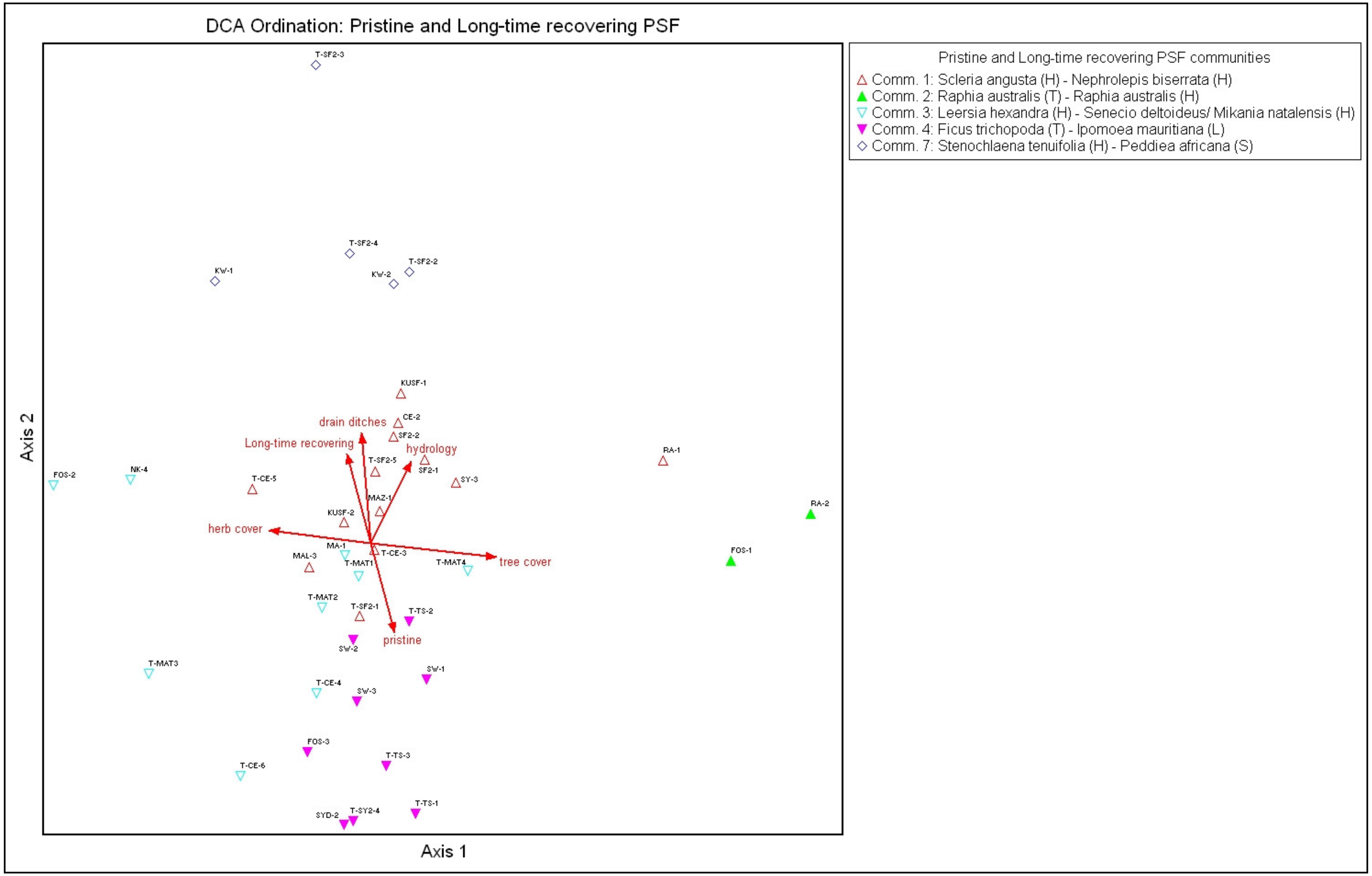


Figure 4.4 Axes 1 and 2 of a Detrended Correspondence Analysis (DCA) ordination of all 38 pristine (uncultivated) and long-time recovering Peat Swamp Forest releves.

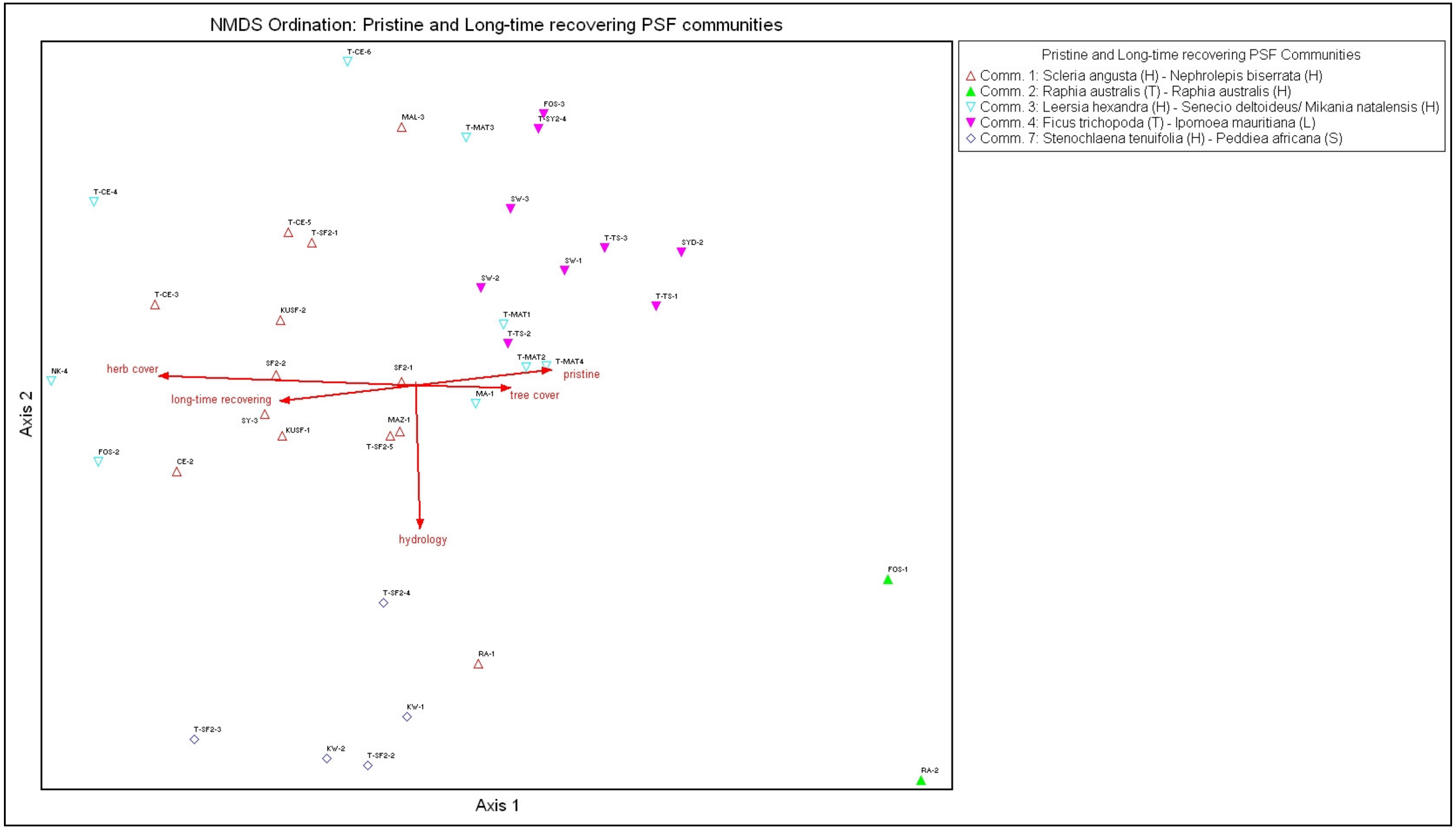


Figure 4.5 Axes 1 and 2 of a Nonmetric Multidimensional Scaling (NMDS) ordination of all 38 pristine (uncultivated) and long-time recovering Peat Swamp Forest releves.

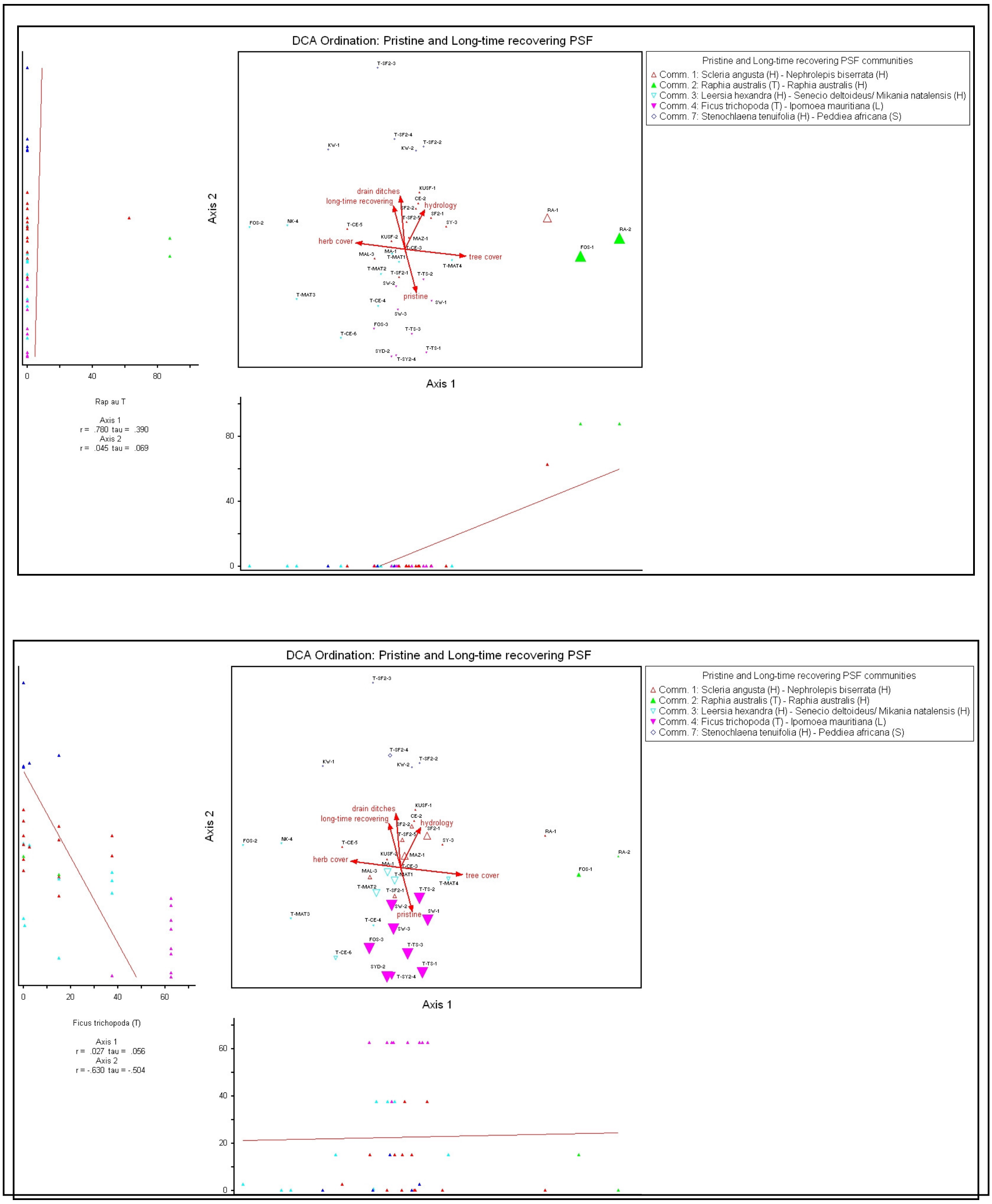


Figure 4.6 Cover abundance and distribution patterns (gradients in ordination space) of the trees *Raphia australis* (Rap au T) and *Ficus trichopoda* associated with each of the 38 releves that formed part of the DCA ordination (the size of each releve icon is related to the cover abundance of the relevant tree species).

The close association between releve RA-1 and community 2 is explained by the cover abundance distribution of the tree *Raphia australis*, which is strongly associated with releve RA-1 and releves of community 2 (Figure 4.6). Pristine and long-time recovering PSF classes, including hydrology and the presence of drainage ditches (furrows) are the recorded variables that correlate best with the second axis of the DCA ordination in the form of biplot vectors (Pearson and Kendall's r-values of -0.49, 0.49, 0.46, and 0.54 respectively), (Figure 4.4). Community 3 displays the greatest variation in a vertical direction along the wetness, as well as the pristine to long-time recovering gradients, while communities 4 to 1 to 7 represent a distinct wet to dry gradient, with the wetter communities being seemingly less influenced by historic cultivation practices (Figure 4.4). The wet *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L) vegetation unit (community 4) is strongly associated with the pristine PSF class and larger than average wetness conditions (Figure 4.4).

The dominant presence of the tree *F. trichopoda* is also indicative of an absence of cultivation practices and it appears that wet conditions next to active channels associated with dense stands of this species have been avoided by farmers in the past (Figure 4.6). Apart from community 3 the communities are generally well clumped together, but overlap partially in the ordination space with shared environmental variables (Figure 4.4 & 4.5). The NMDS ordination displays similar broad patterns in the releve gradient distributions and environmental variables as the DCA ordination, with the main differences being the pristine and long-time recovering PSF classes being correlated with tree cover and herb cover along the first axis (Figure 4.4 & 4.5). This correlation is consistent with expected patterns of denser tree growth in pristine PSF habitat, and less denser tree cover/ more denser herbaceous cover in recovering PSF habitat where the tree stratum is in the process of densification after cultivation activities were abandoned. Axes one and two of the NMDS represent 21.9% and 22.1% of the variance in the PSF communities (cumulative variance = 44%), with the use of three dimensions and a final stress value of 15.48 (iterations = 61).

4.1.5 Discussion

The investigation describes a Peat Swamp Forests physiognomy that differs from other descriptions of this vegetation type (Moll 1980; Mucina & Rutherford 2006). This is to be expected as PSF or Swamp Forests on a broader scale have not yet been thoroughly investigated in South Africa (Wessels 1997; Grobler 2004). Mucina and Rutherford (2006) described Swamp Forest with two main strata, a tree and shrub layer, with the latter (the understory) being sparsely developed.

Results obtained from this investigation indicated a well developed and distinct third layer, a herbaceous stratum, which consists of grasses, sedges, ferns and forbs. It is also the most dense of all thee vegetation strata (average cover = 68.05 %; SD = ±24.02). A tree layer of 12–15 m tall (Mucina & Rutherford 2006), correlates well with an observed average tree height of 12.24 m (SD = ±3.79) for all of the 38 releves. The average tree height value increases to 14.38 m (SD = ±2.85) if only the pristine PSF releves are considered (16 releves). This value is regarded as more representative given the smaller SD value and the fact that the trees in this sample set have not been affected by previous clearing and cutting impacts.

A tree height range of 15–25m specified by Moll (1980) for "good Swamp Forest" habitat differs more substantially from the results of this investigation. However, the subjectivity with which these tree height measurements are carried out may provide a plausible explanation for the difference in the results. The author points out that Swamp Forest communities within Maputaland are best developed around the Kosi Bay Lake System, in particular adjacent to the the Syadla River, and that shifting agriculture (gardening) has already affected these forests through clearing prior to 1980. The difference in cover density of the tree and herb strata is one of the strongest patterns identified through the multivariate analysis, and reflects the gradient of recovery of the respective strata from more recently cleared releves to untransformed PSF releves.

Hydrology is another key driver in uncultivated and longer-time recovering PSF, both as a natural factor and a modified environmental variable. The latter pertains to induced wetness changes created by drainage ditches (furrows) that were previously used by local farms to form more suitable conditions for crop production in saturated peat soils (Grobler 2004). Hydrology influenced patterns include the "stunted" *Stenochlaena tenuifolia* (H) – *Peddiea africana* (S) PSF community on drier and shallower peat, the wet and wide spread *Scleria angusta* (H) – *Nephrolepis biserrata* (H) community on valley bottom slopes, and the *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L) community in close proximity to active channels with flowing water. It is not currently possible to differentiate the effect of the natural hydrology on different PSF communities (e.g. groundwater input versus surface water input) and the impact of induced hydrological modifications (i.e. peat drainage and desiccation). Different wetness gradients do however contribute to the presence of distinct plant species assemblages. The hydrology within a peatland is also different from that of a purely mineral dominated soil environment, as the presence of peat will influence the behaviour of water within an organic rich substrate (Rydin & Jeglum 2006). It is expected that a more in depth knowledge of hydrological processes active in Peat Swamp Forest watercourses will enable an improved understanding of PSF community patterns.

Environmental factors and species composition associated with the *Raphia australis* (T) – *Raphia australis* (H) community may be due in part to its peat characteristics, as this is the only PSF community that is dominated by a palm, with an expected adventitious root system derived peat soil. Input of organic material derived from the stems, leaves and root system of *Raphia australis* can result in unique peat properties that change local conditions in a specific, yet unknown manner. Page *et al.* (1999) refer to the interdependence of peat and Swamp Forest vegetation on each other, but the nature of such interactions in South African PSF systems remain unknown.

Based on the available information it stands to reason that differences in the hydrology and peat characteristics (specifically peat depth) of wet, well developed valley bottom peatlands, and drier, shallow valley bottom peatlands will influence what plant communities will become re-establish following abandoned cultivation activities. Peat depth and hydrology/ wetness is expected to be influenced by the respective valley bottom settings of each community, while the duration of time elapsed since cultivation seized will also contribute to the physiognomy of recovering PSF systems.

4.2 Phytosociology of all Peat Swamp Forest classes

4.2.1 Introduction

A phytosociology analysis was performed on all four Peat Swamp Forest classes, including pristine, long-time recovering, gardening and recently disturbed PSF. The analysis applies a similar methodology to section 4.1, but the agglomerative cluster analysis, phytosociological table and ordination is based on PSF releves that contain species that are present two times and more per releve and have an accumulated cover abundance value of greater than 0.5% within a releve. Cultivated crop species are excluded from the analysis.

Azonal vegetation types, such as PSF have historically been neglected in South African vegetation studies, while their accurate demarcation in vegetation maps is constrained by their narrow widths and elongated dimensions (Mucina & Rutherford 2006). Figure 4.7 illustrates Swamp Forest habitat present within the Kosi Bay Lake System Catchment as derived from Mucina & Rutherford (2006). Swamp Forest delineation is however constrained by the similarities in its spectral signature to that of surrounding Northern Coastal Forest (Walsh 2004), while cultivation activities have transformed unknown sections of PSF habitat (Sliva *et al*. 2004). Discrepancies within the illustrated spatial dataset can be seen with confirmed locations of PSF habitat not matching-up with the demarcated Swamp Forest vegetation type. A total of 65 releves where sampled at various locations throughout the study area and used in the phytosociological description of all the identified PSF classes (Figure 4.7; Table 4.3). Based on the Mucina & Rutherford (2006) spatial dataset 756.52 ha or 49.44 % of Swamp Forest habitat occurs within a protected area, namely the iSimangaliso Wetland Park.

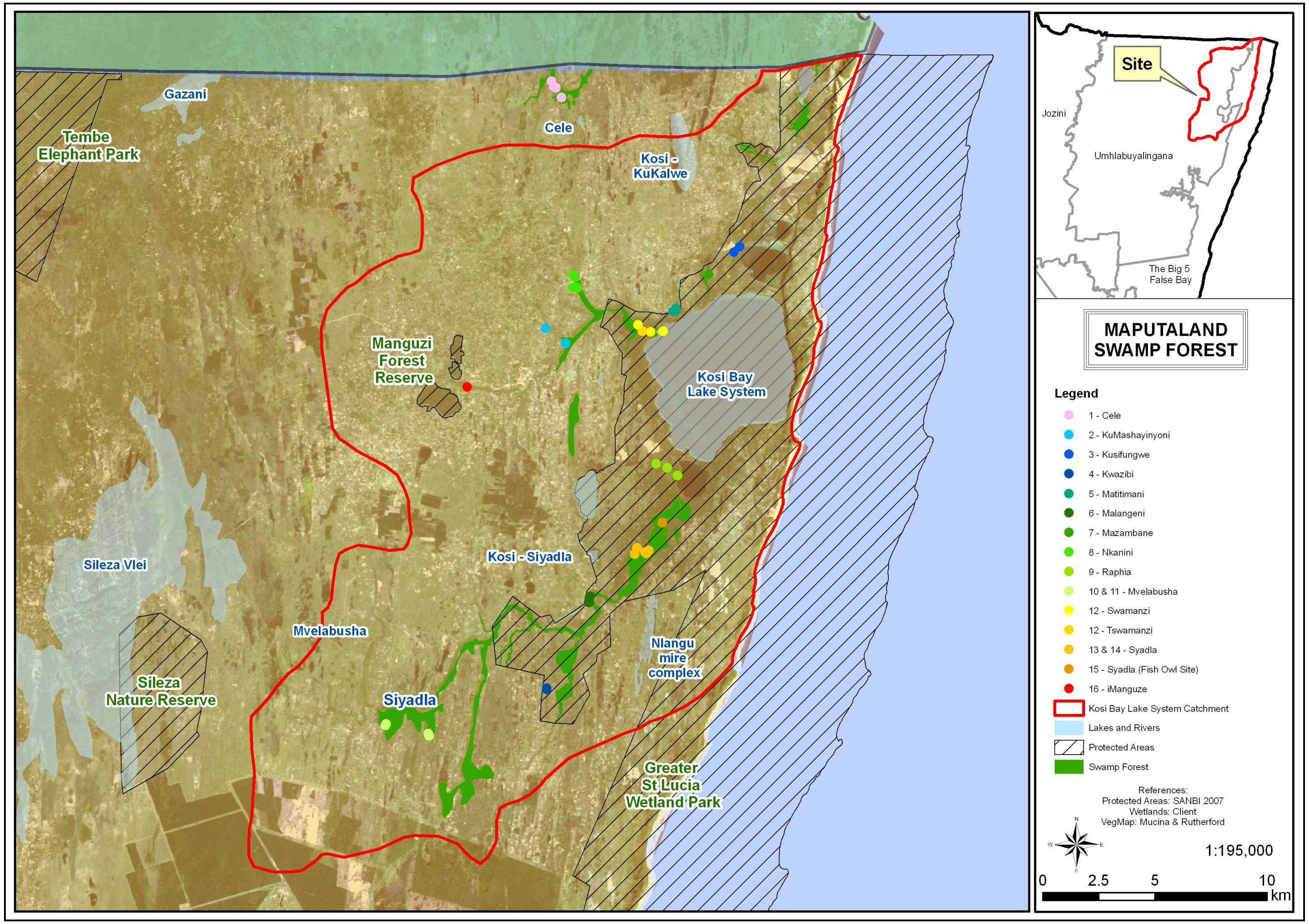


Figure 4.7 Swamp Forest habitat within the Kosi Bay Lake System and surroundings according to Mucina & Rutherford (2006), with all of the sampled sites (Table 4.3 provides more information on the sampled sites).

Table 4.3 List of the 65 recorded sampling plots with their map number, name, abbreviation, Peat Swamp Forest class and coordinates.

Number in Figure 4.6	Site name	Abbreviation	Gardening	Recently disturbed (fire/ gardening)	Long-time recovering	Pristine	Coordinates South (DMS)	Coordinates East (DMS)
1	Cele	CE-1			x		-26° 52' 07"	32° 46' 03"
1	Cele	CE-2				x	-26° 52' 14"	32° 46' 06"
1	Cele	CE-3	x				-26° 52' 30"	32° 46' 17"
1	Cele	Trans-CE-1	x				-26° 52' 16"	32° 46' 09"
1	Cele	Trans-CE-2		x				
1	Cele	Trans-CE-3			x			
1	Cele	Trans-CE-4			x			
1	Cele	Trans-CE-5			x			
1	Cele	Trans-CE-6			x		-26° 52' 16"	32° 46' 09"
2	KuMashayinyoni	KM-1		x			-26° 58' 26"	32° 46' 23"
2	KuMashayinyoni	KM-2		x			-26° 58' 04"	32° 45' 54"
3	Kusifungwe	KUSIF-1			x		-26° 56' 06"	32° 50' 35"
3	Kusifungwe	KUSIF-2			x		-26° 56' 14"	32° 50' 26"
4	Kwazibi	KW-1			x		-27° 06' 44"	32° 45' 56"
4	Kwazibi	KW-2			x		-27° 06' 46"	32° 45' 56"
5	Matitimani	MA-1				x	-26° 57' 38"	32° 49' 01"
5	Matitimani	MA-2		x			-26° 57' 35"	32° 49' 03"
5	Matitimani	Trans-MAT-1				x	-26° 57' 39"	32° 49' 02"
5	Matitimani	Trans-MAT-2				x		
5	Matitimani	Trans-MAT-3				x		
5	Matitimani	Trans-MAT-4				x	-26° 57' 40"	32° 48' 58"
6	Malangeni	MAL-1	x				-27° 04' 40"	32° 46' 56"
6	Malangeni	MAL-2		x			-27° 04' 40"	32° 46' 57"
6	Malangeni	MAL-3				x	-27° 04' 31"	32° 46' 59"
7	Mazambane	MAZ-1				x	-26° 56' 46"	32° 49' 50"

8	Nkanini	NK-1		x			-26° 56' 46"	32° 49' 50"
8	Nkanini	NK-2		x			-26° 57' 05"	32° 46' 38"
8	Nkanini	NK-3	x				-26° 56' 50"	32° 46' 37"
8	Nkanini	NK-4			x		-26° 56' 47"	32° 46' 34"
8	Nkanini	Trans-NK-1		x			-26° 57' 05"	32° 46' 40"
8	Nkanini	Trans-NK-2		x				
8	Nkanini	Trans-NK-3		x				
8	Nkanini	Trans-NK-5		x			-26° 57' 05"	32° 46' 33"
9	Raphia	RA-1				x	-27° 01' 20"	32° 48' 34"
9	Raphia	RA-2				x	-27° 01' 26"	32° 48' 50"
9	Raphia	RA-3		x			-27° 01' 37"	32° 49' 05"
10	Mvelabusha	SF-2-1			x		-27° 07' 50"	32° 43' 05"
10	Mvelabusha	SF-2-2			x			
10	Mvelabusha	Trans-SF2-1			x		-27° 07' 53"	32° 43' 06"
10	Mvelabusha	Trans-SF2-2			x			
10	Mvelabusha	Trans-SF2-3			x			
10	Mvelabusha	Trans-SF2-4			x			
10	Mvelabusha	Trans-SF2-5			x			
11	Mvelabusha	SF-1-1	x				-27° 07' 38"	32° 42' 03"
11	Mvelabusha	SF-1-2		x			-27° 07' 36"	32° 42' 04"
12	Swamanzi	SW-1				x	-26° 58' 08"	32° 48' 44"
12	Swamanzi	SW-2			x		-26° 57' 59"	32° 48' 08"
12	Swamanzi	SW-3				x	-26° 58' 09"	32° 48' 26"
12	Tswamanzi	Trans-TSW-1				x	-26° 58' 08"	32° 48' 14"
12	Tswamanzi	Trans-TSW-2				x		
12	Tswamanzi	Trans-TSW-3				x		
13	Syadla	SY-1	x				-27° 03' 21"	32° 48' 06"
13	Syadla	SY-2		x			-27° 03' 21"	32° 48' 06"
13	Syadla	SY-3				x	-27° 03' 30"	32° 48' 03"
13	Syadla	SYD-1	x				-27° 03' 27"	32° 48' 20"
13	Syadla	SYD-2				x	-27° 03' 27"	32° 48' 20"
13	Syadla	SYD-3		x			-27° 03' 25"	32° 48' 23"
14	Syadla	Trans-SYAD-2-1	x				-27° 03' 27"	32° 48' 18"
14	Syadla	Trans-SYAD-2-2	x					
14	Syadla	Trans-SYAD-2-3		x				

14	Syadla	Trans-SYAD-2-4		x	-27° 03' 29"	32° 48' 20"
15	Syadla (Fish Owl Site)	FOS-1		x	-27° 02' 45"	32° 48' 43"
15	Syadla (Fish Owl Site)	FOS-2		x		
15	Syadla (Fish Owl Site)	FOS-3		x		
16	iManguze	MANG-1	x		-26° 59' 29"	32° 44' 01"

4.2.2 Agglomerative cluster analysis

A division of nine releve clusters provided the most suitable or best possible fit of groupings in terms of ecological interpretation from the sampled dataset (Figure 4.8).The hierarchical structure of these plant communities are represented in two dendrograms, as derived from a cluster analysis and an indicator species analysis, performed at each of the five group membership levels (Figure 4.8 & 4.9).

The first split indicates the most apparent difference between the releves, which is variation in the structural intactness of the communities. The left hand sided releve group’s structure is disrupted as is evident in a poorly developed tree canopy and a well-developed herbaceous layer. It has primarily been caused by human induced disturbances, directly related to gardening practices. The right hand sided releve group has a better-developed structure with an intact tree canopy cover, as is to be expected in more pristine Swamp Forests sites. Subsequent divisions in the dendrogram are bases on smaller and smaller differences until finally only nine groups where left.

The groupings of this classification can be explained along with their relevant indicator species as derived from the indicator species analysis, as follows:

Comm. 1: Wet open disturbed sites with upcoming Swamp Forest trees (with *Voacanga thouarsii*, *Syzygium cordatum* (both shrub and tree layer), *Cyperus prolifera, Cyperus pectinatus*, *Lygodium microphyllum* (shrub layer), *Panicum parvifolium* and *Dissotis canescens* as indicator species ($p < 0.05$).

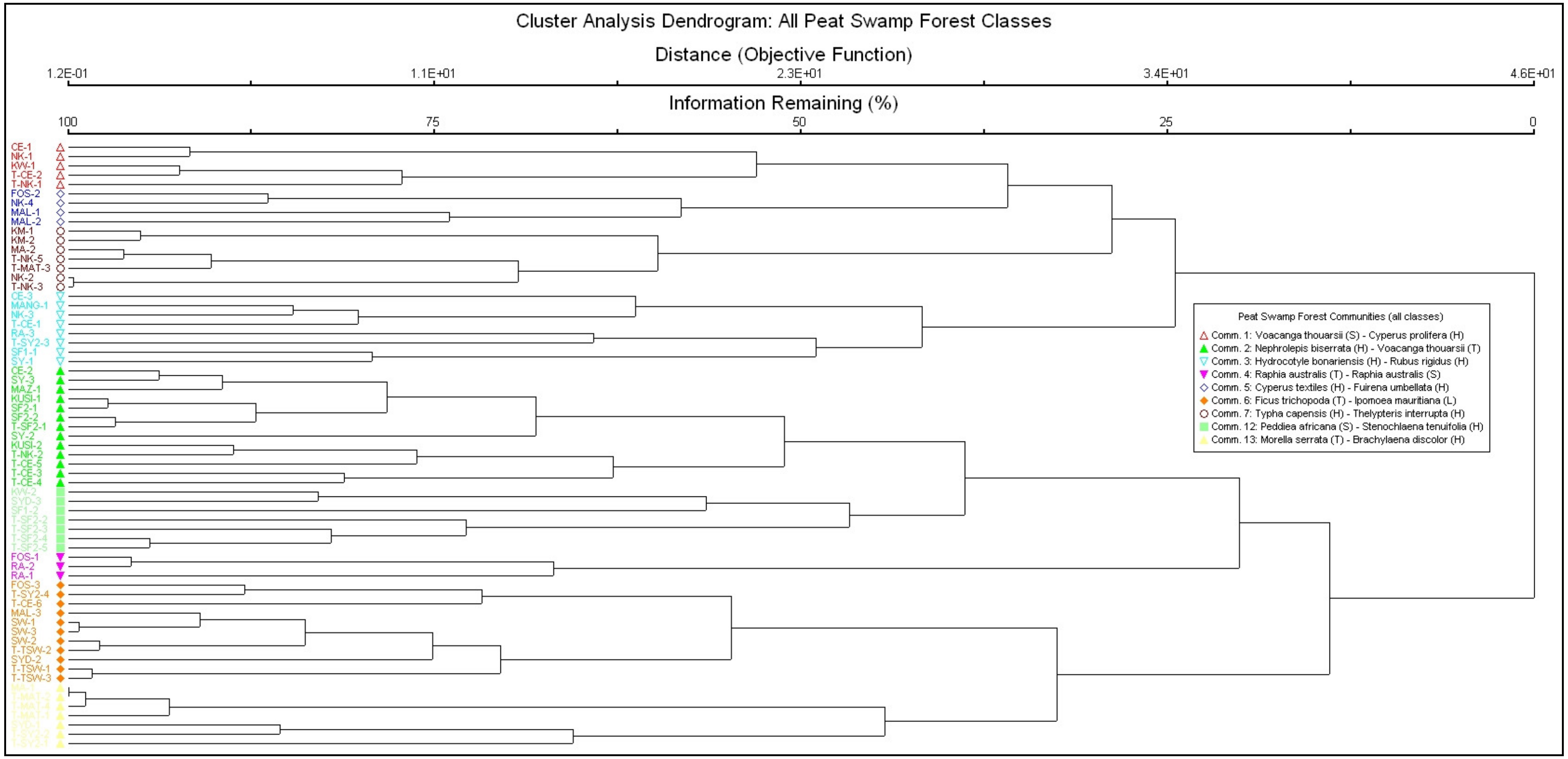


Figure 4.8 A dendrogram of the full range of Peat Swamp Forest classes that illustrates different levels of releve divisions based on the similarity/dissimilarity in species composition at each division level of the agglomerative cluster analysis; the nine identified releve clusters represent plant communities present within the dataset.

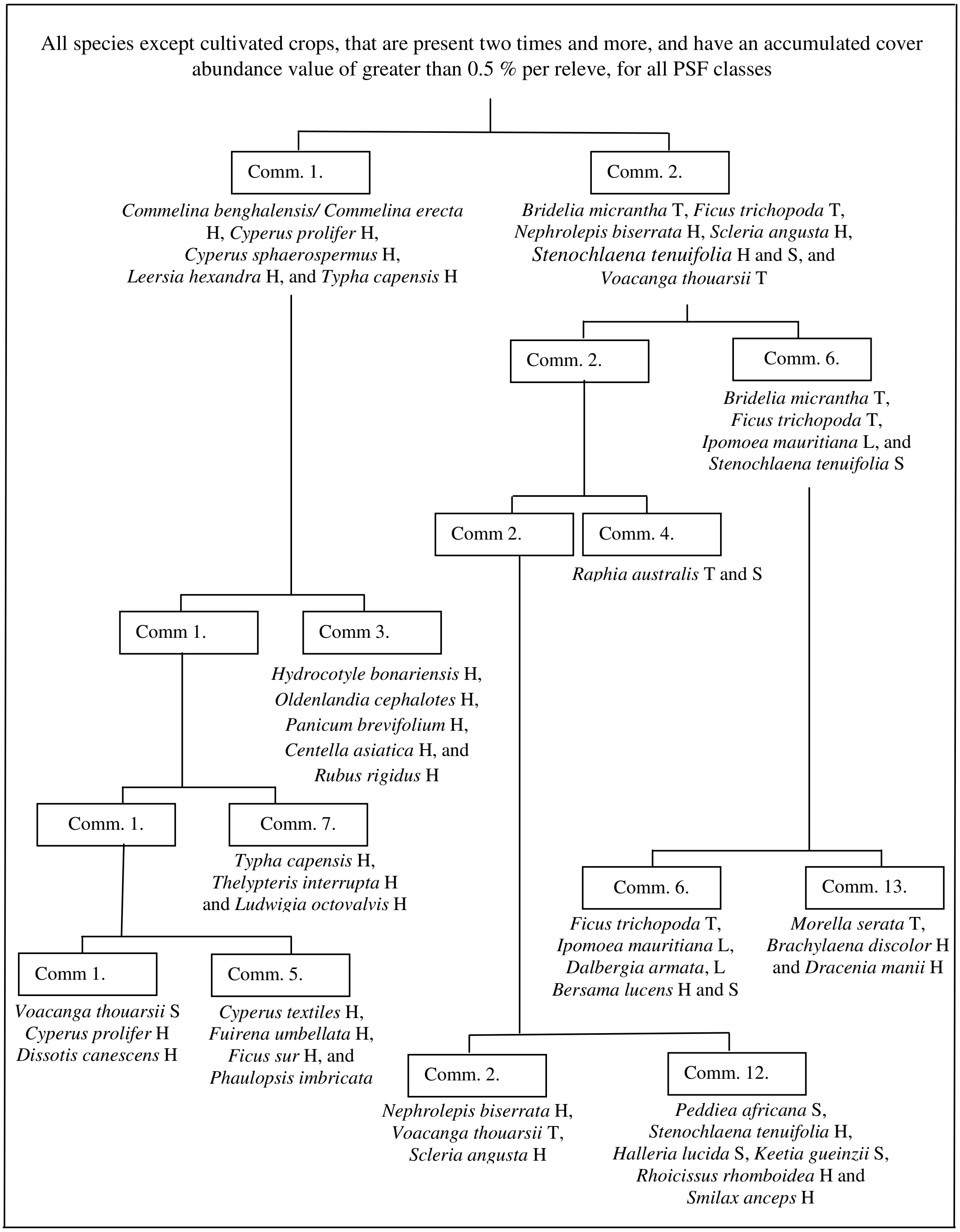


Figure 4.9 A dendrogram of all Peat Swamp Forest classes that illustrates the division hierarchy, including indicator species present at each division level and the resultant nine plant communities (divisions not according to scale).

Comm. 5: Recently disturbed sites dominated by *Cyperus textilis* (with *Cyperus textilus, Senecio polyanthemoides, Fuirena umbellata, Ficus sur* (shrub layer) and *Phaulopsis imbricata* as statistically relevant indicator species.

Comm 7: Very wet recently disturbed sites (with *Thelypteris interrupta* and *Ludwigia octovalvis* as indicator species ($p < 0.05$).

Comm. 3: Gardening sites with permanent or at least recent disturbance and very little or no canopy layer (with *Hydrocotyle bonariensis*, *Panicum brevifolium*, *Pycreus polystachys*, *Pteridium aquelinum, Oldenlandia cephalotes, Centella asiatica* and *Rubus rigidus* as indicator species ($p<0.05$)

Comm. 2: Long-time recovering Swamp Forest (with *Nephrolepis biserrata, Scleria angusta, Voacanga thouarsii* (tree layer) and *Keetia gueinzii* (herb layer) as indicator species ($p<0,05$))

Comm. 12: Dry long-time recovering Swamp Forest (with *Peddiea africana* (shrub layer), *Stenochlaena tenuifolia*, *Rauvolfia caffra* (tree layer), *Keetia gueinzii* (shrub layer), *Halleria lucida* (shrub layer), *Smilax anceps* (herb layer), *Oplismenus hirtellus, Rhoicissus rhomboidea* (herb layer) and *Syzygium cordatum* (tree layer) as indicator species ($p<0.05$)

Comm. 4: *Raphia* Swamp Forest (with *Raphia australis* as indicator species ($p<0.05$)

Comm. 6: Pristine Swamp Forest (with *Ficus trichopoda* (tree layer), *Microsorum punctatum*, *Ipomoea mauritiana* (both liana layer), *Bersama lucens* (herb layer) and *Dalbergia armata* as indicator species ($p<0.05$)

Comm. 13: An indifferent group, with pioneer species such as *Brachylaena discolor.* Other indicator species include *Morella serrata* (tree layer) ($p<0.05$).

4.2.3 Community description and ordinations

Species information used as part of the species diversity calculations were solely based on the presence of a species per releve and were hence not recorded separately in each of the vegetation strata, as used in the multivariate analysis (cluster analysis, phytosociological tables and ordinations), (Table 4.4). Information used for the calculation of species diversity measures for each community is not based on the phytosociological table, with the latter forming part of the multivariate analysis of community data. Fewer species are indicated in the phytosociological table, as rare and total low cover abundance species were removed due to their potential for creating unwanted noise in the analysis.

Table 4.4 Species number indexes for the identified Peat Swamp Forest Communities.

Group Nr.	1	5	7	3	2	12	4	6	13
Total number of species	51	57	66	83	66	44	17	67	69
Average number of species per plot	22.0	25.3	13.6	27.0	20.2	18.3	9.3	19.9	24.3
Standard deviation	5.5	6.7	4.2	5.5	4.1	4.5	2.9	5.9	7.3
Number of plots	5	4	7	8	13	7	3	11	7

A Detrended Correspondence Analysis (DCA) ordination (Figure 4.10 & 4.11) was performed on the vegetation data of all the species except the cultivated crops, which are present two times and more in all of the releves, with an accumulated cover abundance value of greater than 0.5 % per plot. The resultant patterns reveal the gradients of similarity between the different releves and species expressed on different axis. This gradient pattern is solely generated based upon every species' level of abundance, expressed in percentage (Table 4.5), from each individual releve. In this first ordination, only axis 1 meets the statistical requirements to enable the present species and releves to be correlated reliably, having an eigenvalue of higher than the minimum 0.5 (0.55) and having a length of gradient longer than the required value of 2 (3.91).

Predominant environmental influences are displayed as red vector lines, overlaid on top of the releves in the ordination space. The environmental factors expressed should ideally have an r-value of greater than 0.5 in the positive or negative axis direction according to Pearson and Kendall's method for ordination axes correlation. Axis 1 is strongly correlated with the tree cover (r-value = -0.769) as a structural component to the left and recent disturbance and peat draining to the right (r-values = 0.535 and 0.456 respectively). The presence of drain ditches and evidence of recent disturbances that can include fire, clearing and cutting, are all associated with active gardening or cultivation preparationt. A high tree cover on the other hand is indicative of more pristine or well recovered Peat Swamp Forests as can be inferred from the relatively high pristine r-value (-0.412 for axis 1) in more or less the same direction as the tree cover joint plot (vector line) (Figure 4.10). Axis 2, which is not completely statistically significant due to its eigenvalue just below 0.5, is strongly correlated with hydrology that has an r-value of 0.574 and can still be used as a useful indicator to explain the relationship among different releves and species. The hydrology vector in the positive direction of axis 2 indicates drier conditions. The Nonmetric Multidimensional Scaling ordination (NMDS) also provide a satisfactory interpretation of the data and indicated similar broad patterns as the DCA ordination (Figure 4.12). The ordination illustrates that the gardening PSF class is not necessarily associated with a low tree cover, as cultivation often occurred underneath a tree layer (Figure 4.13).

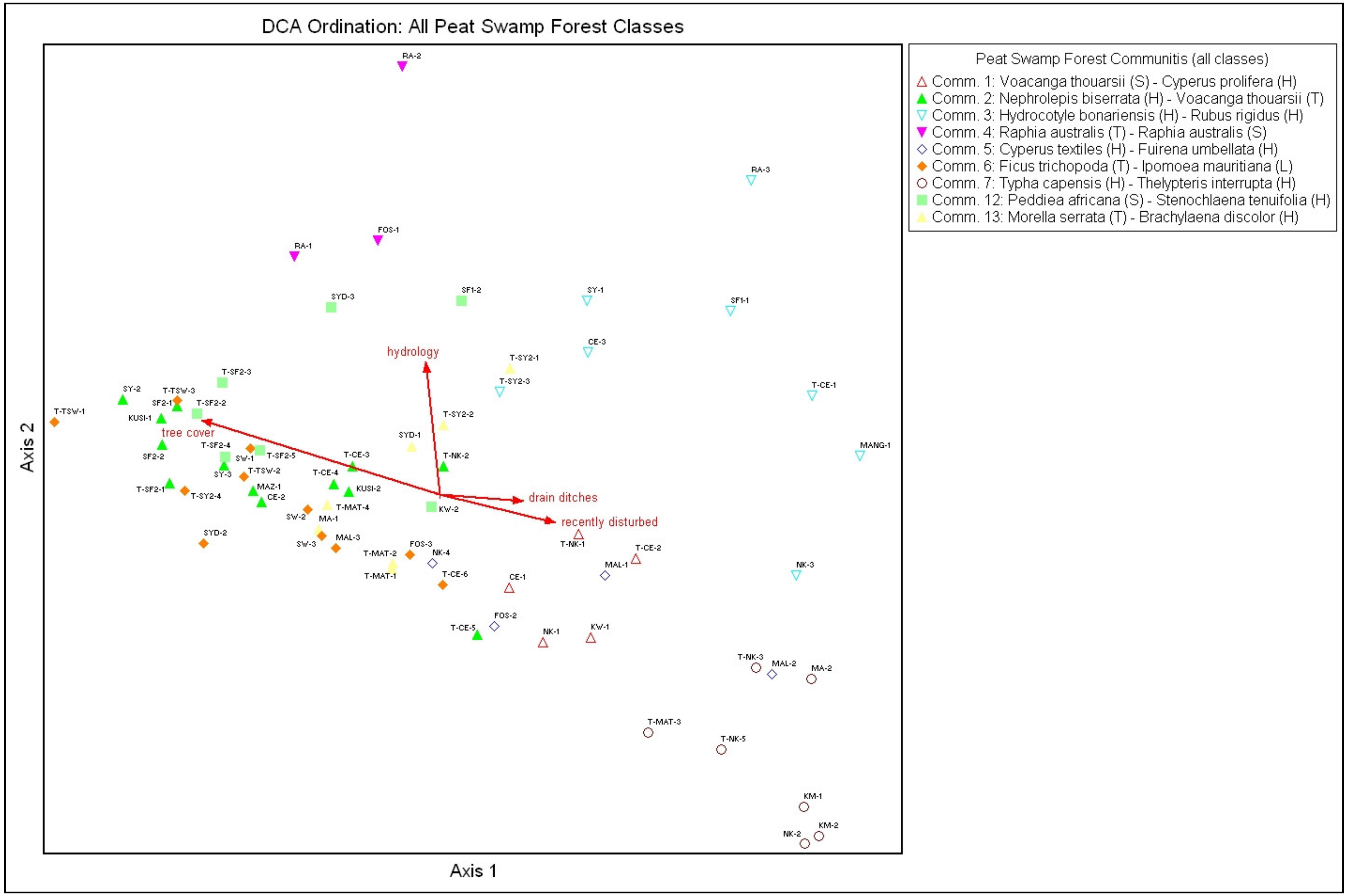


Figure 4.10 Axes 1 and 2 of a Detrended Correspondence Analysis (DCA) ordination that illustrates the relationships between releves in an ordination space, with their respective vegetation communities, and the most important environmental factors, for all the species (except cultivated crops), that are present two times and more, and have an accumulated cover abundance value of greater than 0.5 % per releve; H = herb stratum; S = scrub stratum, T = tree stratum, L= liana stratum.

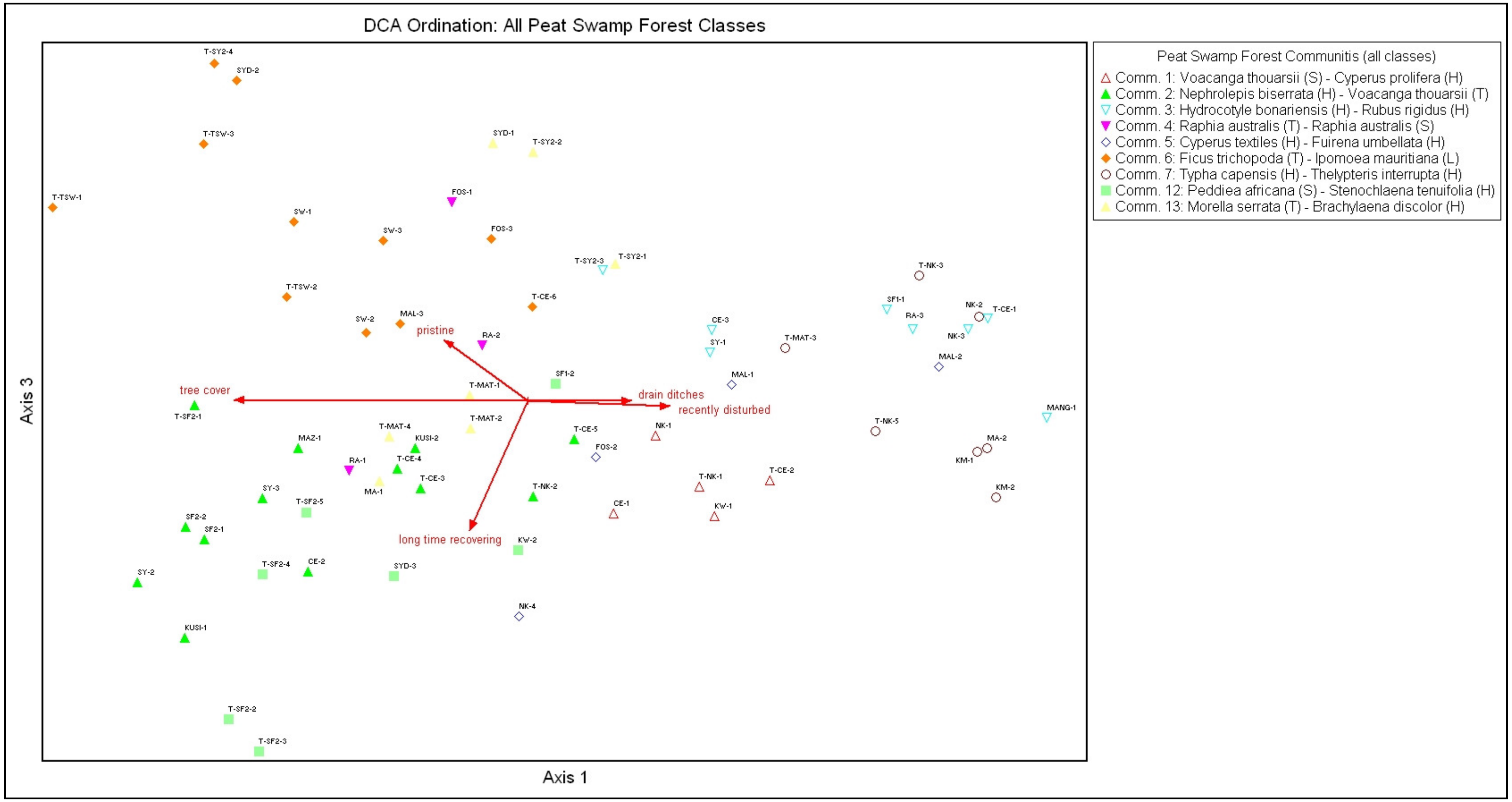


Figure 4.11 Axes 1 and 3 of a Detrended Correspondence Analysis (DCA) ordination that illustrates the relationships between releves in an ordination space, with their respective vegetation communities, and the most important environmental factors, for all the species (except cultivated crops), that are present two times and more, and have an accumulated cover abundance value of greater than 0.5 % per releve; H = herb stratum; S = scrub stratum, T = tree stratum, L= liana stratum.

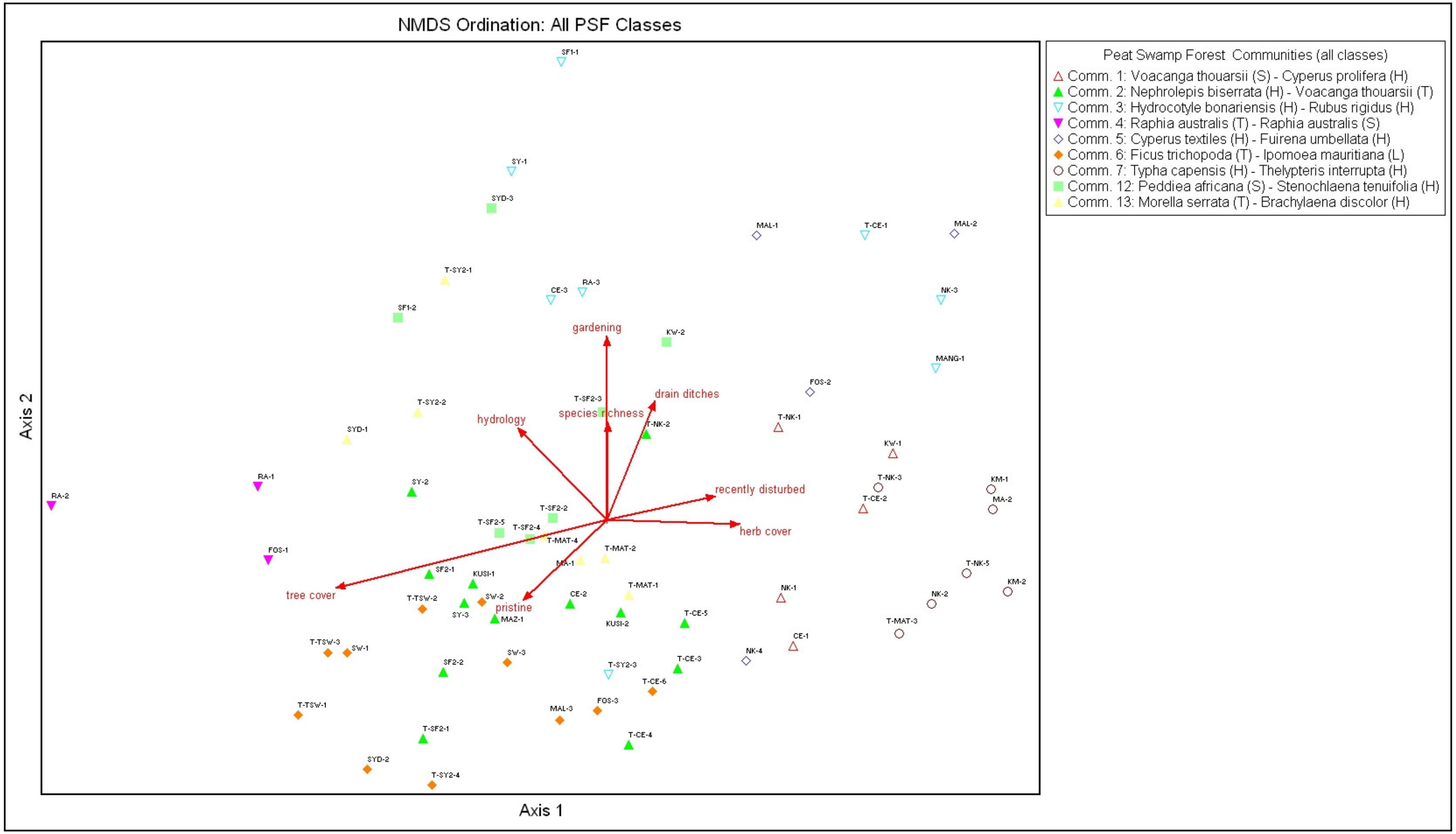


Figure 4.12 Axes 1 and 2 of a Nonmetric Multidimensional Scaling (NMDS) ordination that illustrates the relationships between releves in an ordination space, with their respective vegetation communities, and the most important environmental factors for all species (except cultivated crops), that are present two times and more, and have an accumulated cover abundance value of greater than 0.5 % per releve; H = herb stratum; S = scrub stratum, T = tree stratum, L= liana stratum.

Figure 4.13 Combined Peat Swamp Forest (PSF) disturbance classes: a. A wet *Typha capensis* (H) – *Thelypteris interrupta* (H) plant community with a sparse tree canopy; b. Transformed PSF habitat as a result of extensive cultivation practices (gardening) in the Matitimani Valley; c. Banana cultivation under a thinned-out but existing tree canopy; d. Madumbes (*Colocasia esculenta*) cultivated under a modified but yet intact tree canopy.

Species richness is however strongly associated with the gardening PSF class, as the cultivation-related disturbances provide an opportunity for the recruitment of numerous weedy forb species (Figure 4.12). The NMDS ordination does support the same link (pattern) as the DCA ordination, with regards to the relationship between clearing activities (recent disturbances) and a lower tree cover, and pristine PSF class with a higher tree cover (Figure 4.10 & 4.12). Axes one and two of the NMDS represent 40.7 % and 17.4 % of the variance in the PSF communities (cumulative variance = 58.4 %), with the use of three dimensions and a final stress value of 15.18 (iterations = 164).

Table 4.5 represents the phytosociological table based on the nine Cluster Analysis derived vegetation groups, which have been described as vegetation communities with a total of 23 species groups for all the species except cultivated crops that are present two times and more, and have an accumulated cover abundance value of greater than 0.5 % per releve.

Community 1: *Voacanga thouarsii* (S) – *Cyperus prolifera* (H)

This community consists out of the five releves: CE-1, KW-1, NK-1, T-CE-2, and T-NK-1, which are a combination of recently disturbed and old recovering swamp forest sites (Table 4.3). They are situated at the opposite end of the strong tree cover correlation on axis one (Figure 4.10 & 4.11), indicating that full-grown trees are absent from the habitat, with a more open canopy structure. It also indicates that any recovering that has taken place has not been occurred for long enough to result in a fully developed tree canopy cover, suggesting that this community is somewhere in between a recently disturbed and long-time recovering PSF system. The community has an above average wetness, which creates suitable growing conditions for obligated hydrophytes such as *Cyperus prolifera.* Community releves exhibit a positive correlation with recent disturbances and the presence of drain ditches. The later two environmental factors could be a result of gardening preparation by vegetation clearing, burning (if not too wet) and draining. Alternatively, it represents a wet community that is in the process of recovering from recently abandoned gardening practices. The community is characterized by species group AA (Table 4.5.). No mature trees are present, but *Voacanga thouarsii* and *Syzygium cordatum* shrubs are very diagnostic, both having high indicator species values (Table 4.5).

These tree species are either still in a process of growing towards maturity or are limited in their growth by the wet conditions to which they may not be that well adapted. *Syzygium cordatum* is known to grow on peripheral water logged mineral soils, although it can also develop on stagnant mire surfaces and is therefore tolerant of deep peat soils (Thompson & Hamilton 1983). All other significant diagnostic species are located in the herbaceous layer and include the fern *Lygodium microphyllum,* the herb *Dissotis canescens,* the sedge *Cyperus pectinatus,* and the grass *Panicum parvifolium.* The community has 50 species in total, with an average of 22 species per releve (Table 4.5).

Community 5: *Cyperus textiles* (H) –*Fuirena umbellate* (H)

This community consists of 4 releves: FOS-2, NK-4, MAL-1, and MAL-2 that form a combination of pristine, long-time recovering, gardening and recently disturbed Peat Swamp Forest releves (Table 4.5). The releves are distributed over a wide gradient of environmental conditions (Figure 4.10 to 4.12). The releves display a preference for wetter conditions (Figure 4.10 to 4.12). The wet conditions can also be inferred from the several species that favour saturated, such as sedges, bulrushes (*Typha capensis*) and hydrophytic ferns (*Thelypteris interrupta*) in species group AC (Table 4.5). The community is furthermore characterized by a sparse tree canopy and species group AB (Table 4.5). The community has a total of 57 species and an average of 25 species per releve (Table 4.5)

Community 7: *Typha capensis* (H) – *Thelypteris interrupta* (H)

This community consist out of 7 releves: KM-1, KM-2, MA-2, T-NK-5, T-MAT-3, NK-2 and T-NK-3. The releves represent recently disturbed Peat Swamp Forest sites, with the exception of T-MAT-3, which is regarded as an uncultivated releve that has been affected by vegetation clearing in the past or unfavourable growing conditions for tree canopy development (Figure 4.13). The strongest gradient is in the negative direction of axis 2 and pertains to very wet conditions (Figure 4.10). The other gradient is associated with the structural intactness of the tree canopy being disturbed by natural environmental factors and/or human induced disturbances associated with gardening or garden preparation (Figure 4.10 to 4.12). These releves have been affected by vegetation clearing or have a naturally sparse tree cover due to potentially unfavourable growing conditions. Evidence of historic gardening activities in one releve (T-MAT-3) remains inclusive, with no recorded drainage ditches in the saturated peat soil. The ordination indicates *Thelypteris interrupta* as a statistically relevant indicator species that is associated with saturated, open canopy conditions (Figure 4.13 & 4.14).

The community is characterized by species group AC and include obligated hydrophytes as statistically significant indicator species that include *Typha capensis, Thelypteris interrupta,* and *Ludwigia octovalvis* (Table 4.5). Other diagnostic species include *Melanthera scandens, Cyperus dives,* and *Persicaria hydropiper.* The community has a total of 35 species with an average of 13 species per releve.

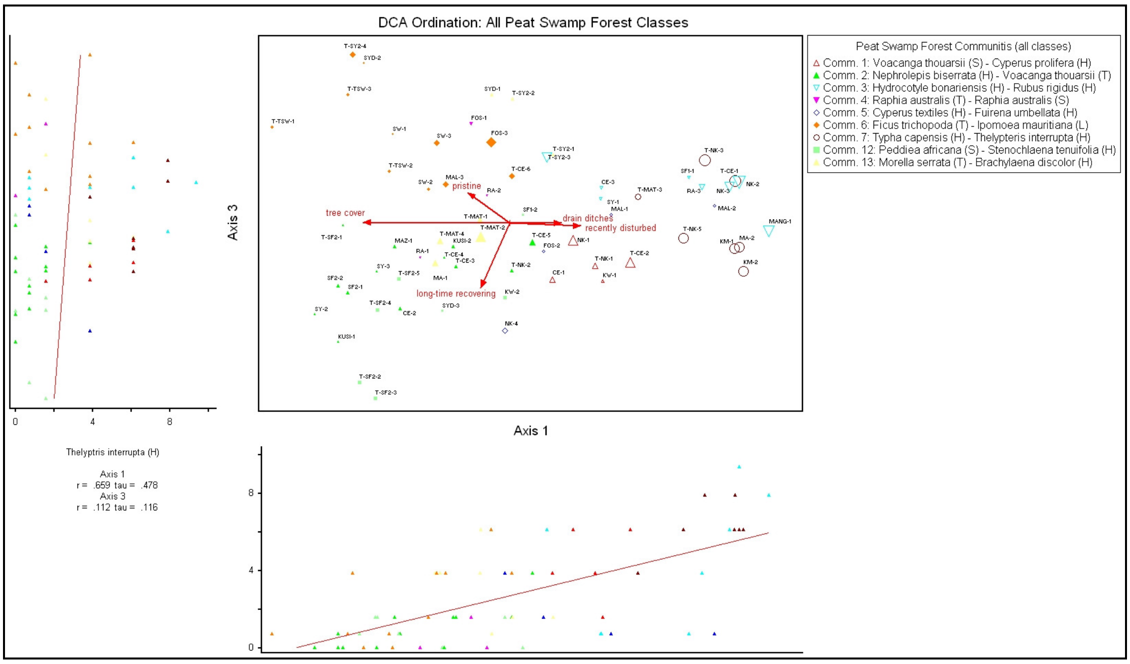


Figure 4.14 Cover abundance and distribution patterns (gradients in ordination space) of the obligated hydrophyte *Thelypteris interrupta*, which is strongly associated with an open tree canopy, as indicated by the DCA ordination (axes 1 and 3).

Community 3: *Hydrocotyle bonariensis* (H) – *Rubus rigidus* (H)

This community consists out of 8 releves: CE-3, MANG-1, NK-3, T-CE-1, RA-3, T-SYAD-2-3, SF1-1 and SY-1 that are combinations of active gardening and recent disturbed sites that have been abandoned after gardening practices. In spite of the similar types of land use they have quite wide distribution gradients in the ordination space, especially along axis 1, but also with reference to axis 2 (Figure 4.10 & 4.11). The reason for their dissimilarity in ordination space relates to an array of cultivation practices that modify the tree canopy (via clearing) and hydrological regime (via draining) of the community in different ways. The releves are grouped towards the positive side of axis 1, but tree canopy cover varies across the community, resulting in a wide structural gradient (Figure 4.10 & 4.11, 4.13). All of the releves do however share influences of recent disturbances and gardening activities, as well as the presence of drainage ditches.

Drainage furrows have been implemented to facilitate more favourable conditions for crop production, in particular for the cultivation of *Musa* x*paradisiaca* (banana), which is the most favoured crop species for the majority of farmers (Grobler 2004; Figure 2.5). *Musa* x*paradisiaca* requires drier peat soil conditions compared to other more hydrophilic crops species such as *Colocasia esculenta*, which results in drainage ditches being more common in banana cultivated areas.

The community is characterized by species group AD and has the highest species richness of all the communities (Table 4.4). The reason being that many species are pioneers of which several are exotic weeds that thrive in the continuously disturbed gardening environment. Prominent species in the herbaceous layer include: *Hydrocotyle bonariensis, Rubus rigidus, Panicum brevifolium, Pteridium aquilinum, Oldenlandia cephalotes,* and *Centella asiatica.* These species have the highest indicator species values that are statistically significant (Table 4.5). The community has a total of 78 species and an average species richness of 27 per releve.

Community 2: *Nephrolepis biserrata* (H) – *Voacanga thouarsii* (T)

The community is the largest of the nine communities, containing 13 releves: CE-2, SY-3, MAZ-1, KUSI-1, SF2-1, SF2-2, T-SF2-1, SY-2, KUSI-2, T-NK-2, T-CE-5, T-CE-3 and T-CE-4. They are predominantly a combination of pristine and old recovering swamp forest sites, containing two recently disturbed releves as well. In the case of the latter, the recorded disturbances were of a lower magnitude with an expected smaller effect on the ordination pattern. These disturbances include selected vegetation clearing and low intensity fires to clear the herbaceous layer as an initial step in gardening preparation. The tree canopy and most of the shrub layer therefore still remain intact.

Peat Swamp Forest plant communities described from here on are more pristine in nature and/or have been recovering for a number of years; they subsequently resemble more pristine PSF systems. This is evident from the ordination space that generally group these releves to the negative side of axis 1, indicating a well-developed tree canopy (Figure 4.10 to 4.12).

Following a similar trend as in the previous communities there is much less dissimilarity in the hydrological regime of the releves, but they generally exhibit an average to above average soil moisture condition. (Figure 4.10 & 4.12). The community is characterized by species group AH and can be portrayed as a relatively general PSF community, similar to Community 1:

Scleria angusta (H) – *Nephrolepis biserrata* (H) described in section 4.1.3. In addition, the diagnostic species with the highest significant indicator species values have wide distributions ranges, and are abundant in several other less disturbed communities (Table 4.5). Indicator species include the fern *Nephrolepis biserrata,* the sedge *Scleria angusta* and the tree species *Voacanga thouarsii* and *Keetia gueinzii,* many of them typical PSF species (Mucina & Rutherford 2006). Other important species associated with the community are: the tree *Schefflera umbellifera,* the fern *Lygodium microphyllum,* which can also grow as a liana, and the liana *Rhoicissus rhomboidea* (Table 4.5). Liana species are dependant on a well developed tree stratum for support and are therefore susceptible to disturbances that impact negatively on the tree and to a lesser degree the shrub layer. The community has a total of 63 species, being the second largest in terms of plant diversity, with an average species richness of 20.2 per releve.

Community 2: *Peddiea africana* (S) – *Stenochlaena tenuifolia* (H)

The community consists of 7 releves: KW-2, SYD-3, SF1-2, T-SF2-2. T-SF2-3, T-SF2-4 and T-SF-5. These releves are primarily all Peat Swamp Forests areas that have been in the process of recovering from human related gardening disturbances for several years (pers. comm. local residents). A small minority (SYD-3 and SF1-2) has been recovering for a much shorter period of time from recent disturbances that are indicated by evidence of recent burning and cutting. These disturbances have not been too severe and left the tree canopy structure partly intact. This results in a vegetation species and structural composition that closely resemble that of long-time recovering Peat Swamp Forest habitat.

The differences in the structural makeup of the releves is reflected in the distribution pattern of the releves with regards to axis 1 indicating a limited tree canopy cover development (Figure 4.10 to 4.12). The community closely resembles Community 7: *Peddiea africana* (S) – *Stenochlaena tenuifolia*, described in section 4.1.3. The community is characterized by species group AJ (Table 4.5). It contains the following important statistically significant indicator species: the shrub *Peddiea africana,* the fern *Stenochlaena tenuifolia,* the tree *Rauvolfia caffra* and the liana *Smilax anceps* (Table 4.5). The species also most typically prefer drier conditions as indicated by their similar orientation as the majority of the releves in the ordination (Figure 4.10 to 4.12). Trees are typically shorter than in other structurally intact Peat Swamp Forests communities and fewer sedges are present, most likely due to the drier conditions. Environmental factors operating in the community are either naturally inherent or artificially induced to support drier conditions that can be characterised by a shorter tree canopy cover and distinct indicator species in the different strata. The community has a total of 41 species with an average of 19 species per releve.

Community 4: *Raphia australis* (T) – *Raphia australis* (S)

This community contains the smallest number of releves (FOS-1, RA-2, RA-1), but is the most characteristics of all the PSF communities in terms of its dominant species composition, in the form of endemic palm *Raphia australis*. The large localized stands of *Raphia australis* Peat Swamp Forest is located on the western shore of Lake Amanzimnyama and is protected within the iSimangaliso Wetland Park. The community has a dense tree canopy development, with all the releves distributed near the same position of axis 1 (Figure 4.10 to 4.12). The community is the driest of the PSF communities, as it is grouped towards the positive margin of axis 2 (Figure 4.10). The community is characterized by species group AM. The only statistically significant diagnostic species is *Raphia australis* in its tree and shrub form (Table 4.5).

Raphia australis palms are commonly found in homogenous plots that appear to form cohorts of *R. australis* in different strata in the same area. It is suggested that this is a result of the palms being monocarpic (Mattson & Uken, 2007). The community is very similar to Community 2: *Raphia australis* (T) – *Raphia australis* (H) described in section 4.1.3. It has a gamma diversity of 16 species, which is the lowest gamma diversity of all the identified communities; the community is however regarded to be under sampled (Table 4.4).

Community 6: *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L)

This community consists of 11 releves: FOS-3, T-SYAD-2-4, T-CE-4, MAL-3, SW-1, SW-3, SW-2, T-TSW-2, SYD-2, T-TSW-1 and T-TSW-3. The majority of them are pristine PSF sites and the remaining belong to the long-rime recovering PSF class (Table 3.1). The releves are structurally well developed with little evidence of disturbances, although there is yet again a range in development regarding the degree of tree canopy closure as displayed in the ordination distribution (Figure 4.10 to 4.12). This Peat Swamp Forest community has a moist to wet hydrological regime that is wetter compared to other PSF communities with a well developed tree canopy (Figure 4.10 to 4.12). This community is often located adjacent to channelled drainage lines that flow towards the Kosi Bay Lake System. Vegetation in the area surrounding channelled flow is therefore subjected to higher energy regimes that are associated with occasional flooding events. A channel in a valley bottom setting is also the most likely landscape position to intercept groundwater discharge and intermitted flow when hydrological conditions are favourable

(DWAF 2005).Plant community 6 is therefore likely to receive groundwater as well as surface water inputs to support peat growth as well as its obligated hydrophytes that include *Ficus trichopoda.* The statistically significant indicator species *Ficus trichopoda* is well adapted for this environment with characteristics buttress and prop roots (Figure 4.3). Dense stands of *F. trichopoda* is strongly associated with pristine PSF environments and an intact tree canopy, as is illustrated by the DCA ordination results (Figure 4.15).

Other statistically significant indicator species within the community include the ferns *Microsorium punctatum* and *Polypodium lycopodiodes,* the lianas *Ipomoea mauritiana*, *Dalbergia armata, Petopentia natalensis,* and *Asparagus falcatus* (Table 4.5). The sedge *Scleria angusta* and the fern *Stenochlaena tenuifolia,* although occurring diagnostically in other communities, are also well represented in this community. Illustrating that they can successfully grow in a variety of unmodified Peat Swamp Forest areas (Table 4.5) The community is characterized by species group AO and closely resembles Community 4: *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L) described in section 4.1.3.

A total of 7 species are grouped as part of the liana stratum within species group AO, the highest number of any Peat Swamp Forest community (Table 4.5). The high number of liana species also indicate a well developed tree stratum, which may have the potential to be used as an indicator of long-time recovering and pristine PSF systems. The absence of weeds species, which are typical of Community 3, is another indicator of pristine conditions, as is the distribution of the community's releves along the pristine environmental vector (biplot) in the ordination space (Figure 4.10 & 4.11). There is a total of 66 species, making it one of the highest species rich structurally intact PSF communities, with an average species richness of 19.9 per releve (Table 4.4).

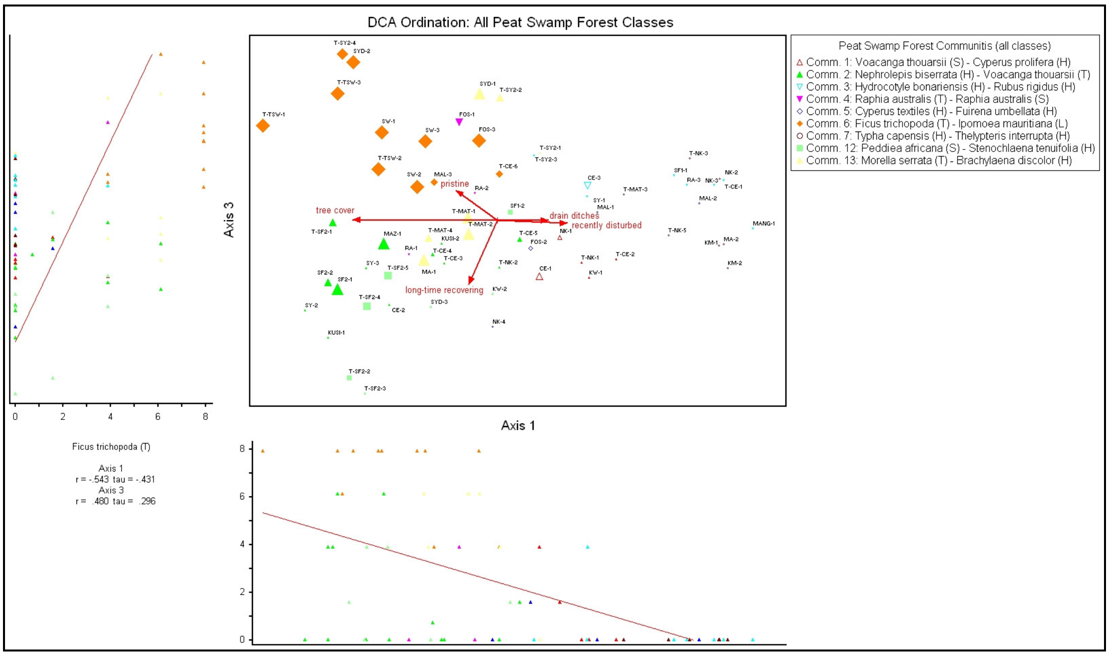


Figure 4.15 Cover abundance and distribution patterns (gradients in ordination space) of *Ficus trichopoda*, which is strongly associated with a well developed tree stratum and pristine conditions.

Community 13: *Morella serrata* (T) – *Brachylaena discolor* (H)

This community consists of seven releves (MA-1, SYD-1, T-MAT-1, T-MAT-2, T-MAT-4, T-SYAD-2-1 and T-SYAD-2-2). Releves from this community consists out of two opposite types of PSF classes: gardening and pristine Peat Swamp Forest plots. The first is actively cultivated, while the latter remains largely untransformed. Both types of PSF classes within the community share a similar tree strata cover density, while both the DCA (axes 1& 3) and the NMDS ordination group the two PSF classes within the group separately (Figure 4.10 to 4.12). The cluster analysis indicates the presence of two groups within the community at a further division level beyond the cut off level of nine groups (Figure 4.8).

Differences in diagnostic species across the two Peat Swamp Forest classes are also present, with *Morella serrata* occurring only in pristine releves (MA-1, T-MAT-1, T-MAT-2 and T-MAT-4), while the pioneer weed species *Brachylaena discolor* is restricted to gardening releves (Table 4.5). Tree species within the community are also well represented in other species groups from other communities, and include most predominantly *Ficus trichopoda,* followed by *Voacanga thouarsii* and *Syzygium cordatum* (Table 4.5).

A shared species composition based on the coalescence of common tree species, as well as the joined presence of other species, such as the ferns *Stenochlaena tenuifolia* (more common in drier PSF habitat) and *Thelypteris interrupta* (more common in wetter and open PSF habitat), result in the incorporation of these diverse PSF classes into a single community (Table 4.4). The community is however regarded as in indistinct group that will not be easily recognisable in the environment as it consists of two sub-groups that are not well defined. The community has a total of 67 species (Table 4.4). The high diversity in only seven releves can be contributed to the contribution form active gardening sites with favourable conditions for the establishment of pioneer and exotic invader species.

4.2.4 Discussion

Four of the five communities identified as part of the phytosociological investigation of pristine and recovering Peat Swamp Forests are repeated within this analysis as communities 2, 4, 6, and 12. From a regional (study area) perspective these communities appear to be associated with specific landscape positions. Community 2: *Nephrolepis biserrata* (H) – *Voacanga thouarsii* (T), (described as Community 1: *Scleria angusta* (H) - *Nephrolepis biserrata* (H) in section 4.1.3) commonly occupy valley bottom peatland slopes on the gradient between an active channel and the upslope outer boundary. The distribution of Community 4: *Raphia australis* (T) – *Raphia australis* (S) is the most geographically restricted of the four pristine to long-time recovering Peat Swamp Forest communities. It occupies the edges of a delta landform position associated with the Syadla River Mouth and in particular the western shore of the receiving Lake Amanzamnyama. This particular delta position does not imply the deposition of large quantities of sediment with numerous channels, but refers to a zone where a flowing river confluences with a larger body of standing water.

Community 6: *Ficus trichopoda* (T) – *Ipomoea mauritiana* (L) is distinct in terms of its physiognomy with a well intact tree canopy, high number of liana species and few exotic species. This community is associated with an active channel and flowing water located within valley bottom peatland systems. Community 12: *Peddiea africana* (S) – *Stenochlaena tenuifolia* (H) is associated with shallow peat soils, located in indistinct valley bottom settings that are more consistent with hillslope seepages that drain into downstream watercourses. This community is more typically of upstream headwater Peat Swamp Forest watercourses that are located further inland within the Kosi Bay Lake System Catchment.

Vegetation patterns associated with cultivation include the transformation of the Peat Swamp Forest tree cover across a wide gradient from a moderately intact to a sparse tree stratum. Both the DCA and NMDS ordinations indicate a distinct negative correlation between tree cover, and the presence of drainage ditches and recently disturbed sites (e.g. gardening preparation areas). Actual gardening sites are not necessarily associated with a low tree cover, as crops are also cultivated underneath the tree canopy. This corresponds with findings by Grobler (2004), regarding the cultivation of shade tolerant crop species such as *Colocasia esculenta* in excessively wet conditions underneath a tree layer, while less shade tolerant crop species such as *Musa xparadisiaca* (the most favoured crop species) are associated with a sparser tree cover on naturally drier or drained peat soils.

Cultivation-related modifications to Peat Swamp Forest peat soils include the desiccation and decomposition in the upper peat stratum as a result of the presence of drainage furrows. However, the magnitude of impact associated with peat dehydration and decomposition is not quantified in areas affected by cultivation and drainage, as it was only assessed via qualitative observations.

The dominance of the herbaceous stratum and the sparse cover of tree species in several communities orientated toward the positive side of axis 1 in the ordination space, cannot be exclusively contributed to cultivation related impacts such as cutting and clearing. Valley bottom peatlands are not always dominated by Peat Swamp Forest vegetation, hence these systems can be dynamic within a specific time scale. Grundling *et al.* (1998) refer to sequences of different hydroseres within Maputaland peatlands such as the Nlangu Mire Complex (Figure 4.7) where peat pollen records indicated successions of open water, sedge dominated and Peat Swamp Forest dominated vegetation cover over time. Informal field observations from the Eastern Shores region, located between the St. Lucia Estuary and the Indian Ocean, indicated inter-dune valley bottom peatlands that were dominated by a well developed herbaceous stratum that lacked tree and shrub strata. Hence, natural processes are also expected to function as drivers of vegetation change in valley bottom peatlands. Fire and peat moisture conditions are expected to be influential as environmental factors in this regard, but the operation and effect of these processes remain poorly understood in linear, inter-dune Peat Swamp Forest systems.

CHAPTER 5: PEAT PROFILES AND VEGETATION GRADIENTS IN INTER-DUNE SWAMP FOREST SYSTEMS

5.1 Introduction and Approach

Gradients and zonal characteristics of Peat Swamp Forests will be investigated in this chapter by describing peat stratigraphy, topography, vegetation structure, and plant species composition in order to identify patterns in PSF vegetation change. The cutting of lateral transect lines through sections of PSF made it possible to investigate these environmental factors across different valley bottom and other potential inter-dune landscape settings. The topography of different PSF valley bottoms could also be determined via cross-sectional profiles (Gordon *et al*. 2004). The measured surface profile was used a reference line to visually illustarte recorded changes in peat depth and humification, vegetation and groundwater properties across relatively short distances. In order to simplify the interpretation of the peat stratigraphy, the Von Post peat humification scale categories were combined into four categories due to the highly oxidised nature of the swamp forest peat at lower depths (Table 3.3).

Other stratigraphic categories present in the peat stratigraphy cross sections include the following:

- Sections normally at the bottom of the peat profile that contain a high percentage of sand intermixed with peat.
- Sand devoid of any peat substrates, which typically underlies peat bodies and covers the surface area of most of Maputaland. The depth of the underlying sand areas were not measured.
- Water underneath a peat layer that contain only a small fraction of actual peat and is in the process of paludification from formerly open water conditions to one which will eventually be filled with peat. On the condition that the environment remains conducive for peat accumulation in the long-term.

Plant community information determined in Chapter 4 that form part of the inclusive nine communities, as well as PSF class information associated with a particular sample plot (Table 3.1), are both represented at sampled transect plots. In addition, graphs were generated to illustrate changes in vegetation strata structure and life form composition, associated with the vegetation gradient change between different sample plots across a particular transect.

For descriptive purposes inter-dune cross-sections of Peat Swamp Forests were divided into three equally sized distance segments or zones. These zones include: two outer-valley zones located adjacent to the upslope terrestrial areas, one central-valley zone located in the middle of a profile (not necessarily at the lowest point) and two inter valley zones located between the outer and central profile zones. Finally the location of a channel can be indicated separately (when present) to form a fourth category that could be located on any one of the distance segments (Figure 5.1).

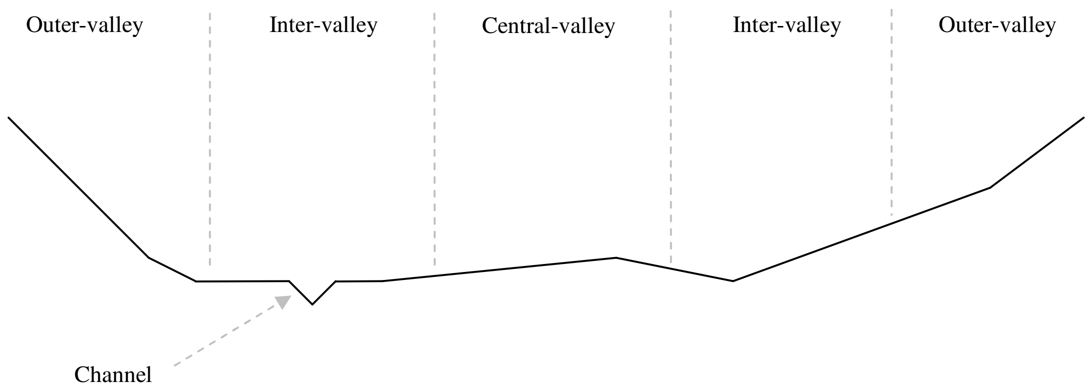


Figure 5.1 Equally spaced distance segments (zones) across a) cross-section of a hypothetical Peat Swamp Forest valley (inter-dune system). The channel position can in theory be located within any of the distance zones.

5.2 Results and Discussion

5.2.1 Matitimani transect

Matitimani peat properties

The transect survey was located in the Matitimani Valley, just within the borders of the Kosi Bay Coastal Forest Reserve (Figure 3.2). The two cross section profiles reveal a well developed peat body with a dome-like profile in different stages of humification, with an average depth of 1.41 m and a maximum depth of 2.95 m at the 64 m interval mark (Figure 5.2). The landscape position or hydro-geomorphic setting of the wetland is a channelled valley bottom system, with inconspicuous stream flow located in the inter-valley bottom zone (Figure 5.1 & 5.2).

Peatland topography in non-isolated valley settings can differ from the topography of channelled watercourses, without peat, in valleys with a similar geological template. In such cases, water flow seeks out the lowest point in the landscape and sets into motion the dynamic process of channel development depending on the ratio of water discharge and sediment load (Lane 1955). In peatland environments peat is formed through sedentation (an autochthonous process), as opposed to deposition from water transported sediment (i.e. sedimentation, an allochthonous process (Brinson 1993). Consequently, peat is formed *in situ* from a variety of plant materials that can include woody components, leaves, rhizomes, and roots (Rydin & Jeglum 2006). Over time the underlying valley bottom topography is transformed by peat accumulation, which can respond not only to linear surface flows, but also to lateral and vertical groundwater inputs to form unusual shapes (e.g. domes) that are determined by plant communities in response to generally low energy flow environments (Rydin & Jeglum 2006). The pattern and process of peat accumulation in combination with generally low surface flows are therefore expected to create a hydrogenetic setting where the channel is not necessarily located at the lowest point in the landscape, as is the case in the Matitimani Valley (Figure 5.3). Through channel incision it may however be possible for the channel bed to be located in the lowest landscape potion, while the channel banks can be higher in comparison to other areas along the valley bottom cross-section.

Table 5.1 Average values and standard deviations (SD.) for peat body thickness, groundwater level, pH, and groundwater electrical conductivity along transect points within the Matitimani valley.

Peat properties	Average value	Standard deviation	Number of samples
Peat body thickness in metre	1.41	±1.03	9
Peat body groundwater depth in metre	-0.39	±0.17	7
Groundwater pH	5.88	±0.57	8
Groundwater electrical conductivity (EC) in micro-siemens per metre	175.13	±47.01	8

The peat surface remains wet along the entire transect with the water level consistently above the surface level, while no drainage furrows (drains) were recorded at any point along the transect (Figure 5.2 & 5.3). The peat is generally little decomposed (H1–H3) at shallow depths and becomes progressively more decomposed or humified (H8–H10) as the peat increases in age and the environment turns more anaerobic (Figure 5.2); this represents a common pattern in peatlands (Clymo 1983).

In warm tropical conditions the youngest peat always occupies the top strata of the profile when a water table level is present that remains at the same distance from the surface throughout the entire profile, even when it does fluctuate (Clymo 1983). Under such conditions the most recently formed surface peat is the least decomposed peat (H2-H3). The majority of the Matitimani valley bottom peatland is consistent with this pattern, as it still contains young fibrous peat at the surface across most of its width with no evidence of any drains being present (Figure 5.2). The woody nature of the peat, especially pronounced on the western side of the transect (right-hand side of the image) and extending through out most of the profile, indicates that Peat Swamp Forest vegetation has been the dominant peat forming vegetation type in the valley bottom mire (Figure 5.3)

Matitimani vegetation gradients

Identified Peat Swamp Forest classes indicate a continuous range of pristine PSF habitat even though vegetation clearance may have taken place in the past or conditions for the development of the tree stratum are unfavourable. This is based on a short average tree height that varies along the transect, compared to a slightly shorter, but more consistent average shrub height (Figure 5.3; Table 5.2).

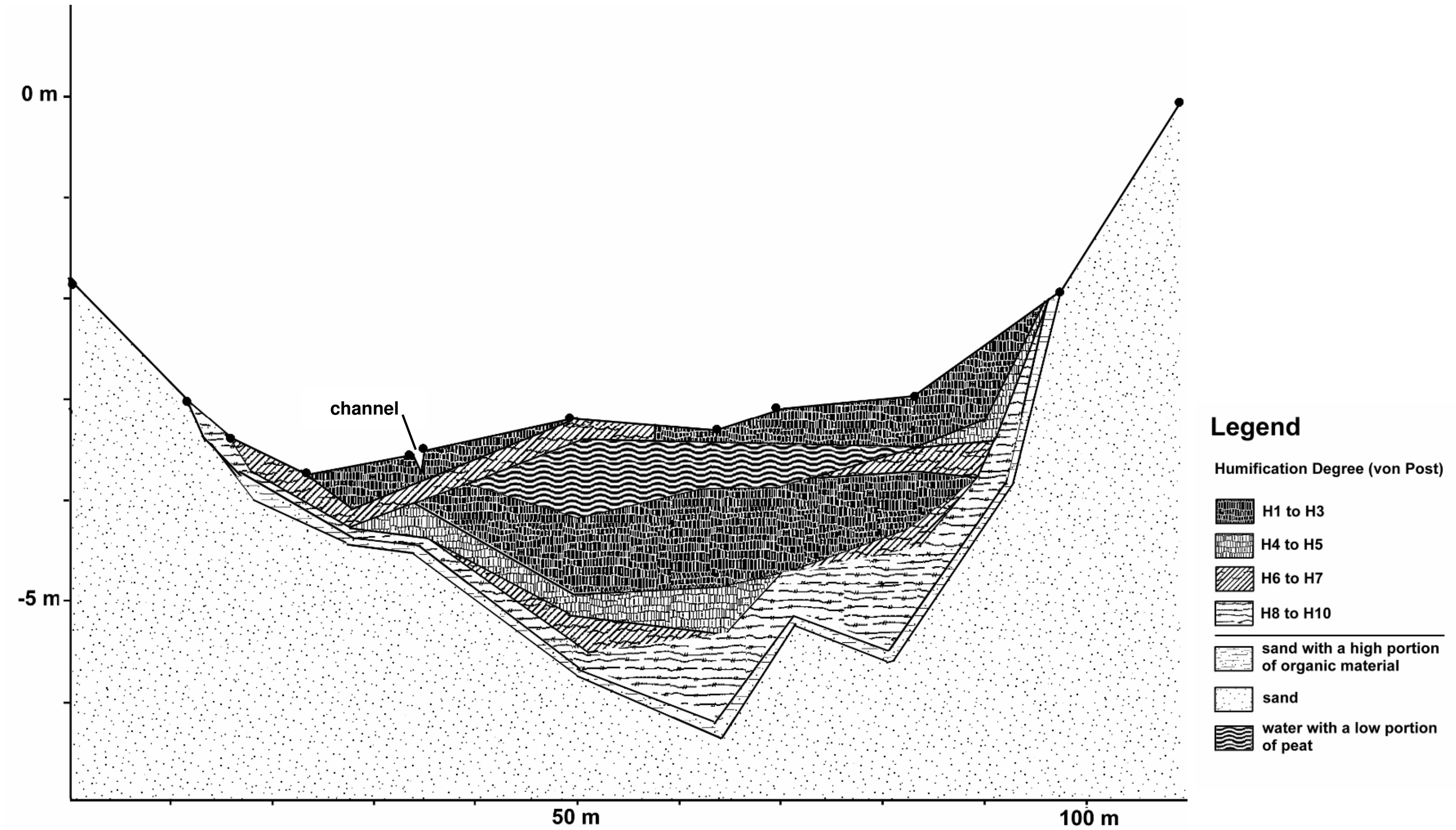


Figure 5.2 The peat stratigraphy of the Matitimani cross-section profile illustrates the sequence of different groupings of the combined Von Post peat humification classes, with the age of the peat body increasing from top to bottom.

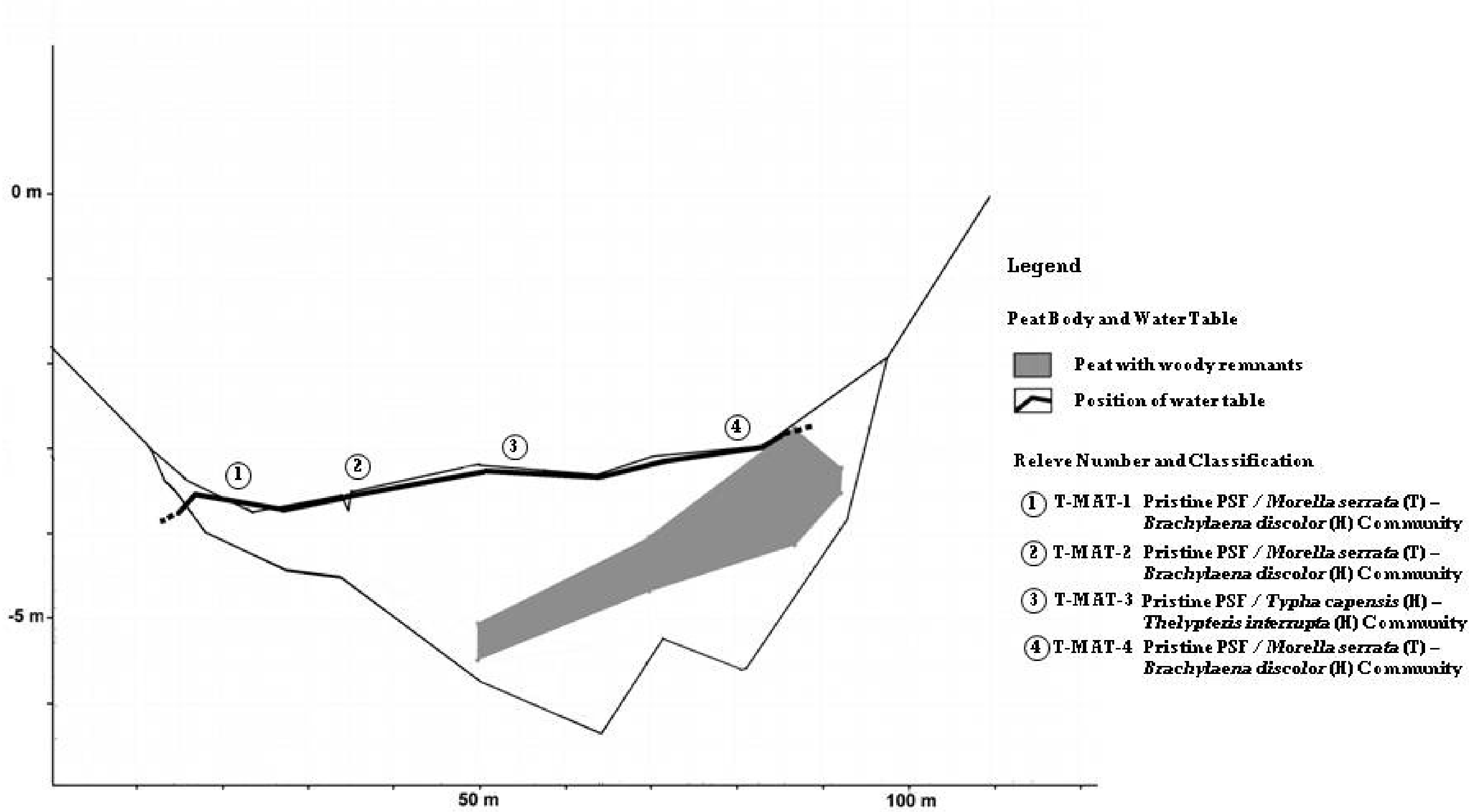


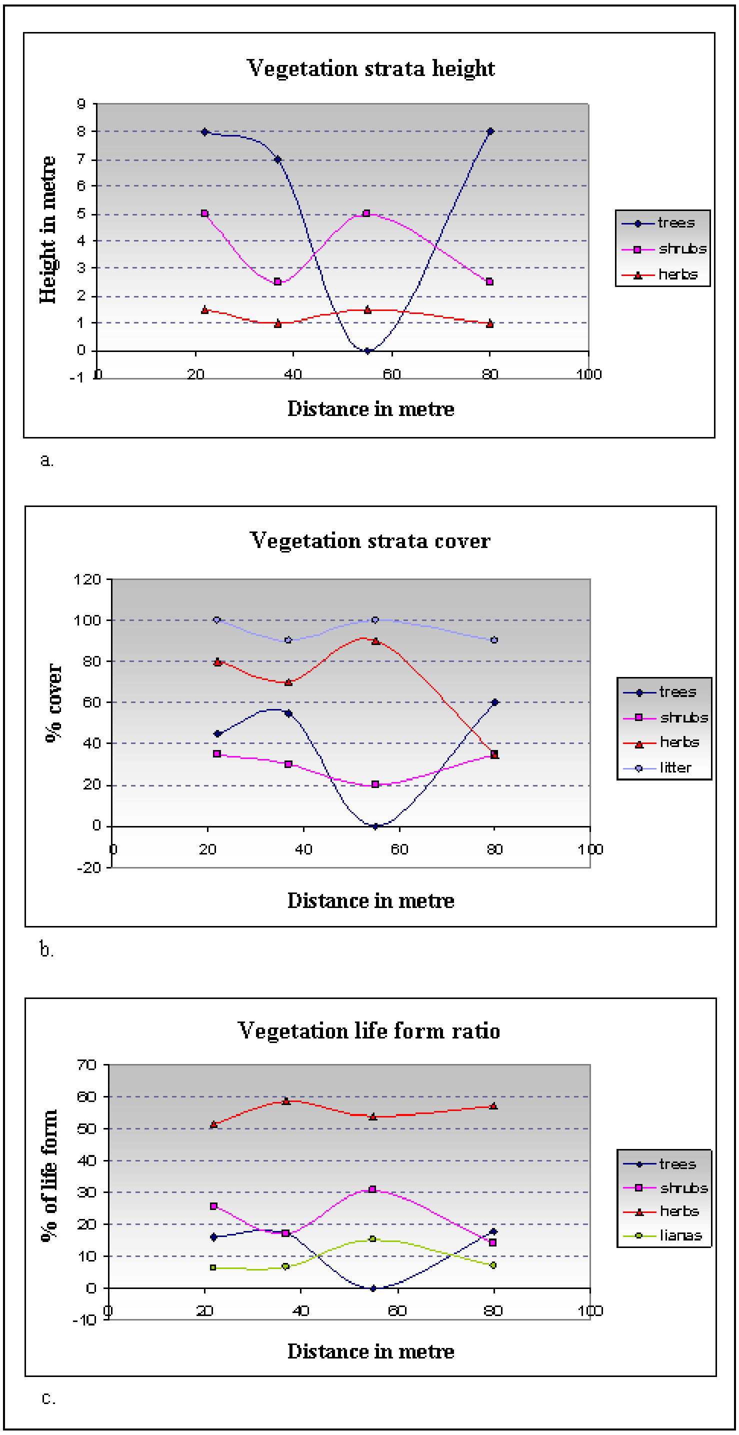
Figure 5.3 The Matitimani valley bottom peat body with woody peat remnants and its recorded groundwater table during September 2003. Described vegetation communities and Peat Swamp Forest classes are also illustrated for each vegetation sampling plot positioned within the profile.

Table 5.2 Average values and standard deviations of recorded vegetation structural properties including different strata height, canopy cover, and life form fraction in percentage for the Matitimani valley bottom transect (n = 5).

Vegetation properties	Average value	Standard deviation
Strata height in meter		
Tree layer	5.75	±3.86
Shrub layer	3.75	±1.44
Herb layer	1.25	±0.29
Strata canopy cover in percentage		
Tree layer	40	±27.39
Shrub layer	30	±7.07
Herb layer	68.75	±23.94
Litter layer	95	±5.77
Strata life form fraction in percentage		
Tree layer	12.80	±8.57
Shrub layer	22.03	±7.62
Herb layer	55.28	±3.17
Liana layer	8.96	±4.29

Figure 5.4 illustrates a distinct absence of the tree layer in the central portion of the wetland. It is hence concluded that the tree strata is currently in a recovering phase, with the sampling plots classified as pristine as opposed to long-time recovering due to tree height not being incorporated as a diagnostic indicator in the PSF disturbance classification (Table 3.1). The area characterised by water with a low portion of peat near the surface of the peat body, in the centre of the transect, is currently in a process of terrestrialisation. This area is expected to be strongly anoxic with a different type of growth media that may create a more unfavourable environment for woody hydrophyte colonisation and development (Figure 5.3). The reestablishment of the tree layer could therefore be inhibited in this area of terrestrilisation, with the woody component still only present in the form of the shrub strata (Figure 5.4).

This pattern of retarded tree development is also visible in the community classification across the profile. Peat Swamp Forest vegetation along the transect belongs in most part to the *Morella serrata* (T) – *Brachylaena discolor* (H) plant community, with the sample plot in the terrestrialisation zone classified as part of the open *Typha capensis* (H) – *Thelypteris interrupta* (H) plant community.



[a.] Vegetation strata height change along valley bottom transect distance (width).

[b.] Vegetation strata cover change along valley bottom transect distance (width).

[c.] Vegetation life form ratio (relative percentage) change along valley bottom transect distance (width).

Figure 5.4 Graphs of Peat Swamp Forest vegetation change along the Matitimani cross section profile.

A set of time series aerial photographs indicate that a denser tree canopy was present at the transect position in 1959 compared to 1942, which again thinned out by 1991 (Figure 5.5). Its recovery since then has been partially aided by a game fence that continues to exclude cultivation to the south Cultivation-related vegetation clearing in the Matitmani Valley to the north has however intensified since 1991 (Figure 4.13 & 5.5).

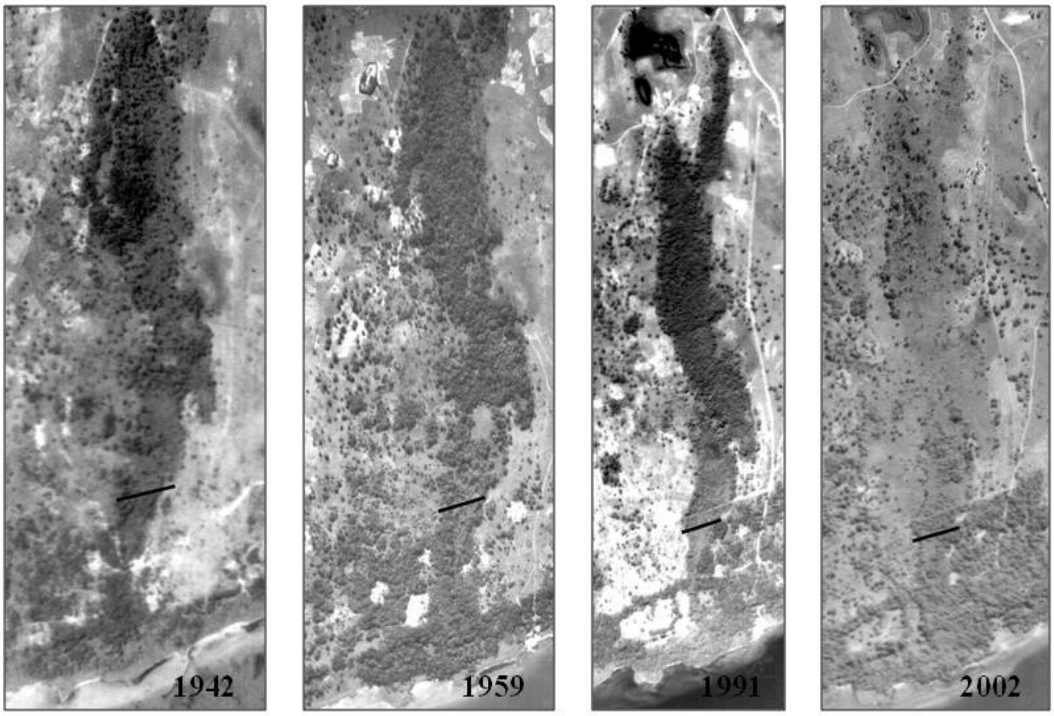


Figure 5.5 Time series aerial photographs from 1942 to 2002, with the approximate Matitimani transect position indicated by the black line.

5.2.2 Nkanini transect

Nkanini peat properties

The Nkanini Valley drains in a south-southeast direction at the transect location before it enters Lake Kosi on its north-western margin. The transect is located in close proximity to the main road linking Manguzi with the Manhoca Mozambican Border Post to the north (Figure 3.2). The channelled valley bottom Peat Swamp Forest has a maximum depth of 3.7 m and an average depth of 2.42 m, with its channel located in the outer valley zone (Figure 5.1 & 5.6; Table 5.3). Figure 5.6 & 5.7 also illustrate a distinct asymmetric peat body profile within the valley cross section profile, with peat soils better developed on the south-western valley slope (right hand bank) compared to the north-eastern slope (left hand bank). The peat body width of ±170 m is considered as wide (Figure 5.6 & 5.7).

The groundwater table remains at or near the surface of the peatland across its entire width, with localised ponding present in several areas, while surface ponding and saturated peat conditions are present at higher elevations compared to the stream channel (Figure 5.7; Table 5.3). A 3 m change in the elevation of the peat surface and the positioning of the stream channel in a low lying outer valley bottom section, is indicative of lateral groundwater inputs into the peat body, especially into the right hand valley slope (Figure 5.1 & 5.6). The location of the channel and the slope in the peat body rules out the regular supply of surface water across the width of the entire peatland from upstream linear surface flow inputs only. The influx of groundwater must be of a frequency and duration that is regular and reliable over time, in order to provide a hydrological regime conducive for the accumulation and preservation of peat in the right hand valley slope.

Channel migration is also likely to be restricted to the outer valley bottom zone and a portion of the inter zone, in the narrower left hand bank of the valley bottom due to the large elevation difference in the peatland (Figure 5.6). The irregular peat stratification pattern is related to alternating peat moisture conditions during the peat formation process, which is related to changes in groundwater and surface water contributions over the same time period (Figure 5.6). A historic fire event within the peatland is indicated by the presence of charcoal within deeper lying peat strata, which indicates a previous desiccation cycle during the development of the peat profile. The peatland also contains a continuous woody peat component across the majority of the peat body (Figure 5.6). This woody peat component is not related to recent root growth, but originates from historic peat accumulation that was in return derived from woody plant material, such as Swamp Forest vegetation. It indicates the uninterrupted presence of this vegetation type during the bulk of the peat forming process.

Table 5.3 Average values and standard deviations (SD.) for peat body thickness, groundwater level, pH, and groundwater electrical conductivity along transect points within the Nkanini valley (n = 6).

Peat characteristics	Average value	Standard deviation
Peat body thickness in metre	2.42	±1.13
Peat body groundwater depth in metre	-0.05	±0.07
Groundwater pH	6.42	±0.40
Groundwater electrical conductivity (EC) in micro-siemens per metre	336.67	±65.93

The peat surface is intermixed with sand and clay on a small scale not indicated in Figure 5.5 in the higher-lying right hand peatland slope and is expected to have resulted from colluvium input at the base of the slope. Gardening activities on the edge of the peatland also induced localised disturbances and soil mobilisation, which led to sand and clay material being washed into the peat body from the surrounding slopes. The most recently formed surface peat (H1–H3) is limited to a strip in the centre of the profile (55–95m) and bordered by successively more decomposed upper peat strata, especially pronounced on the longer right hand slope (Figure 5.6). The general absence of young fibrous peat along the surface of the peatland may be indicative of the extent of draining and peat oxidation that has occurred within the system. It is expected that gardening activities have decomposed the young peat from the peatland boundary towards the centre and in the process exposed the more humified peat strata (Figure 5.6). Younger and more fibrous peat has better draining properties (a higher hydrological conductivity) that is more suitable for cultivation practices, compared to the underlying and increasingly clay-like humified peat strata (Page *et al.* 1999; Joosten & Clark 2002; Price & Role 2003).

The Nkanini peatland cross-section reveals a channelled valley bottom inter-dune system with a long right hand slope that is more consistent with a hillslope seepage hydro-geomorphic (HGM) wetland setting (Figure 5.6 & 5.7). The Peat Swamp Forest system therefore consists of two HGM wetland units, within the larger Nkanini Valley. Lateral intermitted flow is expected to be the main hydrological driver in the hillslope seepage component in particular.

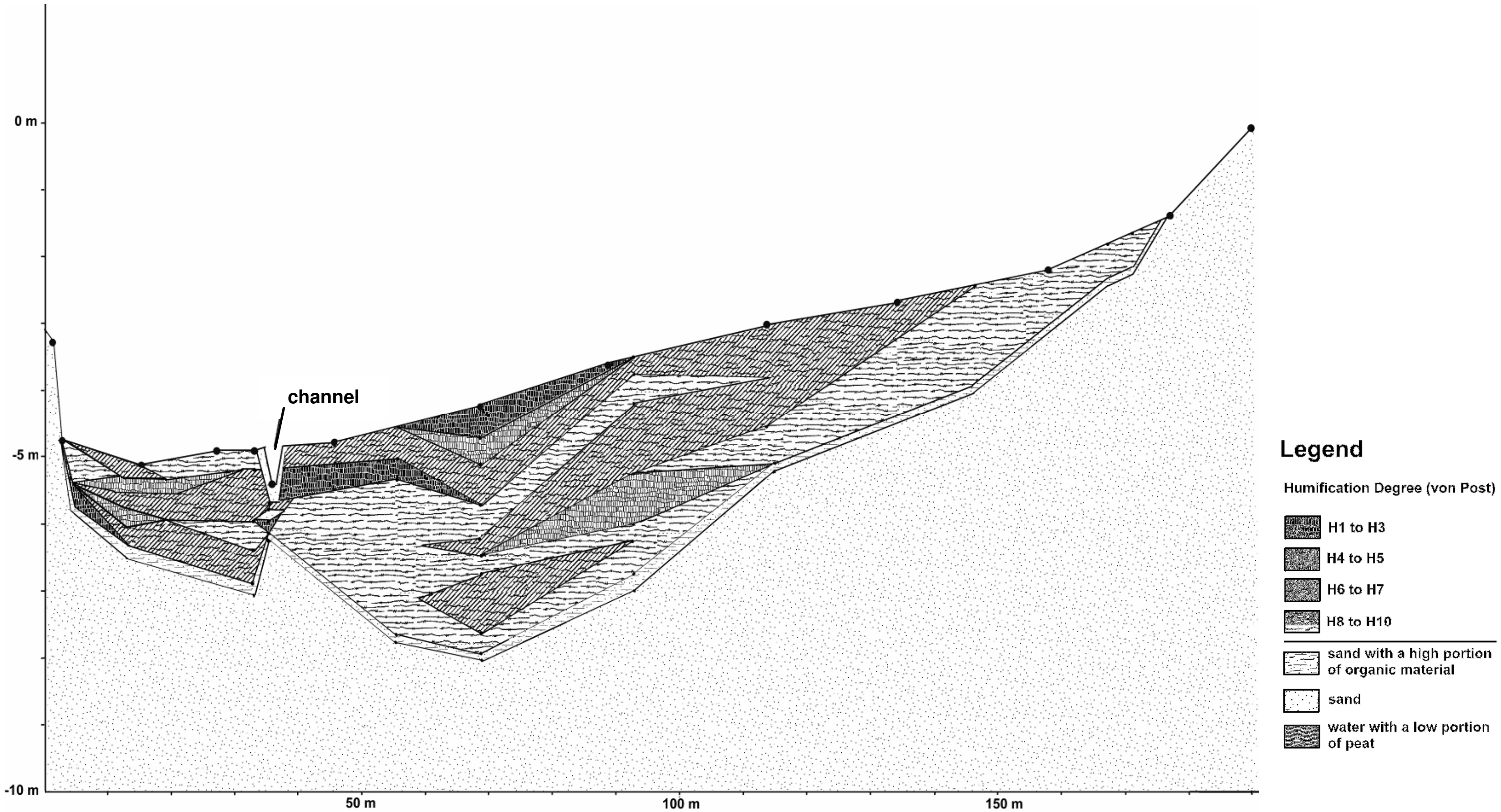


Figure 5.6 The peat stratigraphy of the Nkanini cross-section profile illustrates the sequence of different groupings of the combined Von Post peat humification classes, with the age of the peat body increasing from top to bottom.

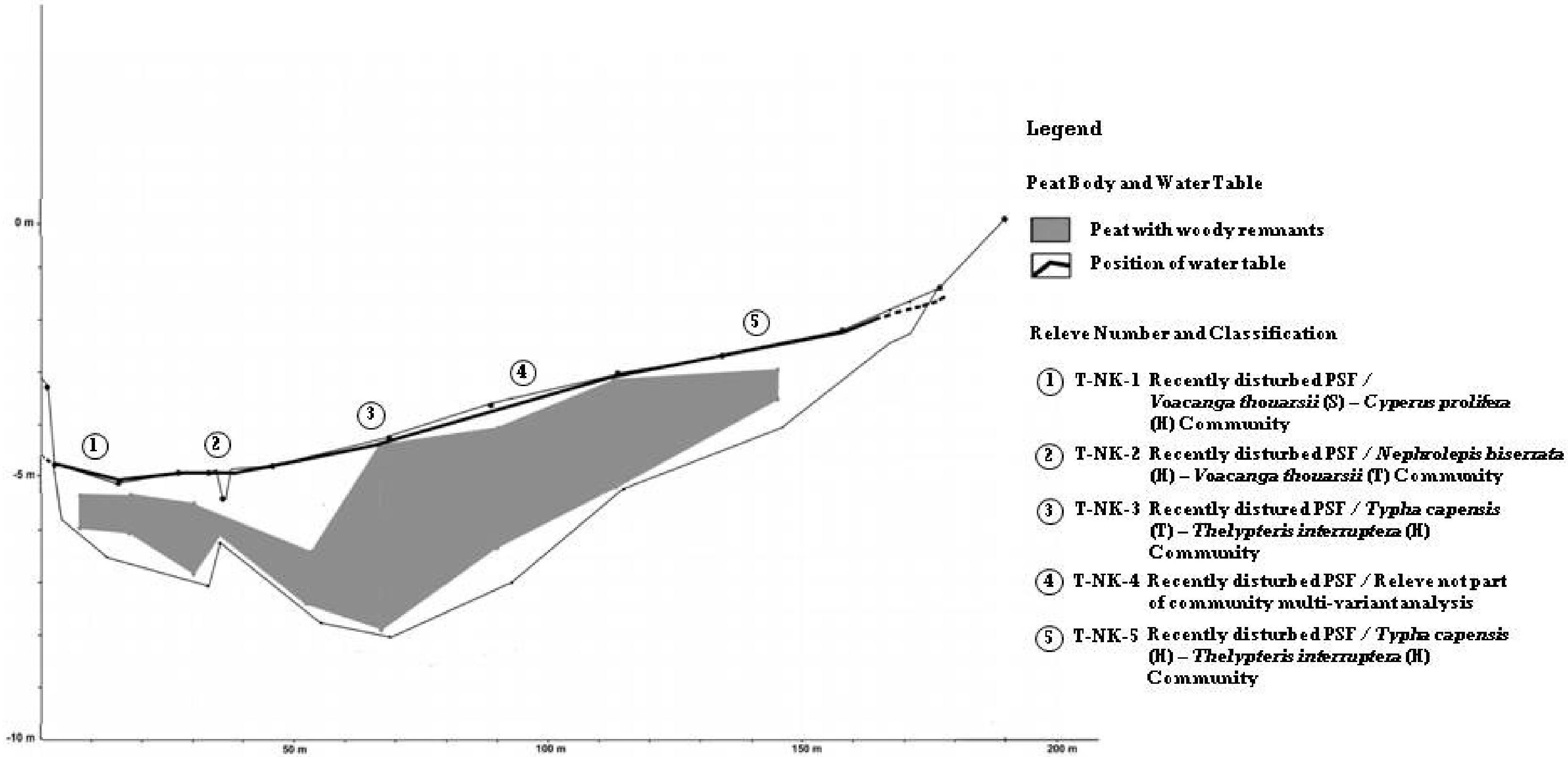


Figure 5.7 The Nkanini valley bottom peat body with woody peat remnants and its recorded groundwater table during September 2003. Described vegetation communities and Peat Swamp Forest classes are also illustrated for each vegetation sampling plot positioned within the profile.

Nkanini vegetation gradients

Peat Swamp Forest vegetation along the transect is disturbed due to clearing impacts and localised small-scale gardening that include *Colocasia esculenta* cultivated on the stream banks (sample plot T-NK-4), (Figure 5.7). A small number of stunted bananas (*Musa* x*paradisiaca*) is present on the fibrous (H1-H3) peat layer at sample plot T-NK-3 (Figure 5.6 & 5.7). This pattern reaffirms the selection of younger more fibrous peat for cultivation, especially banana gardening. The stunted banana growth form is likely to be induced by water stress due to insufficient draining being possible in the shallow H1–H3 fibrous peat strata.

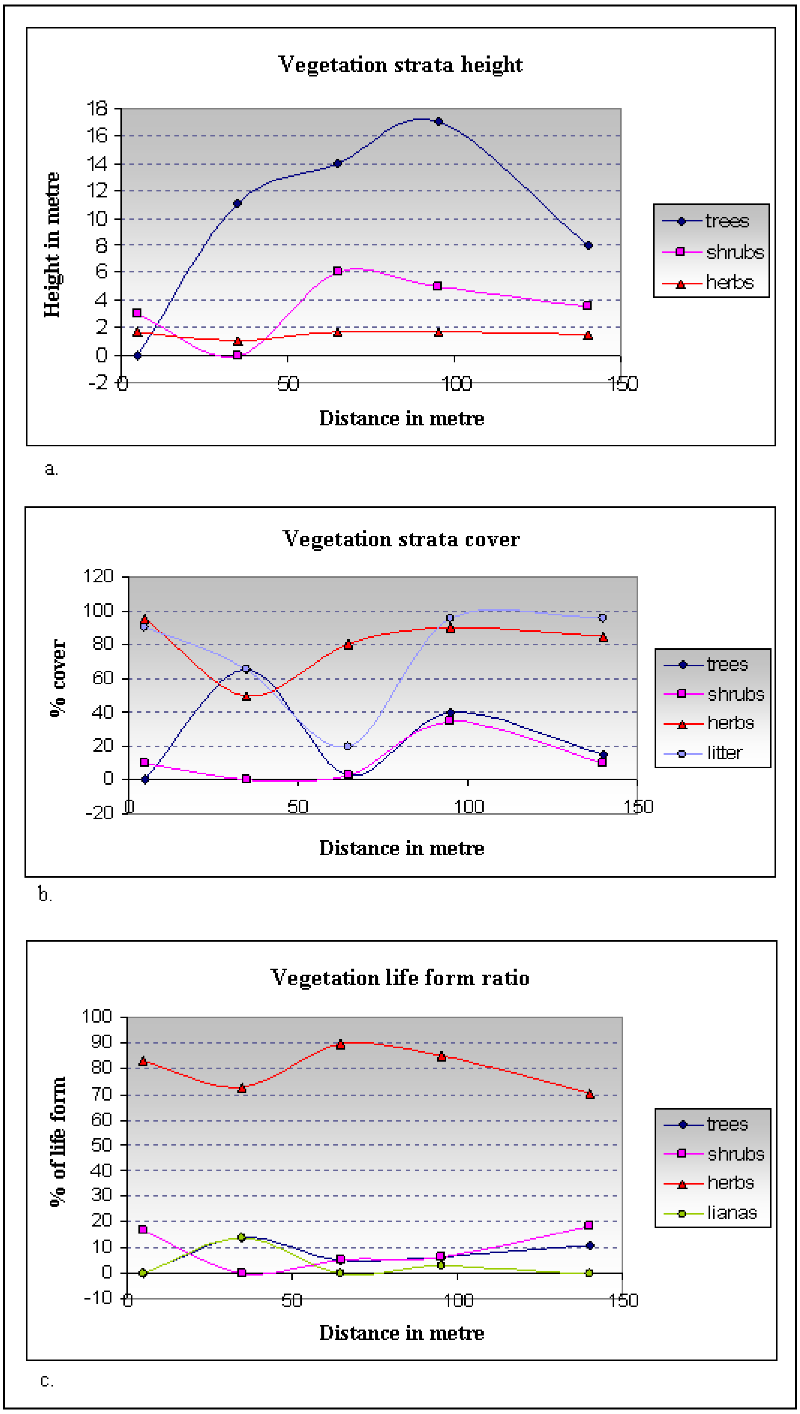
The tree layer cover reaches its maximum density at the channel position and decreases in height in both directions away from the channel, with a complete absence at sampling plot T-NK-1 where banana cultivation is currently practiced (Figure 5.6 & 5.6). Tree and shrub strata height and cover values varies along the transect, while the litter strata cover is also characterised by a high standard deviation (Figure 5.8; Table 5.4). This pattern is related to the extent of vegetation clearing disturbances and cultivation practices over different time periods across the entire inter-dune valley peatland.

Heterogeneity is also present in species assemblages along the Nkanini transect, with three different plant communities at four sampling points (Figure 5.7). Liana species appear to be the most sensitive to disturbances in this transformed peatland system, with the lowest average life form fraction. The liana life form fraction reaches its highest value at the channel position where the tree layer is at its maximum cover (Table 5.4; Figure 5.8).

A set of time series aerial photographs indicate that a well intact and continuous tree canopy was present in the Nkanini Valley in 1959; the vegetation in the valley bottom setting is expected to have consisted of Peat Swamp Forest habitat (Figure 5.9). At this time the area was remote with no road visible. An unpaved road is noticeable in 1991 and coincides with the large scale clearing of the woody strata. Further PSF vegetation clearing occurred in 2002 to leave a sparser tree canopy, while the unpaved road has been replaced with a tar road (Figure 5.9). The correlation between cultivation-induced PSF vegetation clearing and improved infrastructure development is not regarded as a coincidence, as better infrastructure would allow easier access to gardening sites and more distant offset markets.

Table 5.4 Average values and standard deviations of recorded vegetation structural properties including different strata height, strata canopy cover, and strata life form fraction in percentage for the Nkanini valley bottom transect (n = 5).

Vegetation structural properties	Average value	Standard deviation
Strata height in meter		
Tree layer	10	±6.52
Shrub layer	3.50	±2.29
Herb layer	1.55	±0.33
Strata canopy cover in percentage		
Tree layer	24.60	±27.54
Shrub layer	11.60	±13.79
Herb layer	80	±17.68
Litter layer	73	±32.13
Strata life form fraction in percentage		
Tree layer	7.22	±5.31
Shrub layer	9.32	±7.94
Herb layer	80.14	±8.21
Liana layer	3.32	±5.89



a. Vegetation strata height change along valley bottom transect distance (width).

b. Vegetation strata cover change along valley bottom transect distance (width).

c. Vegetation life form ratio (relative percentage) change along valley bottom transect distance (width).

Figure 5.8 Graphs of Peat Swamp Forest vegetation change along the Nkanini cross section profile.

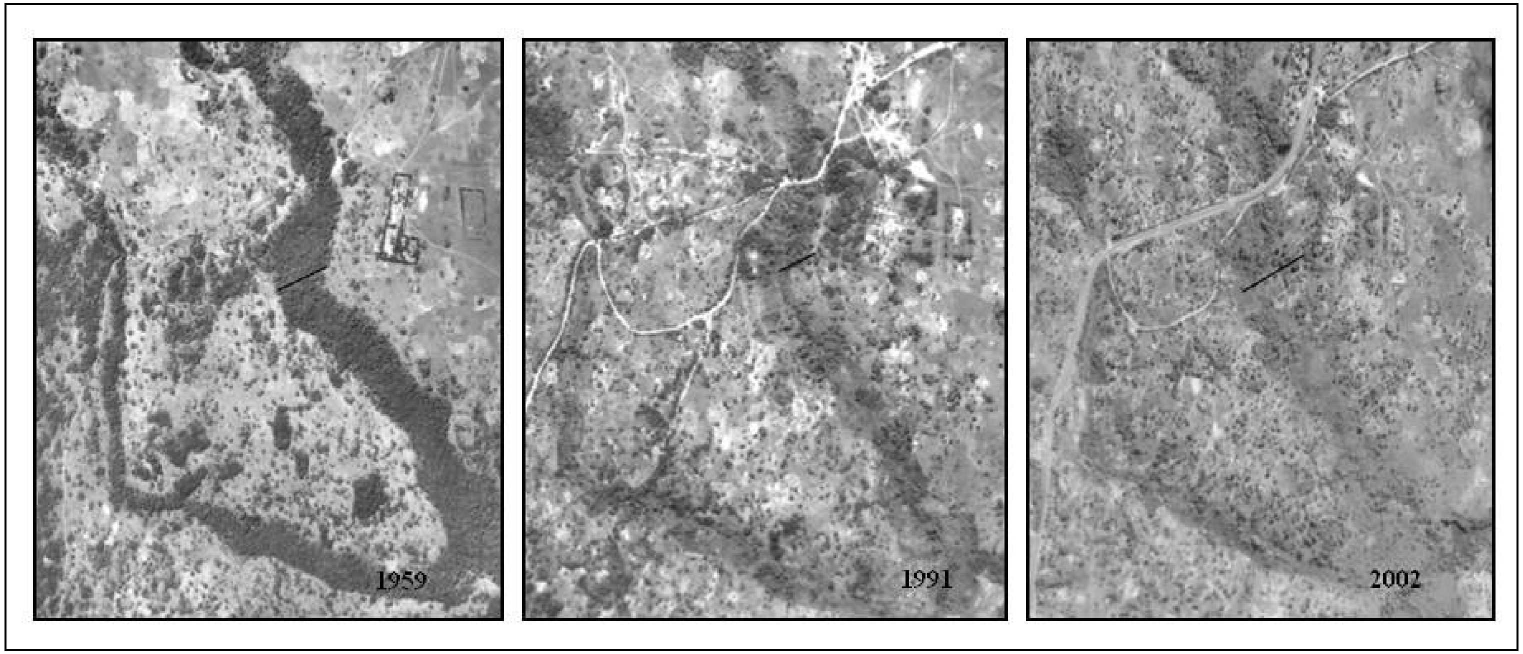


Figure 5.9 Time series aerial photographs from 1959 to 2002, with the approximate Nkanini transect position indicated by the black line.

5.2.3 Tswamanzi transect

Tswamanzi peat properties

The Tswamanzi Valley drains into Lake Kosi at its north-western shoreline, while the Peat Swamp Forest valley bottom transect is located within a portion of the valley that is located within the iSimangaliso Wetland Park, in close proximity to Lake Kosi (Figure 3.2). The wetland can be classified as a channelled valley bottom PSF, with is channel located in the centre of the valley bottom (Brinson, 1993; Figure 5.10). The peatland cross section has a maximum peat depth of 1.48 m located in the centre section of the valley bottom, while the average peat depth is 0.64 m (Table 5.5; Figure 5.10). The two cross-section profiles through the Tswamanzi Valley illustrate peat surface elevation, valley bottom topography, peat stratigraphy, groundwater level, and woody peat content (Figure 5.10 & 5.11).

The peat stratigraphy indicate a non-sequential pattern of peat humification, with sand layers interspersed between the peat strata at different depths (Figure 5.10). These patterns are expected to be associated with episodic sediment (sand) influxes following large storm events that can include cyclones. The groundwater level is constant and remains close to the surface throughout the peat body (Figure 5.11; Table 5.5).

A depression in the peatland is characterised by a relatively young peat on the surface (H4–H5) and located within an outer valley zone that currently lacks a channel (Figure 5.10). The area is expected to represent an old stream channel that is in a process of terrestrialization. The area is covered by a mat of fine *Ficus trichopoda* roots with decaying organic leaf litter on top, which is in the process of changing into peat, while clay and fine organic material is present at the bottom of the watery layer (Figure 5.12). *Ficus trichopoda* is expected to be an important species to contribute to the paludification of peat over water dominant layers that appear to be associated with old stream channels in Peat Swamp Forest systems present in the study area.

Woody peat remnants are present throughout the entire width of the valley bottom peatland, while young (H2–H3) and relatively young (H4–H5) peat layers are present at the surface of the outer valley sections (Figure 5.10 & 5.11). These features are indicators of the dominant presence of PSF habitat during the peat development process and the lack of draining practices within the outer margins of the peatland respectively. The presence of young peat surface layers is also consistent with the absence of drain ditches within the peat body.

Table 5.5 Average values and standard deviations (SD.) for peat body thickness, groundwater level, pH, and groundwater electrical conductivity along transect points within the Tswamanzi valley (n = 5).

Peat properties	Average value	Standard deviation
Peat body thickness in metre	0.64	±0.50
Peat body groundwater depth in metre	-0.05	±0.03
Groundwater pH	6.22	±0.63
Groundwater electrical conductivity (EC) in micro-siemens per metre	372.80	±120.44

Tswamanzi vegetation gradients

A single plant community and Peat Swamp Forest class characterise all of the sampled plots along the valley bottom cross-section profile (Figure 5.11). The PSF area therefore displays undisturbed or pristine conditions associated with the absence of cultivation practices. Similar species are present throughout the PSF continuum, but there are local structural changes, which is consistent with observed patterns in intact tropical PSF from other parts of the world (Page *et al.* 1999).

Strata height remains homogenous with only a slight spike in tree height in close proximity to the channel position, which is possibly due to nutrient influx from upstream surface flow (Figure 5.13; Table 5.6). The herbaceous layer has a low cover and life form fraction in the area of terrestrialisation, presumably due to a poorly developed growth substrate provided by the *Ficus trichopoda* root carpet (Figure 5.12 & 5.13). A few dead and fallen trees were also recorded in the area of terrestrialisation and are considered to be indicative of a stressed environment.

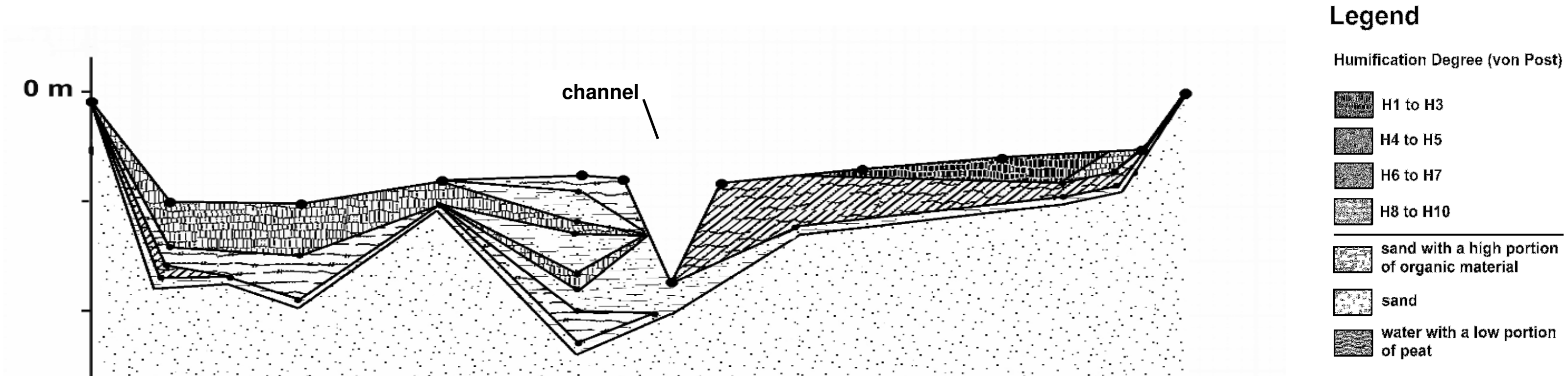


Figure 5.10 The peat stratigraphy of the Tswamanzi cross-section profile illustrates the sequence of different groupings of the combined Von Post peat humification classes, with the age of the peat body increasing from top to bottom.

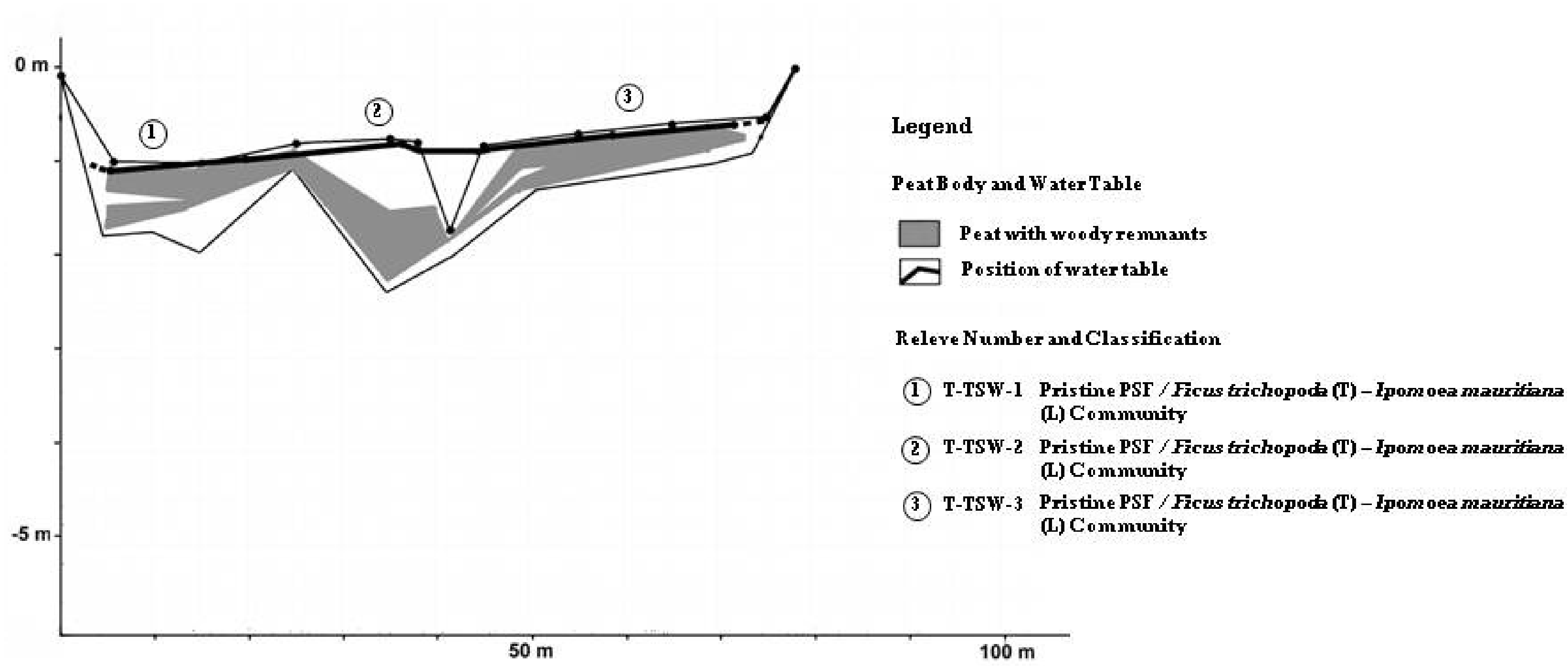


Figure 5.11 The Tswamanzi valley bottom peat body with woody peat remnants and its recorded groundwater table during September 2003. Described vegetation communities and Peat Swamp Forest classes are also illustrated for each vegetation sampling plot positioned within the profile.

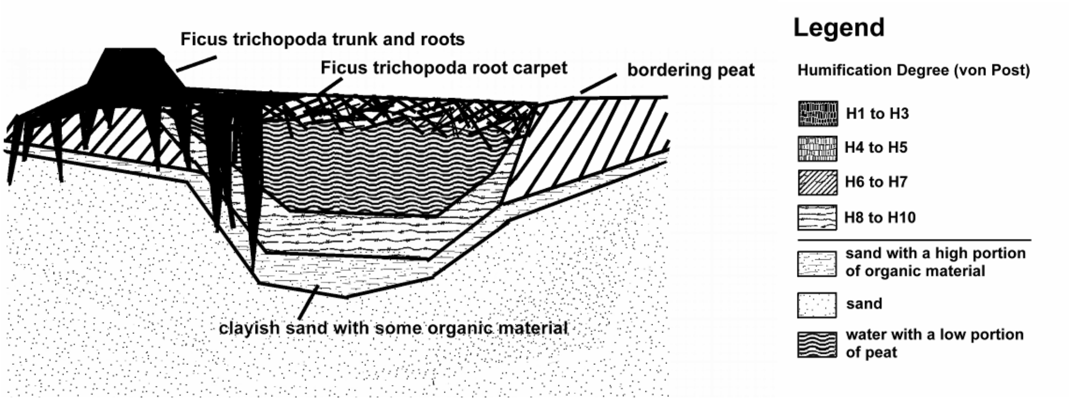
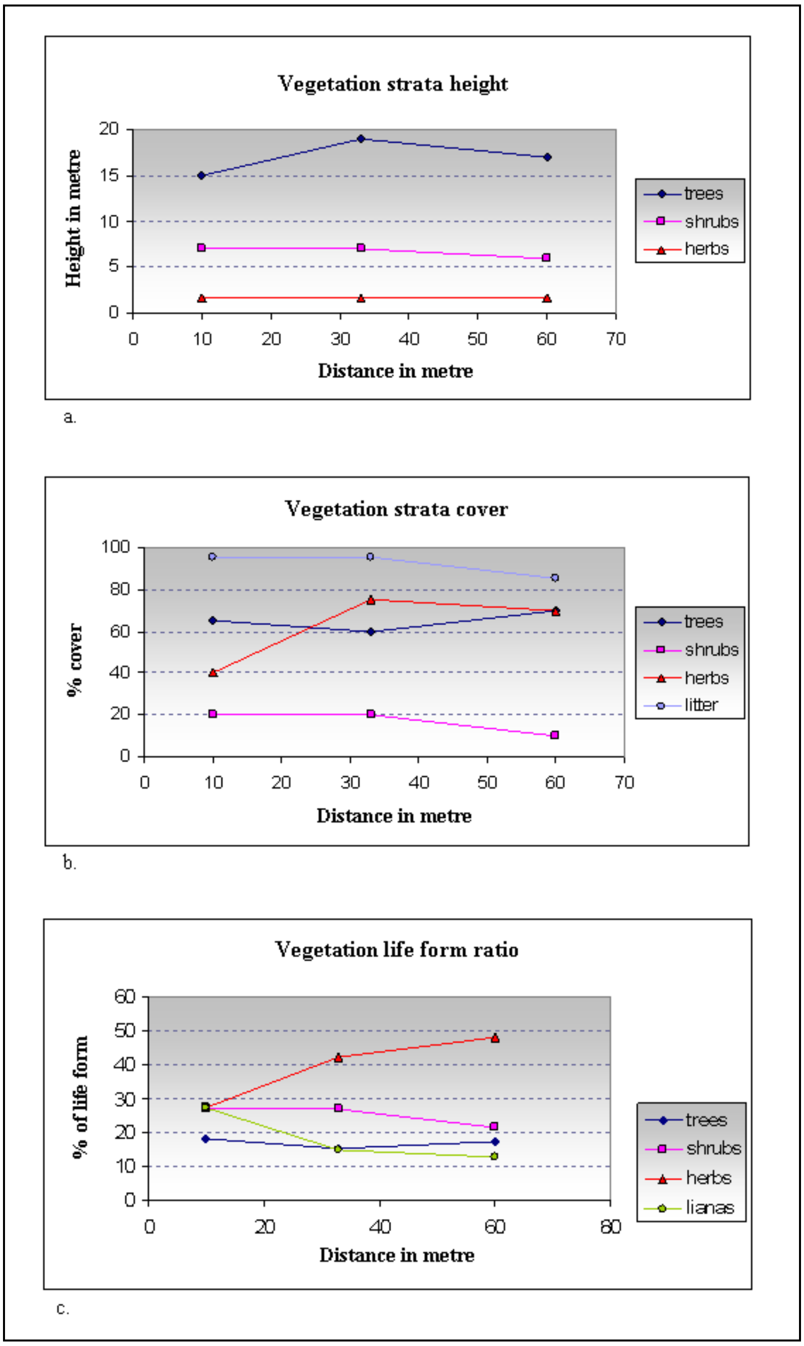


Figure 5.12 Illustrates the peat accumulation process known as terrestrialisation facilitated by root growth and leave litter fall from the species *Ficus trichopoda* over a water dominated layer with limited peat (Sliva *et al.* 2004).

Table 5.6. Average values and standard deviations of recorded vegetation structural properties including different strata height, canopy cover, and life form fraction in percentage for the Tswamanzi valley bottom transect (n = 3).

Vegetation properties	Average value	Standard deviation
Strata height in meter		
Tree layer	17	±2
Shrub layer	6.67	±0.58
Herb layer	1.75	±0
Strata canopy cover in percentage		
Tree layer	65	±5
Shrub layer	16.67	±5.77
Herb layer	61.67	±18.93
Litter layer	91.67	±5.77
Strata life form fraction in percentage		
Tree layer	17	±1.44
Shrub layer	25.30	±3.12
Herb layer	39.13	±3.17
Liana layer	18.43	±4.29



a. Vegetation strata height change along valley bottom transect distance (width).

b. Vegetation strata cover change along valley bottom transect distance (width).

c. Vegetation life form ratio (relative percentage) change along valley bottom transect distance (width).

Figure 5.13 Graphs of Peat Swamp Forest vegetation change along the Tswamanzi cross section profile.

5.2.4 Syadla transect

Syadla peat properties

The Syadla transect is positioned halfway across the Syadla River channelled valley bottom, from the upper margin of the Peat Swamp Forest to the edge of the river bank (Figure 5.14). The Syadla transect is located approximately 3.75 km upstream of the confluence with Lake Amanzimnyama, inside the iSimangaliso Wetland Park (Figure 3.2). The peatland has a maximum depth of approximately 2.5 m and an average depth of 2.09 m, which fluctuates less than 0.5 m along the sampled cross-section profile (Figure 5.14; Table 5.7).

The two cross-section profiles through the Syadla Peat Swamp Forest valley bottom illustrate the surface topography, peat stratigraphy, groundwater level, and woody peat content (Figure 5.14 & 5.15). The peatland displays a chronological gradient sequence of increasing peat age and humification with depth across the majority of the cross-section profile, with irregular layering primarily restricted to the channel position (Figure 5.14). The regular and uninterrupted increase in peat humification and age is consistent with peat stratigraphy patterns associated with untransformed peatlands (Clymo 1983).

The surface topography of the peat body and the topography of the underlying sand body exhibit a similar pattern in terms of elevation changes (Figure 5.14). Channel migration may in return have played a role in shaping the sand body profile in the valley bottom landscape position, while channel migration across the valley width could potentially also have occurred during peat development.

The depression situated across the outer and inter valley bottom zone from interval markers 10–70 m is characterised by relatively young peat (H4–H5) at the surface and the absence of recently formed peat (H1–H3), (Figure 5.14). This particular section of the transect is also dominated by active gardening associated with drainage ditches that have lowered the groundwater level in the centre of the cultivated depression to its lowest position along the transect (Figure 5.14). Hence, localised desiccation is present inside the cultivation area and is expected to have led to the oxidation of young peat material previously located in the top strata. This appear to have been a rapid event given that cultivation was only initiated four years ago according to the farmer.

The presence of woody peat remnants occur throughout the width of the peatland, but not throughout its depth due to the high degree of humificiation in the older underlying peat strata where the woody nature of the peat becomes indistinguishable. However, the extensive presence of woody peat material signifies that the entire peatland has been dominated by swamp forests vegetation during a large part of its development phase (Figure 5.14).

Table 5.7 Average values and standard deviations (SD.) for peat body thickness, groundwater level, pH, and groundwater electrical conductivity along transect points within the Syadla River valley (n = 6).

Peat characteristics	Average value	Standard deviation
Peat body thickness in metre	2.09	±0.47
Peat body groundwater depth in metre	-0.12	±0.10
Groundwater pH	6.56	±0.31
Groundwater electrical conductivity (EC) in micro-siemens per metre	430.67	±109.35

Syadla vegetation gradients

The transect is characterised by intense cultivation-related disturbances in the form of gardening and clearing across the majority of its width, while only the area around the channel is regarded as undisturbed (Figure 5.13). Subsequently, the litter and different vegetation strata display large variations in their height and cover values across the cross-section profile (Figure 5.16; Table 5.8).

Gardening started at the edge of the peatland and encroached inward, with the cultivation front moving up to the 65 m interval mark where a new area has been cleared and completely stripped of trees (Figure 5.15 & 5.16). The percentage litter cover remains at a moderate level in the disturbance zone (cultivated and disturbed area) and then increases sharply next to the undisturbed channel position, while the liana life form fraction also increases with the shrub and tree strata percentage cover values at the channel position (Figure 5.16). The decrease in the high life form fraction values of the herbaceous layer in the undisturbed area display an opposite trend and also highlights the dominant presence of weedy herbaceous species in the disturbed zone (Figure 5.16).

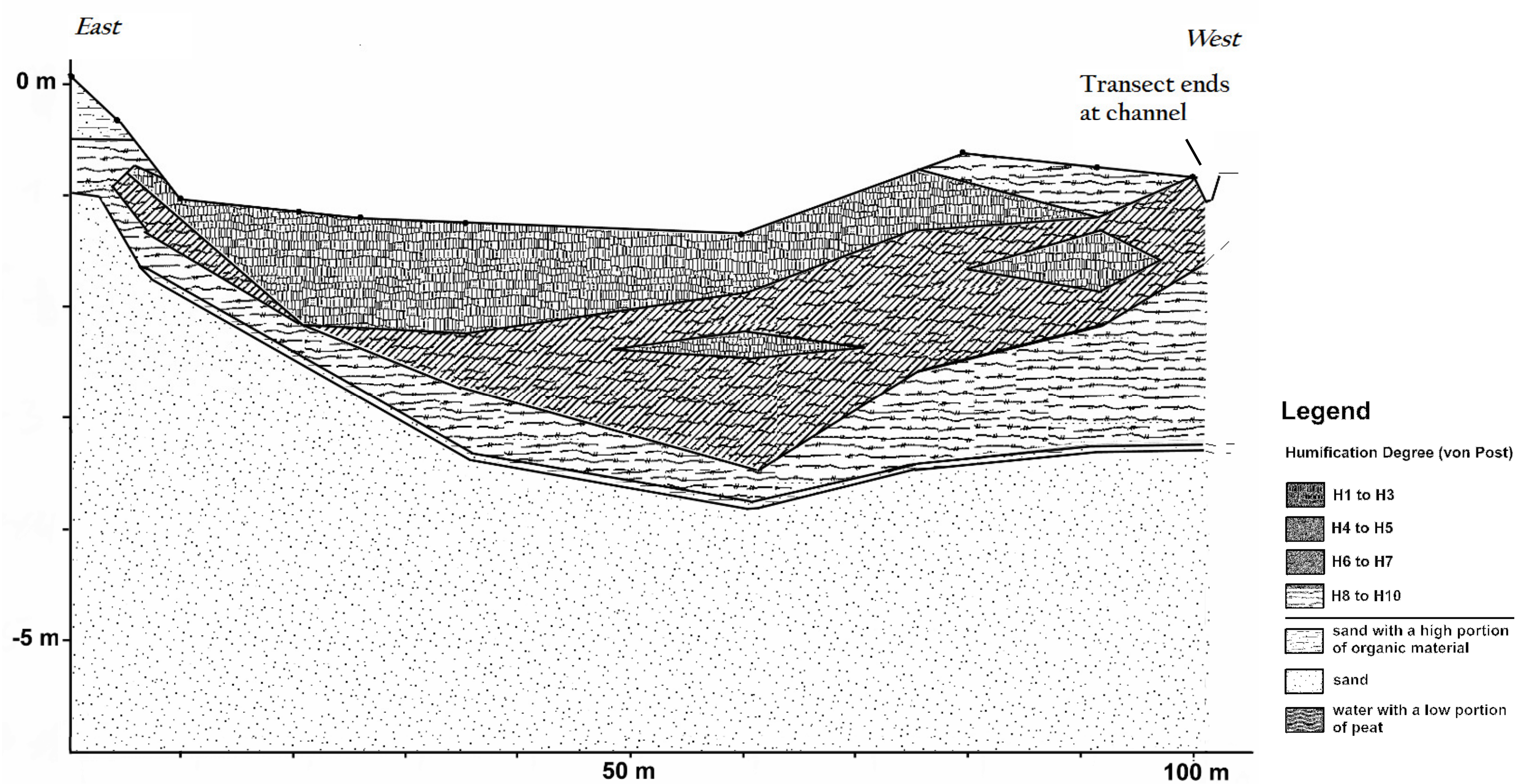


Figure 5.14 The peat stratigraphy of the Syadla cross-section profile illustrates the sequence of different groupings of the combined Von Post peat hummification classes, with the age of the peat body increasing from top to bottom.

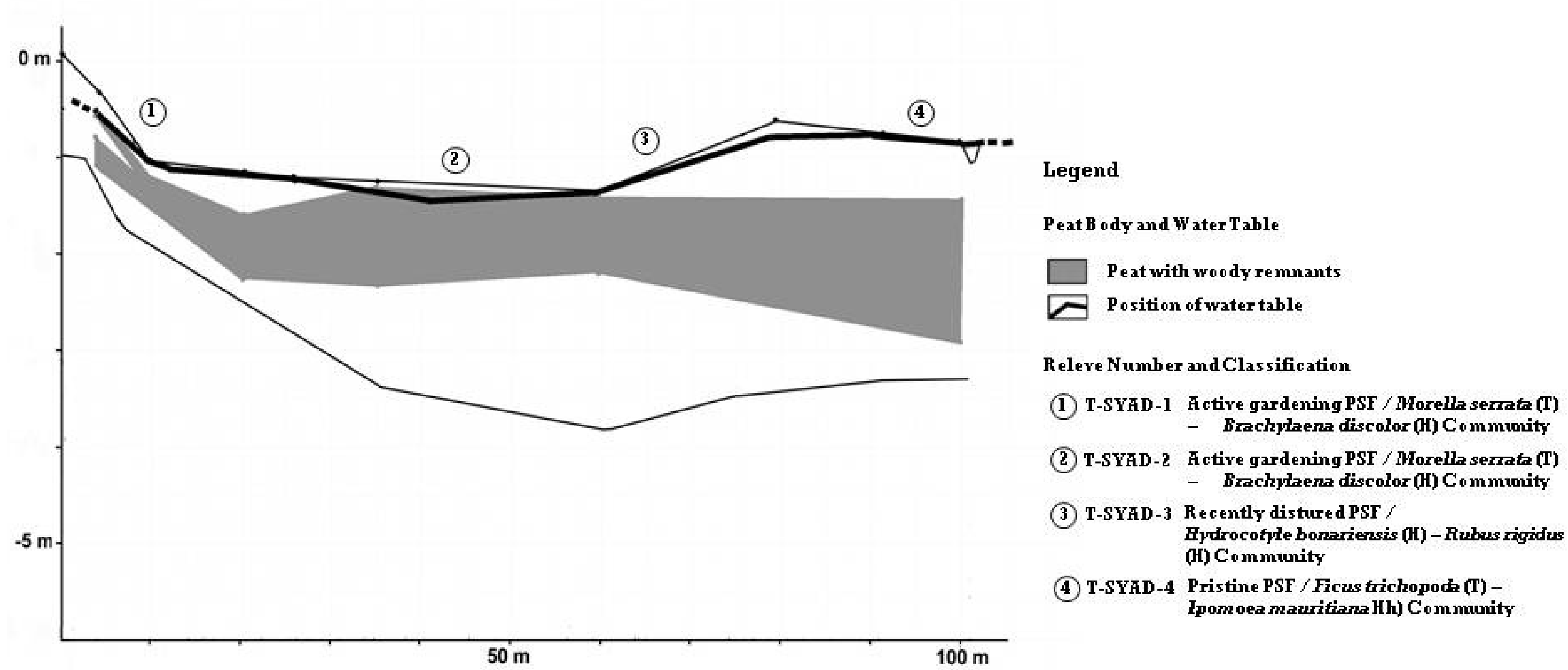


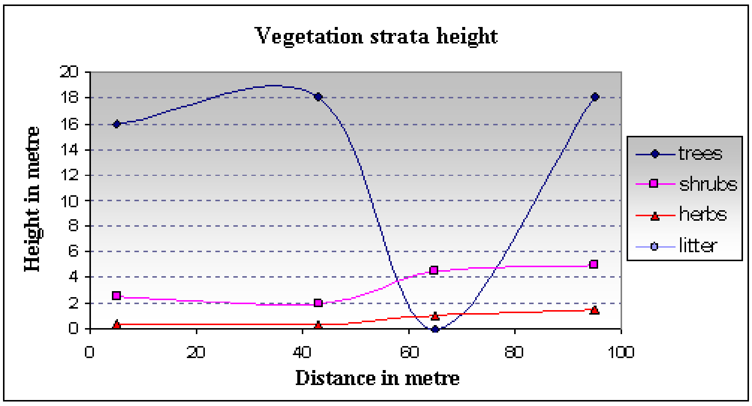
Figure 5.15 The Syadla valley bottom peat body with woody peat remnants and its recorded groundwater table during September 2003. Described vegetation communities and Peat Swamp Forest classes are also illustrated for each vegetation sampling plot positioned within the profile.

The encroachment of weedy species in the disturbance zone benefit from peat desiccation that allows more facultative hydrophyte and even terrestrial weed species to colonise and spread in the area. It is also worthwhile to note the limited fluctuation in the height of the tree strata across the transect, apart from the area where it has been completely cleared (Figure 5.16). The average tree height value that excludes the cleared area is 17.33 m with a standard deviation of only ±1.15. In the active gardening zone mature tree species have been left in place, but their cover has been thinned out to make space for cultivation (Figure 4.13 & 5.16).

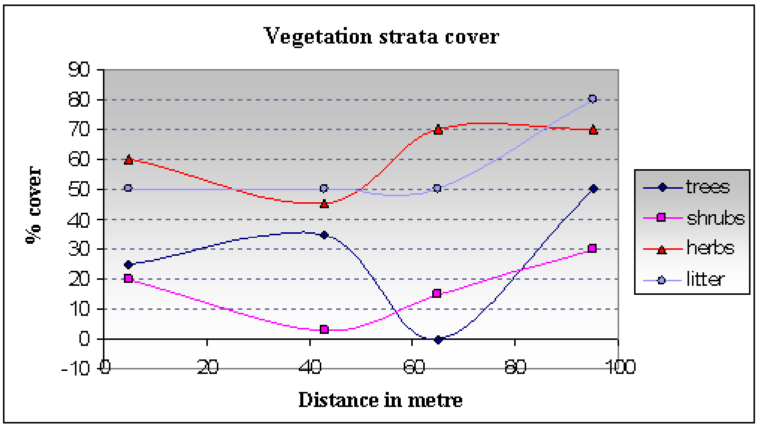
A larger landscape ecological perspective indicate that an area of Peat Swamp Forest habitat situated around the lower reaches of the Syadla River and Lake Amanzimnyama has been reduced in size from 969.4 ha to 790.9 ha from 1942 to 2002 (Figure 5.17). Sliva *et al.* (2004) contribute the loss in habitat to cultivation practices in Peat Swamp Forest habitat as the most likely cause. A helicopter survey in December 2004 confirmed the extensive cultivation of bananas in PSF habitat within the area, which adds further evidence to the effect of wide scale unregulated gardening practices in the area (Figure 2.5).

Table 5.8. Averages and standard deviations of vegetation layers' height, canopy cover and life form fraction along the Syadla Valley transect (n = 3).

Vegetation structural properties	Average value	Standard deviation
Strata height in meter		
Tree layer	13	±8.72
Shrub layer	3.50	±1.47
Herb layer	0.75	±0.59
Strata canopy cover in percentage		
Tree layer	27.50	±21.02
Shrub layer	17	±11.22
Herb layer	61.25	±11.81
Litter layer	57.50	±15
Strata life form fraction in percentage		
Tree layer	4.68	±1.44
Shrub layer	8.65	±3.12
Herb layer	79.48	±10.61
Liana layer	7.25	±7.74



a.



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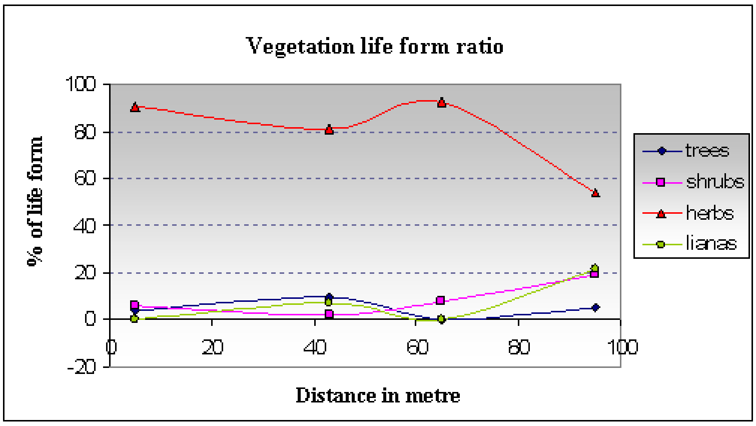


c.

a. Vegetation strata height change along valley bottom transect distance (width).

b. Vegetation strata cover change along valley bottom transect distance (width).

c. Vegetation life form ratio (relative percentage) change along valley bottom transect distance (width).

Figure 5.16 Graphs of Peat Swamp Forest vegetation change along the Syadla cross section profile.

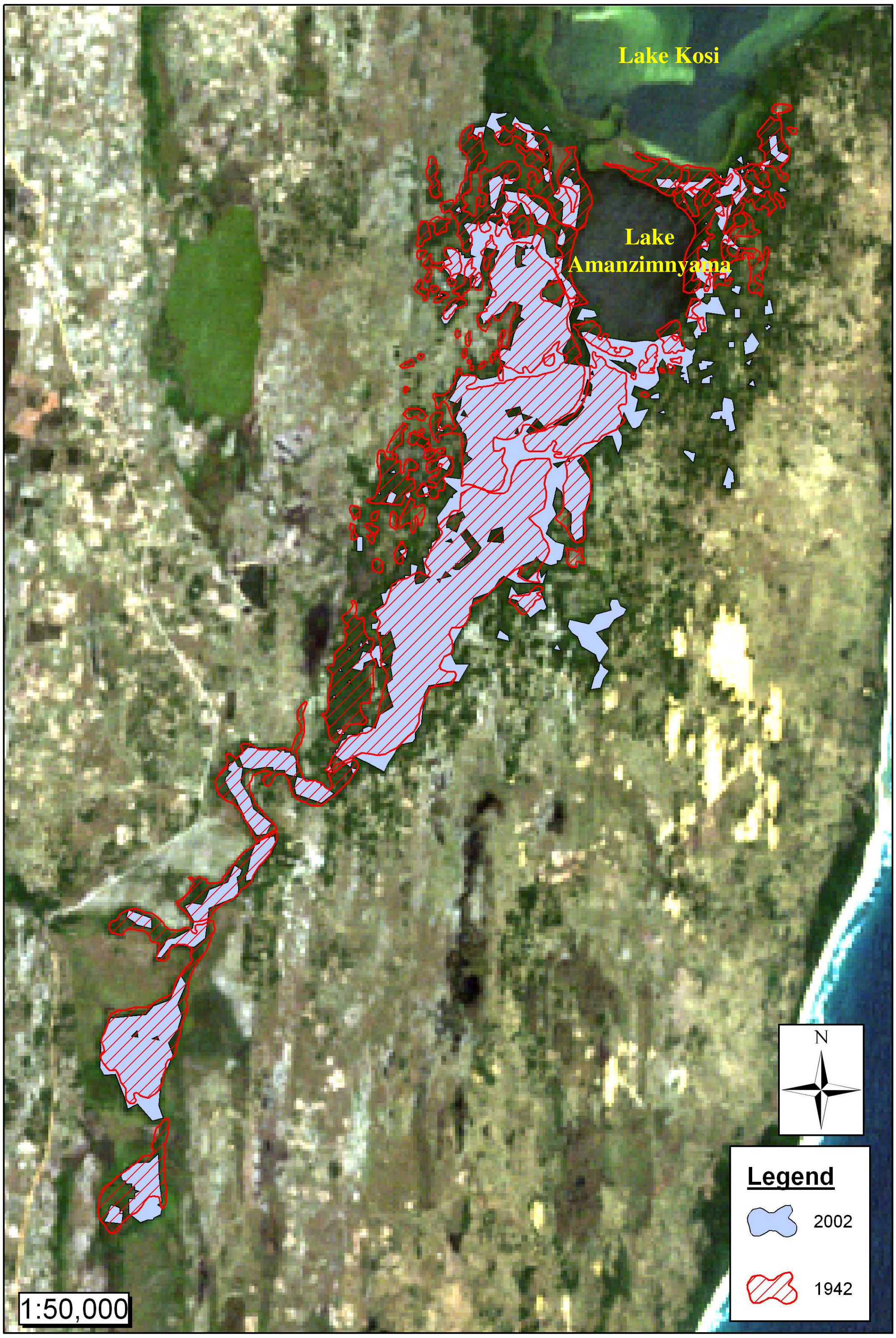


Figure 5.17 Peat Swamp Forest habitat loss in the lower reaches of the Syadla River and around Lake Amanzimnyama (Sliva *et al.* 2004).

5.2.5 Mvelabusha transect

Mvelabusha peat properties

The Mvelabusha transect is the most inland of all the transect sites and is not characterised by bordering steep valley slopes, which is a common feature of Peat Swamp Forest valleys closer to the coast (Figure 3.2). The transect extends along approximately ⅔ of the Peat Swamp Forest system, with no channel present. The cross-section profile display a shallow peat body with a maximum depth of 0.22m and an average depth of 0.17m with little fluctuation across the sampled area (Figure 5.18; Table 5.9). International literature stipulates that a minimum peat depth of 0.3–0.4 m must be present before a peat body can be regarded as a peatland (Joosten & Clark 2002; National Wetlands Working Group 1997). Hence, the Mvelabusha PSF valley bottom is not consistent with this definition and is regarded as a peat-covered area or mire as opposed to a peatland. The average peat depth is also not consistent with the criteria applied in South Africa for an organic-dominant soil, known as a Champagne soil form, which must have an organic rich horizon with a minimum depth of 0.2m (Soil Classification Working Group 1991).

The absence of distinct valley slopes and a valley bottom in the cross-section profile indicate that the Peat Swamp Forest System is more consistent with a hillslope seepage hydro-geomorphic (HGM) wetland unit than a valley bottom HGM wetland system (Brinson 1993; Figure 5.18). The hillslope seepage is connected to the downstream drainage network and is situated in a headwater drainage line position (Figure 3.2). Only highly humified peat and abandoned drainage ditches remain present within the PSF peat body (Figure 5.18). Younger, more fibrous peat is expected to have decomposed as a result of historic gardening activities, especially draining, in association with drier rainfall cycles and reduced groundwater inputs. No woody peat material remains identifiable within the transect and the historic dominance of Swamp Forest vegetation during the peat development process remains uncertain (Figure 5.19).

Table 5.9 Average values and standard deviations (SD.) for peat body thickness, groundwater level, pH, and groundwater electrical conductivity along transect points within the Mvelabusha valley (n = 9).

Peat characteristics	Average value	Standard deviation
Peat body thickness in metre	0.17	±0.04
Peat body groundwater depth in metre	-0.21	±0.20
Groundwater pH	5.73	±0.38
Groundwater electrical conductivity (EC) in micro-siemens per metre	258.44	±109.96

Mvelabusha vegetation gradients

The current dominant vegetation cover in the form of Peat Swamp Forest plant communities on minerotrophic peat (Figure 5.18), with an average tree cover greater than 25% (Table 5.10), is consistent with international criteria for Swamp Forests mires (Rydin & Jeglum 2006). The vegetation has been in a process of recovering and is dominated by a dry *Peddia africana* (S) – *Stenochlaena tenuifolia* (H) PSF community (Figure 5.19). Gradient changes in the vegetation strata also indicate a recovering process with the height and density of the tree layer dipping in a zone expected to be associated with historic tree clearing (Figure 5.20). In addition, the irregular pattern of vegetation strata cover change illustrate that a new equilibrium still has to be reached after gardening practices have seized and that the system is therefore still in a recovering phase from gardening practices (Figure 5.20).

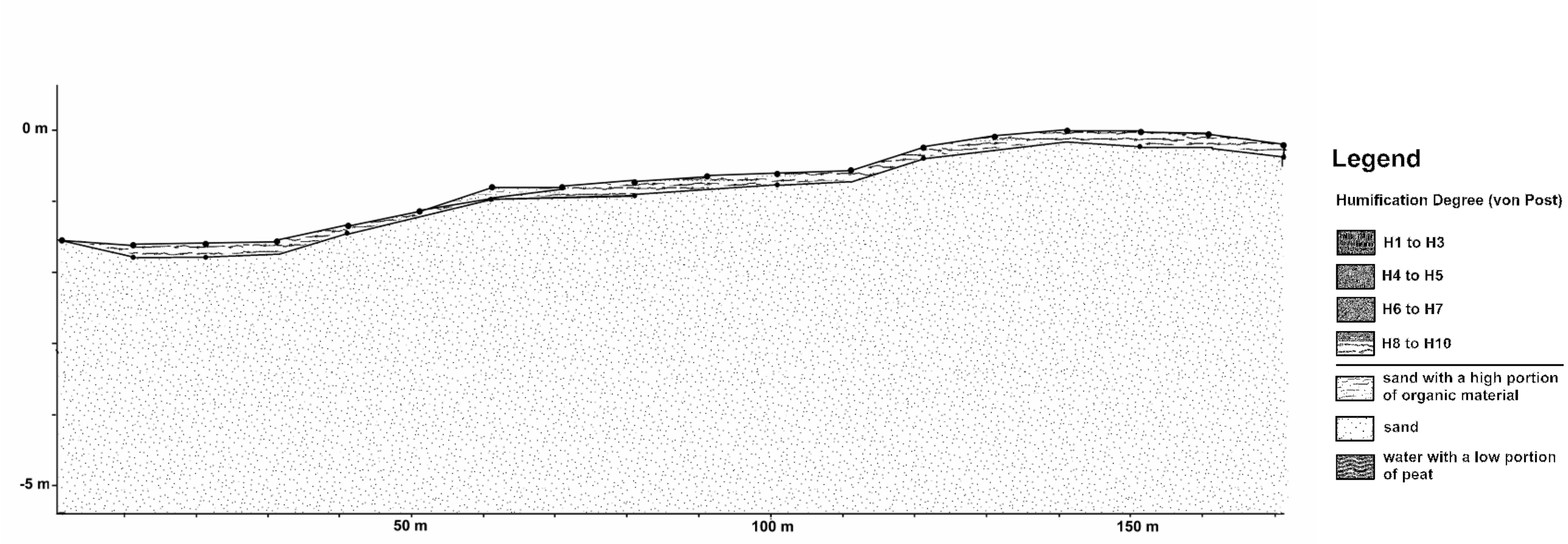


Figure 5.18 The peat stratigraphy of the Mvelabusha cross-section profile illustrates the sequence of only a single grouping (H8–H10) of the combined Von Post peat humification classes, with the age of the peat body increasing from top to bottom.

Legend

Peat Body and Water Table

Peat with woody remnants

Position of water table in peat

Releve Number and Classification

(1) T-SF2-1 Long-time recovering PSF / *Nephrolepis biserrata* (H) – *Voacanga thouarsii* (T) Community

(2) T-SF2-2 Long-time recovering PSF / *Peddiea africana* (S) – *Stenochlaena tenuifolia* (H) Community

(3) T-SF2-3 Long-time recovering PSF / *Peddiea africana* (S) – *Stenochlaena tenuifolia* (H) Community

(4) T-SF2-4 Long-time recovering PSF / *Peddiea africana* (S) – *Stenochlaena tenuifolia* (H) Community

(5) T-SF2-5 Long-time recovering PSF / *Peddiea africana* (S) – *Stenochlaena tenuifolia* (H) Community

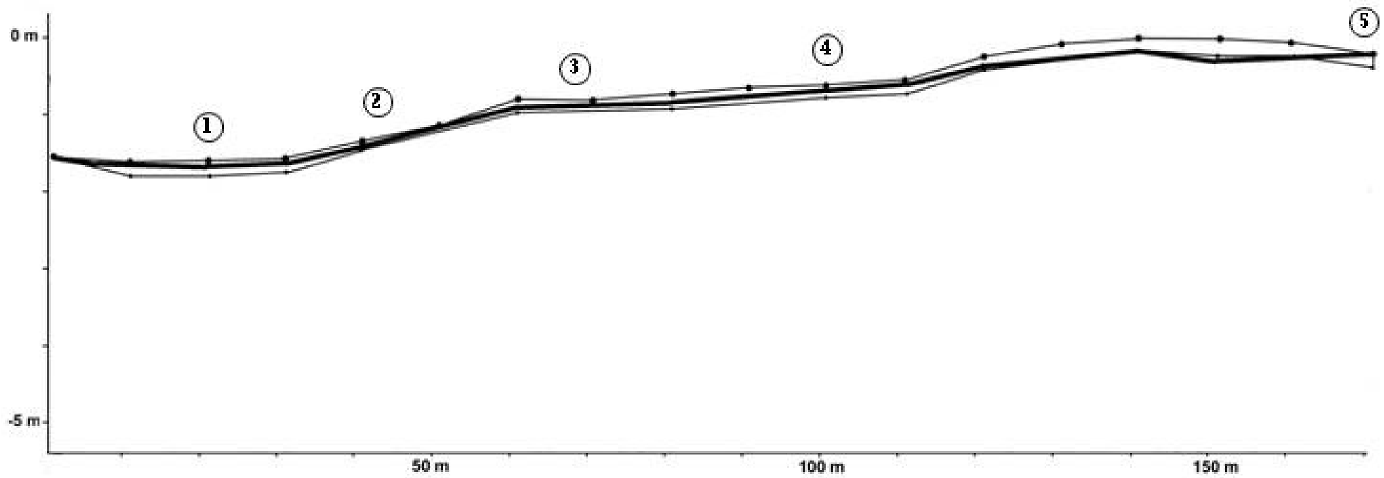
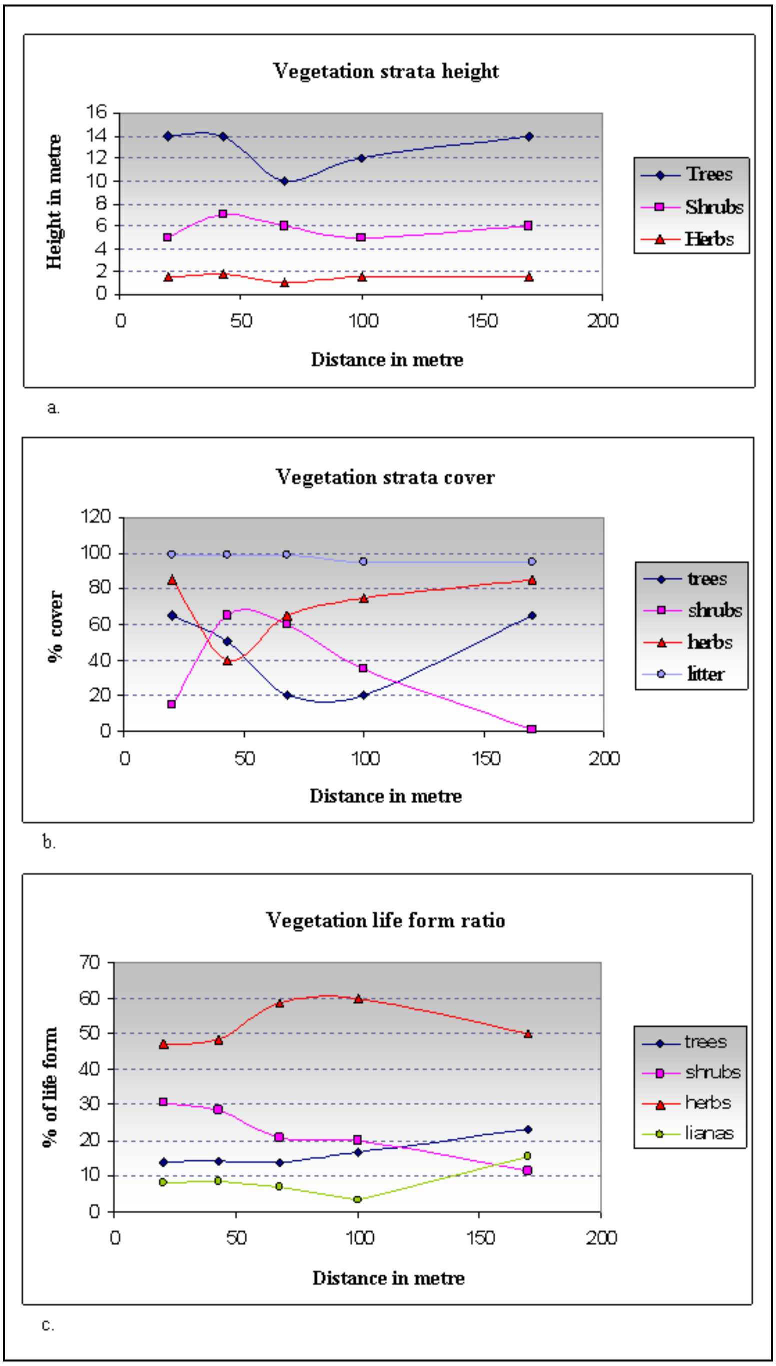


Figure 5.19 The Mvelabusha peat body with woody peat remnants and its recorded groundwater table during September 2003. Described vegetation communities and Peat Swamp Forest classes are also illustrated for each vegetation sampling plot positioned within the profile.

Table 5.10. Average values and standard deviations of recorded vegetation structural properties including different strata height, strata canopy cover, and strata life form fraction in percentage for the Nkanini valley bottom transect (n = 5).

Vegetation structural properties	Average value	Standard deviation
Strata height in meter		
Tree layer	12.80	±1.79
Shrub layer	5.80	±0.84
Herb layer	1.45	±0.27
Strata canopy cover in percentage		
Tree layer	44	±22.75
Shrub layer	35.20	±27.75
Herb layer	70	±18.71
Litter layer	97.40	±2.19
Strata life form fraction in percentage		
Tree layer	16.34	±3.91
Shrub layer	22.28	±7.63
Herb layer	52.88	±5.96
Liana layer	8.50	±4.39



a. Vegetation strata height change along valley bottom transect distance (width).

b. Vegetation strata cover change along valley bottom transect distance (width).

c. Vegetation life form ratio (relative percentage) change along valley bottom transect distance (width).

Figure 5.20 Graphs of Peat Swamp Forest vegetation change along the Mvelabusha cross section profile.

5.2.6 Cele transect

Cele peat properties

The Cele transect falls outside of the Kosi Bay Lake System, but is consistent with the majority of the other Peat Swamp Forest cross section profiles, as the peatland represent a channelled valley bottom wetland system (Figure 3.2 & 5.21). The transect survey identified well developed peat soils with an average depth of 0.87 m that varied largely between different sampling points (Figure 5.21; Table 5.11). The peat strata is well stratified with all four of the Von Post-derived peat humification groupings recorded in the profile (Figure5.21). The peat body remains saturated at the end of the dry season with the groundwater level close to the surface along the entire width of the Peat Swamp Forest valley (Figure 5.22; Table 5.11).

The cross-section profile and peat stratigraphy revealed two depressions at opposite sides of the valley bottom, with corresponding deeper peat soils (Figure 5.21). A maximum peat depth of 2.10 m is present at the 160 m interval transect mark, while the second deepest point of 2 m is located at the 60 m interval mark. Hence, the peat body appears compartmentalised into two main components, with connectivity only maintained through a thin (0.25 m) section of peat (Figure 5.21).

Table 5.11. Average values and standard deviations (SD.) for peat body thickness, groundwater level, pH, and groundwater electrical conductivity along transect points within the Cele valley (n = 8).

Peat characteristics	Average value	Standard deviation
Peat body thickness in metre	0.87	±0.79
Peat body groundwater depth in metre	-0.05	±0.08
Groundwater pH	5.81	±0.35
Groundwater electrical conductivity (EC) in micro-siemens per metre	231	±64.46

The active stream channel is currently located within the outer valley bottom zone, close to the edge of the peat body (Figure 5.1 & 5.21). In the past the channel may have migrated across the two depressions located at opposite ends of the valley profile, alternatively the shape of the underlying sand body provided the template for peat development.

The sequence of peat strata displays a distinct gradient of younger, less humified peat changing into older, more humified and amorphous peat with depth. Similar to the Syadla transect irregular peat layering is restricted to the channel position (Figure 5.21). The majority of the peat body contains remnants of woody peat material, with the exception of the thin portion between the two valley bottom depressions (Figure 5.22). This indicates the likely dominant presence of Peat Swamp Forest habitat over a prolonged period of time within this particular landscape setting.

Cele vegetation gradients

Peat Swamp Forest classes identified along the valley bottom illustrate active cultivation practices in the outer valley bottom zone furthest away from the stream channel, followed by a recently disturbed (cleared) area that is being prepared for new cultivation activities (Figure 5.22). PSF classes closer to the stream are all categorised as long-time recovering PSF with a similar phytosociological species assemblage [*Neprolepis biserrata* (H) – *Voacanga thouarsii* (T) Community], except for the channel section which is distinctly different [*Ficus trichopoda* (T) – *Ipomoea maurituana* (L) Community]. Based on available indicator information and comments from the local farmer, the entire PSF valley has been disturbed (to different degrees) at some time in the past for gardening purposes. The farmer also commented that he has been utilising portions of the valley bottom for crop production for the last 25 years.

Table 5.12 & Figure 5.23 illustrate the average values and related statistics, as well as graphs for structural vegetation properties. The change in height of the tree and shrub strata has a similar pattern with a decrease in the cultivated area and a decrease close to the channel position (Figure 5.22 & 5.23). This is especially pronounced in the tree layer in the active gardening and recently disturbed PSF classes, as a result of selective clearing and felling practices, while the decrease in height near the channel is less pronounced (Figure 5.23).

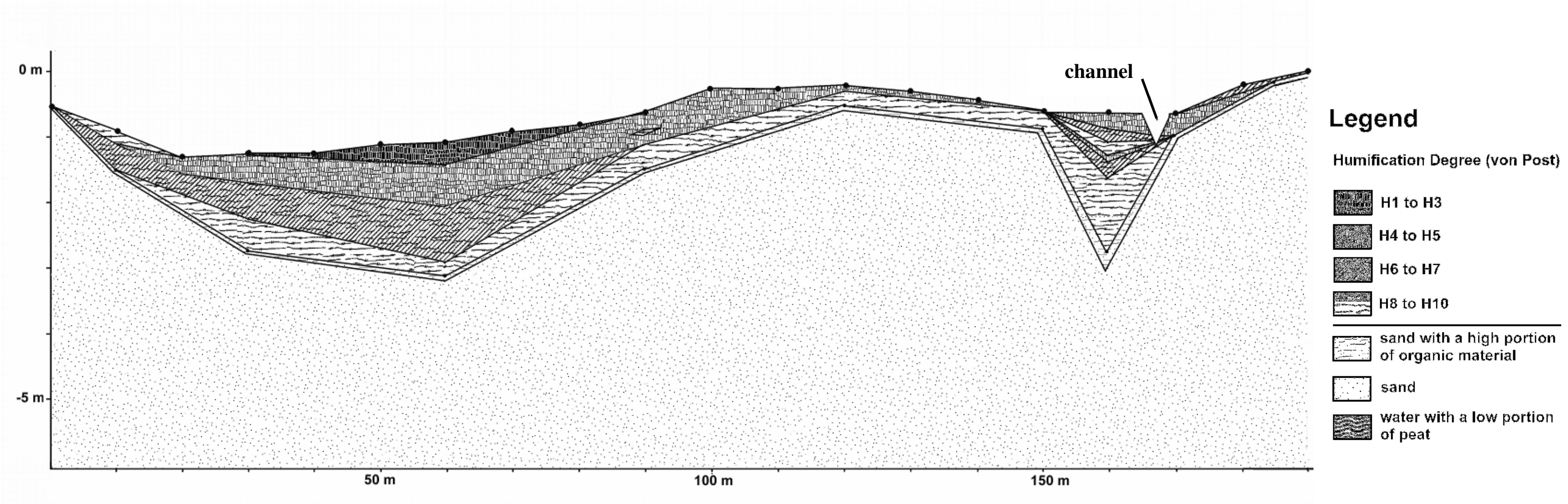


Figure 5.21 The peat stratigraphy of the Cele cross-section profile illustrates the sequence of different groupings of the combined Von Post peat humification classes, with the age of the peat body increasing from top to bottom.

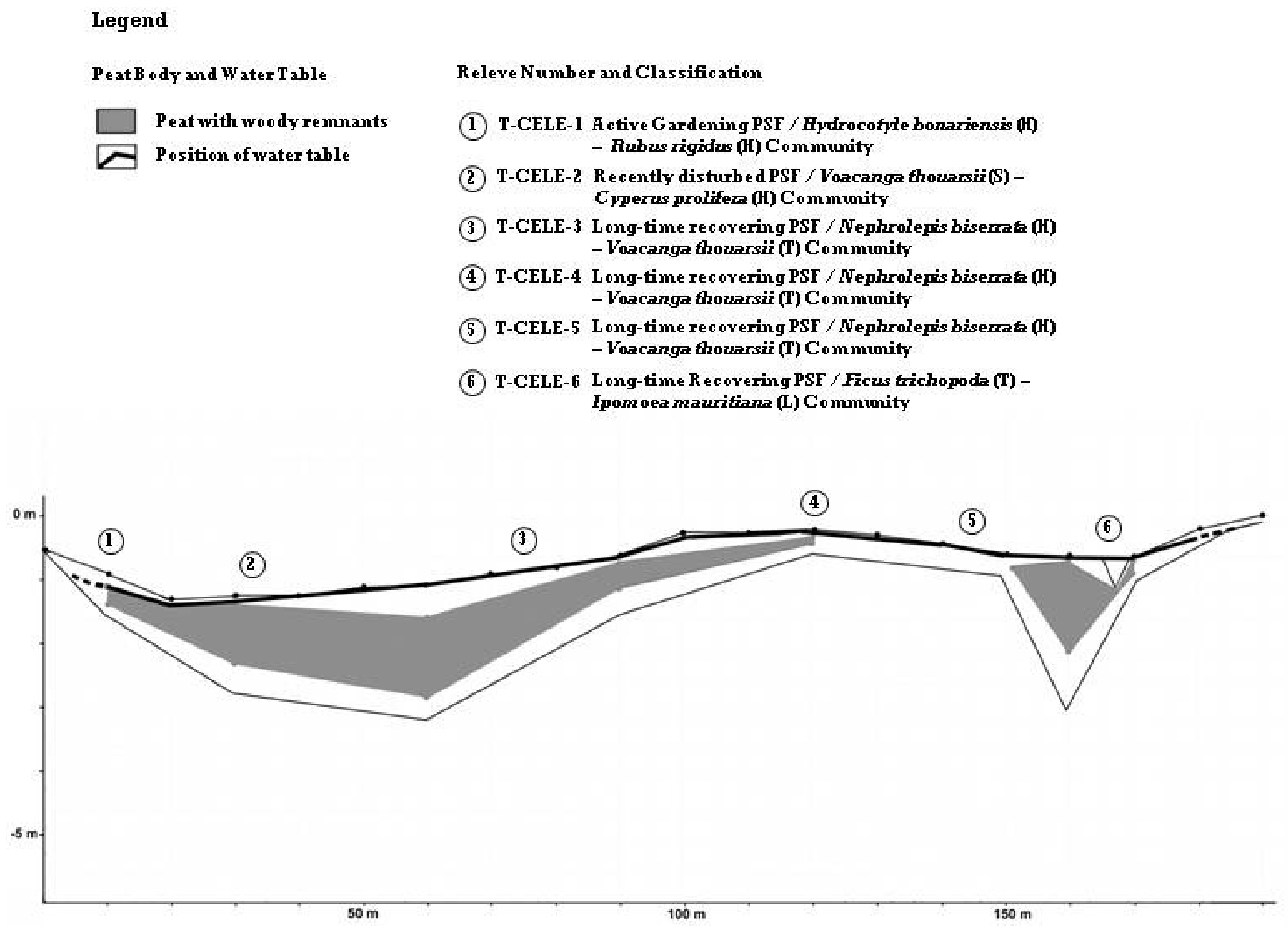
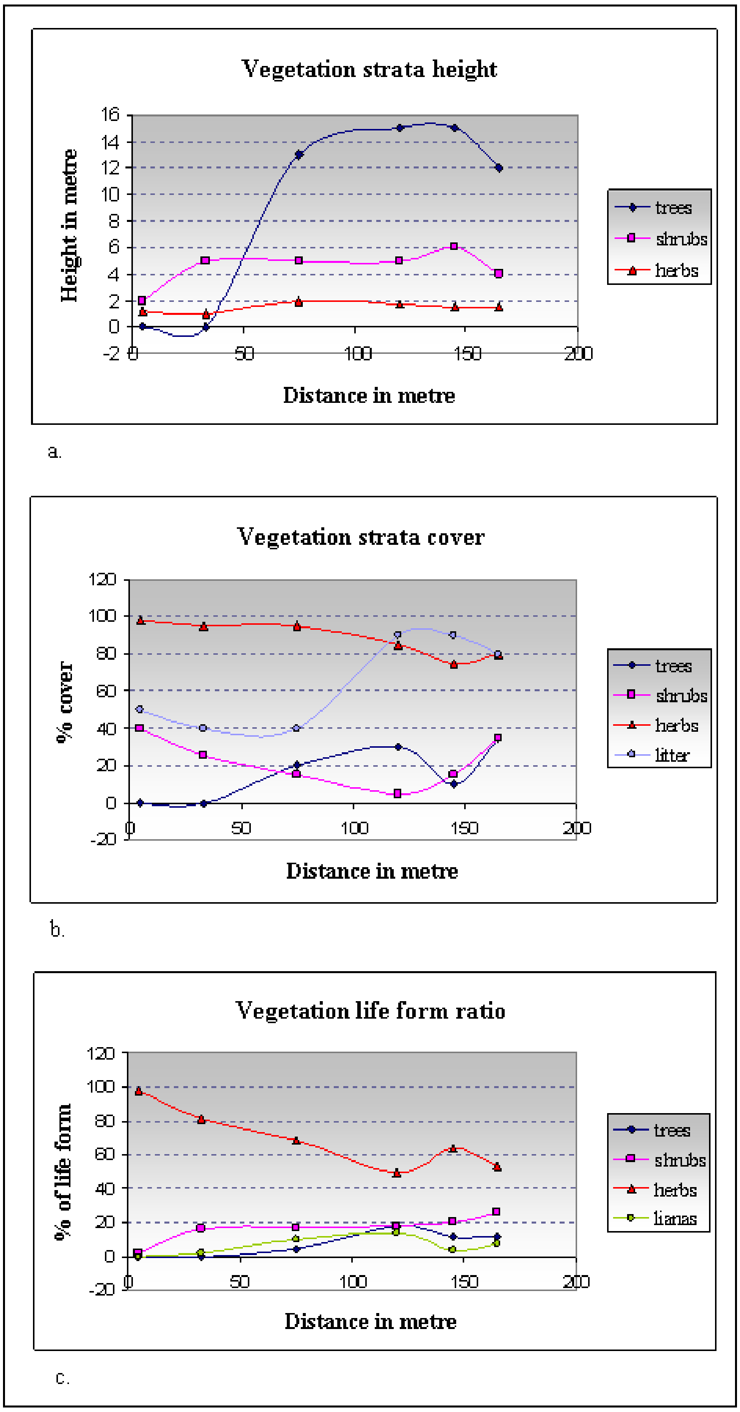


Figure 5.22 The Cele valley bottom peat body with woody peat remnants and its recorded groundwater table during September 2003; the transect is orientated from west (left) to east (right). Described vegetation communities and Peat Swamp Forest classes are also illustrated for each vegetation sampling plot positioned within the profile.

Table 5.12 Average values and standard deviations of recorded vegetation structural properties including different strata height, strata canopy cover, and strata life form fraction in percentage for the Cele valley bottom transect (n = 6).

Vegetation structural properties	Average value	Standard deviation
Strata height in meter		
Tree layer	9.17	±7.19
Shrub layer	4.50	±1.38
Herb layer	1.50	±0.35
Strata canopy cover in percentage		
Tree layer	15.83	±14.97
Shrub layer	22.50	±13.32
Herb layer	88	±9.38
Litter layer	64	±24.29
Strata life form fraction in percentage		
Tree layer	7.68	±7.24
Shrub layer	16.72	±7.84
Herb layer	69.12	±17.77
Liana layer	6.37	±5.26

The tree cover increases steadily toward the channel at the 160 m interval mark, but a clear decrease in cover at the 14 5m mark indicates a clearing in the tree canopy (natural or anthropogenic). The percentage cover for the shrub layer is directional disproportionate to tree cover for the majority of the PSF valley width, but is similar at the channel position (Figure 5.23). A shading effect of the tree layer on the shrub layer may be a possible explanation for the pattern, while nutrient and water influxes at the channel could reduce this effect and result in similar cover values for both strata. In terms of life form ratios the species percentage contributions from the tree, shrub and liana strata changes little with comparable standard deviations, but species numbers decrease in the herb layer from the area of cultivation into long-time recovering PSF areas (Table 5.12; Figure 5.23). The change is expected to be related to a decrease in recent disturbance activities that could have benefitted opportunistic and weedy species in the herbaceous stratum.



[a.] Vegetation strata height change along valley bottom transect distance (width).
[b.] Vegetation strata cover change along valley bottom transect distance (width).
[c.] Vegetation life form ratio (relative percentage) change along valley bottom transect distance (width).

Figure 5.23 Graphs of Peat Swamp Forest vegetation change along the Cele cross section profile.

5.3 Concluding Remarks

The Nkanini transect contains the deepest peat profile (3.7m) from the entire range of investigated Peat Swamp Forests valley bottom cross-section profiles, while the Mvelabusha transect has the shallowest maximum peat depth (0.22m). In between these extremes the average peat depth of the investigated Peat Swamp Forest systems is 1.19m (standard deviation = ±1.06). However, the average peat depth increases to 1.45 m (standard deviation = ±1.03) if the Mvelabusha transect with its distinctly shallow peat soils is excluded from the calculation.

Channelled valley bottom wetlands form the dominant hydro-geomorphic (HGM) setting of investigated Peat Swamp Forest cross-section profiles. There are however also examples of hillslope seepage HGM Peat Swamp Forest systems that are connected to the downstream drainage network at the Nkanini and Mvelabusha transects.

Tswamanzi transect

Plant life form composition is much more homogenous in pristine Peat Swamp Forests such as at Tswamanzi transect. The absence of gardening-related disturbances exclude the presence of a high herbaceous species diversity, as fewer opportunities are available for the establishment of pioneer and exotic weeds. While the intact tree and shrub strata provide a favourable environment for liana species.

Cele transect

The Cele cross-section profile, presents the only example of continuous long term gardening (greater than 25 years) within a peatland where young peat material (H1–H3) is still present and used for cultivation in the outer and inter valley bottom segments. This pattern is evident of more sustainable cultivation practices that have not resulted in excessive draining and peat oxidation. It remains however unknown if this is a result of deliberate restrains in cultivation activities or a direct effect of peat drainage limitations provided by the valley bottom setting and peat properties?

Mvelabusha

Water inputs from lateral groundwater movement (intermitted flow) and surface flow are likely to be less in this particular Peat Swamp Forest site compared to other PSF areas. The reason being that PSF watercourses situated in inland headwater positions have a smaller catchment and lower annual rainfall. Consequently, these headwater PSF watercourses are expected to be drier and more likely to have a weaker developed peat body, with shallow peat profiles that are more susceptible to desiccation and fire damage.

General

Linear surface-water inflows and groundwater discharge are considered as important hydrological drivers in the development of Peat Swamp Forest habitat in inter-dune systems (both types of HGM units). Peat Swamp Forests at lower lying altitudes closer to the Kosi Bay Lake System receive larger amounts of surface water for longer periods of time. This is a result of the confluence of several upstream tributaries that drain progressively larger catchments towards the receiving Kosi Bay Lake System. coast. A larger area is therefore available for water infiltration and intermitted flow, which is further aided by an increase in rainfall towards the coast.

The maximum and average peat depths of the Tswamanzi transect are however lower than that of the Nkanini transect, even though the upstream Nkanini watercourse forms a lower stream-order tributary of the Tswamanzi drainage line. Peatland development is also wider at the Nkanini transect with an altogether larger volume of peat. The smaller downstream peat body at Tswamanzi is contributed to localised groundwater inputs that differ along the drainage trunkline. Groundwater inputs therefore appear to be the dominant driver for Swamp Forest peat development. Peat Swamp Forest can as a result be described as groundwater associated or phreatophytic ecosystems, as defined by Le Maitre *et al.* (1999). This is consistent with the hypothesis of Venter (2003) that Peat Swamp Forests occur where there is groundwater flow (discharge) across the landscape. Linear inter-dune valleys and concave hillslopes form the ideal landscape positions for this type of groundwater interception in a coastal plain environment where shallow groundwater conditions and intermitted flows are expected.

The association of irregular layering at the channel position in valley bottom Peat Swamp Forests is a common peat stratigraphy pattern at several cross-section profiles. This pattern may pertain to different wetness and groundwater discharge conditions in the past during the development process of the mire. Channel migration and scouring process that may have occurred in the past during the development of the mire are not expected to have had a distinct bearing on the shape of the peat body due to the low energy conditions associated with peat development. It is more likely that the underlying geomorphology provided the template for peat development and that groundwater inputs, in particular lateral seepage, added to the peat development process.

Once fibrous, better drained peat has been decomposed, the wetter more amorphous peat material with a lower hydrological conductivity inhibit draining and hence cultivation opportunities within affected areas. The absence of a young peat stratum within a cross section profile, or the restricted presence thereof in or near the centre of a Peat Swamp Forest system, could be indicative of extensive cultivation and draining practices in the past. The presence of intact woody peat remnants throughout several Peat Swamp Forest transects indicate that the associated inter-dune systems within the study area can be dominated by forested mires for consecutive centuries.

CHAPTER 6: CONCLUSION

Channelled valley bottom wetlands form the dominant hydro-geomorphic (HGM) setting of the investigated Peat Swamp Forests (PSF) in the Kosi Bay Lake System Catchment. There are however also examples of hillslope seepage HGM Peat Swamp Forest systems that are connected to downstream drainage networks. Regular groundwater seepage into the lateral sides of a PSF systems enables peat to accumulate and remain intact on sloped sandy soils. Peat Swamp Forests can thus be considered as phreatophytic ecosystems or groundwater associated ecosystems, which are likely to be affected by changes in groundwater discharge and quality.

Peat Swamp Forest can potentially be considered as the stable climax seres in several inter-dune landscape settings within the study area. This is contributed to the dominant presence of forested mires over time in the peat development process, as is indicted by the extensive presence of woody remnant peat material in the majority of investigated PSF transects. However, these systems are still dynamic and can be replaced by other hydroseres (e.g. sedge dominated or open water *Nymphae* spp. dominated mires) in the same hydro-geomorphic setting. Factors affecting the dominance of a specific hydrosere remain uncertain, but hydrology (especially peat moisture content and surface ponding), as well as burning events are expected to be of specific importance.

Recovering Peat Swamp Forests are grouped with uncultivated (pristine) PSF sites in the phytosociological analyses, with similar patterns in terms of their physiognomy and environmental drivers. Hence, it appears that these systems can recover to again represent pristine PSF communities after cultivation activities have been abandoned. Shallow and dry peat substrates are however likely to result in different PSF communities than wetter and better developed peat bodies following the abandonment of cultivation activities. The inter-dune landscape setting and the presence of specific geomorphic features, as well as groundwater discharge dynamics, are regarded to influence the presence of PSF communities. In this regard the presence of an active channel with flowing water within a valley bottom peatland is commonly associated with a specific PSF community [*Ficus trichopoda* (T) – *Ipomoea mauritiana* (L)], while the western shoreline of Lake Amanzamnyama and the Syadla River Mouth is associated with the *Raphia australis* (T) – *Raphia australis* (S) Community.

Vegetation patterns associated with cultivation include the transformation of the PSF tree cover across a wide gradient from a moderately intact to a sparse tree stratum. Actual gardening sites are not necessarily associated with a low tree cover, as crops are also cultivated underneath the tree canopy. The dominance of the herbaceous stratum with an open canopy structure cannot be exclusively contributed to cultivation related impacts such as cutting and clearing, as natural processes responsible for alternating hydroseres in the same valley bottom hydro-geomorphic setting can also be at work.

Cultivation-related modifications to Swamp Forest peat soils include the desiccation and decomposition in the upper peat stratum as a result of the presence of drainage furrows. However, the magnitude of impact associated with peat dehydration and decomposition is not quantified in areas affected by cultivation and drainage, as it was only assessed in terms of qualitative observations.

The results of the investigation partially support the hypothesis in the sense that cultivation (gardening) practices do appear to modify Peat Swamp Forest vegetation structure and species composition. Peat Swamp Forests also respond in a positive way once gardening practices are abandoned. However, the effect of peat properties on Swamp Forest vegetation patterns remains unclear, apart from distinct differences in PSF plant communities on shallow and drier peat bodies.

The shortage of scientific literature and investigations relating to South African Peat Swamp Forest ecosystems result in a narrow knowledge base that hinders recommendations for future management objectives and associated actions. Aspects that are in need of future scientific research in order obtain an improved understanding of PSF ecology and cultivation related impacts include the determination of peat growth and decomposition rates in non-cultivated and cultivated PSF areas. A better understanding of the patterns and processes of groundwater movement and retention within these systems, as well as detailed investigations related to the cultural and socio-economic aspects affecting PSF use, valuation and tenure will also contribute to improved decision-making. Plant ecological studies can be focussed on dispersal and regeneration strategies, as well as intra and inter plant species competition to help formulate community assemblage rules.

The development and implementation of wise use practices related to Peat Swamp Forest cultivation will contribute to mitigating negative impacts associated with farming activities within these systems. Buy in from the local community and land users will be essential in this regard, as their long term participation is likely to be required and existing practices that have been entrenched over several generations will have to be addressed. Participation from commercial farmers is expected to provide different challenges compared to subsistence farmers.

Apart from increasing the scientific knowledge base it remains important to address the "*So what?*" question with regards to the value of further PSF-related research, as well as why these ecosystems are in need of protection and management. Arguments can be made regarding the aesthetic value, uniqueness and rareness of these ecosystems, but there is also a utilitarian component to consider. Functions performed by natural ecosystems, also known as ecosystem services, provide a means of describing the value of a natural system to society and the surrounding natural environment.

Peat Swamp Forests provide several ecosystem services that are in themselves also in need of further investigation and quantification. Some of these PSF ecosystem services include contributions to landscape ecological processes such as the provision of corridors for species movement and gene flow. Carbon sequestration associated with Peat Swamp Forest mires is likely to be of relevance in a carbon sensitive economy. Their buffering capabilities with regards to flooding events by providing high frictional surfaces in drainage lines. The filtering and adsorption of nutrients to help maintain low nutrient water quality conditions within theKosi Bay Lake System. Peat Swamp Forests also provide direct benefits to local land users, which if used wisely will continue to persist in the future. Direct PSF functions include the provision of medicinal plants, indigenous fruits, and other food sources. Harvestable natural resources for construction and firewood are also collected, while water wells are often located on the edge of PSF systems to intercept seepage flow.

LIST OF REFERENCES

ANON. 1991. International Food Policy Research Institute (IFPRI). Facts and Figures: International Agriculture Research. Rockefeller Foundation, New York. In: Africa a Biography of the Continent, J. Reader. 1997.. pp. 291. Penguin Books, London, England.

ADAMS, J.S. & MCSHANE, T.O. 1992. The myth of wild Africa: conservation without illusion. New York: W.W. Norton and Company.

BARBOUR, M.G., BURK, J.H. & PITTS W.D. 1987. Terrestrial Plant Ecology. Second Edition. Menlo Park, California. The Benjamin/Cummings Publishing Company Inc.

BRUTON, M.N. & COOPER, K.H. 1980. Studies on the Ecology of Maputaland – Rhodes University and the Natal Branch of The Wildlife Society of Southern Africa, Durban; Cape and Transvaal Printers (Pty) Ltd, Cape Town.

BEGG, G.W. 1980. The Kosi system: aspects of its biology, management and research. In: Studies on the Ecology of Maputaland. M.N. Burton & K.H. Cooper (eds), pp. 358-373. Rhodes University & Wildlife.

BELL, R.H.V. 1987. Conservation with a human face: conflict and reconciliation in African land use planning, in Anderson, D & Grove, R. (eds.). Conservation in Africa: peoples, policies and practice. Cambridge University Press. Cambridge.

BREDENKAMP, G.J. 1982. `n Plantekologiese studie van die Manyelti-Wildtuin. D.Sc. dissertation. University of Pretoria. Pretoria.

BREDENKAMP, G.J. & BEZUIDENHOUT, H. 1995. A proposed procedure for the analysis of large phytosociological data sets in the classification of South African grasslands. Koedoe 38(1): 33–39.

BREDENKAMP, G.J. & DEUTSCHLäNDER, M.S. 1995. New azonal sntaxa from thehills and river banks of the Manyeleti Game Reserve, Northern Trasnvaal Province, South Africa. Koedoe 38(1):41–58.

BRINSON, MARK M.1993. A hydrogeomorphic classification for wetland / by Mark M. Brinson ; prepared for U.S. Army Corps of Engineers.

BURGESS, N.D., CLARKE, G.P. & RODGERS, W.A. 1998. Coastal forests of eastern Africa: status, endemism patterns and their potential causes. Biological Journal of the Linnean Society 64: 337-367.

BRYANT, A.T. 1949. The Zulu People – As They Were Before the White Man Came. The Natal Witness, Ltd., Pietermaritzburg, South Africa.

CLYMO, R.S. 1983. Peat. In: Ecosystems of the world 4A. Mires: Swamp, Bog, Fen and Moor, ed. A.J.P. Gore, pp 159-223. Elsevier Scientific Publishing Company, Amsterdam.

COWAN G.I (ed) 1995. Wetlands of Southern Africa. Department of Environmental Affairs and Tourism. Pretoria, South Africa.

COWAN, G.I. & VAN RIET, W. 1998. A Directory of South African Wetlands. Research Report Series, South African Wetlands Conservation Program. Department of Environmental Affairs & Tourism, Pretoria.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. (1998). National Water Act, Act No. 36 of 1998. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 2003. National Water Resource Strategy (Final draft). Department of Water affairs and Forestry. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 2005. A practical field procedure for identification and delineation of wetlands and riparian areas. Department of Water affairs and Forestry. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY 2006. Position Paper for The Protection, Use, Development, Management And Control Of Wetlands (Draft version 0.1). Department of Water affairs and Forestry. Pretoria, South Africa.

DUFRêNE, M. & LEGENDRE P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345–366.

DU PLESSIS, F. 2001. A phytosociological synthesis of Mopaneveld. MSc dissertation. University of Pretoria, Pretoria.

EELEY, H.A.C., LAWES, M.J. & PIPER, S.E. 1999. The influence of climate change on the distribution of indigenous forest in KwaZulu-Natal, South Africa. Journal of Biogeography 26: 595-617.

FELGATE, W.S. 1982. The Tembe Thonga of Natal and Mozambique: An Ecological Approach. Occasional Publications No. 1, Department of African Studies, University of Natal, Durban.

GELDENHUYS, C.J. ed. 1989. Biogeography of the mixed evergreen forests of southern Africa. Ecosystems Programmes Occasional Report no. 45. FDR, Pretoria.

GERMISHUIZEN, G. & MEYER, N.L. (Eds.) 2003. Plants of southern Africa: an annotated checklist. Strelitzia 14. National Botanic Institute, Pretoria.

GOODMAN, P. 1990. Soil, vegetation and large herbivore relations in Mkuzi Game Reserve, Natal – PHD Thesis; University of Witwatersand; Johannesburg

GORDON, N.D., McMAHON T.A., FINLAYSON B.L., GIPPEL C.J. & NATHAN R.J. 2004.

Stream Hydrology: An Introduction for Ecologists. 2nd Ed. John Wiley & Sons, Ltd. West-Sussex, England.

GROBLER L.E.R. 2004. The Impact of subsistence banana (Musa × paradisiaca) farming on the vegetation of peat swamp forest surrounding the Kosi Bay Lake System. Unpublished BSc Hons thesis, University of Pretoria.

GRUNDLING P-L. 1996: Sustainable Utilisation of Peat in Maputaland, KwaZulu-Natal, South Africa. In LÜTTIG, G.W.(Ed.) Abstracts of the 10th International Peat Society Congress. May 1996, Bremen. 1.6.

GRUNDLING, P-L, MAZUS, H., BAARTMAN, L. 1998. Peat Resources in northern Kwa-Zulu Natal wetlands: Maputaland. Department of Environmental Affairs and Tourism, Report no. A25/13/2/7, Pretoria.

GRUNDLING, P-L. & GROBLER, R. 2005. Peatlands and mires of South Africa. In: Steiner, G.M. (ed.) Mires from Siberia to Tierra Del Fuego. Stapfia 85, Landesmuseen Neue Serie 35, pp. 379-396.

HARRISON, J.A.; ALLAN, D.G.; UNDERHILL, L.G.; HERREMANS, M.; TREE, A.J.; PARKER, V. AND BROWN, C.J. (eds.) (1997): The Atlas of Southern African Birds. Vols 1 (Passerines) and 2 (Non-passerines); BirdLife South Africa; Johannesburg

HART, R.C. 1995. South African coastal lakes. In G.I. Cowan (ed.) Wetlands of Southern Africa, pp.103-130. Department of Environmental Affairs and Tourism. Pretoria, South Africa.

HERRINGTON, S. (Producer). 2003. Greater St. Lucia Wetland Park. 50/50 Programme screened March 23, 2003. Interviewer: R Crompton, SABC, Johannesburg.

HILL, M.O. 1979. DECORANA – a FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecology and Systematics, Cornell University, Ithaca, NewYork.

HOBDAY, D.K. 1979. Geological evolution and geomorphology of the Zululand coastal plain - In: Allanson, B.R. (ed.): Lake Sibaya - Monographiae Biological; W. Junk Publishers; London; 36; pp. 1-20

JOOSTEN, H. & CLARKE, D. 2002. Wise use of mires and peatlands. International Mire Conservation Group and International Peat Society, Saarijärven Offset Oy, Saarijärvi, Finland.

KLOPPERS, R.J. 2001. The Utilisation of Natural Resources In The Matutuine District of Southern Mozambique: Implications For Transfrontier Conservation. MA (Anthropology) dissertation, University of Pretoria, Pretoria.

KOTZE, D.C., MARNEWECK G.C., BACHELOR A.L., LYNDLEY D.S. & COLLINS N.B. 2005. Wet-EcoServices. South African National Botanical Institute. Pretoria. South Africa.

KRUSKAL, J.B. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. Physchometika 29:1-27.

LANE, E.W. 1955. The importance of fluvial morphology in hydraulic engineering, Proceedings. American Society of Civil Engineers 81: 1-17.

LEGENDRE, P. & LEGENDRE, L. 1999. Numerical Ecology, 2nd English edition. Elsevier Science BV. Amsterdam, The Netherlands. In: McCUNE, B. & GRACE J.B. 2002. Analysis of Ecological Communities. 2nd Printing. MJM Software, Gleneden Beach, Oregon, United States of America.

LE MAITRE D.C., SCOTT D.F. & COLVIN C. 1999. A review of information on interactions between vegetation and groundwater. Water SA, 25: 137-152.

LOW, A.B. & REBELO, A.G. (eds). 1996. Vegetation of South Africa, Lesotho and Swaziland, 84pp. Department of Environmental Affairs and Tourism, Pretoria.

LUBBE, R.A. 1997. Vegetation and flora of the Kosi Bay Coastal Forest Reserve in Maputaland, northen KwaZulu-Natal, South Africa. M.Sc. dissertation. University of Pretoria, Pretoria.

MAUD, R.R. 1980. The climate and geology of Maputaland. In: Studies on the ecology of Maputaland, eds. M.N. Burton & K.H. Cooper. Rhodes University & Wildlife.

MACFARLANE D.M, KOTZE D, WALTERS D, ELLERY W, KOOPMAN V, GOODMAN P, and GOGE C. (2007). WET-Health: A Technique for Rapidly Assessing Wetland Health. Unpublished draft report submitted to the Water Research Commission, Pretoria.

MATHER, P.M. 1976. Computational methods of multivariate analysis in physical geography. Wiley & Sons, London.

MATTSON M. & UKEN R. 2007. Towards a Broad Understanding of the Palm *Raphia australis*. Unpublished Report. St Lucia, South Africa.

McCUNE, B. 1997. Influence of noisy environmental data on canonical correspondence analysis. Ecology 78:2617-2623

McCUNE, B. & GRACE J.B. 2002. Analysis of Ecological Communities. 2nd Printing. MJM Software, Gleneden Beach, Oregon, United States of America.

McCUNE, B. & MEFFORD M.J. 2006. PC-ORD. Multivariate Analysis of Ecological Data. Version 5.10. MJM Software, Gleneden Beach, Oregon, United States of America.

MEADOWS, M.E. 1985. Biogeography and ecosystems of South Africa – Juta, Cape Town

MOLL, E.J. 1980: Terrestrial plant ecology - In: Burton, M.N. and Cooper, K.H. (eds.): Studies on the ecology of Maputaland, Rhodes University and Wildlife, pp. 52-68

MOLL, E. J. & WHITE, F. 1978. The Indian Ocean coastal belt – In: Werger, M.J.A. (ed.): Biogeography and Ecology of Southern Africa - Junk, The Hague; pp. 562-598

MUCINA, L. & RUTHERFORD, M.C. (eds) 2006. The vegetation map of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute.

MUELLER-DOMBOIS, D.S. & ELLENBERG, H. 1974. Aims and Methods of Vegetation Ecology. Wiley, New York.

NATIONAL WETLANDS WORKING GROUP. 1997. The Canadian wetland classification system. 2nd edition. University of Waterloo. Canada.

PAGE, S.E., REILEY, J.O., SHOTYK, Ø.W. & WEISS, D. 1999. Interdependence of peat and vegetation in a tropical peat swamp forest. Philosophical Translations of the Royal Society of London 354: 1885-1897.

POOLEY, E. 1993. The Complete Field Guide to Trees of Natal Zululand & Transkei. Natal Flora Publications Trust, Durban.

POST, W.M. & SHEPERD J.D. 1974. Hierarchical Agglomeration. Department of Botany, University of Wisconsin, Madison. Unpublished typescript.

PRICE, J. S. 2002. Role and character of seasonal peat soil deformation on the hydrology of undisturbed and cutover peatlands, Water Resour. Res., 39(9), 1241, doi:10.1029/WR001302, 2003.

RAMSAR CONVENTION SECRETARIAT. 2004. The Ramsar Convention Manual: A Guide to the Convention on Wetlands (Ramsar, Iran, 1971), 3rd ed. Ramsar Convention Secretariat, Gland, Switzerland.

RODGERS, K.H. 1995. Riparian wetlands. In G.I. Cowan (ed.) Wetlands of Southern Africa, pp.41-52. Department of Environmental Affairs and Tourism. Pretoria, South Africa.

RYDIN H. & JEGLUM J.K. 2006. The Biology of Peatlands. Oxford University Press, England.

SCHULZE, R.E. 1982. Agrohydrology and climatology of Natal, pp. 136. Water Research Commission, Pretoria.

SLIVA J., GRUNDLING P., KOTZE D., ELLERY F., MONING C., GROBLER R., Taylor P.B. 2004. MAPUTALAND – Wise Use Management in Coastal Peatland Swamp Forests in Maputaland, Mozambique / South Africa. Wetlands International, Project No: WGP2 – 36 GPI 56.

SMITH, A.J.J. 1961. Meteorological aspects especially surface winds and associated weather along the Natal coast. C.S.I.R. Symposium No. 32. Pretoria, C.S.I.R.

SMUTS W.J. & L.S. KIRSTEIN 1995. Peat and related biofuels as potential renewable alternative energy option in part of KwaZulu-Natal . DMEA Report no: EO9417.

SMUTS, W.J. 1997. Characteristics of South African peats and their potential exploitation. PhD dissertation. University of Pretoria, Pretoria.

SOIL CLASSIFICATION WORKING GROUP. 1991. Soil classification. A taxonomic system for South Africa. Mem. agric. nat. Resour. S. Afr. No. 15. Dept. Agric. Dev., Pretoria.

STATTERSFIELD, A. J.; CROSBY, M. J.; LONG, A. J. AND WEDGE, D. C. 1998. Endemic Bird Areas of the World. Priorities for biodiversity conservation - BirdLife Conservation Series No. 7. BirdLife International, Cambridge, United Kingdom

TAYLOR, D. & HAMILTON, A. 1994. Impact of climate change on tropical forests in Africa: implications for protected area planning and management. J.C. Pernatta, R. Leemans, D. Endler, & S. Humprey (eds). Impacts of climate change on ecosystems and species: implications for protected areas. 77-94. IUCN, Gland.

TER BRAAK, C.J.F. 1995. Ordination. In: Jongman, R.H.G., Ter Braak, C.J.F., & Van Tongeren, O.F.R. (eds.): Data Analysis in Community and Landscape Ecology. Cambridge University Press, UK.

THOMPSON, K. & HAMILTON, A.C. 1983. Peatlands and swamps of the African continent. In: Ecosystems of the world 4B. Mires: Swamp, Bog, Fen and Moor, ed. A.J.P. Gore, pp 331-373. Elsevier Scientific Publishing Company, Amsterdam.

VAN TONGEREN, O.F.R. 1995. Cluster analysis. In: Jongman, R.H.G., Ter Braak, C.J.F., & Van Tongeren, O.F.R. (eds.): Data Analysis in Community and Landscape Ecology. Cambridge University Press, UK.

VAN WYK, A.E. & SMITH, G.F. 2001. Regions of Floristic Endemism in Southern Africa. A Review with Emphasis on Succulents. Umdaus Press, Hatfield, South Africa.

VAN WYK, A.E. 1994. Maputaland-Pondoland Region. In S.D. Davis, V.H. Heywood & A.C. Hamilton (eds), *Centers of plant diversity. A guide and strategy for their conservation*. Volume 1, pp.227-235, IUCN Publications Unit, Cambridge

VAN WYK, A.E. 1994. Maputaland-Pondoland Region – In: Davis, S.D.; Heywood, V.H. and Hamilton, A.C. (eds.): Centres of Plant Diversity, a Guide and Strategy for their Conservation - Vol. 1. Information Press, Oxford; pp. 227-235

VENTER, C.E. 2003. The Vegetation Ecology of Mfabeni Peat Swamp, St Lucia, KwaZulu-Natal. MSc dissertation, University of Pretoria, Pretoria.

VENTER, H.J.T. 1972. Die Plantekologie van Richardsbaai, Natal. PhD dissertation, University of Pretoria, Pretoria.

VON POST, L. & GRANLUND, E. 1926. Södra Sveriges tortillangar I. Sver. geol Unders., Arsb. 19, Ser. C, No 335, Stockholm.

WALSH, B. 2004. The Use of Remote Sensing to Map the Swamp Forests of the Greater St. Lucia Wetland Park. BSc Hons dissertation, University of KwaZulu-Natal, Durban.

WATKEYS, M. K.; MASON, T. R. AND GOODMAN, P. S. 1993. The role of geology in the development of Maputaland, South Africa - Journal of African Earth Sciences 16; pp. 205-221

WERGER, M.J.A. 1973. Phytosociology of the Upper Orange River Valley, South Africa. Ph.D. dissertation, University of Nijmegen.

WESSELS, N.G. 1997. Aspects of the Ecology and Conservation of Swamp Forests in South Africa. MSc. dissertation, Port Elizabeth Technikon, Port Elizabeth.

WHITTAKER R.H. (1972). Evolution and Measurements of Species Diversity. Taxon 21:213-251.

WWF 2001. Kirkwood, D.: Maputaland Coastal Forest Mosaic (AT0119) - WWF Terrestrial Ecoregions; http://www.worldwildlife.org/wildworld/profiles/terrestrial/at/at0119_full.html

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APPENDIX A: IDENTIFIED SPECIES LIST

List of identified plant species found at all investigated sites (142 species in total), species marked with an * indicate crop species.

Ageratum houstonianum
Albizia adianthifolia
Allophylus dregeanus
Allophylus melanocarpus
Ananas comosus
Aneilema aequinoctiale
Anthericum sp.
Antidesma venosum
Apodytes dimidiata
Arundo donax
Asparagus falcatus
Asystasia gangetica
Bersama lucens
Bidens pilosa
Brachylaena discolor
Bridelia micrantha
Burchellia bubalina
Casearia gladiiformis
Cussonia arenicola
Cussonia sphaerocephala
Cassytha sp..
Cavacoa aurea
Centella asiatica
Chlorophytum krookianum
Cirsium sp.
Cissampelos torulosa
Cladium mariscus
Clematis cf. *brachiata*
**Colocasia esculenta*
Commelina benghalensis/ Commelina erecta
Conyza canadensis
Eriosema squarrosum
Erythrina lysistemon
Erythroxylum emarginatum
Ficus sur
Ficus trichopoda
Fuirena umbellata
Gomphocarpus physocarpus
Halleria lucida
Helichrysum aureonitens
Helichrysum tongense
Hewittia malabarica
Hibiscus surattensis
Hibiscus tiliaceus
Hibiscus trionum
Hydrocotyle bonariensis
Ilex mitis
Imperata cylindrica
Ingofera sp.
**Ipomoea batatas*
Ipomoea mauritiana
Isoglossa sp.
Keetia gueinzii
Kraussia floribunda
Lactuca dregeana
Leersia hexandra
Lepidium sp.
Ludwigia octovalvis
Ludwigia sp.
**Lycopersicon esculentum*
Lygodium microphyllum
Macaranga capensis
Persicaria hydropiper
Persicaria sp.
Petopentia natalensis
Phaulopsis imbricata
Phoenix reclinata
Phragmites australis
Podocarpus falcatus
Polypodium lycopodioides
Psilotum nudum
Psychotria capensis
Pteridium aquelinum
Pycreus nitidus
Pycreus polystachyos
Rapanea melanophloeos
Raphia australis
Rauvolfia caffra
Rhipsalis baccifera
Rhoicissus rhomboidea
Rhus chirindensis
Rhus cf. *nebulosa*
Rhus pyroides
Rhynchospora corymbosa
Rubus rigidus
**Saccharum officinale*
Sacciolepis curvata
Schefflera umbellifera
Scleria angusta
Scolopia stolzii
Senecio polyanthemoides
Setaria megaphylla
Smilax anceps

Crassocephalum crepidiodes	**Mangifera indica*	*Sonchus* cf. *oleraceus*
Crassocephalum picridiformis	**Manihot esculenta*	*Stenochlaena tenuifolia*
Crocosmia aurea	*Melanthera scandens*	*Syzygium cordatum*
Cucumis zeyheri	*Microsorium punctatum*	*Syzygium guineense*
Cyperus textiles	*Mikania natalensis/ Senecio deltoideus*	*Tabernaemontana ventricosa*
Cyperus dives	*Mimusops obovata*	*Tacazzea apiculata*
Cyperus papyrus	*Morella serrata*	*Tarenna pavettoides*
Cyperus pectinatus	**Musa* x*paradisiaca.*	*Thelypteris interrupta*
Cyperus prolifer	*Neonotonia wightii*	*Trema orientalis*
Cyperus sphaerospermus	*Nephrolepis biserrata*	*Trichopteryx dregaena*
Dalbergia armata	*Oldenlandia cephalotes*	*Triumfetta pentandra*
Desmodium adscendens	*Oplismenus hirtellus*	*Typha capensis*
Desmodium salicifolium	*Panicum brevifolium*	*Urera* cf. *trinervis*
Digitaria eriantha	*Panicum parvifolium*	*Voacanga thouarsii*
Dissotis canescens	*Paspalum urvillei*	*Zehneria scabra*
Dracaena mannii	*Peddiea africana*	
Erigeron cf. *daggera*	*Pereskia aculeata*	

APPENDIX B: SPECIES ABBREVIATIONS USED IN THE PHYTOSOCIOLOGICAL TABLES

Abbreviations for plant species names used in the phytosociological tables.

Species	Abbreviation	Species	Abbreviation
Ageratum houstonianum	Age hou	*Kraussia floribunda*	Kra flo
Albizia adianthifolia	Alb adi	*Lactuca dregeana*	Lac drg
Allophylus dregeanus	All dre	*Leersia hexandra*	Lee hex
Allophylus melanocarpus	All mel	*Lepidium* sp.	Lep spe
Ananas comosus	Ana com	*Ludwigia octovalvis*	Lud oct
Aneilema aequinoctiale	Ane aeq	*Lycopersicon esculentum*	Lyc esc
Anthericum sp..	Ant spe	*Lygodium microphyllum*	Lig mic
Antidesma venosum	Ant ven	*Macaranga capensis*	Mac cap
Apodytes dimidiata	Apo dim	*Mangifera indica*	Man ind
Asparagus falcatus	Asp fal	*Manihot esculenta*	Man esc
Asystasia gangetica	Asy gan	*Melanthera scandens*	Mel sca
Bersama cf. *lucens*	Ber luc	*Microsorum punctatum*	Mic pun
Bidens pilosa	Bid pil	*Mikania natalensis*	Mik nat
big leafed climber/ cf. *Tacazzea apiculata*	big lea	*Mimusops obovata*	Mim obo
Boere pumpkin	Boe pum	*Morella serrata*	Myr ser
Brachylaena discolor	Bra dis	*Musa xparadisiaca*	Mus xpa
Bridelia micrantha	Bri mic	*Neonotonia wightii*	Neon wig
Burchellia bubalina	Bur bub	*Nephrolepis biserrata*	Nep bis
Casearia gladiiformis	Cas glad	*Oldenlandia cephalotes*	Old cep
Cussonia arenicola	Cus are	*Oplismenus hirtellus*	Opl hir
Cussonia sphaerocephala	Cus sph	*Panicum brevifolium*	Pan bre
Cassytha sp.	Cas spe	*Panicum parvifolium*	Pan par
Cavacoa aurea	Cav aur	*Paspalum urvillei*	Pas urv
Centella asiatica	Cen asi	*Peddiea africana*	Ped afr
Chlorophytum krookianum	Chl kro	*Pereskia aculeata*	Per acu
Cirsium sp..	Cir spe	*Persicaria hydropiper*	Per hyd
Cissampelos torulosa	Cis tor	*Petopentia natalensis*	Pet nat
Cladium mariscus	Cla mar	*Phaulopsis imbricata*	Pha imb

Clematis brachiata	Cle bra	*Phoenix reclinata*	Pho rec
Colocasia esculenta	Col esc	*Phragmites australis*	Phr aus
Commelina benghalensis/ Commelina erecta	Com ben/ Com ere	*Podocarpus falcatus*	Pod fal
Conyza canadensis	Con can	*Polypodium lycopodioides*	Pol lyc
Crassocephalum crepidioides	Cra cre	*Psilotum nudum*	Psi nud
Crassocephalum picridiformis	Cra pic	*Psychotria capensis*	Psy cap
Crocosmia aurea	Cro aur	*Pteridium aquilinum*	Pte aqu
Cucumis zeyheri	Cuc zey	*Pycreus nitidus*	Pyc nit
Cyperus textiles	Cyp tex	*Pycreus polystachyos*	Pyc pol
Cyperus dives	Cyp div	*Rapanea melanophloeos*	Rap mel
Cyperus papyrus	Cyp pap	*Raphia australis*	Rap aus
Cyperus pectinatus	Cyp pec	*Rauvolfia caffra*	Rau caf
Cyperus prolifer	Cyp pro	*Rhipsalis baccifera*	Rhi bac
Cyperus sphaerospermus	Cyp sph	*Rhoicissus rhomboidea*	Rho rho
Delbergia armata	Del arm	*Rhus* cf. *nebulosa*	Rhu neb
Desmodium adscendens	Des ads	*Rhus chirindensis*	Rhu chi
Desmodium salicifolium	Des sal	*Rhus pyroides*	Rhu pyr
Digitaria eriantha	Dig eri	*Rhynchospora corymbosa*	Rhy cor
Dissotis canescens	Dis can	*Rubus rigidus*	Rub rig
Dracaena mannii	Dra man	*Saccharum officinale*	Sac off
Erigeron cf. *daggera*	Eri dag	*Sacciolepis curvata*	Sac cur
Eriosema squarrosum	Eri sq	*Schefflera umbellifera*	Sch umb
Erythrina lysistemon	Ery ly	*Scleria angusta*	Scl ang
Erythroxylum emarginatum	Ery em	*Scolopia stolzii*	Sco stol
Ficus sur	Fic su	*Senecio deltoideus/ Mikania natalensis*	Se/Mik
Ficus trichopoda	Fic tri	*Senecio polyanthemoides*	Sen pol
Fuirena umbellata	Fui umb	*Setaria megaphylla*	Set meg
Gomphocarpus physocarpus	Gom phy	*Smilax anceps*	Smi anc
Halleria lucida	Hal luc	*Sonchus* cf. *oleraceus*	Son ole
Helichrysum aureonitens	Hel aur	*Stenochlaena tenuifolia*	Ste ten
Helichrysum tongense	Hel ton	*Syzygium cordatum*	Syz cor
Hewittia malabarica	Hew mal	*Syzygium guineense*	Syz gui
Hibiscus surattensis	Hib sur	*Tabernaemontana ventricosa*	Tab ven
Hibiscus tiliaceus	Hib til	*Tarenna pavettoides*	Tar pav
Hibiscus trionum	Hib tri	*Thelypteris interrupta*	The int
Hydrocotyle bonariensis	Hyd bon	*Typha capensis*	Typ cap

Ilex mitis	Ile mit	*Trema orientalis*	Tre ori
Indigofera sp.	Ind sp	*Trichopteryx dregeana*	Tri der
Ipomoea batatas	Ipo bat	*Triumfetta pentandra*	Tri pen
Ipomoea mauritiana	Ipo mau	*Urera trinervis cf*	Ure tri
Isoglossa spec.	Iso spe	*Voacanga thouarsii*	Voa tho
Keetia gueinzii	Kee gue	*Zehneria scabra*	Zeh sca
Kraussia floribunda	Kra flo		