USING A SOCIAL-ECOLOGICAL SYSTEMS APPROACH TO INVESTIGATE HILLSLOPE SEEP WETLANDS ECOSYSTEM STRUCTURE AND FUNCTIONALITY IN THE TSITSA RIVER CATCHMENT, EASTERN CAPE, SOUTH AFRICA

A thesis submitted in fulfilment of the

requirements for the degree of

DOCTOR OF PHILOSOPHY

of

RHODES UNIVERSITY

By

NOTISWA LIBALA

RHODES UNIVERSITY
Where leaders learn

January 2019

ABSTRACT

Wetlands are critical ecosystems that can provide services of great social, economic and environmental value to the society. Yet, in South Africa, hillslope seep wetlands are among the most threatened ecosystems due to human-induced activities and are disappearing rapidly. Further, despite the potential vulnerability of hillslope seep wetland to disturbances, and their criticality in relation to all year round provision of forage for livestock grazing, they are among the most poorly studied wetland systems. Using a social-ecological system framing, and drawing on a range of ecological and social sciences methods, this study shed light on ways in which an integrative approach can contribute to sustainable utilisation of hillslope seep wetlands in the Tsitsa River catchment in the Eastern Cape province of South Africa. The study specific objectives were to i) evaluate the performance of Floristic Quality Assessment Index (FQAI), WET-Health and Floristic Assessment Quotient for Wetlands Index (FQAWet) indices for assessing hillslope seep wetlands ecological health ii) develop a trait-based approach for assessing the potential resilience and vulnerability of hillslope seep wetland plant species to disturbances, iii) assess the role of hillslope seep wetlands in the local communities in relation to livestock, and explore understanding of local people about the value of hillslope seep wetlands, iv) demonstrate collaborative insights emerging from an integrative social-ecological system research process to inform sustainable management of hillslope seep wetlands.

A total of 11 hillslope seep wetlands were visually classified based on the level of erosion. Plant species composition within the wetlands was determined along a 100 m line transects across the hillslope wetland sites. 5 quadrats of $0.2m^2$ were also placed along transect for vegetation collection and cover. The plant species collected were used to calculate (FQAI) and FQAWet scores to evaluate the condition of hillslope seep wetlands. The degree of human disturbances was assessed using the Anthropogenic Activity Index (AAI), an index for qualitatively assessing the degree of human disturbance based on visual inspection of a wetland site. Factors represented in the AAI, include: (i) surrounding land use intensity; (ii) soil disturbance; (iii) hydrological alteration; (iv) habitat alteration within wetland; (v) vegetation community quality. The vegetation samples were collected in summer 2016 and winter 2017. All assessed indices were regressed against AAI to evaluate their performances.

All assessed indices FQAI, FQAWet and WET-Health showed that hillslope seep wetland were impacted by human activities. FQAIall and WET-Health showed the strongest response to AAI in winter, while FQAIdom and FAQWet showed a weak response to AAI in all seasons. Overall, the findings of this study suggest that FQAIall and WET-Health are potentially better tools for assessing the biological conditions of hillslope seep wetland in South Africa.

A novel trait-based approach was developed using seven plant traits and 27 trait attributes. Based on the developed approach, plant species were grouped into three potentially vulnerable groups in relation to grazing pressure. It was then predicted that species belonging to the highly vulnerable group would be less dominant at the highly disturbed sites, as well as in the winter season when grazing pressure is at its highest. The result corresponds largely with the seasonal predictions; however this was not the case for sites. The approach developed in this study worked and it was useful for predicting the potential responses of plant species in hillslope seep wetlands to grazing pressure. The success of the approach seasonally could be attributed to the careful selection of the traits, reflecting the mechanistic relationship between the grazing mode of stress on vegetation and trait-mediated biotic response. However, this still need to be refined using accurate vegetation cover methods that might have had impact on the lack of correspondence within sites.

The results of the present study revealed that communities largely perceive hillslope seep wetlands as important ecosystems for their livelihoods. They recognise that the importance stems from services provided by the wetlands, particularly for livestock grazing during the dry season. Although hillslope seep wetlands are viewed as important ecosystems for livelihoods, the communities also perceive these wetlands as highly eroded ecosystems. Community members indicate willingness to strengthen local natural resource governance systems, which could lead to better management of hillslope seep wetlands. A range of protective strategies for hillslope seep were suggested by community members, including fencing, active herding and rotational grazing. The study suggests that active involvement of local communities is critical to the successful management of natural resources. The study highlights the need to consider the role of local people as influential components within social-ecological systems in order to promote effective management and conservation interventions of hillslope seep wetlands. Overall, the study highlights the criticality of an integrative social-ecological system approach for holistic management of hillslope seep wetlands within the studied catchment.

TABLE OF CONTENT

CHAPTER 5: ENGAGING WITH COMMUNITIES TO DEVELOP AN UNDERSTANDING OF LIVESTOCK GRAZING PRACTICES IN RELATION TO ECOSYSTEM SERVICES PROVIDED BY HILLSLOPE SEEP WETLANDS........... Error! Bookmark not defined.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAI: Anthropogenic Activity Index

CARA: Conservation of Agricultural Resources Act

CC: Co-efficient of conservatism

CCA: Canonical correspondence analysis

CHAT: Cultural Historical Activity Theory

CMA: Catchment Management Agency

CMF: Catchment Management Forum

CSES: Complex Social- Ecological Systems

DAFF: Department of Agriculture Forestry and Fisheries

DEA-NRM: Department of Environmental Affairs- Natural resource Management

DWAF: Department of Water and Forestry

DWS: Department of Water and Sanitation

EPWP: Expanded Public Works Programme

ERS: Environmental Resource Solutions

FAQWet: Floristic Assessment Quotient for Wetlands Index

FQAI: Floristic Quality Assessment Index

HMA: Hydrologic metric alone

HGM: hydro-geomorphic

IWR: Institute for Water Research

LDMC: Leaf dry matter content

LS: Leaf size/area

NEMA: National Environmental Management Act

NGOs: Non-Governmental Organizations

NRF: National Research Foundation

NWA: National Water Act

PES: Present ecological states

SANBI: South African National Biodiversity

SES: Social Ecological Systems

SLA: Specific leaf area

TBA: Trait-based approach

UCPP: uMzimvubu Catchment Partnership Programme

WC: Wetness coefficient

ACKNOWLEDGEMENTS

I am grateful to Almighty God for giving me strength, and the ability to persist throughout this research project. Special gratitude goes to my supervisors Prof Tally Palmer and Dr Nelson Oghenereko Odume for their encouragement, patience, support and guidance. Thank you for believing in me, I cannot thank you enough for your critical feedback that has given direction to this thesis and patience over the last three years. I would like to thank people of Tsitsa River Catchment (Caba and Manditshe village) for their cooperation and for offering their time and useful insights during the household survey. A special thank goes to Chief Matiwane for allowing me to work in his villages. I would like to extend my sincere thanks to Prof Fred Ellery for his assistance and guidance in this study. I would like to thank Mr. Tony Dold, Prof Donovan Kotze, Mr Craig Cowden and Mr Matthew Janks for assigning the plant species coefficient of conservatism (CC), their support is highly appreciated. I also thank Dr Carin Van Ginkel and Dr Tony Palmer, for providing their expertise on plant species classification. Special thanks go to Mr Japie Buckle for assisting me with site selection at the beginning of the study.

Special thanks to Juanita McLean, David Forsyth, Ntombekhaya Mgaba and Margaret Wolff for the administrative and technical support provided. I would like to show appreciation to the Institute for Water Research (IWR) students Frank Akamagwuna, Pindiwe Ntloko, Qawekazi Mkabile, Bawinile Mahlaba, Mzwanele Mkatali and Caleena De Carvalho for their assistance during data collection. I would also like to thank my friends Asiphe Sahula, Dr Tandile Ndobeni, Dr Nolwazi-Bhembe Magadaza, Ziyanda Naile and Dr Chika Nwaneri for their support and encouragement during the study. Special thanks also go to Luyanda Thobela for his support and encouragement. I am sincerely grateful to the National Research Foundation (NRF) and Department of Environmental Affairs (DEA) for funding this study.

I am also thankful to anonymous reviewers who provided some insightful comments during review of submitted manuscript that helped improving chapter 3.

Lastly my heartfelt gratitude goes out to my beloved family: Atwell Libala (dad), Mamtolo (granny) and Pumla Libala (aunt) for their support and motivation when I was going through hard times.

DEDICATION

This thesis is dedicated to my late mom (Nomacebisa Mavis Ndenge-Libala)

CHAPTER 1: GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Wetlands are among the most productive and functionally important ecosystems globally. They provide all four categories of ecosystem services to society: **regulating,** e.g. water quality/waste purification; **provisioning,** e.g. food and water; **supporting,** e.g. soil formation, and **cultural,** e.g. recreational and spiritual (MEA, 2005).

In South Africa, wetlands make an important direct contribution to supporting rural people's livelihood (Breen et al., 1997; Pollard et al., 2010). They are used for multiple purposes, such as crop production, dry season livestock grazing, water collection for domestic use, medicinal plant collection, fishing, sedge and reed collection, and hunting (Schuyt, 2005; Adekola et al., 2012). Wetlands also provide habitats for the biodiversity of endangered, threatened, and vulnerable plant and animal species. However, despite their importance, wetlands remain one of the most threatened ecosystems on our planet (Gardner et al., 2015). In South Africa, estimates of wetlands that have been lost or degraded stand at more than 50% (Kotze et al., 1995; SANBI, 2006). The main, direct threats are agriculture, forestry and mining; poor land management, such as overgrazing and incorrect burning practices; alien species expansion, and pollution. Indirect threats include increased population growth, poverty, and a lack of awareness of the value and importance of wetlands (Swanepoel and Barnard 2007). People whose livelihoods largely depend on wetland resources are the most vulnerable to effects of wetland degradation (Pollard et al., 2010).

The present study focuses on hillslope seep wetlands which are known to be critical and fragile ecosystems, but which are able to supply ecosystem services such as biomass production for livestock grazing (Walters et al., 2006). Hillslope seep wetlands are a small but extremely important part of the South African landscape; however, their importance has been largely overlooked, probably on account of their small size. Adekola et al. (2012) indicate that the economic value of smaller wetlands has been studied very little, possibly because they are considered insignificant. However, because small wetlands are extensively used for subsistence agriculture, they are probably as important as the larger ones to national development in Africa (Taylor et al., 1995).

The Tsitsa River Catchment, where the present study was undertaken, is recognised as a highly degraded catchment as a result of overgrazing, over-cultivation, and social and political issues (Pretorius, 2016). Rural communities within the Tsitsa River Catchment are among the poorest and least developed in South Africa (DWS, 2014). The hillslope seep wetlands in the catchment are considered vulnerable because of their relatively small size and the steep slopes that consist of shallow soils prone to erosion. The vulnerability of these seeps is intensified because there is a point in the erosion process where the hillslope seep is irreparably eradicated. These wetlands are particularly important to local people since they provide livestock grazing, particularly during the dry season (Palmer et al., 2002; Collins, 2005; Kotze and Malan, 2010). Considering the dependence of local people on hillslope seep wetlands and the potential fragility of the wetlands in the event of disturbances, it is clear that, if they are not well managed, they could easily disappear with serious social-economic consequences for people and their livelihoods.

Given the importance of hillslope seep wetlands, is imperative to develop an integrated holistic approach to study their conditions, their vulnerability to threat, as well as local management practices. This study proposes a social-ecological system approach (SES); an approach that recognises humans as an integral part of the ecosystems (Pollard et al., 2010). The integration of humans and nature is based on an argument that these two systems are interdependent and cannot be treated independently (Berkes, 2017). This integration allows analysis of the complex interplay between social and ecological processes and the insights from such analysis could offer possible solutions for sustainable wetlands management. The integration is also important because, in any protection and conservation efforts, there are interactions and feedback between society and nature (Berkes et al., 2014). The study focuses on assessing SES conditions through methodologies drawn from natural and social sciences in understanding hillslope seep wetland ecosystems and grazing practices.

The social-ecological system approach used in the current study integrates three forms of knowledge: a fundamental ecological understanding of i) the functional traits of hillslope seep wetland vegetation and wetland ecological health, ii) the functional role of hillslope seep wetlands within a livestock-grassland system; and iii) a social science-based understanding of the ways livestock owners view the value of hillslope seep wetlands. Liehr et al. (2017) indicate that an appropriate approach to sustainable natural resource management needs to integrate different disciplines and link science with society, addressing critical relevant societal problems at the science-practice interface. The approach used in this study is integrative, drawing from both natural and social sciences, while engaging with critical stakeholders on the landscape. The overall aim of the study is to understand the importance of hillslope seep wetland ecosystem functionality and structure, and reaction to disturbances, particularly grazing systems, in terms of supporting landscape and social processes using a SES perspective.

The section that follows in this chapter provides a critical literature review of wetlands and livelihoods in South Africa, threats to hillslope seep wetlands, biological tools for assessing wetlands, and the legislative framework for sustainable management of wetland resources. This chapter also provides a description of an SES approach, an integrative framework for understanding and managing hillslope seep wetlands.

1.2 Wetlands and livelihoods in South Africa

Wetlands have been classified using a variety of approaches. In South Africa a hydro-geomorphic (HGM)-based classification system has been developed as the basis for classifying wetlands (Kotze et al., 2008; Macfarlane et al., 2008; Ollis et al., 2013). The classification system recognises five generic palustrine wetland types: i) floodplains, ii) channelled valley bottom, iii) unchanneled valley bottom, iv) channelled, hillslope seepage linked to a stream and isolated hillslope seepage and v) depressions (Kotze et al., 2008; Macfarlane et al., 2008). Floodplain wetlands generally occur on a plain and are typically characterised by a suite of geomorphological features associated with river-derived depositional processes, including point bars, scroll bars, oxbow lakes and levees (Ollis et al., 2013). Channelled valley-bottom wetlands are characterised by their location on valley floors, the absence of characteristic floodplain features, and the presence of a river channel flowing through the wetland. By contrast, unchanneled valley-bottom wetlands are also located on valley floors but lack distinct channel banks, and flows are therefore diffuse. Seep wetland areas are located on gently to steeply sloping land and dominated by colluvial (i.e. gravity-driven), unidirectional movement of water and material downslope. A depression is a wetland or aquatic ecosystem with closed (or near-closed) elevation contours, which increases in depth from the perimeter to a central area of greatest depth and within which water typically accumulates (Ollis et al., 2013). However, the focus of this study is on hillslope seep wetlands because they are poorly studied globally and, within the Tsitsa catchment, they seem to be disappearing at an increasing rate. Further, studies of the effects of livestock grazing on these wetlands in southern African is limited (Kotze and Malan, 2010).

1.2.1 Livestock grazing on wetlands

Wetlands provide valuable grazing lands for livestock, particularly during drought and dry seasons when vegetation cover and quality is poor in the surrounding rangeland (Collins, 2005). During dry seasons, wetlands – and hillslope seeps – become attractive to livestock as these ecosystems often have green grass all year round (Palmer et al. 2002). The importance of wetlands to farmers is their high grazing potential compared with the surrounding uplands (Turpie and Malan, 2010). The grazing capacity of a wetland is usually 1.5 times higher than a non-wetland area of equal size, though a range of factors, such as types of grasses and their nutritional quality, can influence the grazing return from wetlands. According to Kotze and Malan (2010), livestock grazing in wetlands is one of the most frequent activities that takes place on South African wetlands, yet one of the least well understood.

1.2.2 Cultivating crops

Wetlands have relatively higher soil moisture and nutrient levels than the surrounding landscape, and are thus favoured places for cultivation, particularity in the dry season (Hay et al., 2014). The net income from the additional productivity is the value derived from cropping in wetlands, but constant cultivation of wetlands can easily impact on the overall health of such areas. In contrast, crop cultivation is less pronounced on hillslope seeps.

1.2.3 Medicinal plants and handicraft production

Wetlands provide valued material for production such as mats and baskets (Hay et al., 2014). Handicraft production from harvested wetland plants serves as a source of employment, income and incentive to protect wetlands. Species such as *Juncus krausii* and *Cyperus latifolius* are used extensively for handcraft production in South Africa (Collins, 2005). Wetlands are also home to plant species, such as *Alepidea amatymbica* and *Helichrysum nudifolium,* which are used for medicinal purposes (Ngcaba and Maroyi, 2017). Traditional uses of *Alepidea amatymbica* species have been reported, and these include the treatment of malaria, diarrhea, cold, coughs, influenza, chest complaints, and management of asthma and rheumatism (Wintola and Afolayan, 2014). *Helichrysum nudifolium* species on the other hand is used on wounds to prevent infection.

1.2.4 Water for domestic use

Water is extracted directly from wetlands for domestic consumption, livestock drinking, irrigation, and other purposes (Collins, 2005). A hillslope seep connected to a stream is generally assumed to be sustained by supply of sub-surface water discharging to the ground surface. The greater the extent to which an HGM unit is important for stream flow regulation, the greater the likelihood that it will provide a reliable supply of drinking water (Macfarlane et al., 2008). Many of the wetlands that are important for stream flow regulation and which generally provide a reliable source of clean water would be described as springs. However, in the study area the use of hillslope seep wetlands as source for drinking water is less pronounced.

Although wetlands contribute to the above social, economic and environmental development, they are threatened by a range of human-induced activities which can easily diminish the overall services these critical ecosystems provide.

1.3 Threats to wetlands

Anthropogenic factors have the most significant impact on the ecological health of wetlands (Dickens et al., 2003). Poor grazing practices, introduction of alien species, uncontrolled harvesting of wetland species and poor institutional capacity for wetland management are key factors contributing to wetland degradation (Naidoo, 2014; Bella et al., 2018). Although wetland degradation is seen as a problem globally, the causes and extent of this degradation may differ from place to place. For example, a study conducted by Jogo (2010) provided a list of the main threats to wetlands in southern Africa ranked according to the extent of their occurrences (Table1.1). Overgrazing has been identified as a serious problem for wetlands in most parts of South Africa.

Table 1. 1: Major threats to wetlands in southern Africa ranked according to the extent of their occurrence (Jogo, 2010). Rank: 1= threats that are a widespread problem, seriously disrupting ecological and hydrological processes; 2= threats that are causing serious damage, but is not yet widespread; 3= threats that are present, but not yet widespread.

Threat	Rank	Areas at risk
Dams	1	All dam areas, especially the Lower Zambezi
Irrigation	1	Most river basins and floodplains in the region
Overgrazing	1	Most parts of southern Africa

Vegetation clearing	1	Most parts of southern Africa
Over-hunting (poaching)	1	Largely in Zambia, Angola, Tanzania and Mozambique
Overfishing	1	Most rivers, small lakes and floodplains
Over-extraction of water resource	1	Potentially Zambezi River and Okavango Delta
Population growth and human settlements	2	Coastal zone of Mozambique and dambos of Zimbabwe
Siltation (infilling)	2	Luangwa and Save rivers
Pollution (pesticides)	2	Common in all parts of the region
Pollution (agri-chemicals)	2	Common in all parts
Pollution (industrial)	3	Urban areas and mining sites
Eutrophication	3	Lake Chivero (Zimbabwe) and Kafubu (Zambia)

1.3.1 Livestock grazing as threats to hillslope seep wetlands

The impact of livestock disturbance in hillslope seep wetland ecosystems can be both direct and indirect. The direct impacts include vegetation trampling that results in erosion and loss of sediment from the wetland, and causes changes in community structure and composition of wetland species (Kotze and Malan, 2010). The effect of grazing on wetland can also be influenced by variation in climatic conditions. For example, in drier seasons, livestock tend to graze more intensely in wetlands than in wetter seasons and hillslope seep wetlands are relatively vulnerable to livestock grazing because of their steep slope and small size. The indirect effects of overgrazing can cause shifts in vegetation communities, which may affect wetland productivity (Morris and Reich 2013). In the absence of appropriate management strategies, livestock grazing could present a serious threat to hillslope seep wetlands.

The social importance of these wetlands cannot be ignored: rural poor people often depend on natural resources, including hillslope seep wetlands and, if the livelihoods of those depending on wetlands are to be sustained, then it is imperative to assess wetland conditions in order to recommend appropriate management strategies (Macfarlane et al., 2016). A number of tools and techniques have been developed for this purpose. However, before any appropriate management practice can be put in place, tools are needed for assessing the current state of wetlands, particularly hillslope seep wetlands. Ideally, such tools should be sufficiently sensitive to detect changes in hillslope seep wetland conditions.

1.4 Assessment tools for managing wetlands

Over the past 20 years, a number of wetland assessment methods, techniques, and tools have been developed and used successfully for a variety of wetland monitoring and assessment purposes. Bioassessment tools based on vegetation and surrounding impacts are considered to be the most effective and precise indicators of wetland conditions because plant species respond quickly to environmental stress (U.S. EPA 2006). Most bioassessment tools, such as the Floristic Quality Assessment Index (FQAI), Floristic Assessment Quotient for Wetlands (FQAWet), have been well-established internationally and are often used to provide early warning of deteriorating wetland conditions, to diagnose stressor types, assist management, and evaluate the effectiveness of protection and restoration activities (U.S. EPA, 2006).

The Floristic Quality Assessment Index (FQAI) is an example of a biological assessment approach that has been widely used since it was first developed in the late 1970s (Wilhelm, 1977). It is based on the coefficient of conservatism (CC) (intolerance to habitat degradation), which employs a subjective numeric quality rating, ranging from zero to ten. The scores reflect species' tolerance to disturbance and specificity to a particular habitat type. Higher CC scores are assigned to plant species intolerant of environmental disturbances, and lower CC scores are assigned to species that are tolerant of disturbances (see Chapter 3, section 3.3). The Floristic Quality Assessment Index is widely used for assessing ecological conditions of wetlands (De Berry, 2015) and its usefulness has been tested in various ways: a "dose-response" analysis that plots the Floristic Quality Assessment (FQA) metric against a pre-determined anthropogenic disturbance gradient (e.g., Miller et al., 2006; Bried et al., 2013); and through comparisons with other biological integrity metrics such as species richness, diversity, evenness, percent native species, wetness indices (e.g. Ervin et al., 2006; Yepsen et al., 2014).

In South Africa, the FQAI approach has been applied in only two studies. It was first used by Cowden et al. (2014) to assess the ecological conditions of wetlands after rehabilitation, and Van Deventer et al. (2014) used it to assess wetland conditions associated with proposed bulk water pipelines. Both studies found the FQAI a useful tool for wetland assessment.

Other international assessment approaches are based on the degree of wetness in a wetland, or wetland boundary, and wetness coefficients. These indices include: i) Floristic Assessment

Quotient for Wetlands (FAQWet index) (Ervin et al., 2006) ii) Prevalence Index (PI) and iii) Hydrophytic Cover Index (HCI). The indices use the Wetland Indicator Status (WIS), which is a weighted average score ranging from 1 to 5, where a score of 1 indicates obligate species that are found in wetlands 99% of the time, and a score of 5 indicates upland (terrestrial) species, which are found in wetlands only 1% of the time.

WET-Health, the tool most widely used in South Africa for assessing wetland conditions (Macfarlane et al., 2008), assesses the deviation of wetland structure and function from the reference condition. It is based on the impacts of human activities on hydro-geomorphic processes and vegetation responses (Kotze et al., 2012). The index is useful when making decisions about wetland rehabilitation/protection because it determines the ecological health of a wetland and so provides a starting point for rehabilitation. WET-health offers two levels of assessment: Level One which is a desktop evaluation, and Level Two, which involves data collection from the catchment and wetland. WET-Health integrates three separate submetrics: hydrology, vegetation, and geomorphology. The hydrology submetric reflects the distribution and movement of the water through a wetland and its soils, focusing on changes in water inputs caused by anthropogenic activities in the catchment upstream of a wetland. The geomorphology submetric reflects the distribution and retention patterns of sediment within the wetland, focusing on changes in both depositional and erosional patterns within the wetland as a result of human activities. The vegetation submetric is used to quantify changes in vegetation composition and structure as a result of current and historic human disturbance. A detailed description of WET-Health is provided in Chapter 3, section 3.3.)

With the exception of WET-Health index, none of the above indices have been evaluated specifically for hillslope seep wetlands. Given the unique features of hillslope seep wetlands, it is necessary to evaluate the performances of the multiple indices for these unique wetlands and identify those that provide the best assessment.

In order to realise the objective of sustainable wetland management, strong and functional institutions based on the law are necessary. In South Africa, several legislative frameworks exist that guide the management, utilisation and protection of wetland resources.

1.5 South African legislative framework for sustainably managing wetland resources

In response to the importance of wetland systems in South Africa, a number of pieces of legislation enable the various governmental entities to protect, conserve and manage wetland resources. Although implementation remains a challenge, and the legislative framework for wetland management in South Africa is complex, the legislation provides guidance regarding wetland use and protection (Dickens et al., 2003) with a number of Acts.

1.5.1 National Water Act, 1998 (Act No 36 of 1998)

The National Water Act (NWA No 36 of 1998) is the primary piece of legislation that guides the use and protection of water resources, including wetlands. Its main purpose is to ensure the sustainable use, protection, development, and management of water resources from an integrated, catchment-based perspective. The NWA clearly requires and makes provision for public participation as an integral part of water resource management; public participation is a key feature of the National Water Policy. Participatory governance is a platform where local people have the knowledge and confidence to engage effectively with those governance institutions where land and water resource management decisions are made (Palmer and Wolff, 2018). In the Tsitsa River Catchment, a participatory land and water governance system is emerging which is part of the Department of Environmental Affairs-Natural Resource Management (DEA-NRM). The emerging participatory governance system in the Tsitsa River Catchment could have a positive influence on livestock owners with regard to hillslope seep wetlands, as the system creates platforms for community participation in natural resource management decisions.

The NWA also provides for the establishment of Catchment Management Agencies (CMAs) to take responsibility for water resources management at a regional or catchment level. One of the main purposes for establishing CMAs in South Africa is to involve local communities in integrated water resources management (Silima, 2007) through the formation of Catchment Management Forums (CMFs), which are non-statutory bodies that are established to democratise the water resource management process (DWS, 2013) and provide a potentially effective platform for organising stakeholder participation in natural resource management. CMFs serve as a communication channel between local residents and government institutions (Munnik et al., 2016).

In the Tsitsa River Catchment, there is already an ongoing process of CMF formation as a starting point for developing a participatory governance system (Palmer and Wolff, 2018). Part of the present study was to evaluate the willingness of people to form and participate in a governance structure such as a forum, to ensure not only participation of local communities and traditional leaders in the management of wetlands, but to improve communication between local people and government.

1.5.2 Conservation of Agricultural Resources Act, 1983 (Act No 43 of 1983)

The Conservation of Agricultural Resources Act (CARA) is the primary piece of legislation for controlling natural resources in the agricultural sector, with the aim of preventing over-utilisation of South Africa’s natural resources. The Act promotes the conservation of natural resources by maintaining the production potential of land, combating and preventing erosion and avoiding over-exploitation of water resources. It also seeks to protect vegetation and combat weeds and invasive plant species. The Tsitsa River Catchment is highly degraded; restoration and active conservation are necessary to retain hillslope seep wetlands and improve their value to local people. This legislation can be used to ensure that hillslope seep wetland degradation is minimised.

1.5.3 National Environmental Management Act, 1998 (Act No 107 of 1998)

This important piece of legislation effectively promotes sustainable development of natural resources. It is concerned with the management of all natural resources, including those that could impact catchment health (Teixeira-Leite and Macfarlane, 2013). The Act also recognises that development must be socially, environmentally and economically sustainable and that the disturbance of ecosystems and loss of biological diversity are avoided, or, where they cannot be avoided, are minimised. The National Department of Environmental Affairs (DEA) is the lead agent for the implementation of NEMA.

Even though South Africa has several pieces of legislation for managing wetland resources, they are complex, and regulators face a myriad of implementation challenges (Schreiner, 2013). One such challenge is the confusion between national, provincial and local governments as to which level of the state should control and manage wetland resources (Koch, 2004). It is clear that, if wetland resources are to be managed sustainably, a complex social-ecological systems (CSES) approach is needed to integrate biophysical and social components and interactions.

1.6 Integrative framework for understanding and managing hillslope seep wetland: a SES approach.

The social-ecological systems approach is increasingly recognised by the scientific community as an approach for analysing complex phenomena (Hossain and Szabo, 2017). Social-ecological systems are regarded as complex systems in which human sub-systems (e.g. communities, society, and economic, political and cultural components) interact with the ecological sub-system (e.g. ecosystems) in a multiple feedback relationship (Berkes et al., 2014). In order to understand complex SES, both the social and ecological components of a system must be considered simultaneously (Folke, 2007). In situations where only a single component of the system is considered, decisions made with respect to the management of that system might not be successful (Carpenter and Gunderson, 2001).

Hillslope seep wetland ecosystems can be viewed as CSESs characterised by a range of interactions, feedback loops, and cross-scale dynamics. It is critical to delineate the SES boundary of investigation. Given the complexity and the range of interactions in hillslope seep wetlands as a complex SES, this study delineates and focuses on biophysical assessment, resilience and vulnerability of plant species to grazing, and social use and value of hillslope seep wetlands.

1.6.1 Assessing the biophysical condition of wetlands, and the resilience and vulnerability of plant species

The current study critically assesses the biophysical conditions of hillslope seep wetlands for management purposes using a combination of international assessment tools: FQAI, FQAWet, and WET-Health. In South Africa, WET-Health is widely used, but its performance relative to other indices used internationally has not been evaluated, particularly for hillslope seep wetlands. It is therefore imperative to critically evaluate the performance of these indices and tools so as to recommend to managers appropriate tools for hillslope seep wetlands.

Wetland vegetation can be vulnerable and/or resilient to a range of pressures, including livestock grazing. Resilience shares many principles with vulnerability and they are relevant concepts in both biophysical and social research (Gallopin, 2006). One of the aspects shared by both resilience and vulnerability is adaptive capacity. The resilience aspect appeared in ecology in 1970s with a coherent definition regarding the persistence of a system after disturbance, without changing its structure and functioning (Holling, 1973). Resilience is an integrated approach that has been developed by ecologists and social scientists in order to understand the dynamic behaviour of SES (Holling, 2003; Biggs et al., 2012; Folke et al., 2016). According to Biggs et al. (2015), social-ecological resilience is the ability to transform in the face of change, particularly unexpected change, in ways that continue to contribute to human well-being.

Ecological vulnerability, by contrast, occurs when individuals or communities of species are stressed, and where thresholds of potentially irreversible changes are experienced through environmental changes (Adger, 2000). Vulnerability in social-ecological systems is based on the capacity of a system that is exposed to disturbances to adapt. Vulnerability has the following aspects: a) e**xposure** – the degree, duration and extent to which a system experiences environmental disturbance; b) **sensitivity** – the degree to which a system is modified or affected by internal and external disturbance, and, c) **adaptive capacity –** the ability of a system to adjust to a disturbance, moderate potential damage, take advantage of opportunities and cope with the consequences of a transformation (Adler, 2000; Fortini and Schubert, 2017).

The hillslope seep wetlands investigated in the present study area are among the ecosystems that provide green vegetation for livestock grazing throughout the year, and more so in the dry winter period. In the face of the growing pressure on these vulnerable ecosystems, their potential to continue to supply important ecosystem services could be influenced by their level of resilience and vulnerability to disturbances, particularly grazing. Therefore, this study uses a plant trait-based approach to assess the resilience and vulnerability of seep wetland vegetation to disturbance.

Assessing the vulnerability of hillslope seep wetland plants species to grazing using the trait-based approach

The trait-based approach has recently appeared as a promising way to predict vegetation response to disturbance (de Bello et al., 2005; Díaz et al., 2007). Plant traits are defined as morphological and physiological characteristics that represent ecological strategies and determine how plants respond to environmental drivers (Violle et al., 2007; Pérez-Harguindeguy et al., 2013; Garnier and Navas, 2012). The trait-based approach assumes that plants with similar ecologically relevant trait attributes respond to environmental changes in a similar way (Violle and Jiang, 2009). The traits are also useful for predicting community responses to environmental gradients (Webb et al., 2010). Trait-based approaches help to show underlying mechanisms leading to changes in plant species composition, which could be difficult to detect through a floristic analysis alone (Drobnik et al., 2011). In this study, a functional trait-based approach was used to assess and predict the potential vulnerability and resilience of plant species in seep wetlands to human-induced disturbances, particularly grazing (Chapter 4). Trait selection was informed by trait mechanistic relationship to grazing pressure.

1.6.2 Social use of wetlands and Cultural Historical Activity Theory (CHAT)

It is important to recognise that people and institutions are integral components of any ecological system; this is eminently true of hillslope seep wetlands (Pollard et al., 2010). If ecological systems are to be managed sustainably, the knowledge and experiences of people living in the catchment are critical. Local people often have a wealth of understanding and knowledge of processes influencing ecological systems that are not always documented in academic literature and their willingness to engage in protective and conservation measure to sustain ecological systems can improve the health and resilience of such systems. The current study investigated the social use of hillslope seep wetlands with a specific focus on understanding the ways livestock owners view the value of seep wetlands as well as their understanding of the ecological health of hillslope seep wetlands. In order to engage research participants constructively, to elicit depth of information and to probe the willingness of these key stakeholders to act to protect and conserve hillslope seep wetlands, it is critical to use appropriate social science methods. In the current study the Cultural Historical Activity Theory (CHAT) was used as an overarching framework for data collection (Engeström, 2001).

Cultural Historical Activity Theory (CHAT) as an approach for data collection

Any human activity has a range of elements that influence the trajectories of relationships. Rationality is a primary driver in CSESs (Palmer et al., 2015) and CHAT is a useful theory that provides a framework for analysing interactions between people undertaking a purposeful activity that includes not only the interpersonal/communicative aspects of those relationships, but also the cultural, historical, political, and economic dimensions.

Engeström (2001) has driven the development of CHAT which has evolved through three generations. The first generation focused on cultural mediated action, the second generation focused on the individual collective activity, and the third generation currently focuses on multiple, interacting activity systems and boundary-crossing between them.

First-Generation Activity Theory: Mediated Action

First-generation activity theory was deeply contextual and focused on understanding historically specific local practices, their objects, mediating artefacts, and social organisation (Cole and Engeström, 1993). The culturally mediated nature of human activity is one of the most important concepts of CHAT. This mediation occurs between the subject – typically the individual human being – and the object or purpose of the activity. This system is usually pictured as a triangle with the labels 'subject', 'object', and 'artefacts' at its vertices (Figure 1.1) (Feldman and Weiss 2010). Vygotsky (1978) argued that the explanatory principle of human mind must be sought in the society and culture as they evolve historically rather than in the human brain or individual mind.

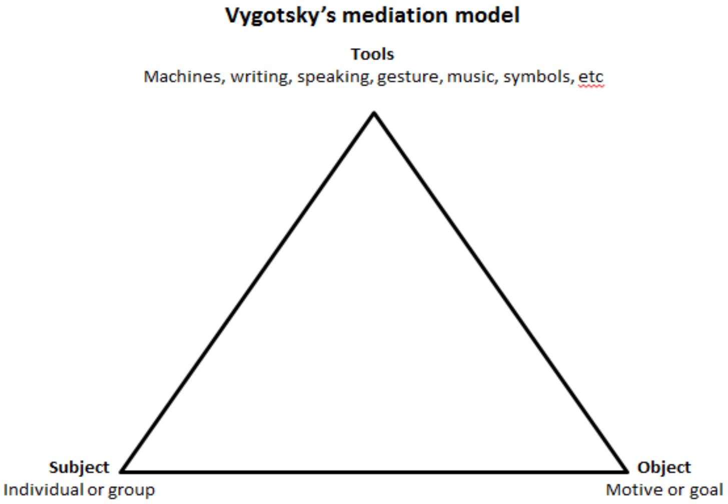


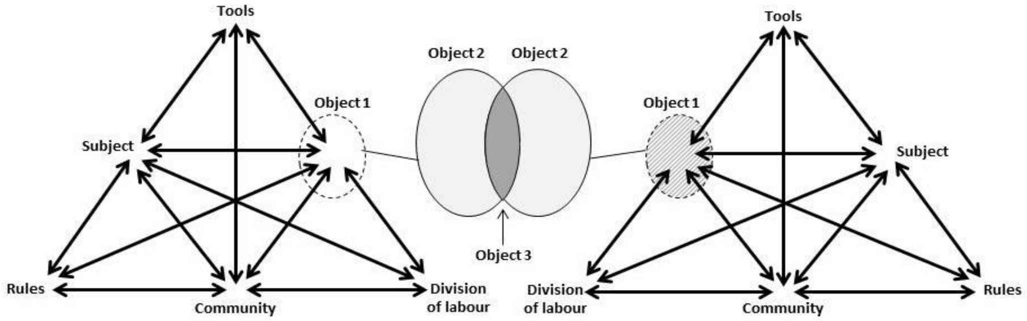
Figure 1. 1: **First-generation Activity Theory: Mediated Action.**

Second-Generation Activity Theory: From Individual to Collective Activity

In recognition of the importance of the collective aspect of human activity, Leont'ev (1978) expanded Vygotsky's concept to provide a distinction between an 'individual action' and 'collective activity'. Leont'ev's (1978) depiction of the structure of an activity does not indicate the roles and responsibilities of individuals involved in carrying out the collective activity, which then necessitated the development of a third-generation activity theory.

The Third-Generation Activity Theory: Multiple Interacting Activity Systems

The purpose of the third generation of activity theory was to develop conceptual tools to understand dialogue, multiple perspectives, and networks of interacting activity systems by expanding upon the previous two generations (Figure 1.2). Engeström (2000a) described five principles relevant to the third-generation activity system. The principles speak to an activity system as a unit of analysis, which is undertaken in community with traditions and interest. Activity system needs reflect the historical context as well as the central role of contradictions and tensions as opportunities for change and transformative knowledge and practices. With regard to the current study, the **object of the activity** is livestock production for livelihood and cultural purposes, the **subject of the activity** is the reason why communities own livestock. **Tools** include facilities like kraals, and the knowledge and experience of farmers about livestock and landscape. The **rules** are customs or agreements that people adhere to while engaging in livestock grazing; **community** refers to the farmers who are interested and willing in shaping the goal of livestock activity. **Division of labour** is the division of work among participants towards reaching a goal, for example, herders, government departments, and livestock owners. (See Chapter 5, section 5.2).



Adapted from: Engeström, 2001

Figure 1. 2: Third-generation Activity Theory: Multiple interacting activity systems.

1.7 Methodological framing and significance of the research

This study follows a social-ecological systems approach, recognising the inextricable connections between people and hillslope seep wetlands in the catchment. In doing so, methods, tools and techniques are drawn from ecological and social sciences to better understand the complexity of the SES, paying particular attention hillslope seep wetland conditions, seep plants' potential vulnerability to grazing as a human-induced activity system, and the value ascribed to hillslope seep by the local communities, as well as understanding and knowledge of the systems (Figure 1.3). It can be argued that community aspirations to participate in governance structure for sustainable natural resource management, and the realisation of such aspiration could enhance collective actions aimed at protecting hillslope seep wetlands and preserving their health and resilience. Given that the hillslope seep wetlands within the study catchment play a critical role in the livelihoods of the people, and are being degraded, the present study contributes to efforts aimed at better understanding and managing hillslope seep wetland ecosystems in South Africa.

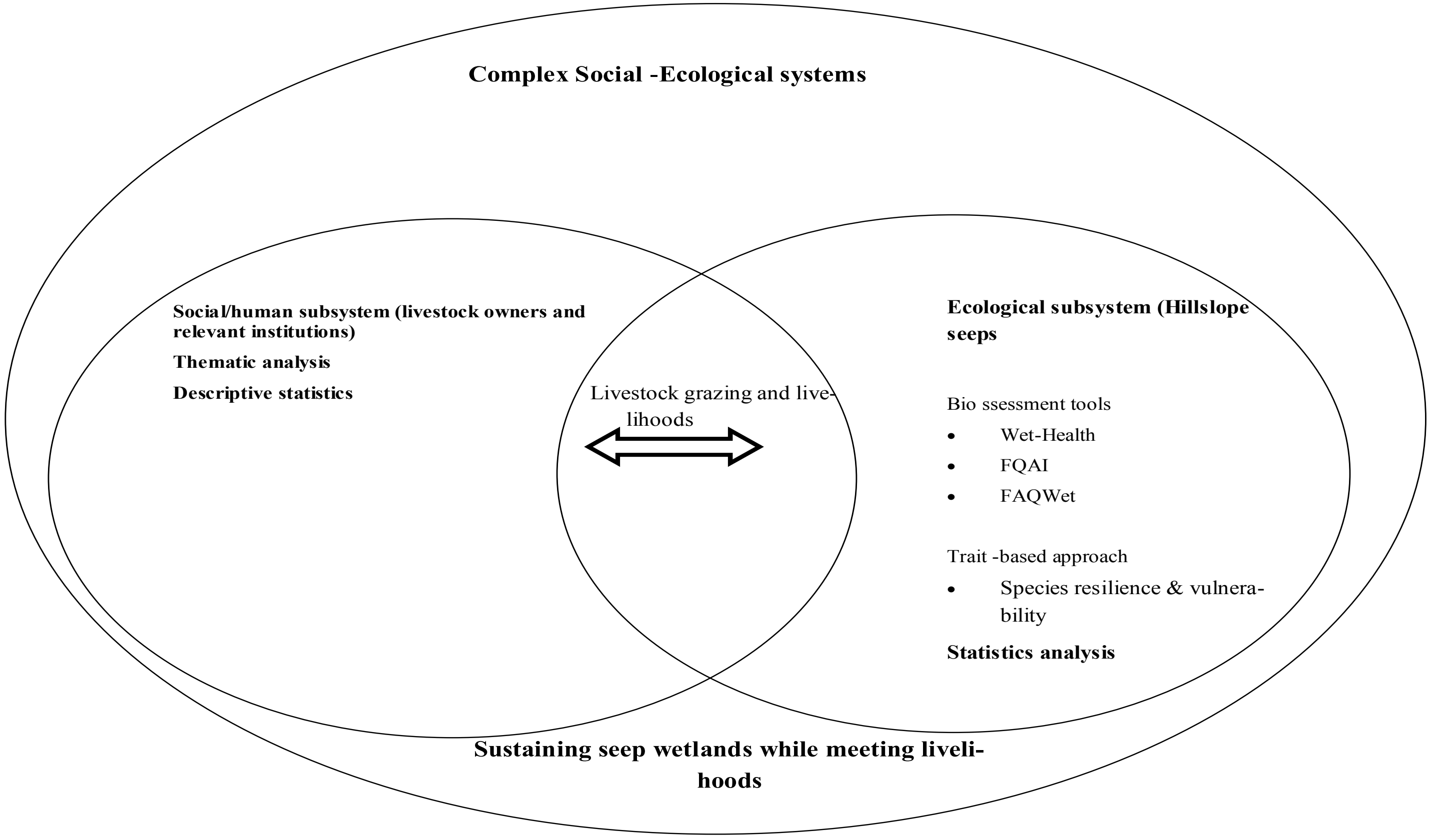


Figure 1. 3: **Methodological framing of the study indicating methods, tools and techniques used.**

1.8 Aim and objectives of the study

1.8.1 Aim

The overall aim of this study was to use a social-ecological systems perspective to investigate the structure and functionality of hillslope seep ecosystems in relation to grazing.

1.8.2 Specific objectives

i) To evaluate the performances of selected indices and tools for assessing the ecological conditions of hillslope seep wetlands, while providing basic soil characteristics of the selected systems.

ii) To develop a trait-based approach for assessing the potential vulnerability and resilience of hillslope seep wetland plant species to grazing pressure.

iii) To engage with the community to develop an understanding and knowledge of grazing practices in relation to hillslope seep functionality.

iv) To demonstrate collaborative insights emerging from an integrative social-ecological system research process to inform sustainable management of hillslope seep wetlands.

1.9 Thesis structure

Chapter One provides the general introduction and literature review. It introduces wetlands ecosystems and provides the context of the problem and causes of wetland degradation and loss. It also provides the CSES framework for the thesis and concludes with the aim and objectives of the research.

Chapter Two: This chapter gives a contextual perspective of the study site in terms of its defining attributes, geographic location, regional and catchment characteristics, as well as biophysical and socio-economic characteristics.

Chapter Three presents an assessment of wetland ecological health using bioassessment indices and tools.

Chapter Four details the trait-based approach for assessing the potential vulnerability of hillslope seep wetland plant species to grazing pressure.

Chapter Five focuses on engaging with communities to develop a common understanding of livestock grazing practices in relation to ecosystem services provided by hillslope seep wetlands.

Chapter Six: This chapter presents a synthesis with key findings, conclusions and recommendations.

CHAPTER 2: STUDY AREA CONTEXT

2.1 Introduction

This chapter describes the study area, the dominant land uses, climate, vegetation, geology, soils and social-economic attributes within the Tsitsa River Catchment.

2.2 Study site selection and description

2.2.1 Biophysical factors

The Tsitsa River is a tributary of the uMzimvubu River, and the study area is situated in the Tsitsa River Catchment in the Eastern Cape of South Africa. Within the Tsitsa River Catchment (Figure 2.2), the study was conducted in two quaternary catchments (T35D and T35E) (Figure 2.2). A quaternary catchment is defined as a fourth-order catchment in a hierarchal classification system in which a primary catchment is a major unit. The hillslope seep wetlands were selected taking account of biophysical factors, and the degree of erosion was visually assessed (Table 2.1). The biophysical factors described in the study are as follows:

Climate

Tsitsa River Catchment rainfall occurs predominantly in summer with the climate characterised as sub-humid (Le Roux et al., 2015). The average rainfall varies from 625 to 1415 mm per annum (Le Roux et al., 2015), with the maximum rainfall occurring in summer and minimum rainfall in winter . Temperatures range from an average of 14 ^{o}C in winter to an average of 25 ^{o}C in summer (Pretorius, 2016). In the winter season, snow is common at the higher altitudes (Sigwela et al., 2017).

Vegetation

The catchment consists mainly of Grassland biome with narrow bands of Eastern Valley Bushveld (Le Roux et al., 2015). The Grassland biome has four bioregions, of which the three largest are Mesic Highveld Grassland, Sub-escarpment Grassland and Dry Highveld Grassland (Mucina and Rutherford, 2006). The most prevalent tree species within the catchment is the alien invasive black and silver wattle (*Acacia dealbata*) which poses a threat to indigenous vegetation (ERS, 2011). The catchment is severely infested with alien species which cause problems with bank stability and access, reduce base flows, and damage downstream infrastructure during flood events (ERS, 2011). The common grass species include thatching grass (*Hyparrhenia hirta*), redgrass (*Themeda triandra*), narrow-leaved turpentine grass (*Cymbopogon plurinoides*), weeping love grass (*Eragrostis curvula*), spear grass (*Heteropogon controtus*), ngongoni grass (*Aristida junciformis*), and ratstail dropseed grass (*Sporobolus africanus*) (Sigwela et al., 2017). The natural vegetation covers 72% of the catchment area. Grassland covers 65%, thicket 5%, forest 2% and shrubland/fynbos 0.1% (Pretorius, 2016). Seasonally saturated hillslope seep wetlands are dominated by a mixture of grasses, forbs, and sedges, while temporarily saturated hillslope seep wetlands are dominated by grasses and permanently saturated ones are dominated by sedges.

Land uses and human-induced disturbances

The catchment is broadly divided into two distinct socio-cultural domains: the western areas, which are dominated by freehold title tenure; and the eastern sections, which are communal areas (Sigwela et al., 2017). The freehold title areas are characterised by the combined land uses of commercial agriculture and plantation forestry, while the communal areas are characterised by subsistence farming, which includes both livestock and crop production (Van Tol et al., 2014). Commercial and subsistence farming agriculture and livestock grazing are the predominant anthropogenic land use in the catchment, making up to 15% of the land cover. Plantation, forests, water bodies, and towns make up 13% of the land use in the catchment. One of the most extensive landholdings in the area is that of the forestry and timber company, PG Bison, with over 70,000 hectares of land (Sisitka et al., 2016). With 70% of the catchment area under communal land tenure characterised by poor land management practices (ERS, 2011), overgrazing is an issue.

Geology and soils

The geology within the catchment consists of sedimentary shales, mudstones and sandstones of the Tarkastad subgroup and Beaufort Karoo super group, with the presence of some dolerite intrusions (Blackhurst et al., 2002). The siliceous lithology from which the soils develop makes them highly unstable and erosive, increasing the susceptibility of hillslope seep wetlands to gully erosion (ERS, 2011).

The Tsitsa River Catchment is characterised by poorly drained, shallow to moderately deep loamy soils, usually with minimal development on hard or weathering rock (Le Roux et al., 2015). Evidence of gully erosion and rills within the catchment demonstrate the presence of dispersive and duplex soils (Le Roux et al., 2015; Parwada and Van Tol, 2016). These soils are usually categorised as duplex or layered soils because of their high clay content in the subsoil caused by leaching (Mavimbela and van Rensburg, 2015).

2.2.2 Site selection

A total of eleven (11) hillslope seep wetlands were selected for the study. Three less eroded (LE1, LE2, LE3) hillslope seep wetlands were selected in the T35D quaternary catchment on privately-owned land (Figure 2.1). Eight wetlands were selected in T35E, of which four were moderately eroded (ME1, ME2, ME3, ME4) and four were highly eroded (HE1, HE2, HE3, HE4). These wetlands are situated in a communal area where there were no grazing management strategies (Figure 2.1). These wetlands were selected taking into account biophysical factors such as the degree of erosion, which was visually assessed. These sites were also chosen because they are surrounded by communities and they are used for livestock grazing. Of the eleven wetlands, five were seasonally, four permanently, and two temporally saturated wetlands (Appendix 1a). The permanent, seasonal and temporal wetness zones are characterised by the soil wetness indicators that they display: Temporal is the outer edge of the temporary zone of wetness and characterised by minimal grey matrix (<10%), few high chroma mottles, and short periods of saturation (less than three months per annum). A seasonally saturated wetland is characterised by grey matrix (>10%), many low chroma mottles and significant periods of wetness (at least three months per annum). The permanent zone of wetness is characterised by prominent grey matrix, few to no high chroma mottles, wetness all year round, and sulphuric odour (DWAF, 2005). Hillslope seep wetlands are usually relatively small, found on slopes and highly dependent on ground water flows (Ollis et al., 2014). Because of their small size and steep slope, they are the most vulnerable ecosystems in the landscape. The size of the selected hillslope seep wetland in the study ranged between of 0.05 to 1.2 ha. Agricultural practices, including livestock grazing, have significantly altered or destroyed the majority of hillslope seep wetlands in the catchment.

The present study is nested within the larger Tsitsa River Project restoration and research intervention in the Tsitsa River Catchment, Eastern Cape, which is coordinated and funded by the Department of Environment Affairs. The vision of the Tsitsa River project is “To support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services”. The study area is in one of the poorest, most degraded and the least developed regions of South Africa (DWS, 2014). Here, local people could be given the opportunity to build a more sustainable future, based on improving natural resources and building the resilience of ecosystems they depend on (Powell et al., 2017). This aspirational vision of the Tsitsa River project drove the CSES-linked method selection and research team's learning and reflection processes (Cockburn et al., 2018).

Table 2. 1: Visual erosion assessment of the selected hillslope seep wetlands. Method of visual assessment was modified from Bunning et al. (2011).

Erosional category	Description
Low	A few shallow (<0.5 m depth) gullies affecting no more than 5% of the surface; the vegetation cover is good with little soil exposure.
Moderate	Presence of shallow to moderately deep gullies (0.5–1.0 m depth) and/or gullies affecting 5–25% of the surface area; plant cover is moderate with small bare patches.
High	Presence of deep gullies (>1 m depth) and/or affecting >25% of the surface; plant cover is very sparse with large bare areas.

2.2.3 Socio-economic description of the catchment

Population

The study area has a total population of approximately two million people, occupying about 386 villages. Elundini and Mhlontlo are the two local municipalities within the area. The Elundini Local Municipality has an estimated population density of 27 people per square kilometre, while the population density of Mhlontlo Local Municipality is 67 people per square kilometre (Hodgson, 2017). The communal lands of (2845.4 km^2 ~58%) have a mean human population density of ~78 km^2, which ranges from 1 to 240 people km^2 (Sigwela et al., 2017). The communal areas in the municipality are governed by traditional councils, comprising chiefs, headmen, and sub-headmen. Councils co-operate with municipalities and democratically elected ward councillors (Cockburn et al., 2018).

Socio-economic and ecological aspect

The Elundini municipality is one of the poorest, beset with socio-economic threats. Rural areas are characterised by greater poverty and inequality than urban areas, and many households are still trapped in the vicious cycle of poverty. The poverty intensity of the municipality has increased from 41% to 44%. Household size has increased from 3.4 to 4 people. Currently 75% of people are dependent on social grants (Elundini Local Municipality IDP, 2018/19). There are very low levels of employment in the rural areas and the municipality has a high unemployment rate of 44%. Low levels of employment in the rural areas can be caused by lack of a strong economic base, and are partly because most inhabitants are involved in subsistence-related activities with little surplus being produced for economic profit (ECSECC, 2017). The situation is exacerbated by low levels of skills and education, which remains a problem in the municipality (Elundini Local Municipality IDP, 2018/19). Livestock production is the leading agricultural activity in Elundini (84.5%); however, there is severe deterioration of ecosystems and wetlands that might negatively affect livestock production, if not managed. Most rural communities in the catchment rely on natural resources, such as hillslope seep wetlands, for livelihoods and socio-cultural activities. However, social-ecological convergence of history – lack of natural resource management, particularly grazing practices, and highly erodible duplex soils negatively reinforcing feedback cycles to produce a particularly high degradation pressure of hillslope seep wetlands – will pose serious consequences for livelihood and landscape (Cockburn et al., 2018).

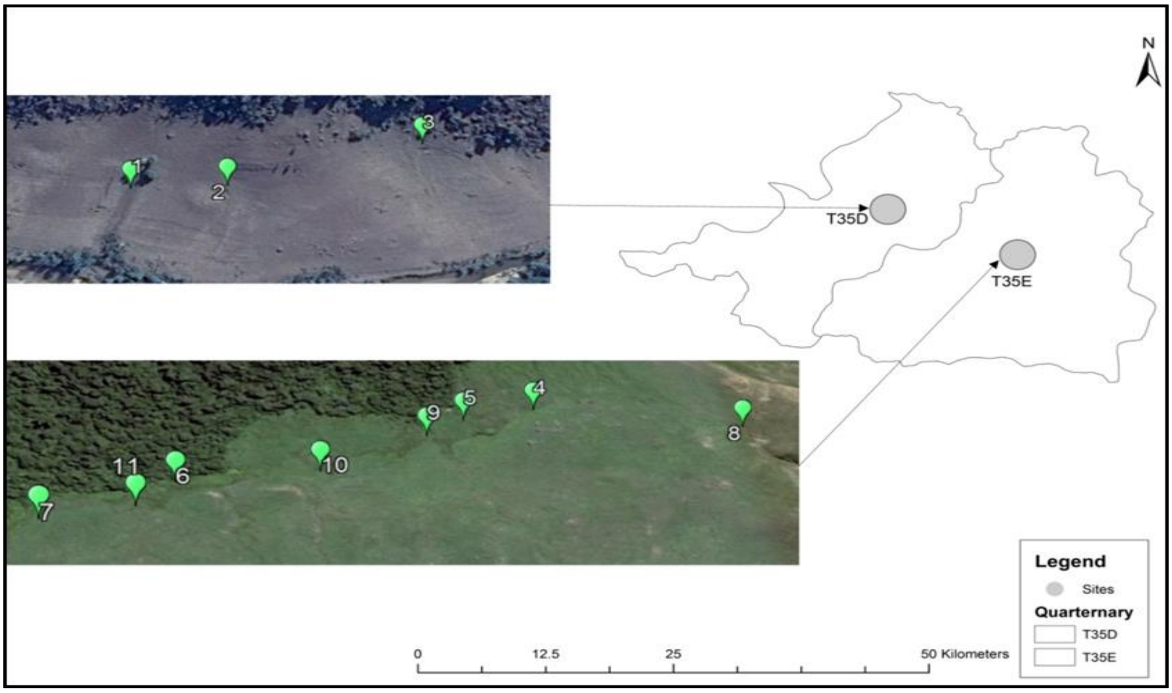


Figure 2. 1: **Locality map of selected hillslope seep sites in quaternary catchment T35D and T35E of the Tsitsa River Catchment.**

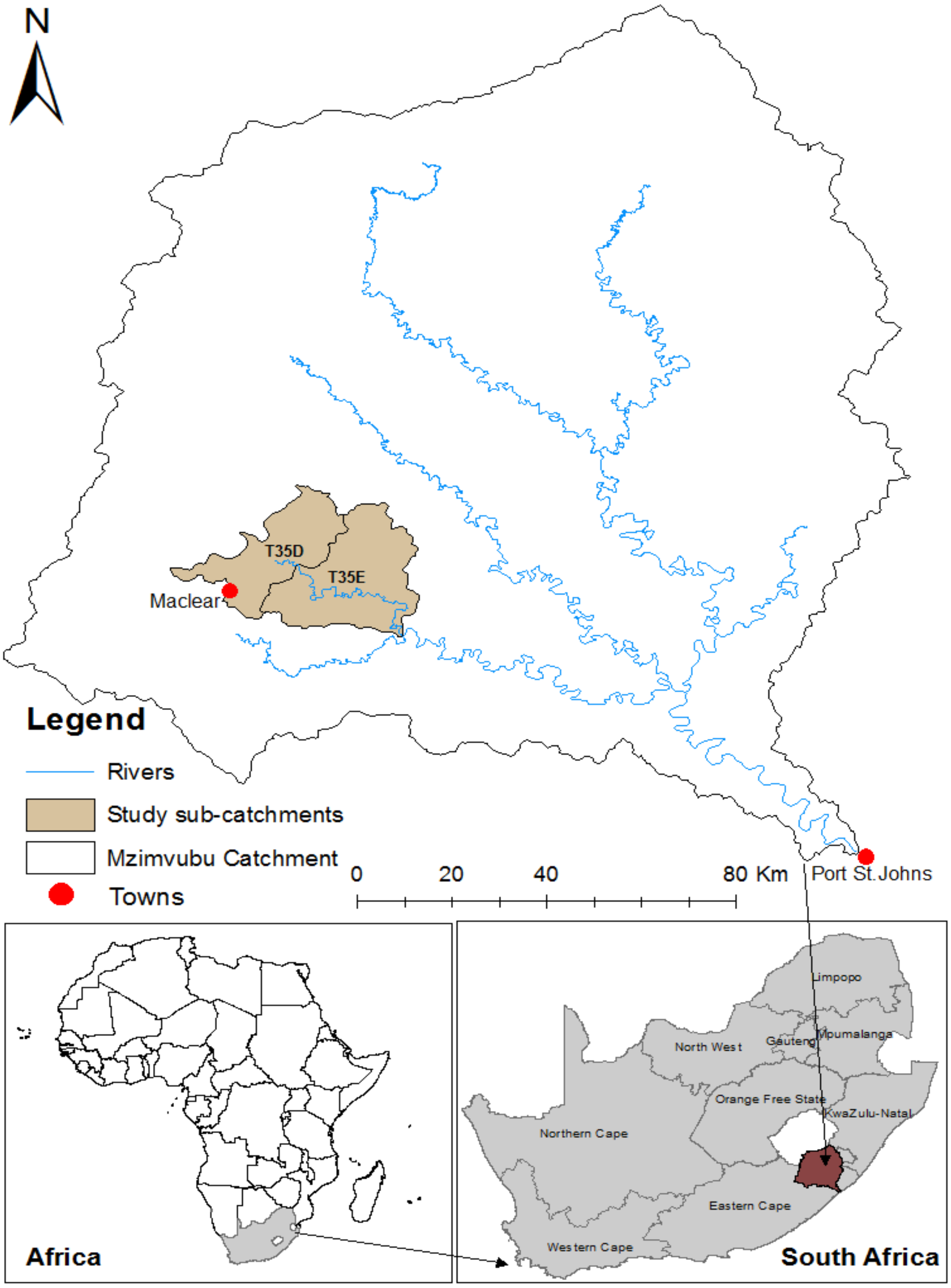


Figure 2. 2: **Locality map of quaternary catchments T35D and T35E in the Tsitsa River Catchment within the uMzimvubu catchment, Eastern Cape, South Africa.**

Table 2. 2: Geographic location of selected hillslope wetlands

Sites		**Coordinates**	**Altitude masl**
Site1	**Less eroded 1:**	Latitude: 31° 0'19.55"S and Longitude: 28°29'33.24"E	1158
Site 2	**Less eroded 2:**	Latitude: 31° 0'22.52"S and Longitude: 28°29'30.17"E	1160
Site 3	**Less eroded 3:**	Latitude: 31° 0'19.34"S and Longitude: 28°29'39.32"E	1162
Site 4	**Moderately eroded 1:**	Latitude: 31° 3'22.09"S and Longitude: 28°36'0.26"E	1289
Site 5	**Moderately eroded 2:**	Latitude: 31° 3'22.37"S and Longitude: 28°35'59.25"E	1285
Site 6	**Moderately eroded 3:**	Latitude: 31° 3'25.22"Sand Longitude: 28°35'55.51"E	1266
Site 7	**Moderately eroded 4:**	Latitude: 31° 3'29.45"Sand Longitude: 28°35'46.32"E	1277
Site 8	**Highly eroded 1:**	Latitude: 31° 3'21.57"S and Longitude: 28°36'10.00"E	1269
Site 9	**Highly eroded 2:**	Latitude: 31° 3'24.44"S and Longitude: 28°35'59.06"E	1284
Site 10	**Highly eroded 3:**	Latitude: 31° 3'25.42"S and Longitude: 28°35'55.32"E	1262
Site 11	**Highly eroded 4:**	Latitude: 31° 3'27.50"S and Longitude: 28°35'50.60"E	1274

CHAPTER 3: AN EVALUATION OF WETLAND INDICES FOR ASSESSMENT OF THE ECOLOGICAL HEALTH OF HILLSLOPE SEEP WETLANDS IN THE TSITSA RIVER CATCHMENT

3.1 Introduction

Wetlands play a crucial role in maintaining the functioning of aquatic ecosystems in the landscape (Meng et al., 2017). They are among the most utilised ecosystems, providing valuable services such as water for domestic use, grazing for livestock, land for cultivation and fibre for crafts and construction (Collins, 2005; Sieben et al., 2016).

Despite their importance, wetlands are under severe threat (Gardner et al., 2015; Hu et al., 2017; Sieben et al., 2017). It has been estimated that 50% of the world's wetlands have been lost because of agricultural activities (Drayer and Richter, 2016). Human pressure on wetland ecosystems has necessitated the development of a range of wetland assessment techniques and approaches to assess the health and condition of wetlands, such as the Floristic Quality Assessment Index (FQAI) (Swink and Wilhelm, 1979, 1994), Wetland Index Value (WIV) (Cowden et al., 2014), WET-Health (Macfarlane et al., 2008) and Floristic Assessment Quotient for Wetlands FAQWet (Ervin et al., 2006). Understanding the health and condition of wetlnds is necessary to inform management decisions.

The Floristic Quality Assessment (FQA), used for estimating the biological condition of wetlands, is based on the overall conservatism of the species assemblage (Rocchio et al., 2007) and is one of the most widely used wetland assessment tools in the United States of America (Swink and Wilhelm, 1994; Chamberlain and Brooks, 2012; Bell et al., 2017; Bauer et al., 2018). The FQA employs a numeric quality rating and a coefficient of conservatism (CC) to indicate the affinity of plant species to a particular habitat, or tolerance to disturbances (Cohen et al., 2004). The CC ranges from 0 to 10, with a high CC score (9–10) indicating that such plants have a high fidelity to particular habitat types and are less tolerant of disturbances, whereas plants with low CC (scores of 0–3) are those that are found in a wide variety of habitat types and disturbance regimes (Chamberlain and Brooks, 2016). The resulting list of CC scores is used to calculate indices such as the FQAI and a mean CC (Freyman et al., 2016).

Because the FQAI requires a comprehensive list of species with CC that are not readily available in most countries, Bourdaghs (2006) and Chamberlain and Brook (2016), modified FQAI using only dominant species. When FQAI (dominant) and FQAI (all species) were compared, no significant differences in their response to human pressure was observed (Bourdaghs, 2012). FQAI (dominant) is useful because most users are able to identify common wetland plants (Chamberlain and Brook, 2016), but using only dominant species may result in homogenisation of plant lists, making the tool less sensitive to anthropogenic disturbance (Chamberlain and Brook, 2016).

Similarly, because comprehensive records of species CCs are unavailable for most regions, Ervin et al. (2006) developed an index called the Floristic Assessment Quotient for Wetlands (FAQWet index). The FAQWet index incorporates WIS and the native status of plant species, and serves as an alternative to FQAI where CCs are unavailable (Ervin et al., 2006). The FAQWet index includes information on the presence of exotic species not included in the original FQAI. Ervin et al. (2006) argue that exotic species may have negative consequences for wetland condition, regardless of regional conservatism of native species present.

In South Africa, the most widely used wetland assessment tool is the WET-Health (Macfarlane et al., 2008) which was designed for assessing the ecological condition of wetlands based on the impacts of human-induced stressors on hydro-geomorphic processes and vegetation responses (Kotze et al., 2012). It uses the Present Ecological State (PES) of the hydrology, geomorphology and vegetation cover of a wetland, and the anticipated future trajectory of change. In assessing the ecological condition, unlike FQAI and FAQWet that use site specific information, WET-Health uses whole catchment information.

Indices developed to date are used for assessing general wetland conditions, but their performance for assessing hillslope seep wetlands has not been widely tested. Hillslope seep wetlands are unique because i) they are small, making them extremely vulnerable to disturbances; ii) they depend completely on groundwater, which is easily influenced by seasonality; iii) they are located on steep slopes, further exacerbating their potential vulnerability to pressure; iv) their evergreen nature within the context of the broader catchment makes them attractive for all-year grazing, and thus subject to intense pressure. Given the uniqueness of hillslope seep wetlands, the main objective of this chapter is to assess the ecological health of hillslope seep wetlands using biological assessment. The sub-objectives to achieve Objective 1 were: i) to evaluate the performances of FQAIall, FQAIdom, FAQWet and WET-Health in assessing the ecological health of the selected hillslope seep wetlands; ii) to evaluate the sensitivity of the indices to hydrological alteration activities; iii) to assess the spatial-temporal redundancy between FQAIall and FQAIdom to ascertain whether they can be used interchangeably in the context of hillslope seep wetland and iv) to provide basic physico-chemical properties of soils of the studied hillslope seep wetlands. This chapter fulfils Objective 1 of the overall study (Chapter 1, section 1.8).

3.2 Methods

3.2.1 Vegetation sampling

The vegetation of the eleven hillslope seep wetlands was sampled in summer (February) 2016 and winter (August) 2017 to assess the wetland conditions in the two seasons. A 100 m transect was established from the highest to the lowest elevation of each hillslope seep wetland. Each transect was marked with small steel pegs so that they could be accurately located in the next sampling season. The vegetation in each site was sampled in two ways. First, the assessment of vegetation collection and cover was carried out using a quadrat method. Five (0.2 m^2) quadrats were placed along each transect at intervals of 20, 40, 60, 80, and 100 m. In each 0.2 m^2 quadrat, species relative cover and total vegetation cover was recorded. Secondly, all the vascular species were recorded along the transect to determine species composition using the step-point method (Evans and Love, 1957).

3.2.2 Indices used for assessing hillslope seep wetland condition

Floristic Quality Assessment Index (FQAIall and FQAIdom)

A range of indices was used to assess the biological condition of the studied hillslope seep wetlands and the indices were then evaluated for their performances. For each hillslope seep wetland, species were listed and assigned a CC, which is a subjective rating from 0 to 10. The CCs were assigned based on the opinion of a panel of four expert botanists. The original FQAI developed by Swink and Wilhelm (1979, 1994) was modified to include non-native species, which were taken as indicators of anthropogenic disturbances (Allain et al., 2004). FQAI was calculated based on both total (FQAIall) and dominant species (FQAIdom) for each site assessed. Dominant plant species in each site were defined as those whose cover was equal or greater than 20% (Yepsen et al., 2014).

The CC scoring criteria in this paper followed Chamberlain and Ingram (2012):

- 0–3 plants with a broad range of ecological tolerances that are found in a variety of plant communities;

- 4–6 plants with an intermediate range of ecological tolerances that are associated with a specific plant community;
- 7–8 plants with a narrow range of ecological tolerances that are associated with advanced successional stage;
- 9–10 plants with a high degree of fidelity to a narrow range of pristine habitats.

The FQAI score for each site was calculated using the following equation developed by Miller and Wardrop (2006):

$$\mathrm{FQAI} = \left(\frac{C}{10}\right) * \left(\frac{\sqrt{N}}{\sqrt{S}}\right) * 100$$

Where: C = Mean coefficient of conservatism (determined by dividing the sum of the coefficient of conservatism values of each species);

N = Native plant species richness;

S = Total species richness at a site including non-native species.

Floristic Assessment Quotient for Wetlands (FAQWet index)

This index is based on wetness coefficients (WC), derived from the five main Wetland Indicator Categories given by Reed (1988). Each species is assigned a WC value from +5 (uplands) to -5 (obligates) (Table 3.1). The WC values for the present study were assigned based on the wetland plant species database developed by Sieben et al. (2014) and the wetland plant guide by van Ginkel et al. (2011). A low FAQWet score indicates low native species richness or high levels of disturbances within the site; a high score indicates high native species richness or low levels of disturbances (Yepsen et al., 2014). The FAQWet scores for each site were calculated based on Ervin et al. (2006):

$$\mathrm{FAQWet} = \sum \mathrm{WC} \,/\, \sqrt{\mathrm{S}} \; * \mathrm{N} \,/\, \mathrm{S}$$

Where WC is the wetness coefficient value assigned to each species;

S is the species richness per site;

N is the number of native species at each site.

Table 3. 1: **Wetness coefficients based on Wetland Indicator Status (WIS) categories (Herman et al., 2001 and Ervin et al., 2006)**

Indicator Status	Probability of Occurrence in Wetlands	Wetness Coefficient
Obligate wetland (OBL)	>99%	+5
FACW+		+4
Facultative Wetland (FACW)	67–99%	+3
FACW-		+2
FAC+		+1
Facultative (FAC)	34–66%	0
FAC-		-1
FACU+		-2
Facultative Upland (FACU)	1–33%	-3
FACU-		-4
Upland (UPL)	<1%	-5

The WET-Health assessment tool

The WET-Health tool developed by Macfarlane et al. (2008) was employed in this study to assess the present state of the hillslope seep wetlands and identify the stressors contributing to their diminished health. A fieldwork assessment based on observed and measured attributes of each hillslope seep wetland was carried out to assess the present state using three components at the hydro-geomorphic (HGM) unit level (Macfarlane et al., 2008). The index uses three submetrics, hydrology, geomorphology and vegetation to assess wetland present ecological status. Each metric within the index is assessed and the score aggregated to provide an overall score reflecting the status of the site. A score range from 0–10 were calculated for each of the three component metrics, calculations of each of the three components per site are provided in appendix 1c. The scores of the components were then placed into the following equation: ***Health = [(Hydrology category x 3) + (Geomorphology category x 2) + (Vegetation category x 2)] / 7.***

WET-Health assessment is an impact-based approach that employs a scale of 0 to 10, with higher scores (8-10) indicating critical impact, and lower scores (0-0.9) indicating a small impact or natural condition ((Macfarlane et al., 2008) (Table 3.2). The WET-Health assessment was only conducted in winter as it is based on the catchment characteristics, which are prone to fewer changes, compared with site level characteristics that can easily change, given the sizes of hillslope seep wetlands.

Table 3. 2: **Relationship between impact scores and present state of wetland condition (Macfarlane et al., 2008).**

Impact category	**Description**	**Impact score range**	**Present state category**
None	Unmodified, natural.	0 – 0.9	A
Small	Largely natural with few modifications in ecosystem processes and a small loss of natural habitats and biota.	1 – 1.9	B
Moderate	Moderately modified with moderate change in ecosystem processes; loss of natural habitats has taken place, but natural habitat remains predominantly intact.	2 – 3.9	C
Large	Largely modified with a large change in ecosystem processes and loss of natural habitat and biota.	4 – 5.9	D
Serious	The change in ecosystem processes and loss of natural habitat and biota is great, but some remaining natural habitat features are still recognisable.	6 – 7.9	E
Critical	Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8 – 10	F

3.2.3 Assessing anthropogenic pressure in the studied hillslope seep wetlands

The Anthropogenic Activity Index (AAI) is an index for qualitatively assessing the degree of human disturbance based on visual inspection of a site (Yepsen et al., 2014). In this study, the AAI was used to assess the degree of disturbance at each of the hillslope seep wetlands using the AAI protocol developed by Ervin et al. (2006), which is a modification of the index used by the Minnesota Department of Environmental Quality (Gernes and Helgen, 2002) and includes some sections from Rapid Assessment Method (RAM), the USA disturbance ranking system (Mack, 2001). The AAI scoring system is based on the idea that human disturbance contributes to the degradation of wetland condition (Fennessy et al., 2007) and each wetland studied was scored based on five influence metrics: (i) surrounding land-use intensity, (ii) soil disturbance, (iii) hydrological alteration, (iv) habitat alteration within the wetland, (v) vegetation community quality.

Because the AAI disturbance criteria are subjectively assessed, two assessors undertook the exercise in the field and their results were compared and harmonised. The AAI scores range from 1 to 15 (Table 3.3). Wetlands with scores 1 to 5 are regarded as least disturbed, 6 to10 moderately disturbed, and >10 highly disturbed. Scores from the five metrics are summed to obtain the degree of disturbance per site per season. Given that hillslope seep wetlands are sensitive to hydrologic disturbance, an indirect hydrologic measure (hydrologic alteration metric (HMA)), a component of the AAI, was used to assess hydrological activities likely to alter the wetland hydrological regime, including the degree of hydrologic alteration caused by human activities. Sites were classified into three groups, based on the observed activities likely to alter hydrologic processes (AAI metric 3, Table 3.3). The hydrologic alteration scores were: Low (score of 1), Moderate (score of 2), or High degree of alteration (score of 3) (Ervin et al. 2006)

Table 3. 3: **Anthropogenic Activity Index (AAI) for the Tsitsa River Catchment, modified from Ervin et al. (2006).**

	METRIC 1: Surrounding land-use intensity	
Degree of intensity	**Description**	**Rating**
Low	Mostly undisturbed but some human/animal influence (e.g. a few livestock trails and footpaths).	1
Moderate	Moderate evidence of human/animal influence (e.g. active livestock grazing and or small-scale agriculture).	2
High	Extensive evidence of human influence e.g. commercial or large-scale farming (plantations).	3
	METRIC 2: Soil disturbance	
Degree of disturbance	**Description**	**Rating**
Low	Small areas of bare soils (e.g. patches of soil and vegetation).	1

Moderate	Moderate areas of bare soils and/or desiccated soils (e.g. cracks in the soil).	2
High	Extensive areas of soil disturbance (e.g. gully, rills and soil compacted).	3
	METRIC 3: Hydrologic alteration	
Degree of alteration	**Description**	**Rating**
Low	Low-intensity alteration (not currently affecting wetland).	1
Moderate	Significant and visible influence that is current and active.	2
High	High-intensity activity with major disturbance currently and actively affecting hydrology, e.g. ditch inlet, installed weir, levee, used for drainage, road bed, excavation, trampling, cultivation, dead vegetation and others.	3
	METRIC 4: Habitat alteration within the wetland	
Degree of alteration	**Description**	**Rating**
Low	Some removal of vegetation but vegetation is able to recover.	1
Moderate	Significant alteration (e.g. trampling, grazing and/or footpaths).	2
High	Intensive disturbance (e.g. overgrazing, trampling, bare soils).	3
	METRIC 5: Vegetation community quality	
Vegetation Quality	**Description**	
High	High species diversity and a predominance of native species, with non-native species absent or virtually absent.	1
Moderate	Moderate to moderately high species diversity and a predominance of native species although non-native or disturbance-tolerant species may be present.	2
Low	Low species diversity and/or predominance of non-native or disturbance-tolerant native species.	3

3.2.4 Assessing wetness zone and indicators species

The zone of wetness within each wetland was determined, based on the method used by Kotze et al. (1994) and DWAF (2005). The delineation method involves an assessment of the degree of mottling and measurement of soil matrix chroma using a *Munsell Soil Colour Chart* at a soil depth of 0–10 cm and 30–40 cm, using a one-metre soil auger within each vegetation plot. After measuring, morphological properties such as the matrix chroma, the mottles, the predominant vegetation were measured against a delineation chart to determine the long-term soil wetness and wetness zone as temporary, seasonal, or permanent (Table 3.4). On the basis of the description provided in Table 3.4, the sites were classified as temporary, seasonal and permanent wetlands.

Plant species were classified as indicators of wetland species following the methods of Reed (1988) and Lichvar et al. (2012) (Table 3.5). To determine whether vegetation is predominantly hydrophytic or non-hydrophytic, plant species were assessed using indicator status ratings based on the wetland plant guide by van Ginkel et al. (2011) and the wetland plant species database developed by Sieben et al. (2014).

Table 3. 4: **Soil and vegetation characteristics used to delineate wetlands and the determine wetland zonation. Matrix chroma is measured using a Munsell Soil Colour Chart (Kotze et al., 1994).**

	Wetness		
Soil	**Temporary**	**Seasonal**	**Permanent/Semi-permanent**
Soil depth 0–10 cm	Matrix brown to greyish brown (chroma 0–3, usually 1 or 2). Few/no mottles. Non-sulphidic.	Matrix brownish grey to grey (chroma 0–2). Many mottles. Sometimes sulphidic.	Matrix grey (chroma 0–1). Few/no mottles. Often sulphidic.
Soil depth 30–40 cm	Matrix greyish brown (chroma 0–2, usually 1). Few/many mottles.	Matrix brownish grey to grey (chroma 0–1). Many mottles.	Matrix grey (chroma 0–1). No/few mottles. Matrix chroma: 0–1.
Vegetation	Predominantly grass species; mixture of species which occur extensively in non-	Hydrophytic sedge and grass species which are restricted to wetland areas, usually <1m tall.	Dominated by: (1) emergent plants, including reeds (*Phragmites australis*),

	wetland areas, and hydrophytic plant species which are restricted largely to wetland areas.		**sedges** and bulrushes (*Typha capensis*), usually >1 m tall (**marsh**); or (2) floating or submerged aquatic plants.

Table 3. 5: **Classification of plants as indicators of wetlands based on their frequency of occurrence in wetland ecosystems (Reed, 1988; Lichvar et al., 2012)**

Species Designation	**Indicator Status (abbreviation)**	**Indicator Value**	**% Occurrence in Wetlands**	**Ecological Description**
Hydrophyte	Obligate (OBL)	1	99	Almost always occur in wetlands
Hydrophyte	Facultative Wetland (FACW)	2	67–99	Usually occur in wetlands, but may occur in non-wetlands
Hydrophyte	Facultative (FAC)	3	34–66	Occur in wetlands and non-wetlands
Non-hydrophyte	Facultative Upland (FACU)	4	1–33	Usually occur in non-wetlands, but may occur in wetlands
Non-hydrophyte	Upland (UPL)	5	1	Almost never occur in wetlands

3.2.5 Soil sampling

Two soil samples were collected in each hillslope seep wetland at a soil depth of 0–10 cm and 30–40 cm, using a one-metre soil auger. The two samples were then mixed in one bag to create a composite single sample for the site (eleven samples in total per season). Soil samples were placed in a polyethylene plastic bag, labelled, and stored in a refrigerator at 4 ^{o}C. Soil variables – pH, nitrogen (N), electrical conductivity (EC), phosphorus (P), and potassium (K), calcium (Ca), magnesium (Mg), total cations, acid saturation and zinc (Zn) – were analysed at the Dohne Analytical Laboratory in Stutterheim. The variables were analysed according to the protocols described in the standard methods from the Agri Laboratory Association of Southern Africa, AgriLASA Soil Handbook (AgriLASA, 2004). These variables were selected since they are key major elements in plant growth. The soil was spread evenly on a drying tray and dried at an oven temperature of 50 to 60^{o} C. After drying, it was ground with a motorised roller-type grinder, then crushed between four metal wip rollers; the resiliency and absorbency of the rubber ensures that no concretions or hard parent material is crushed. A 1 mm sieve mounted on a rotating eccentric shaft sieved the material immediately. The milled sample was transferred to a polyethylene sample container and labelled with the appropriate laboratory number.

3.3 Statistical analysis

3.3.1 Evaluating the performance of FQAIall, FQAIdom, FQAWet, and WET-Health for assessing hillslope seep wetland health

In order to evaluate the performance of the studied indices in relation to hillslope seep wetland conditions, the indices, i.e. FQAIall, FQAIdom, FQAWet, and WET-Health, were regressed against the AAI for each season with the AAI being used to measure of anthropogenic disturbance. Simple linear regression was used to understand the association between independent or predictor variable and continuous dependent variables. In this study it was necessary to use the regression approach because the indices used such as FQAIall, FQAIdom and FAQWet, are considered as continuous dependent data, while AAI was used as an independent or predictor variable. Given the sensitivity of hillslope seep wetlands to hydrologic alteration, the indices were regressed against the hydrologic metric of the AAI alone (HMA) to evaluate their sensitivity to hydrologic changes. The hydrologic metric of the AAI quantifies activities likely to impact the hydrological regime of wetlands and was therefore used as an indirect measure of hydrological alterations. The linear regression analyses were undertaken using R version 3.4.0.

3.3.2 Assessing the redundancy between FQAIall and FQAIdom

The redundancy between FQAIall and FQAIdom was tested using Spearman's rank correlation analysis. Redundancy between the two indices was assessed in order to ascertain whether they can be used interchangeably, particularly because FQAIall usually demands CC values for all species, which may not always be available. The significance of the correlation was assessed at $p \leq 0.05$. Spearman rank correlation analyses were run in STATISTICA version 13.3.

3.3.3 Relating plant species assemblage to soil properties

Canonical correspondence analysis (CCA) was performed using Vegan package 2.4.4 in R version 3.4.0 (Oksanen et al., 2017, R Core Team, 2017) to examine the relationship between plant species distribution and the associated environmental variables. This analysis was used to identify correlations between the biological and environmental data (soil physico-chemical properties). Canonical correspondence analysis was chosen as the most appropriate ordination technique for both winter and summer results because, during data exploration, detrended correspondence analysis (DCA) returned a gradient length >2.5, indicating that the datasets met the unimodal assumption of a CCA (ter Braak and Smilauer, 2002).

3.4 Results

3.4.1 Plant species assemblage structure, the coefficient of conservatism (CC) and indicator status

A total of 78 species were identified over the study period. Of these, 52% were recorded in summer, 17% in winter, and 31% in both summer and winter. Across all the sites, most of the species identified were facultative upland and obligate wetland species, with the highest percentages of 33% and 27%, respectively (Table 3.6). A high number of sensitive species, such as *Kyllinga erecta, Themeda triandra*, *Tristachya hispida* with high CC scores (9–10) were observed in summer. These species are less tolerant of ecological disturbance and are restricted to largely unimpacted areas. However, most of the species observed in winter were those with a high and moderate range of tolerance to ecological disturbance, for example, *Stenotaphrum secundatum, Cynodon dactylon, Verbena brasiliensis* (Table 3.6). Among the recorded species in summer, the most dominant species were *Cymbopogon validus, Cyperus denudatus, Cyperus longus, Digitaria eriantha, Eragrostis curvula, Eragrostis plana, Haplocarpa lyrata, Helichrysum aureonitens, Hemarthria altissima, Juncus acutus, Mentha aquatic, Miscanthus capensis, Paspalum distichum, Scirpus nodosus, Senecio coronatus, Sporobolus Africanus*, and *Richardia brasiliensis*, while the most dominant species in winter were *Centella asiatica, Cymbopogon validus, Cyperus congestus, Cyperus longus, Eragrostis curvula, Eragrostis plana, Helichrysum nudifolium, Hyparrhenia dregeana, Juncus effusus, Marsilea minuta, Miscanthus capensis,* and *Paspalum distichum, Paspalum dilatatum,* and *Cynadon dactylon*

Table 3. 6: **Plant species present in all study sites with their assigned coefficient of conservatism and Wetland Indicator Status (WIS). Species marked with superscript (a) are dominant, (x) indicates species occurrence.**

Plant Species	Seasons		
Indicator status	**Winter/Summer**		**Coefficient of conservatism (CC)**
Obligates			
Callitriche spp		x	5
Cyperus denudatus^a		x	7
Cyperus fastigiatus		x	7
Cyperus longus^a	x	x	6
Cyperus marginatus		x	6
Ficinia spp		x	0
Ficinia nodosa		x	0
Fimbristylis complanata		x	6
Hemarthria altissima^a		x	7
Isolepis fluitans	x		8
Juncus dregeanus		x	8
Juncus effusus^a	x	x	4
Juncus lomatophyllus		x	4
Kniphofia spp		x	8
Kyllinga erecta		x	9
Marsilea minuta^a	x		6
Mentha aquatica^a		x	7

Paspalum distichum[a]	x	x	3
Knowltonia bracteata		x	7
Phragmites australis		x	6
Scirpus nodosus[a]		x	7
Facultative Wetland (FACW)			
Commelina africana		x	5
Cyperus congestus[a]	x	x	5
Helichrysum aureonitens[a]	x	x	6
Helichrysum mundtii		x	7
Juncus acutus[a]	x	x	5
Miscanthus capensis[a]	x	x	8
Panicum maximum	x	x	3
Paspalum dilatatum	x	x	0
Schizachyrium sanguineum		x	1
Sporobolus fimbriatus	x	x	6
Facultative (FAC)			
Hyparrhenia hirta	x		5
Kyllinga alata		x	9
Polygonum spp	x	x	5
Sporobolus africanus[a]	x	x	4
Richardia humistrata	x	x	0

cp Ajuga ophrydis		x	9
Trifolium repens		x	0
Facultative upland species (FACU)			
Alepidea amatymbica	x	x	9
Alloteropsis semialata		x	8
Berkheya spp		x	3
Centella asiatica[a]	x	x	0
Conyza scabrida		x	5
Cynodon dactylon	x	x	3
Digitaria eriantha[a]		x	5
Eragrostis capensis		x	5
Eragrostis curvula[a]	x	x	5
Eragrostis plana[a]	x	x	4
Eragrostis planiculmis	x		6
Haplocarpa lyrata[a]		x	8
Hyparrhenia dregeana[a]	x	x	5
Hypoxis acuminata		x	7
Hypoxis colchicifolia	x		7
Hypoxis spp		x	7
Lithospermum papillosum	x		6
Richardia brasiliensis		x	0
Senecio coronatus[a]		x	6

Senecio spp		x	3
Senecio speciosus		x	6
Stenotaphrum secundatum	x		0
Gerbera viridifolia		x	6
Verbena brasiliensis	x		0
Wahlenbergia spp		x	8
Upland (UP)			
Argyrolobium stipulaceum		x	7
Baleria spp	x		3
Cheilanthes hirta		x	8
Corchorus asplenifolius	x		6
Cymbopogon plurinodis	x		7
Cymbopogon validus[a]	x	x	7
Eragrostis aspera		x	2
Erigeron karvinskianus	x		0
Geranium sanguineum	x	x	6
Helichrysum nudifolium[a]	x	x	6
Ornithogalum spp		x	1
Senecio inaequidens	x		6
Taraxicum officinale	x	x	0
Themeda triandra	x	x	9
Tristachya leucothrix		x	9

3.4.2 Assessing the conditions of the hillslope seep using WET-Health, FQAI and FAQWet

WET-Health assessment results showed that the present state of ten out of eleven wetlands were categorised as category C, signifying that these hillslope seep wetlands had undergone moderate modifications. One site, HE1, had the highest impact score of 4.57 and was categorised as a category D present state, signifying that the wetland had undergone large modifications in ecosystem processes and habitat loss. Although ten wetlands were listed as category C, less eroded sites had lower scores than the highly eroded sites (Figure 3.1).

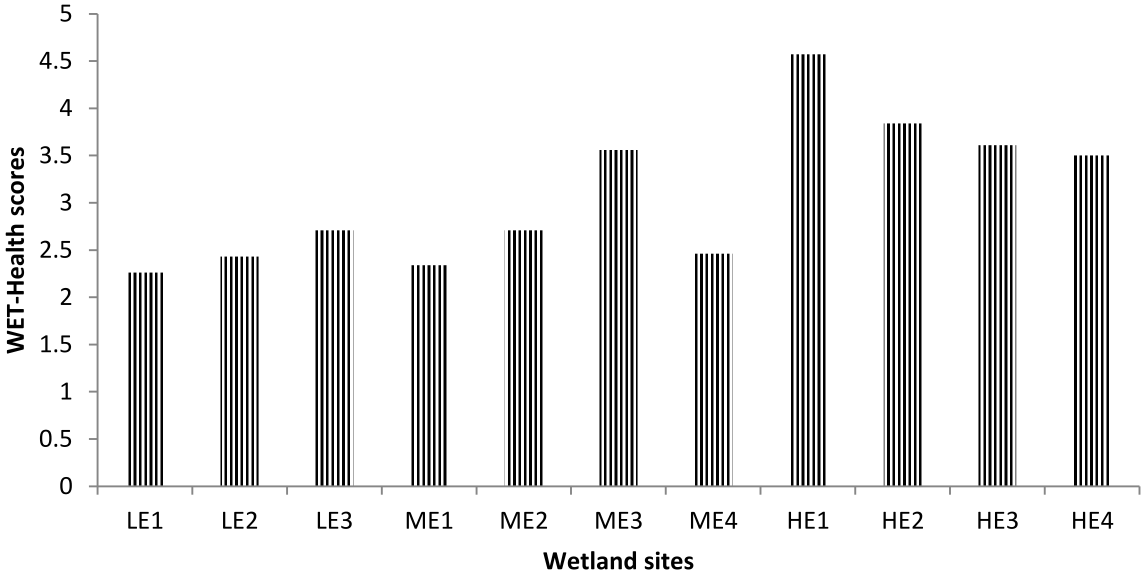


Figure 3. 1: The WET-Health scores recorded in each of the selected wetland sites (LE 1-3 = Less Eroded, ME1-4 = Moderately Eroded, HE1-4 = Highly Eroded).

The Floristic Quality Assessment Index (FQAIall and FQAIdom) scores were relatively lower in winter than in the summer season (Figure 3.2). In winter, most of the sites had FQAI scores of 38 to 45, while in the summer season, most of the sites had FQAI scores of 55 to 60. Comparison of the sites in winter showed that the scores for the LE sites were significantly higher than those of the highly eroded sites. However, scores for the summer season showed that there was not much difference in FQAI scores for the sites. Judging from the FAQWet index, the sites in summer had FAQWet scores close to 6, which was significantly higher than the winter site scores of close to -3 (Figure 3.3). A low FAQWet score indicates low native species richness or high levels of disturbance within the site while, a high score indicates high native species richness or low levels of disturbance.

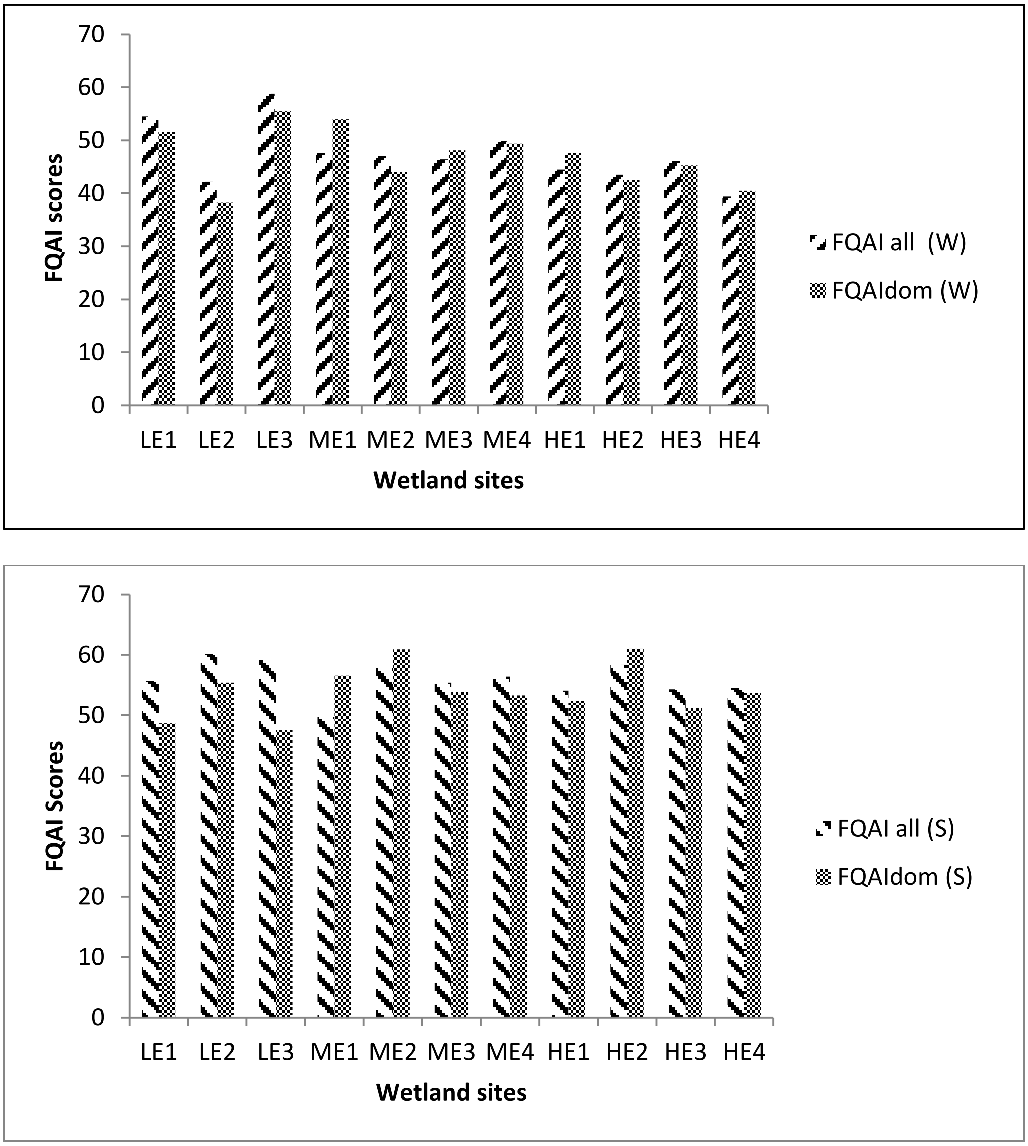


Figure 3. 2: **Floristic Quality Assessment Index (FQAI recorded in each of the selected wetlands in two seasons (LE 1-3 = Less Eroded, ME1-4 = Moderately Eroded, HE1-4 = Highly Eroded).**

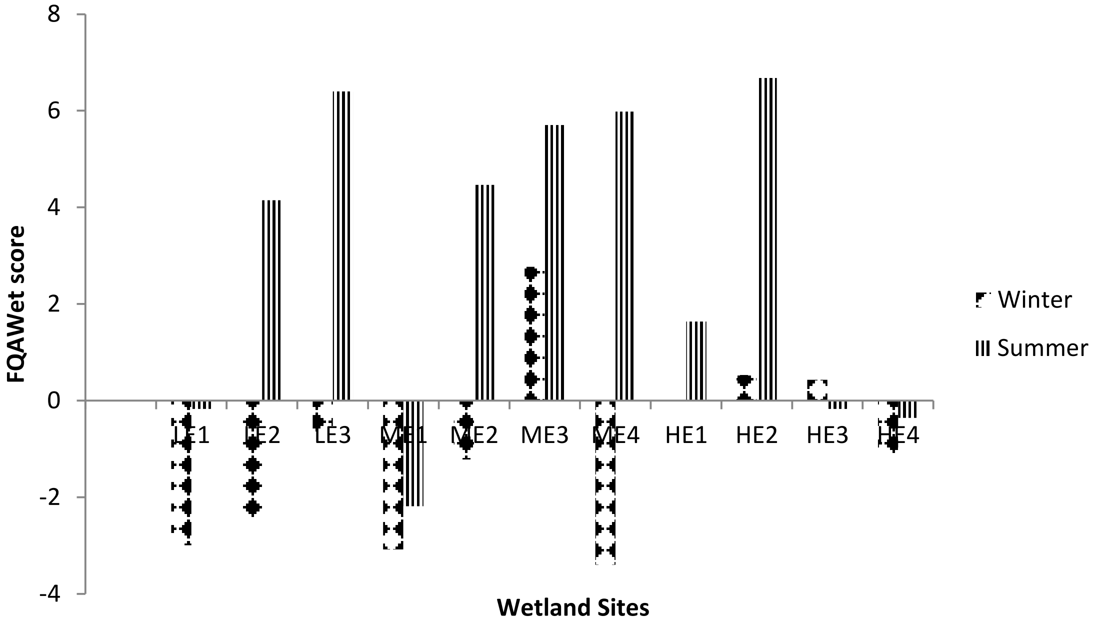


Figure 3. 3: **FAQWet scores recorded in each of the selected wetland sites and seasons (LE 1-3 = Less Eroded, ME1-4 = Moderately Eroded, HE1-4 = Highly Eroded).**

3.4.3 Evaluating the performance of FQAIall, FQAIdom FQAWet, and WET-Health in relation to human disturbance

The performance of the four indices was evaluated separately for the winter and summer seasons. In winter, all indices FQAIall, FQAIdom, FQAWet, and WET-Health were correlated to the AAI. Both FQAIall and WET-Health indices showed a strong significant relationship to the AAI. WET-Health had the strongest positive significant relationship to the AAI (R^2 = 0.85, *p* = 0.0007), while FQAIall had a strong negative significant relationship to the AAI (R^2 = 0.68, *p* = 0.021) (Figure 3.4). However, FQAIdom and FQAWet showed a non-significant but moderate negative (FQAIdom), and positive (FQAWet) relationship with the AAI in winter (R^2 = 0.53, p = 0.08 FQAIdom; R^2 = 0.56, p = 0.07 for FQAWet). In a comparison of all indices with HMA in winter, WET-Health showed a strong positive significant relationship with HMA (R^2 = 0.84, p = 0.0009); FQAIall showed a moderate negative significant relationship with HMA (R^2 = 0.6.0, p = 0.05); FQAWet had a moderate positive relationship that was not significant with HMA (R^2 = 0.53, p = 0.08), and FQAIdom had a weak negative correlation that was not significant with HMA (R^2 = 0.47, p = 0.13). In summer, all indices FQAIall, FQAIdom, and FQAWet, showed weak relationships that were not significant with AAI (Figure 3.5). Comparing the indices with HMA, FQAIall showed a moderate negative relationship that was not significant with HMA (R^2 = 0.54, p = 0.08), while no relationship was observed for FQAIdom and FQAWet with HMA (Figure 3.5).

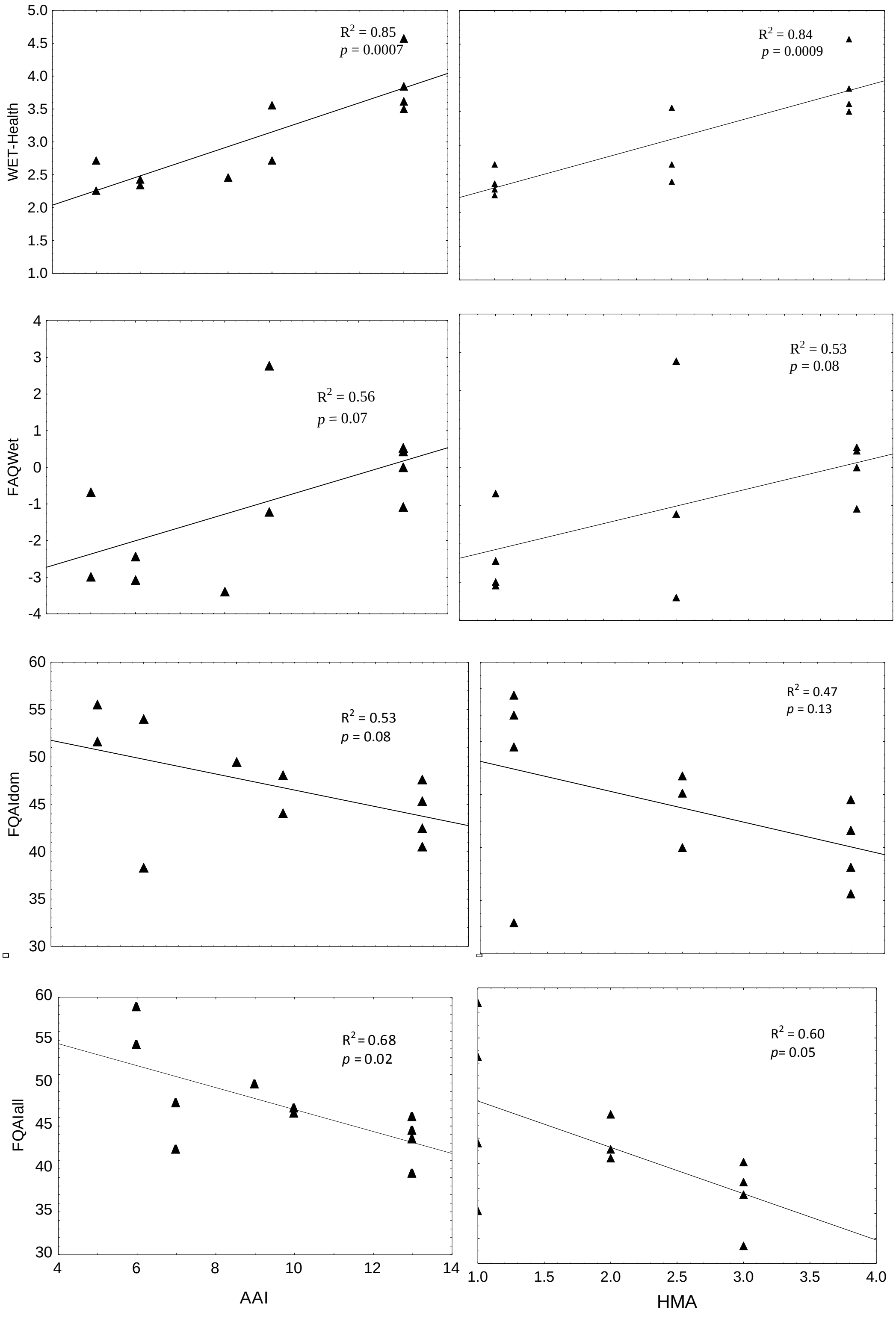


Figure 3. 4: Linear regression analyses for FQAIall, FQAIdom, FQAWet and WET-Health with full AAI (15 point scale) and HMA (3 point scale) during winter season for the 11 surveyed wetland sites.

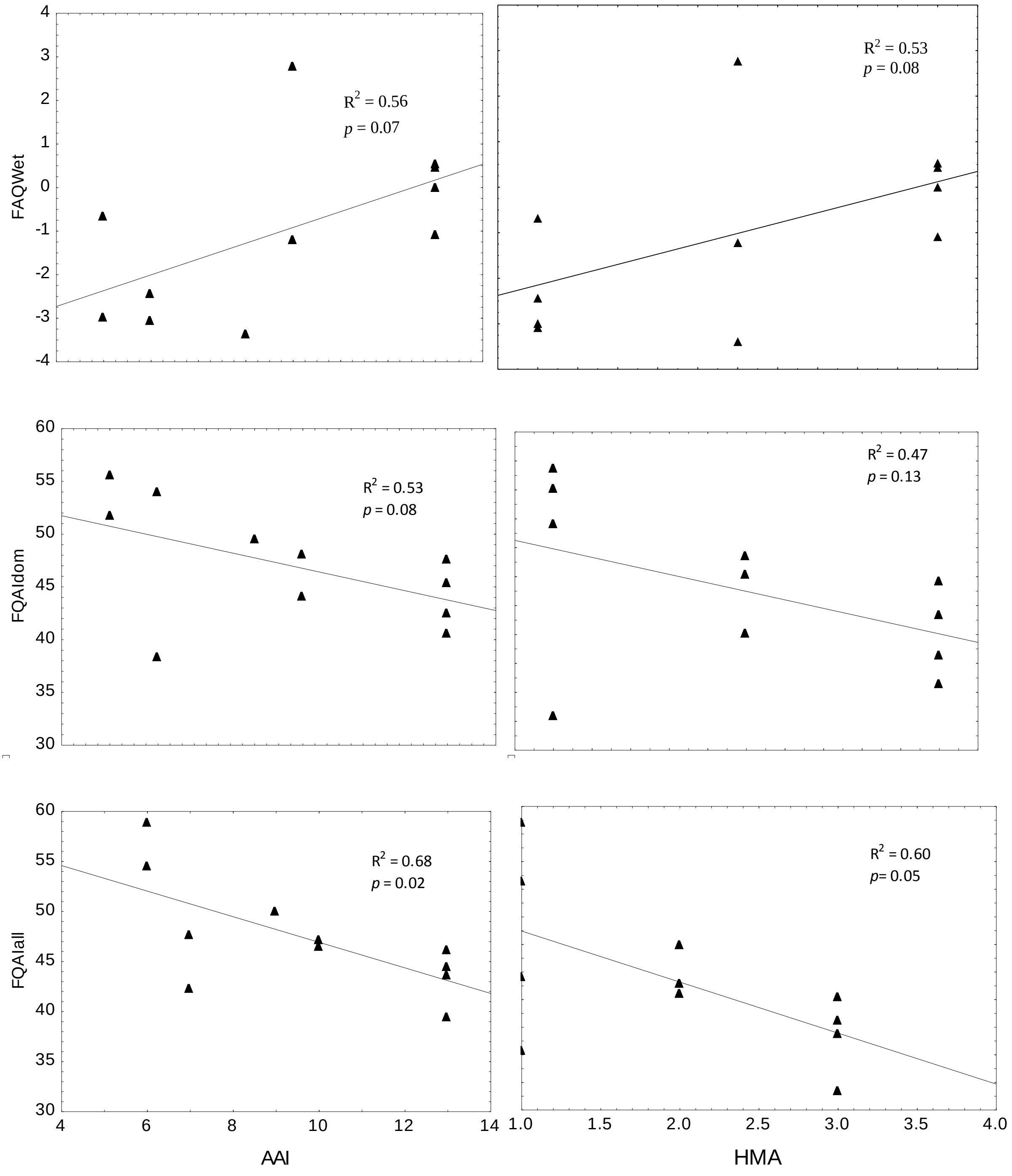


Figure 3. 5: **Linear regression analyses for FQAIall, FQAIdom and FQAWet with full AAI (15 point scale) and HMA (3 point scale) during summer season for the 11 surveyed wetland sites.**

3.4.4 Evaluating redundancy (co-linearity) between FQAIall and FQAIdom

Spearman's correlation was run to assess the correlation between FQAIall and FQAIdom. The results showed a strong positive correlation between the two indices in winter (r = 0.9, p = 0.0001) (Figure 3.6), indicating that the two indices were highly redundant in winter. In summer, there was no significant correlation (r = 0.15, p = 0.72) between the two indices (Figure 3.6) indicating non-redundancy. Overall, the result suggests that seasonality plays a significant role in terms of whether FQAIall or FQAIdom is used.

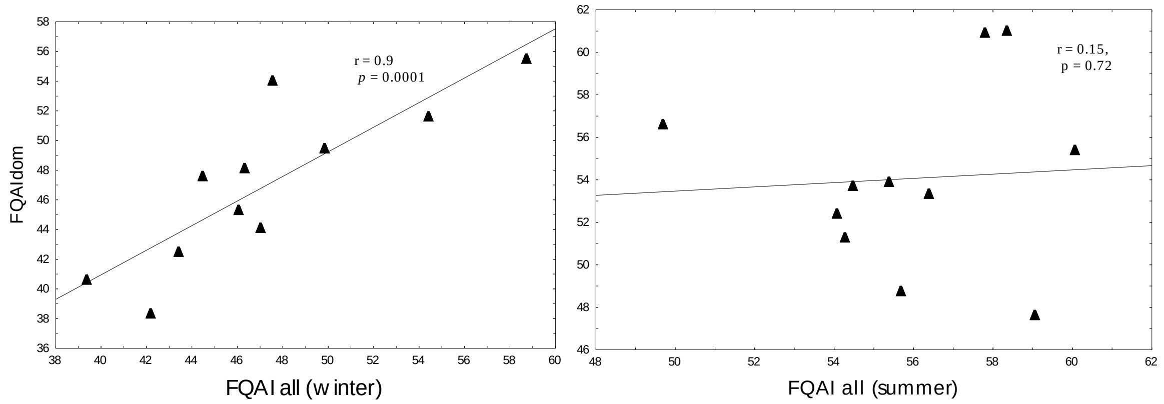


Figure 3. 5: **Correlation between FQAIall (all species) and FQAIdom (dominant species) for winter and summer season for the eleven hillslope seep wetlands.**

3.4.5 Basic soil physico-chemical variables for the studied sites by season

Soil environmental factors have important effects on plant growth and reproduction. The demand for soil nutrients in wetland plants also changes with the seasons. Seasonal differences in soil variables are therefore important in understanding the functionality of the wetland ecosystem. In summer, soil pH ranged between 3.91and 3.97 for LE sites, 3.89 and 4.59 for moderately eroded, 4.02 and 4.43 for highly eroded (Table 3.7). In winter, soil pH ranged between 3.76 and 4.37 for LE sites, 3.99 and 4.37 for moderately eroded, 3.72–4.48 for highly eroded sites. Although the pH was acidic in all sites, highly eroded sites were less acidic. Comparisons between readings taken in summer and winter indicated that, in all sites, the highest EC was observed in winter; the total nitrogen was higher in summer than in winter; the highest phosphorus was observed in the summer season, while the highest potassium (K) value was observed in the winter season. In both less and moderately eroded sites, the highest values of calcium were observed in winter, while in highly eroded sites, high Ca values were observed in summer (Table 3.7). In LE sites the highest value of Mg was observed in winter, while in moderately and highly eroded sites, Mg was observed in summer. Looking at total cations in less eroded sites, the highest value was observed in winter; in moderately and highly eroded sites, the highest value was in summer. Acid saturation and zinc varied little with site or season.

Table 3. 7: **The basic soil physico-chemical variables for the studied sites and seasons.**

	LE		ME		HE	
Variables	**S**	**W**	**S**	**W**	**S**	**W**
pH (KCl)	3.91–3.97	3.76–4.37	3.89–4.59	3.99–4.37	4.02–4.43	3.72–4.48
EC (uS/cm)	19.58–40.5	24.1–41.3	20.7–35.1	42.2–36.1	37.4–64.01	40.1–66.1
TN (%)	0.25–0.35	0.2–0.31	0.14–0.23	0.11–0.22	0.16–0.3	0.11–0.24
P (mg L^{-1})	18–26	03–12	06–29	8–9	8–24	4–10
K (mg L^{-1})	59–84	91–175	35–87	131–55	47–117	166–182
Ca (mg L^{-1})	687–1354	859–2221	1064–2305	1964–2360	1006–3369	936–2486
Mg (mg L^{-1})	140–258	156–458	303–842	206–454	250–702	148–614
Total cations (cmol L^{-1})	6.74–10.06	6.91–15.52	9.53–17.62	12.97–16.16	19.18–22.93	8.55–18.13
Acid Saturation (%)	10–22	2–18	1–16	3–15	1–20	7–21
Zn (mg L^{-1})	0.1–0.2	0.2–0.2	0.2–1	0.2–0.5	0.3–0.3	0.1–0.6

3.4.6 The relationship between individual species and environmental variables

The CCA ordination results of the relationship between plant species and environmental variables in summer revealed that all the less eroded sites (LE1, LE2, and LE3) were closely clustered, with the less tolerant species closely associated with the three sites. These species included *Digitaria eriantha, Panicum maximum, Themeda triandra, Sporobolus fibriutus,* and *Kyllinga alata*. The variables that were correlated with these species were acid saturation and exchange acidity (Figure 3.7). The highly eroded sites (HE1, HE3, and HE4) and moderately eroded site (ME1) were closely associated, sharing species such as *Eragrostis aspera, Terraria* spp*, Berkheya* spp*, Ornithogalum* spp, and *Haplocarpa lyrata*, and were strongly associated with pH, magnesium, calcium, electrical conductivity and total cations. The moderately eroded sites (ME2, ME3, and ME4) and the highly eroded Site HE1 were all clustered, sharing species such as *Polygonum* spp*, Hypoxis acuminate, Paspalum dilatatum, Mentha aquatic, Scirpus nodosus* and *Cyperus denudatus*, which were closely associated with zinc. Species such as *Tristachya hispida, Conyza scabrida, Cynodon dactylon* and *Centella asiatica* were closely clustered and were associated with phosphorus, total nitrogen and potassium variables (Figure 3.7).

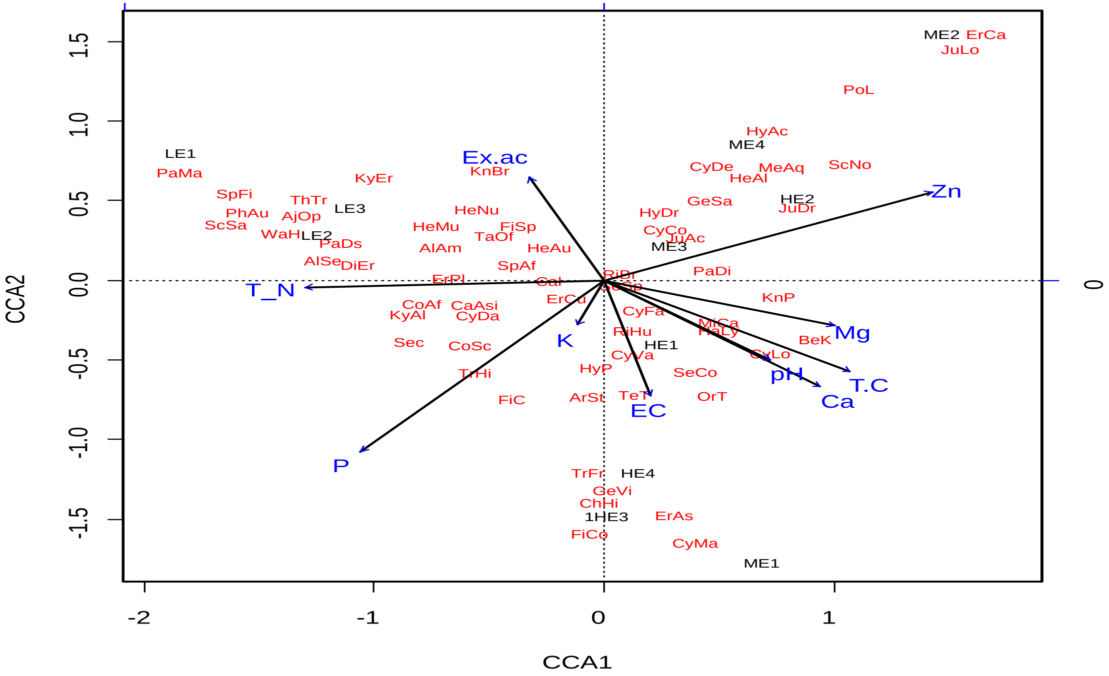


Figure 3. 6: **Canonical correspondence ordination diagram showing the correlations between species, environmental variables, and sites, during summer for the selected wetlands. Species abbreviations: CyMa=*Cyperus marginatus*, ErAs=*Eragrostis aspera*, GeVi=*Gerbera viridifolia*, OrT=*Ornithogalum* spp, SeCo=*Senecio coronatus*, CyVa=*Cymbopogon validus*, CyLo=*Cyperus longus*, BeK=*Berkheya* sp, HaLy=*Haplocarpa lyrata*, MiCa=*Miscanthus capensis*, CyFa=*Cyperus fastigiatus*, KnP=*Kniphofia* sp, SeSp=*Senecio speciosus*, PaDi=*Paspalum dilatatum*, RiBr=*Richardia brasiliensis*, CyCo=*Cyperus congestus*, JuAc=*Juncus acutus*, GeSa=*Geranium sanguineum*, HeAl=*Hemarthria altissima*, MeAq=*Mentha aquatic*, ScNo=*Scirpus nodosus*, CyDe=*Cyperus denudatus*, HyAc=*Hypoxis acuminate*, PoL=*Polygonum* sp, ArSt=*Argyrolobium stipulaceum*, FiC=*Ficinia* sp, TrHi=*Tristachya hispida*, CoSc=*Conyza scabrida*, Sec=*Senecio* sp, CyDa=*Cynodon dactylon*, KyAl=*Kyllinga alata*, CoAf=*Commelina Africana*, CaAsi=*Centella asiatica*, ErCu=*Eragrostis curvula*, Cal=*Callitriche* sp, ErPl=*Eragrostis plana*, SpAf=*Sporobolus Africanus*, HeAu=*Helichrysum aureonitens*, AlAm=*Alepidea amatymbica*, DiEr=*Digitaria eriantha*, AlSe=*Alloteropsis semialata*, PaDs=*Paspalum distichum*, HeMu=*Helichrysum mundtii*, ThTr=*Themeda triandra*, SpFi=*Sporobolus fibriutus*, PaMa=*Panicum maximum*. Environmental variables: (Ca)=Calcium, (Mg)=Magnesium, (Zn)=zinc, (P)=Phosphorus, (K)=Potassium, acid saturation, (Ex.ac)=exchange acidity, Total nitrogen (TN), electrical conductivity (EC). Site abbreviations: LE1 (Less eroded 1), LE2 (Less eroded 2), LE3 (Less eroded 3), ME1 (Moderately eroded 1), ME2 (Moderately eroded 2), ME3 (Moderately eroded 3), ME4 (Moderately eroded 4), HE1 (Highly eroded 1), HE2 (Highly eroded 2), HE3 (Highly eroded3), and HE4 (Highly eroded 4).**

The CCA ordination results for the relationship between environmental variables and species in the winter season are presented in Figure 3.8 and indicated that the less eroded sites (LE1 and LE2) were closely clustered together, sharing species such as *Eragrostis planiculmis, Hypoxis colchicifolia, Stenotaphrum secundatum, Helichrysum aureonitens, Verbena brasiliensis* and *Panicum maximum*. These species show a correlation with phosphorus. Sites ME1, ME4, HE1, HE3 and LE3 were closely clustered together, sharing species such as *Centella asiatica, Taraxicum officinale Lithospermum papillosum, Miscanthus capensis, Erigeron karvinskianus, Helichrysum nudifolium,* and *Paspalum dilatatum,* which are closely associated with zinc and exchange acidity. Sites ME2, ME3, and HE4 were closely associated, sharing species such as *Cyperus longus, Cyperus congestus, Sporobolus africanus,* and *Paspalum distichum* which have strong associations with potassium, calcium, and total cations. Species such as *Hyperrhia hirta, Marsilea minuta,* and *Sporobolus fibriutus,* which are closely associated with manganese pH and magnesium, shared the highly eroded site (HE2) (Figure 3.8).

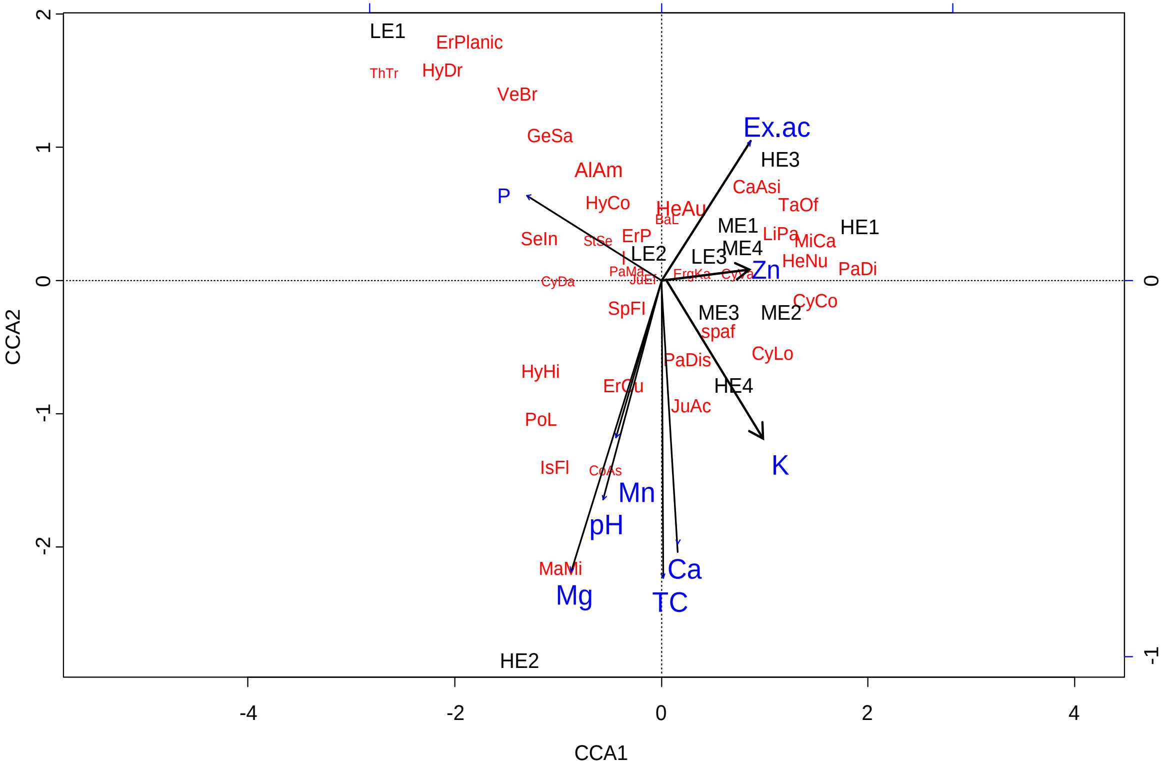


Figure 3. 7: **Canonical correspondence ordination diagram showing the correlations between species, environmental variables, and sites, during winter for selected wetlands**. **Species abbreviations:** ***AlAm=Alepidea amatymbica, BaL=Baleria*** **spp,** ***CaAs=Centella asiatica, CoAs=Corchorus asplenifolius, CyDa=Cynadon dactylon, CyVa=Cymbopogon validus, ErCu=Eragrostis curvula, ErPla=Eragrostis plana, ErgKa=Erigeron karvinskianus, GeSa=Geranium sanguineum, HeAu=Helichrysum aureonitens, HeNu=elichrysum nudifolium, HyDr=Hyparrhenia dregeana, HyHi=Hyperrhia hirta, HyCo=Hypoxis colchicifolia, IsFl=Isolepis fluitans, JuAc=Juncus acutus, JuEf=Juncus effuse, LiPa=Lithospermum papillosum, MaMi=Marsilea minuta, MiCa=Miscanthus capensis, PaDis=Paspalum distichum, PaDi=Paspalum dilatatum, PoL=Polygonum*** **sp,** ***SeIn=Senecio inaequidens, SpAf=Sporobolus africanus, SpFI=Sporobolus fibriutus, StSe=Stenotaphrum secundatum, VeBr=Verbena brasiliensis, PaMa=Panicum maximum, TaOf=Taraxicum officinale.*** **Environmental variables: (P) Phosphorus, (K) potassium, (Ca) calcium, (Mg) magnesium, (TC) total cations, zinc (Zn), (Ex.ac) exchange acidity, (Mn) Manganese. Site abbreviations: LE1 (Less eroded1), LE2 (Less eroded 2), LE3 (Less eroded 3), ME1 (Moderately eroded 1), ME2 (Moderately eroded 2), ME3 (Moderately eroded 3), ME4 (Moderately eroded 4), HE1 (Highly eroded 1), HE2 (Highly eroded 2), HE3 (Highly eroded3), and HE4 (Highly eroded)**

In summer, the first CCA axis, with an eigenvalue of 0.388, explains 20.85% of the total variance; the second axis, with an eigenvalue of 0.25, explains 13.4% of the total variance. The first three axes explain a cumulative variance of 46% (Table 3.8).

In winter, the first CCA axis, with an eigenvalue of 0.44, explains 25.17% of the total variance; the second axis, with an eigenvalue of 0.38 explains 22.01% of the total variance, and the first three axes explain a cumulative variance of 59%, showing that the CCA model captured the majority of the variance within the dataset (Table 3.8).

Table 3. 8: **Properties of the CCA ordination between the environmental variables and species in winter and summer for the studied seep wetland.**

Canonical properties	**Axis**		
Summer	1	2	3
Eigenvalue	0.388	0.2503	0.235
% Variance explained	20.85	13.4	12.49
Cumulative % variance explained	20.85	34	46
Winter			
Eigenvalue	0.44	0.38	0.22
% Variance explained	25.17	22.01	12.61
Cumulative % variance explained	25.17	47	59

3.5 Discussion

Hillslope seep wetlands are critical ecosystems in the Tsitsa catchment because of their potential to supply vegetation for year-round grazing. From a biophysical perspective, they are unique because of their small sizes, their complete dependence on groundwater, their location on steep slopes, and their evergreen nature within the context of the broader catchment. Despite these unique features of hillslope seeps, no assessment tool has been developed specifically for hillslope seep wetlands. In this study, widely used wetland indices FQAI, FQAWet and WET-Health were combined to assess the conditions of hillslope seep wetlands, and their performances assessed and compared.

The results of the WET-Health showed that the majority of hillslope seep wetlands were under category C, suggesting that the wetlands has been moderately impacted, mostly by agriculture activities. Similar results were reported by Digby Wells Environmental (Roy et al., 2017), which indicated that hillslope seep wetlands in the studied catchments were largely allocated a PES of C, as well as D. According to these authors, the major impacts relate to overgrazing and trampling by livestock.

With both the FQAI and FAQWet indices, high scores reflect less disturbance within a site, indicating high ecological integrity, while low scores reflect more disturbance (Ervin, 2009). The FQAI results indicate that hillslope seep wetlands in communal areas were more degraded than those in privately-owned lands. The FQAI results further indicate that evidence of degradation was more pronounced during the winter season than the summer season. The degradation of hillslope seep wetlands in communal areas could be attributed to poor wetland management practices, such as intense livestock grazing, and invasive alien invasive species around the communal wetlands. Similarly, a study conducted by Bella et al. (2018) in the Free State, South Africa, comparing the ecological status of wetlands in communal and private commercial farms found that communal wetlands were generally in a poor state as a result of uncontrolled livestock grazing. Walters et al. (2006) also report seeps as favoured foraging and drinking areas for livestock in communal areas and found that seep wetlands in communal areas had three times more bare ground than areas under conservation. The lower FQAI scores in communal areas can be also attributed to the high richness of species with low CC (species such as *Centella asiatica*, *Richardia humistrata*, and *Verbena brasiliensis*). These species, which tolerate heavy grazing, were dominant in communal areas. A study conducted by Palmer et al. (2002), reports that seep wetlands are the most commonly grazed in winter when wetlands provide the only good grazing.

Similar to the FQAI results, FAQWet results indicated that the degradation was more pronounced during winter than summer. However, this trend was not observed in all sites. In winter, FQAWet scores were lower, indicating a high level of anthropogenic disturbance, such as overgrazing. Because FQAWet uses indicator status, the lower scores could be attributed to less abundance of obligate species in winter because of their sensitivity to grazing. Coles- Ritchie (2007) reports an increase in obligate species found in wetlands where livestock activities were excluded compared to adjacent grazed wetlands. These results agree with those of Yepsen et al. (2014), who also found lower FAQWet negative values that were caused by the dominance of facultative and upland species in prior-converted wetland sites in USA.

Generally, the results show that all the indices used to assess wetland condition concurred that the selected hillslope seep wetlands in the Tsitsa River catchment have been impacted by anthropogenic disturbance: WET-Health results found most wetland sites were category C, and the relatively low scores of FQAI and FAQWet in the winter season strengthen this finding. The results suggest that all studied indices can be used individually to assess the ecological health of hillslope seep wetlands.

A number of studies (e.g. Bried et al., 2013; Spyreas, 2016) investigate the inter-annual and seasonal variability of FQAI scores. In the present study, FQAI scores were found to be consistently higher during summer than winter. The higher FQAI scores observed during the summer season could be explained by the high species richness of *Kyllinga erecta*, *Themeda triandra*, and *Tristachya hispida*, all of which had the highest CC score allocated to them. The results indicate less disturbance in hillslope seep wetlands since rangelands are also highly foraged during summer. Although this study recorded seasonal variability for the FQAI score, Spyreas (2016) found not much difference in FQAI scores across years; the study also indicates that variation of FQAI scores across years could be the result of fluctuations in species composition, and that changes in disturbance regimes led to exotic species establishment and invasion which can decrease FQAI scores.

3.5.1 Evaluating the performance of FQAIall, FQAIdom, FQAWet, and WET-Health in assessing hillslope seep wetlands

The relationship between FQAIall, FQAIdom, FQAWet, and WET-Health with the AAI/HMA was examined using linear regression for winter and summer seasons. The results of this study showed that both FQAIdom and FQAWet indices were weakly associated with AAI, compared with FQAIall and WET-Health. The results therefore indicate that FQAIdom and FQAWet are less useful indicators of ecological conditions of hillslope seep wetlands than FQAIall and WET-Health. Gianopulos et al. (2018) show that, by nature, many rapid indices such as FQAIdom would exclude rare species; therefore, the lower performance of FQAIdom could be attributed to eliminating rare species that might have had negative consequences for wetland conditions. Cohen et al. (2004) also suggest that targeting only abundant species introduces uncertainty related to intra- and inter-annual variability, and this approach needs to be adopted with caution. The findings of this study are also based only on eleven data points in each season and so necessarily have to be treated with caution. Decisions about use of measurement indices often come down to a cost-benefit assessment between accuracy and time i.e. some indices (FQAIdom) are designed to be rapid but necessarily produce slightly less accurate findings. Thus, FQAIall may be the more useful indicator overall (because it clearly combines more information) but only if you have the time to apply it.

Given that the study wetlands are impacted by disturbances such as grazing, indices using CC scoring criteria would give better results of ecological condition because CC are based on the ecological tolerance of species to disturbances. This could explain why FAQWet performed less effectively than FQAI as it is based on WC and species richness, which are less directly related to disturbances. Yepsen et al. (2014) also found that FQAI responds more strongly to anthropogenic activities than FAQWet. Although a study conducted by Ervin et al. (2006) found that the FAQWet method performs as well as the widely accepted FQAI across a broad gradient of human activity, they also found that the FQAI and disturbance correlation was stronger than the FAQWet.

The stronger response of WET-Health to anthropogenic activities observed in the present study could be attributed to the fact that, unlike the other tools, the overall score of WET-Health is based on three environmental components: hydrology, geomorphology and vegetation. These results demonstrate the crucial importance of these components in assessing wetlands, especially hillslope seeps that are heavily dependent on groundwater hydrology and are vulnerable to erosion.

Similar to the AAI, the results showed that FQAIall and WET-Health were strongly associated with HMA, compared with FQAIdom and FQAWet. The strong relationship between WET-Health and HMA could be attributed to the fact that the hydrology component of WET-Health takes into accounts the hydrologic characteristics that are used in HMA. The strong relationship between FQAI and HMA, compared to FQAWet, was surprising because FQAWet incorporates indicators of hydrologic characteristics; it was, therefore, expected to perform better than FQAI.

Generally, the current study suggests that both FQAIall and WET-Health are better indicators of hillslope seep wetland ecological health than the others tested.

3.5.2 Assessing the redundancy between FQAIall and FQAIdom

The study by Chamberlain and Brooks (2016) indicates that neglecting species either unintentionally, or through an inability to identify taxa to species level, or deliberately using only dominant species may be of little consequence in the overall assessment results. However, in the present study, when Spearman's rank correlation between FQAIall and FQAIdom was performed, the overall result suggests that seasonality plays a significant role in terms of whether FQAIall or FQAIdom can be used interchangeably. The winter results showed a high redundancy between the two indices, indicating that there might be minimal consequences in using only dominant species. In summer, however, little redundancy was observed between the two indices, indicating high consequences in using only dominant species. The results of this study imply that assessing the ecological health of hillslope seep wetland, particularly using dominant species in the summer season, might provide insufficient insight into the wetland condition. Additionally, because hillslope seep wetlands provide biomass for livestock grazing during the winter season, winter assessment might provide better results on the ecological assessment of FQAIall or FQAIdom. One reason for this could be the ability of the recorder to identify some of these plant species during the winter, which is notoriously difficult.

3.5.3 Plant species assemblage structure and relationship with soil physico-chemistry

Plants are regarded as good indicators of wetland condition because they often have a high level of species richness, rapid growth rates, and they respond quickly to ecological changes (Sieben et al., 2014). The number of species recorded in the present study was similar to that reported by Ngcaba and Maroyi (2017) who conducted a floristic composition in the grassland of the same catchment. The results of this study indicate that sensitive species were identified in winter however; their abundance was less compared to summer, which could be attributed to the fact that it is easier to identify some of the more sensitive species in summer before they are heavily grazed in the winter season. These species include *Kyllinga erecta Themeda triandra,* and *Tristachya leucothrix* which are preferred by grazing animals because of their palatability. The dominance of more sensitive species in summer than in winter suggests that grazing pressure in hillslope seep wetlands increased during winter as a result of the lack of fresh green vegetation in the surrounding rangeland; therefore, livestock graze more on hillslope seep wetlands during the dry season. This grazing pressure has led to the decline of sensitive species which are likely to be palatable. Similarly, a study conducted by Nsor and Obodai (2014) found a shift of species composition in the vegetation of wetlands driven by high grazing pressure in the dry season.

CCA ordination was used determine the associations between species, sites, and soil variables. Comparison of the ordinations of the two seasons showed a clear relationship between the site gradient and species in summer: most of the species that were found in LE sites were *Digitaria erientha, Panicum maximum, Themeda triandra, Sporobolus fibriutus,* and *Kyllinga alata*. The distribution of these species in LE sites could be attributed to low grazing intensity in these sites. These palatable species were mainly influenced by acid saturation and exchange acidity. Soil acidity influences the solubility of various elements in the soil, particularly some plant nutrients that influence the productivity of wetland plants. In southern Africa, the above-mentioned species are known to be palatable and they are the key indicators of good wetland condition. It is also clear from the results of this that there is a relationship between plant sensitivity and palatability; the species that were found to be palatable were sensitive to heavy grazing.

The species that were most associated with the highly eroded sites are *Eragrostis aspera, Terraria* spp, *Berkheya* spp, *Ornithogalum* spp, and *Haplocarpa lyrata,* this association could be attributed to the fact that they tolerate heavy grazing; hence their abundance is not surprising in communal areas where there is no grazing practice strategy. These species are mainly influenced by pH, magnesium, calcium, electrical conductivity and total cations. Electrical conductivity and pH were higher in these sites than in less and moderately eroded sites. The pH is a general indicator of soil nutrient availability in the soil, but it should be neither too low nor too high, because at low pH values, the availability of certain plant nutrients such as phosphorus, nitrogen, calcium, and magnesium may be limited, while at high pH values, (>7.5) the availability of phosphorus, copper, and zinc is limited.

In winter, there was no clear relationship between site gradient and species. For example, most species found in both less and highly eroded sites adapted well to overgrazing or disturbed areas. Livestock tend to avoid grazing these species. The lack of an obvious gradient in winter is more a reflection of species that were not being identified at this time. The distribution of *Eragrostis planiculmis, Hypoxis colchicifolia, Stenotaphrum secundatum, Helichrysum aureonitens, Verbena brasiliensis* and *Panicum maximum* was mainly affected by phosphorus. Phosphorus plays a fundamental role in plant nutrition and the concentration and availability of P determines, to a great extent, the soil fertility and site productivity as plants require P in relatively large amounts (Razaq et al., 2017).

3.6 Conclusion

All three indices showed that hillslope seep wetlands have been modified by anthropogenic disturbances. The performance of FQAIall, FQAIdom, WET-Health and FQAWet in assessing anthropogenic activities suggests that FQAIall and WET-Health were better indicators of hillslope seep wetland condition, proving to be useful tools for assessing the biological integrity of hillslope seep wetland ecosystems. In South Africa, WET-Health is the primary tool for assessing wetland condition, but no studies have compared WET-Health performance with tools such as FQAI and FQAWet, which are used elsewhere. The present study therefore provides evidence for the use of WET-Health and FQAIall to assess the health of hillslope seep wetlands. A key limitation of the present study is that South Africa has no comprehensive list of species with assigned CC scores, indicating that research is needed to compile a database of regional wetland plant species with their coefficients of conservatism. Unfortunately, the limitation could not be circumvented through the use of only dominant species as the current results indicated that FQAIall and FQAIdom were not redundant during the summer season.

CHAPTER 4. A NOVEL TRAIT-BASED APPROACH FOR ASSESSING THE VULNERABILITY AND RESILIENCE OF HILLSLOPE SEEP WETLAND PLANT SPECIES TO DISTURBANCES IN THE TSITSA RIVER CATCHMENT, EASTERN CAPE, SOUTH AFRICA

4.1 Introduction

Hillslope seep wetlands are among the least studied wetlands, yet most vulnerable to disturbances because of their small sizes and steep slope (Ellery et al., 2008). They are typically formed when groundwater flows over an impermeable rock forcing the water to the surface so that on the surface, a hillslope seep is formed (Collins, 2005). Although hillslope seep wetlands are recognized as being important, they are disappearing rapidly because of human disturbances (Roy et al., 2017). In the Tsitsa River catchment in South Africa, hillslope seeps are declining (Buckle pers. comm) due to disturbances such as poor land use management practices and grazing.

Human-induced disturbances are the most important factors structuring the taxonomic and functional composition of vegetation of wetlands (Bernhardt-Romermann et al., 2011). In this study, the potential effect of livestock grazing on the resilience and vulnerability of hillslope seep wetland vegetation is investigated. Livestock grazing is known to be a major disturbance altering the condition of wetlands and rangeland (Jones et al., 2010). The impact of livestock grazing on grasslands has been the subject of many studies (Dorrough et al., 2004; Adler et al. 2004; Cingolani et al. 2005, Pakeman and Marriott, 2010), but not much attention has been paid to plant resilience/vulnerability in hillslope seep wetland in relation to grazing. Engelhardt and Kadlec (2001) show that plant species losses and changes in diversity can decrease the resilience of ecosystems after a disturbance and can also alter ecosystem functioning. The biological responses of ecosystems to environmental perturbation depend largely on the individual species traits possessed by the assemblage. Traits play a central role in understanding species - environment relationships because they influence the response of species to environmental disturbances (Piliere et al., 2016). Focusing on species traits therefore provides opportunity for understanding the mechanistic relationship between biological response and the driver of change, as well as predicting the potential responses of biological assemblages to disturbances such as grazing (McGill et al., 2006). A trait-based approach (TBA) to predict vegetation response to human activities could help in understanding the potential vulnerability of plant species to a specific stressor and a group of stressors (Odume et al., 2018).

Several models about the effect of livestock on plant communities in terms of species traits have been developed to predict plant responses to grazing (Díaz et al., 2007). The generally held hypothesis is that the sensitivity of plant communities to grazing depends on the frequency and strength of plant adaptations to avoid or tolerate herbivory (Vesk and Westoby 2001; Díaz et al., 2001). This hypothesis predicts that grazing impacts are likely to be minimal in systems where grazing-resistant traits are well developed and common among plant species, as opposed to systems where such traits are poorly developed or rare (Dubey et al., 2011). Many of these plant trait models have been developed and applied in terrestrial ecosystems, such as grasslands (de Bello et al., 2010). At the moment, however, very little is known about traits and vegetation resilience or vulnerability in hillslope seep wetlands. Therefore, the objectives of this component of the study is to develop a TBA to

i. assess and predict the potential vulnerability and resilience of plant species in seep wetlands to human-induced disturbances, including grazing, using a combination of traits, and
ii. Assess wetland species response to disturbances, using individual trait attributes.

It was hypothesized that species deemed vulnerable to human disturbances, based on the developed TBA, were likely to be less associated with disturbed sites than those designated as resilient.

4.2 Methods

4.2.1 Developing a trait-based approach (TBA) for assessing plant species vulnerability to livestock grazing in hillslope seep wetlands

The capacity to predict vegetation responses to disturbances, such as grazing, requires an understanding of the mechanistic relationship between plant-environmental disturbances, mediated by traits (Lavorel and Garnier, 2002). Trait-based approaches, in general, have become recognized as an important approach to bioassessment (Baird et al., 2008). Trait-based approaches could provide signals regarding what environmental factors may be responsible for the impairment and, thereby, provide causal insight into the interaction between species and stressors (Baird et al., 2008). The approach followed in this study was largely adapted from Odume et al. (2018) and follows five steps in classifying plant species into vulnerable groups:

i. Reviewing the literature reported on grazing modes of stress on plant species;

ii. Trait selection and measurement;

iii. Identifying plant traits deemed mechanistically linked to disturbance factors, such as livestock grazing;

iv. Identifying vulnerable trait attributes from the selected trait categories;

v. Grouping plant species into three vulnerability groups, based on the combination of plant traits.

Reviewing the literature for grazing modes of stress on vegetation

Grazing is a complex process that has several effects on plants (Xu et al., 2013). The impact of livestock grazing was reviewed in this study and showed that the impact on vegetation systems follows direct and indirect pathways. As reflected in Table 4.1, direct impacts are related to trampling, plant biomass removal and soil compaction, while indirect impacts are related to shifts in species composition.

Table 4. 1: **A summary of modes by which grazing impact on plant communities.**

Grazing mode of stress	Impacts on vegetation
Trampling	Trampling of plant by livestock is common in wetland ecosystems and it negatively impacts on ecosystem functioning, leading to a reduction in vegetation cover and degradation of plant communities (Pescott and Steward, 2014). Trampling has a direct mechanical effect on plants by causing physical damage through either excess flexural loading or by crushing plant organs (Sun and Liddle, 1993). Species have differential response to trampling and the impact of trampling differs among individual plant traits. Smaller leave sizes and shorter plants are likely to be more resilient to trampling because of their traits (Sun and Liddle, 1993). Trampling may also compact the soil surface, rendering it more susceptible to runoff and erosion (Dunne et al., 2011).
Removal of plant biomass	Grazing may reduce plant biomass and leads to bare patches. Bare ground in wetlands increases soil erosion and accelerates water runoff which increases the amount of soil particles entering the water column (Morris and Reich, 2013). The reduction in plant biomass may provide opportunities for unpalatable species to replace palatable ones (Collins, 2005). The removal of biomass can reduce the amount of water infiltrating the soil which can lead to reduced plant growth. All these factors may in turn have negative impact on wetland condition. Removal of plant biomass is not spatially homogeneous but rather manifests as a patch mosaic within a landscape strongly influenced by the growth form of the plant itself, its palatability, its accessibility (e.g. on a steep slope versus a valley bottom) and the grazing animal species present and their ability to selectively forage - animals make selective choices at patch scales and selective grazers such as sheep do this more effectively than bulk grazers such as cattle.
Shift in vegetation communities	The shift in vegetation communities is an indirect effect of grazing. This may occur due to overgrazing or trampling that may allow changes from the dominance of palatable grasses and forbs towards dominance by unpalatable forbs and weedy annuals (McIntyre and Lavorel, 2001).

Trait selection and measurement

The selected plant traits were those that were deemed mechanistically linked to livestock grazing disturbances. Seven plant traits and 27 trait attributes were selected. The seven plant traits were measured according to the standardised world-wide protocol described by Cornelissen et al. (2003) and included plant height, specific leaf area, palatability, leaf size, leaf dry matter content, longevity (years), and resprouting potential (Table 4.2).

Specific Leaf Area (SLA) was calculated by measuring an area of a fresh leaf divided by its oven dry mass, mm^2 $mg\text{-}^1$. At least two fully expanded, hardened, healthy and light-exposed leaves per plant were collected from 32 individual species. Samples were wrapped in moist paper and then placed in sealed plastic bags. The collected samples were stored in a cooler box in the field and measured in the laboratory within 24 hours of collection. The collected samples were scanned and their leaf areas calculated using a leaf area meter. After measuring the fresh area, each leaf sample was placed in an oven at 60 ^{0}C and left for at least 72 hours to measure the dry weight. Leaf Dry Matter Content (LDMC) is an oven dry mass (mg) of a leaf divided by its water-saturated fresh mass (g) expressed in mg $g\text{-}^1$. Values of LDMC were calculated as the ratio of the leaf dry mass to the saturated fresh mass (mg $g\text{-}^1$). Plant height was measured from the base of the stem to the tip of the highest leaf using a tape measure or a metre rule. Palatability and longevity were literature derived (Vesk and Westoby, 2001; Cornelissen et al., 2003; Dubey et al, 2011; Pausas et al., 2015). Resprouting potential was derived from literature and expert knowledge (Cornelissen et al., 2003) and resprouting potential numbers, ranging from 0 to 100, were assigned to species according to the literature. These are arbitrary numbers, where 0 means never resprouting and 100 very abundant resprouting.

Identifying vulnerable traits attributes from the selected trait categories

Trait attributes likely to confer vulnerability on the species in the context of grazing were identified and termed "*vulnerable trait attributes"* following the approach developed by Odume et al. (2018). Vulnerable trait attributes were described as trait features possessed by a plant species that increase the plant's likelihood of being vulnerable to a particular environmental stressor (Odume et al., 2018), in the context of this study, grazing. The literature-based identification of vulnerable traits was largely on the predicted responses of specific trait attributes to grazing (Díaz et al., 2001; Vesk et al., 2004; Díaz et al., 2007; Dubey et al, 2011).

Table 4. 2: **Plant traits, trait attributes, vulnerable trait attributes and rationalised relationship of the vulnerable trait attributes to grazing stress.**

Trait category	**Trait attribute**	**Vulnerable trait attribute(s)**	**Rationale**
Plant height (cm) (Díaz et al., 2001).	Short (< 40cm) Medium (40–80) Tall (> 80)	**Med-Tall (> 40)**	Plant height is hypothesised to decrease under increased grazing pressure and taller species which are within the active grazing height zone of livestock tend to be grazed more than shorter species out of the active grazing zone of livestock, particularly cattle. Shorter plant species therefore tend to dominate in response to grazing (e. g. Díaz et al., 2001; 2007; Dubey et al., 2011). Cingolani et al. (2005) suggest that shorter plants have a higher growth rate, growing quickly after disturbances, and are more tolerant of herbivory than taller plants. Therefore, taller plant species were deemed more vulnerable to grazing than shorter plant species (Maire et al., 2009)
Life cycle (years) (Dubey et al., 2011).	Annual Perennial	**Perennial**	Perennial plants develop more extensive root systems to support their longer lives. However, when grazed heavily, they usually take longer to re-establish than annual and biannual species (Díaz et al., 2007). On the other hand, annual plant species, being short-lived and mostly opportunistic with a high relative growth rate, are more resilient to herbivory (Vesk et al., 2004). Grazing thus promotes annual over perennial species (Dubey et al., 2011).
Palatability (Dubey et al., 2011).	Highly palatable Moderately palatable Unpalatable	**Highly palatable**	Generally, livestock such as cattle and sheep select the most palatable plant species and avoid species that are difficult to digest (unpalatable) (Grime et al., 1996). Therefore, the impact of grazing on highly palatable species is

			expected to be higher than that on moderately palatable and unpalatable plant species (Vesk and Westoby, 2001; Dubey et al., 2011)
Specific leaf area (mm^2 mg^{-1}) (Walker et al., 1999)	SLA 1 (< 4) SLA 2 (4-8) SLA 3 (8-12) SLA 4 (12-16) SLA 5 (>16)	**SLA 1 (< 4)**	Specific leaf area (SLA) is an important leaf trait that integrates plant investment into growth versus defence (Hodgson et al., 1999). Grazing favours species with high SLA and low leaf toughness (Díaz et al., 2001; Cingolani et al., 2005). A high SLA may provide an advantage under heavy grazing because plant species with a high SLA trait turn over leaves rapidly and regrow quickly after grazing (Westoby, 1999). Therefore, species with low SLA tend to be more vulnerable to grazing than those with a high SLA
Leaf size (mm^2) (Willby et al., 2000)	LS1 (<10) LS2 (10-200) LS3 (200-1000) LS 4 >1000	**LS 4 >1000**	Leaf size is a one-sided, projected surface area of a single or an average leaf expressed in mm^2. Larger leaves provide better bites for grazers, whereas smaller leaves require more bites in a given leaf (and mass) (Vesk et al., 2004). Plant species with larger leaves are therefore likely to be more attractive to livestock than species with smaller leaves, and are therefore more vulnerable
Resprouting potential (Cornelissen et al., 2003).	0 – Never resprout 20 – Very poor resprouting 40 – Moderate resprouting 60 – Substantial	**0 - Never resprout** **20 - Very poor resprouting**	Resprouting refers to the capacity of plants to regenerate from disturbances after damage to the living tissues (Pausas et al., 2015). Resprouting is an important trait for species persistence in an ecosystem with an episodic disturbance regime (Cornelissen et al., 2003). Resprouters survive and accumulate additional belowground biomass through multiple disturbances, and thus their roots are frequently older and larger than those of non-

	resprouting 80 – Abundant resprouting 100 – Very abundant resprouting (these are subjective numbers assigned to species for resprouting capacity after disturbance).		resprouters (Pausas et al., 2015).
Leaf Dry Matter Content (mg g^{-1}) (Pérez-Harguindeguy et al., 2013)	LDMC 1 (<150) LDMC 2 (150–300) LDMC 3 (300–500) LDMC 4 > 500	**LDMC 1 (<150)**	Leaves with high LDMC tend to be tough and thus assumed to be more resistant to livestock grazing than leaves with low LDMC. Species with low LDMC tend to be associated with often highly disturbed environments (Pérez-Harguindeguy et al., 2013)

Classifying species into vulnerability groups

Species were classified into three vulnerability groups using percentile distributions of the number of vulnerable trait attributes possessed, the rationale being that species possessing a higher number of vulnerable trait attributes are likely to be more vulnerable than species with fewer vulnerable trait attributes. Species above the 75th percentile mark were categorised as highly vulnerable, 75th– 50th percentile mark as moderately vulnerable, and less than the 50th mark as resilient (Table 4.3).

Table 4. 3: **Plant species vulnerability groups using percentile distribution of the number of vulnerable attributes possessed.**

Vulnerability group	**Percentile distribution**	**Description**
Group A	>75th percentile	Highly vulnerable
Group B	<75th – 50th percentile	Moderately vulnerable
Group C	<50th percentile	Resilient

Predictions using the percent relative abundance of the vulnerability groups

Using percent relative abundance data for the three vulnerability groups, it was predicted that species designated as highly vulnerable (Group A) and moderately vulnerable (Group B) would be less frequently associated with the highly disturbed sites (e.g. HE 1, HE 2, HE 3 and HE 4) and the season of intense grazing (winter) than the resilient species.

4.2.2 Disturbance gradient

Vegetation cover

Vegetation cover was used as a surrogate measure for grazing intensity within each hillslope seep wetland. Direct grazing measurement could not be taken but, given that the hillslope seeps were situated in a rural catchment where no other major activity other than grazing impacts vegetation cover, this measure was deemed an appropriate, indirect estimate of grazing intensity. Vegetation cover and biomass assessment was carried out using quadrat sampling. A 100 m transect was established from the highest to the lowest elevation of each hillslope seep wetland. The aboveground biomass and cover were determined simultaneously following a non-destructive and rapid method for determining the aboveground primary net production (ANPP) developed by Flombaum and Sala (2007). Five (0.2 x 1 m) quadrats were placed along each transect. In each quadrat, a total percentage vegetation cover was visually estimated based on the quadrat area covered by grass using categories shown in Table 4.4.

Table 4. 4: **Scale used to determine the canopy cover during the present study (DAFF, 2014).**

Categories	% cover	Explanation
1	1–10	Plant cover is very sparse with large bare areas
2	11–25	Cover is sparse with some bare areas
3	26–50	Cover is moderate with small bare patches
4	51–75	Cover is good with only a little soil exposure
5	76–100	Cover is dense with no soil visible

Measure of general disturbance gradient

The Anthropogenic Activity Index (AAI) as described in Chapter 3, section 3.2.3 was used to quantify general anthropogenic disturbance in the studied hillslope seep wetlands. The index consists of five metrics: i) surrounding land-use intensity, ii) soil disturbance, iii) hydrology and habitat alteration, and iv) vegetation community.

Slope measurement

The slope of the wetland was determined using an Abney level. Four slope measurements were taken at intervals across the width of the wetland and each measurement was repeated three times. The average slope angle for each wetland was calculated. The slope of each hillslope seep was determined, based on the suggestion that wetlands with high slope are deemed more vulnerable to erosion, while those wetlands with a low slope are considered to be less vulnerable to erosion (Ellery et al., 2009).

In this study therefore, slope, vegetation cover and individual AAI metrics were used as environmental disturbance metrics applied in RLQ and fourth-corner analysis.

4.3 Statistical and data analysis

4.3.1 Assessing the predicted responses of plant species to disturbance

To assess the predicted responses of plant species to disturbance, the relative abundance of plant species belonging to groups A, B and C were regressed against the AAI and vegetation cover (VC) using linear regression analysis. The linear regression was used because the groups of species (A, B and C) are comprised of continuous independent data, while AAI and VC were used as dependent variables. Linear regression analyses were undertaken using STATISTICA software package version 13.3. Boxplots were used to visualise the distribution of species in each of the vulnerability groups across the three site groups (i.e. the less eroded, moderately eroded and highly eroded site groups). Box plots enable visualisation of summary statistics such as median, interquartile ranges and outliers. The Kruskal-Wallis multiple comparison test was used to test for significant differences between site groups in terms of plant species belonging to the vulnerability groups.

4.3.2 Association between species and the site groups

The Pearson's point-biserial correlation coefficient was run to determine the strength and statistical significance of the relationship between species and groups of sites (De Cáceres and Legendre, 2012). The purpose of this analysis was to check if species designated as highly vulnerable were less associated with highly disturbed sites than sites with fewer disturbances. For this analysis, the significance of associations was tested using 999 random permutations. The Pearson point-biserial analysis was carried out using the 'indicspecies' package for R version 3.5.1 (De Cáceres and Legendre, 2012; R Development Core Team, 2014).

4.3.3 Association between species, trait attributes and environmental stress

The RLQ analysis was used to assess the relationship between species abundance, species traits and environmental stress using three data matrices: the matrix of species composition (sample ×

species matrix **L**), the matrix of environmental variables (sample × environmental variables matrix **R**), and the matrix of species attributes (species × traits matrix **Q**) (Brown et al., 2014). To prepare the matrices for the RLQ analysis, three separate ordinations were analysed: a correspondence analysis (CA) was applied to the species matrix **L,** followed by a Hill-Smith analysis for environmental matrix **R,** and a principal component analyses (PCA) was applied to the trait matrix **Q.** After the three separate ordinations, a combination of RLQ analysis was applied. Once the RLQ analysis was done, a fourth-corner analysis was run on the RLQ scores to assess and illustrate the statistical significance of a species trait and individual environmental variable. All tests were performed with 49,999 permutations (Dray et al., 2014). The results were then plotted on a schematic diagram with trait and environmental variables, showing correlations between species traits and environmental metrics using three coloured codes: blue representing a negative correlation, red a positive correlation and grey no correlation. Both RLQ and fourth-corner analysis were performed using the "ade4" package in R version 3.1.4 (The R Core Team, 2014).

4.4 Results

4.4.1 Seep wetland disturbances gradient across sites and seasons

In winter, the results showed that sites selected as less eroded were least disturbed with AAI scores of 1–5, while highly eroded sites were highly disturbed with AAI scores greater than 10 (Figure 4.1). In summer, all the less eroded sites were least disturbed, while two of the highly eroded sites were moderately disturbed (6–10) and the other two were highly disturbed (Figure 4.1). In comparison of the seasons, the results showed that the winter season presented more disturbances to hillslope seep wetlands.

With regard to the VC, in winter, most of the less eroded sites had high VC compared to the highly eroded sites, implying that in the highly eroded sites the grazing pressure was higher (Figure 4.2). In summer, there was no observable trend across the sites as the VC was high in all the sites, indicating that the grazing intensity was low in seep wetlands (Figure 4.2).

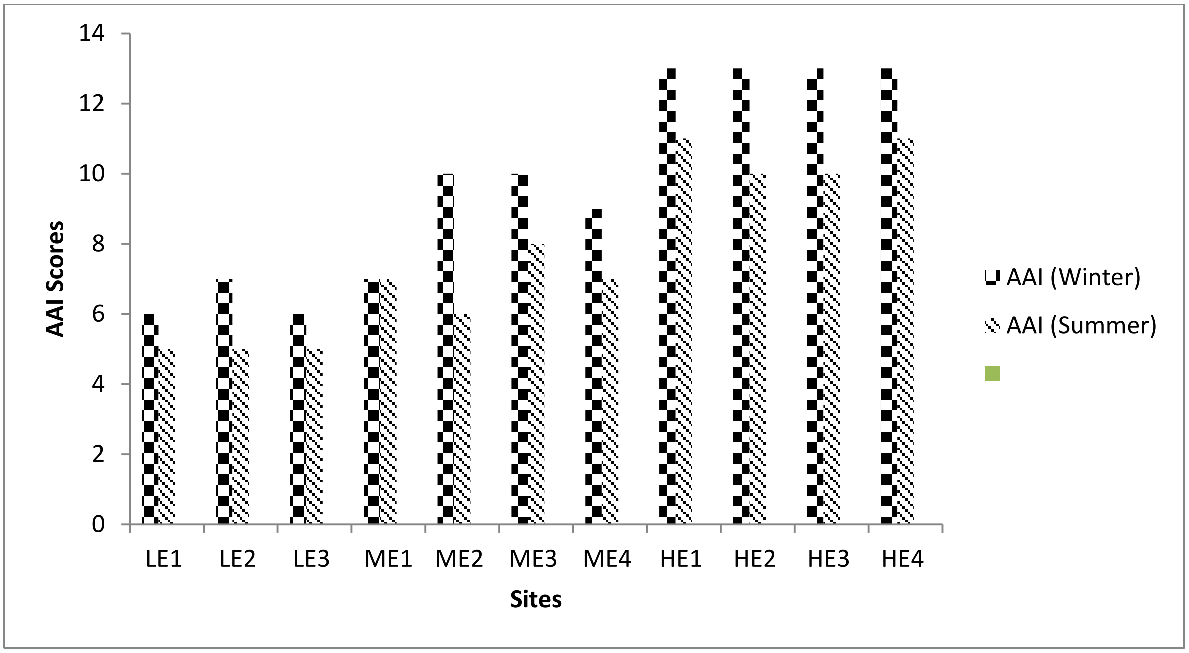


Figure 4. 1: **AAI index showing disturbance gradient across the sites per season (LE=less eroded site, ME=moderately eroded sites, HE=highly eroded sites.**

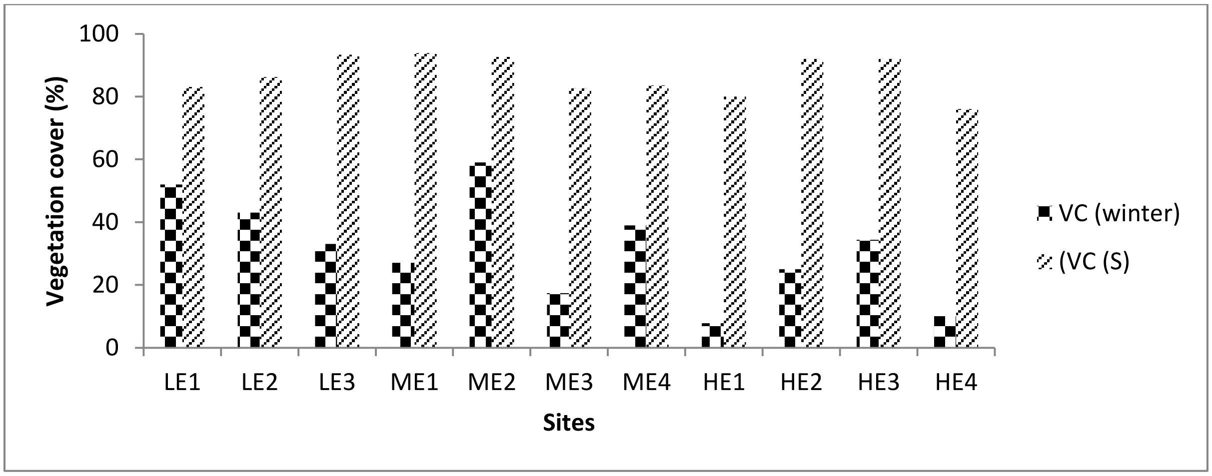


Figure 4. 2: **Vegetation cover (VC) across the sites per season, showing that seeps had higher cover in summer than in winter (LE=less eroded site, ME=moderately eroded sites, HE=highly eroded sites.**

4.4.2 Grouping of plant species according to their potential vulnerability to disturbance

A total of 32 plant species were collected, identified, and classified according to their potential vulnerability to grazing. Of the 32 species recorded, nine were classified as highly vulnerable, sixteen as moderately vulnerable and seven as resilient (Table 4.5). The highly vulnerable species include *Themeda triandra, Hemarthria altissima* and *Digitaria erientha*. *Richardia brasiliensis, Centella asiatica,* and *Eragrostis plana* were classified as resilient species (Table 4.5).

Table 4. 5: **Plant species grouped according to their potential vulnerability to grazing using the developed TBA.**

Highly vulnerable	**Moderately Vulnerable**	**Resilient**
Digitaria erientha	*Alepidea amatymbica*	*Richardia brasiliensis*
Hemarthria altissima	*Alloteropsis semialata*	*Centella asiatica*
Hypoxis acuminata	*Berkheya* spp	*Commelina africana*
Miscanthus capensis	*Cymbopogon validus*	*Eragrostis aspera*
Paspalum dilatatum	*Gerbera viridifolia*	*Eragrostis curvula*
Panicum maximum	*Haplocarpha lyrata*	*Eragrostis plana*
Taraxicum officinale	*Helichrysum aureonitens*	*Tristachya leucothrix*
Themeda triandra	*Helichrysum nudifolium*	
Conyza scabrida	*Knowltonia bracteata*	
	Mentha aquatica	
	Ornithogalum spp	
	Paspalum distichum	
	Polygonum spp	
	Senecio coronatus	
	Senecio speciosus	
	Wahlenbergia spp	

4.4.3 Predicted response of vulnerable groups to disturbances

The results indicated that during winter, the relative abundance of species designated as highly vulnerable (A) decreased with increasing AAI, while no direction was observed for VC, but the relationship was not statistically significant for either AAI or VC to group A. The relative abundance of species designated as moderately vulnerable (B) decreased with increasing VC, yet no direction was observed for AAI, and the relationship was not statistically significant (Figure 4.3). The relative abundance of species designated as resilient (C) increased with increasing AAI, but decreased with increasing VC, and the relationship was not statistically significant. During summer, the results indicated that the relative abundance of species designated as highly vulnerable (A) decreased with increasing AAI and VC, but the relationship was not statistically significant (Figure 4.4). The relative abundance of species designated as moderately vulnerable (B) increased with increasing AAI and VC; the relationship was not statistically significant. The relative abundance of species designated as resilient (C) decreased with increasing AAI, while no direction was observed for VC and the relationship was not statistically significant (Figure 4.4).

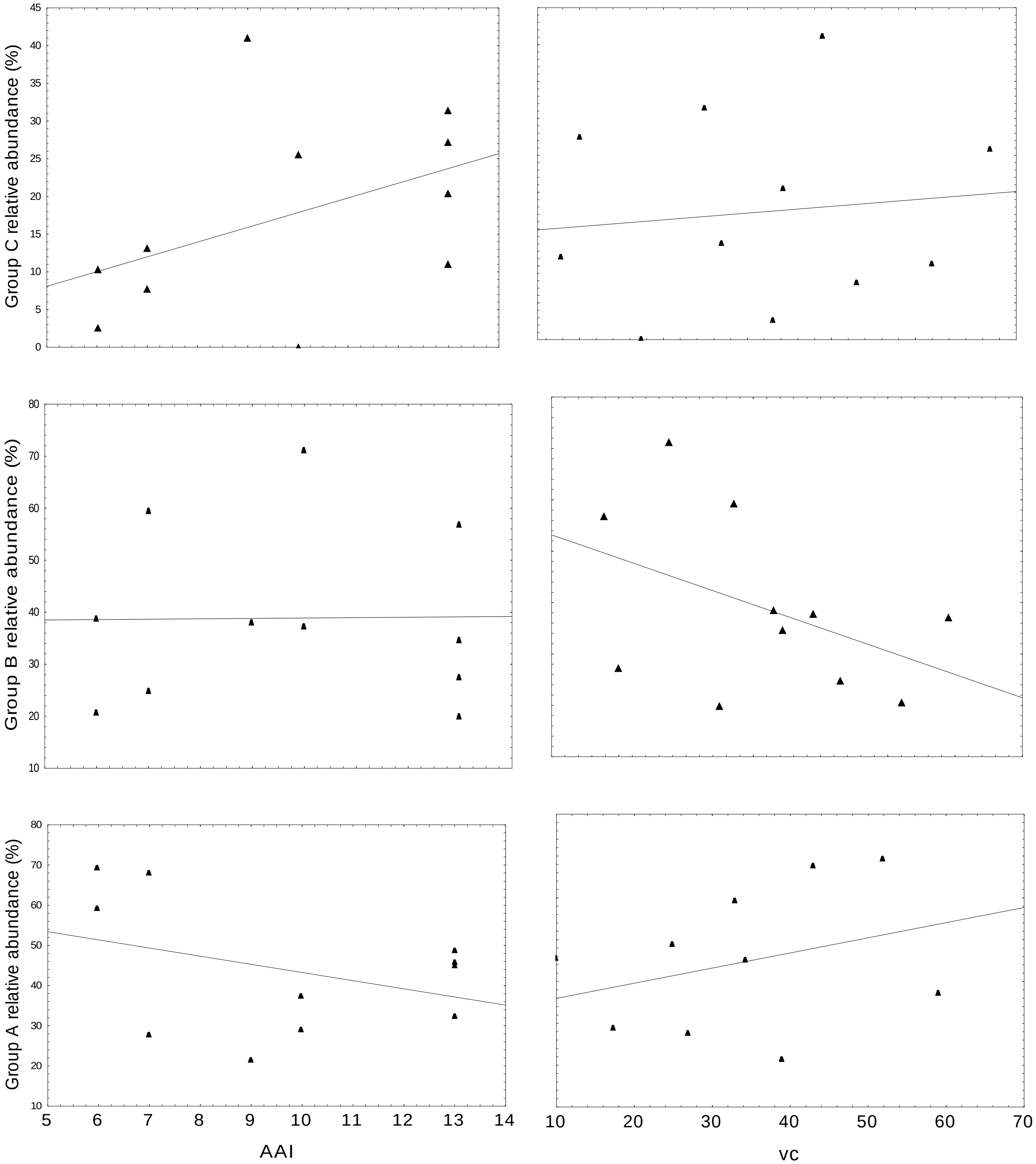


Figure 4. 3: **Linear regression analyses between the relative abundance of species in groups A, B and C with AAI, and vegetation cover for the eleven surveyed wetland sites in winter.**

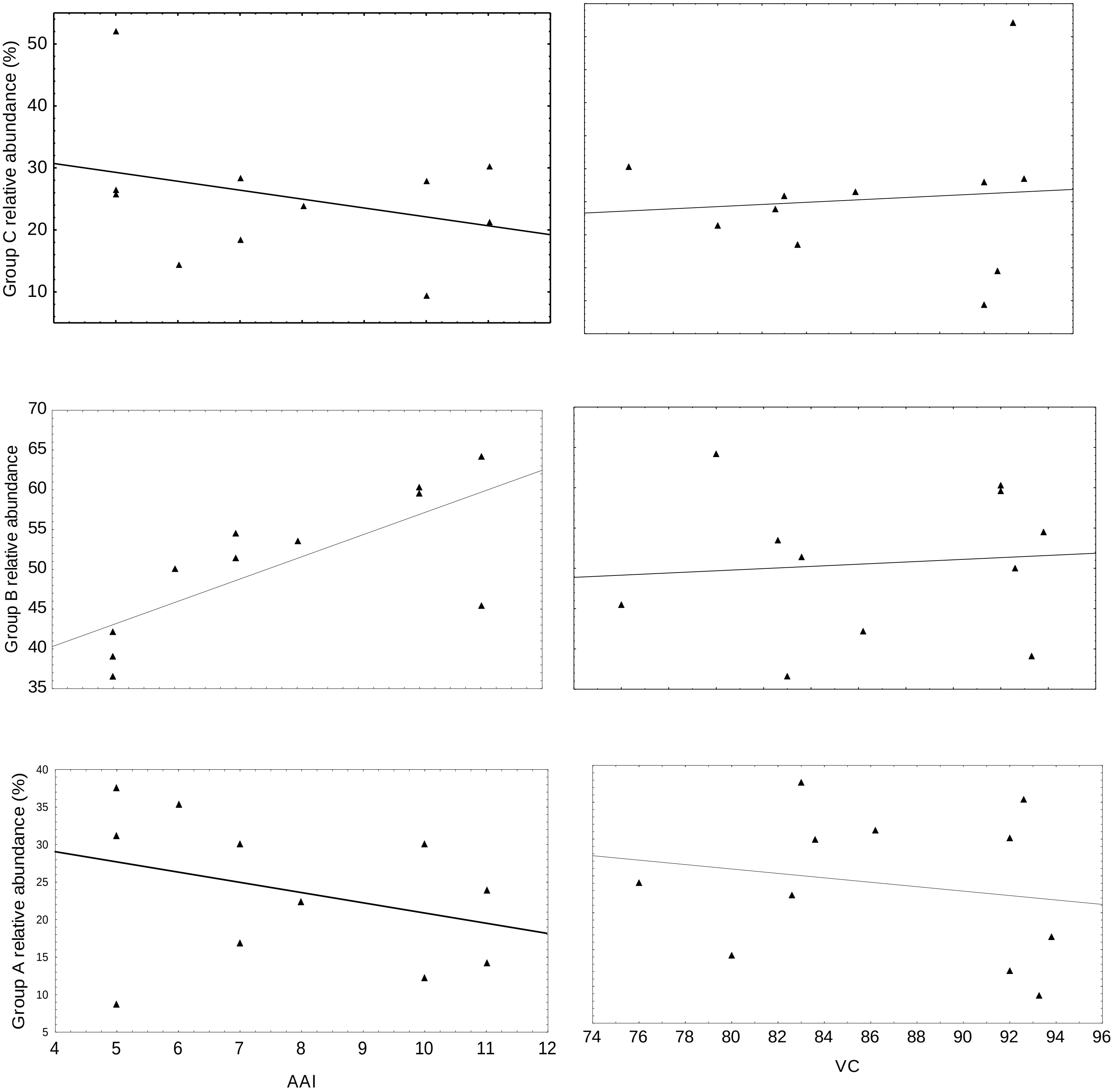


Figure 4. 4: **Linear regression analyses between the relative abundance of species in groups A, B and C with AAI and vegetation cover for the eleven surveyed wetland sites in summer**

4.4.4 Relative abundance (%) of species belonging to vulnerability groups across the site groups per season.

Within site groups, the winter results indicated that the relative abundance of species designated as highly vulnerable (A) were less dominant in impacted site groups (highly eroded sites) when compared to moderately vulnerable (B) (Figure 4.5), but there was no statistically significant difference observed for any of the three groups (p=0,087) (Figure 4.5). The winter results also indicated that most vulnerable species are more abundant at the most degraded sites compared to the least degraded sites (Figure 4.5). As in the highly eroded sites, in moderately eroded sites, relative abundance of the highly vulnerable (A) and moderately vulnerable (B) groups was dominant compared to the resilient group (C). A statistically significant difference was observed between the three groups (p =0.0001). In the less eroded sites, any of the vulnerability group could occur in high abundance since there was no disturbance. The results showed that in less eroded sites the relative abundance of moderately vulnerable group (B) was dominant and there was a statistically significant difference for all three groups with less eroded sites (p=0.0001) (Figure 4.5). During summer, no clear pattern was observed on the lower dominance of the highly vulnerable (A) group in highly disturbed sites because the grazing pressure is not high on hillslope seep wetlands; the whole catchment is green and livestock have variety in terms of where to graze. For example, in highly eroded sites, the relative abundance of highly vulnerable (A) and resilient group (C) was dominant compared to the moderately vulnerable group (B), and a statistically significant difference was observed between the three groups with the highly eroded sites (p=0.0003). In moderately eroded sites, the highly vulnerable (A) group was dominant compared to moderately vulnerable (B) and resilient (C) groups; there was a statistically significant difference for all three groups with ME sites (p =0.031) (Figure 4.5). In less eroded sites, the relative abundance of highly vulnerable (A) and resilient group (C) were dominant compared to the moderately vulnerable group (B) (Figure 4.5). No statistically significant difference was observed for any of the three groups with less eroded sites (p=0.06).

Generally looking at both season (winter and summer), (Figure 4.5), highly vulnerable species are less in winter compared to summer, implying that the prediction was only true for seasonality.

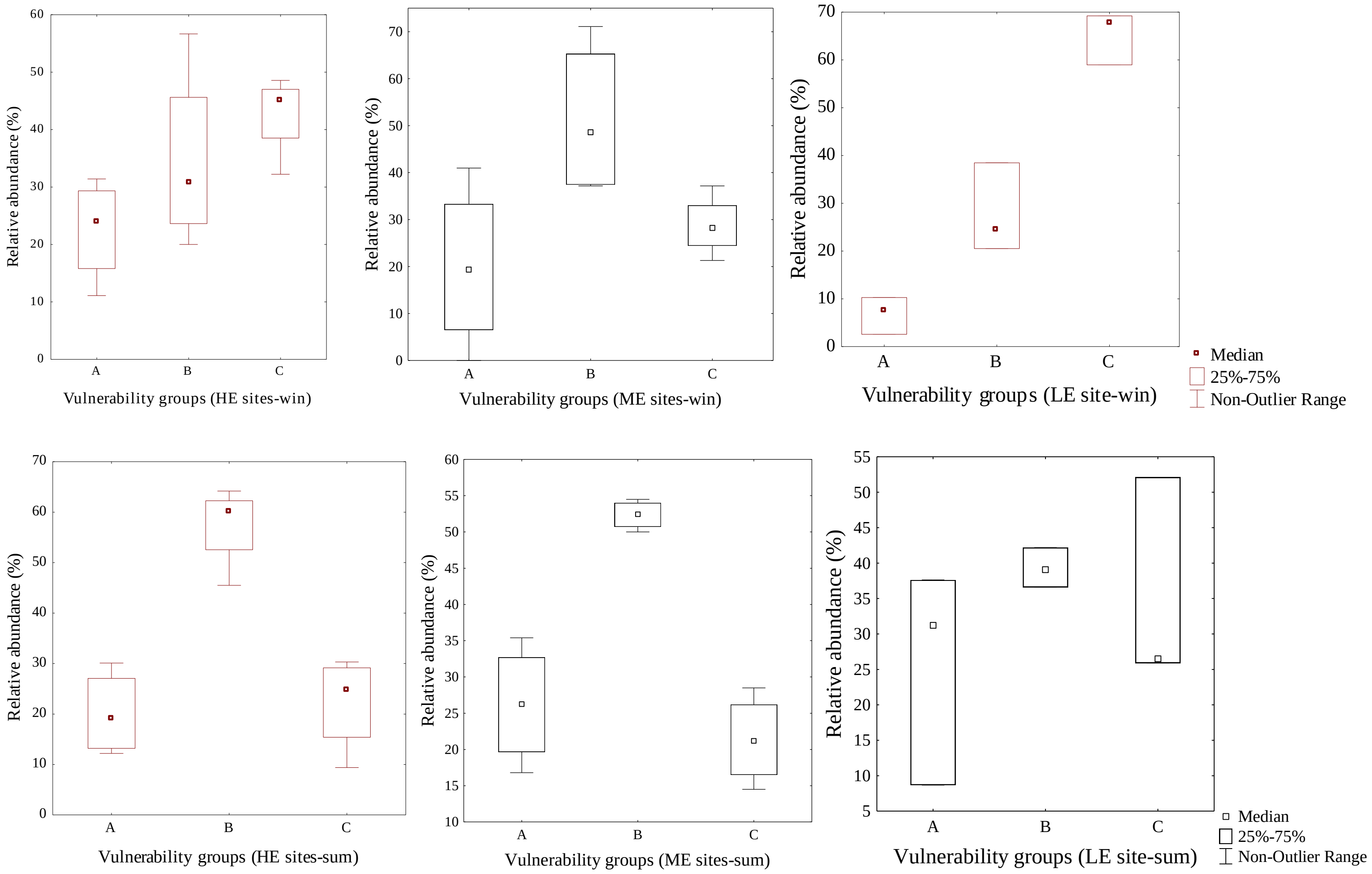


Figure 4. 5: Relative abundance of species belonging to three vulnerability groups in LE, ME and HE sites for summer and winter. Sites: LE=Less eroded, ME=moderately eroded, HE=Highly eroded. Season: win=winter, sum=summer. Abbreviation: groups: A=highly vulnerable, B=moderately vulnerable, C=resilient.

4.4.5 Relating individual plant species and the site groups

The Pearson's point-biserial correlation analysis was run to assess the association of plant species with the site groups (3LE, 4ME and 4HE). Six distinct community types were observed (Table 4.6). The first community, comprising six grass species, was associated with less eroded sites. The species in the community included: *Panicum maximum, Themeda triandra, Alloteropsis semialata, Paspalum dilatatum, Wahlenbergia* sp and *Commelina Africana*. Of these, only *Themeda triandra* showed a significant association with the less eroded sites ($P < 0.05$). Three of the associated species were considered to be highly vulnerable to disturbance, while two were considered to be moderately vulnerable, and only one was resilient (Table 4.6).

The second community consisted of two species, i.e. *Ornithogalum* sp. and *Polygonum* sp. These species were associated with the moderately eroded sites. The association between *Ornithogalum* sp. and the moderately eroded sites was statistically significant ($P < 0.05$). Both species were classified as moderately vulnerable (Table 4.6).

The third community consisted of only one species, *Gerbera viridifolia,* which was associated with the highly eroded sites. The association was not significant.

The fourth community, consisting of eight species, was associated with site groups less eroded and moderately eroded. The species belonging to the community include *Hemarthria altissima, Hypoxis acuminata, Taraxicum officinale, Alepidea amatymbica, Helichrysum aureonitens, Knowltonia bracteata, Eragrostis curvula* and *Eragrostis plana*. None of the species showed a significant association with the two sites combined.

The fifth community, comprising six species, was concurrently associated with the less eroded and highly eroded site groups. The species in the community include *Tristachya hispida, Centella asiatica, Senecio speciosus, Helichrysum nudifolium, Conyza scabrida* and *Digitaria erientha*. None of the associations between the species and the site groups was significant. Two of these species, *Conyza scabrida* and *Digitaria erientha,* were considered highly vulnerable; two, *Helichrysum nudifolium* and *Senecio speciosus,* were moderately vulnerable, and two, *Tristachya hispida* and *Centella asiatica*, resilient. The sixth community, comprising nine species was associated with site groups 2 and 3. The species in the community include *Miscanthus capensis, Paspalum distichum, Berkheya* sp, *Cymbopogon validus, Mentha aquaticaa, Senecio coronatus, Richardia brasiliensis, Haplocarpha lyrata* and *Eragrostis aspera*. Only *Senecio coronatus* showed a significant association (p < 0.05) with the site group. The majority of these species were considered moderately vulnerable (Table 4.6).

Table 4. 6: **Pearson point-biserial correlation analysis of species association with site groups. The numbers 1 and 0 under the respective site group columns indicate when a species is associated and not associated with the site group. Code: 1 (species associated with site group 1); 2 (species associated with site group 2); 3 (species associated with site group 3); 4 (species associated with site groups 1 and 2); 5 (species associated with site groups 1 and 3); 6 (species associated with site groups 2 and 3). Site group 1 (LE1, LE2 and LE3), Site group 2 (ME1, ME2, ME3 and ME4), Site group 3 (HE1, HE2, HE3 and HE4). VG = species vulnerability group. Bold face indicates significant associations at P<0.05.**

Species	**Site group 1**	**Site group 2**	**Site group 3**	**Code**	**Coefficient**	***p* value**	**VG**
Panicum maximum	1	0	0	1	0.57	0.2	A
Themeda triandra	1	0	0	1	0.91	**0.031**	A
Alloteropsis semialata	1	0	0	1	0.73	0.1	B
Paspalum dilatatum	1	0	0	1	0.91	0.063	A
Wahlenbergia sp	1	0	0	1	0.8	**0.051**	B
Commelina africana	1	0	0	1	0.69	0.14	C
Ornithogalum sp	0	1	0	2	0.83	**0.04**	B
Polygonum sp	0	1	0	2	0.7	0.26	B
Gerbera viridifolia	0	0	1	3	0.7	0.2	B
Hemarthria altissima	1	1	0	4	0.811	0.87	A
Hypoxis acuminata	1	1	0	4	0.65	0.4	A
Taraxicum officinale	1	1	0	4	0.59	0.68	A
Alepidea amatymbica	1	1	0	4	0.78	0.39	B
Helichrysum aureonitens	1	1	0	4	0.68	0.64	B
Knowltonia bracteata	1	1	0	4	0.65	0.41	B
Eragrostis curvula	1	1	0	4	0.86	0.41	C
Eragrostis plana	1	1	0	4	0.93	0.07	C
Tristachya hispida	1	0	1	5	0.53	0.71	C
Centella asiatica	1	0	1	5	0.44	1	C
Senecio speciosus	1	0	1	5	0.63	0.61	B
Helichrysum nudifolium	1	0	1	5	0.78	0.27	B
Conyza scabrida	1	0	1	5	0.65	0.4	A

Digitaria erientha	1	0	1	5	0.84	0.09	A
Miscanthus capensis	0	1	1	6	0.66	0.6	A
Paspalum distichum	0	1	1	6	0.8	0.09	B
Berkheya sp	0	1	1	6	0.61	0.71	B
Cymbopogon validus	0	1	1	6	0.85	0.24	B
Mentha aquatica	0	1	1	6	0.92	0.074	B
Senecio coronatus	0	1	1	6	0.96	**0.01**	B
Richardia brasiliensis	0	1	1	6	0.81	0.54	C
Eragrostis aspera	0	1	1	6	0.61	0.7	C
Haplocarpha lyrata	0	1	1	6	0.85	0.24	B

4.4.6 Association between sites, traits, species and environmental variables, using the RLQ analysis for summer season

The associations between the sites, individual traits, species and environment were computed separately for the summer and winter seasons. In summer, the first two combined RLQ axes explained 95.8% cumulative variance. The first axis with eigenvalue 0.74 explained 87.5% variance, and the second axis with eigenvalue 0.07 explained 8.3% variance (Table 4.7).

Because the combined RLQ analysis contains environmental variables, species abundances and traits, the proportions of the variance attributed to each matrix of the final RLQ analysis were compared to those resulting from their separate analyses. The first RLQ axis (with an eigenvalue of 0.74, covariance of 0.86, and correlation of 0.36) accounted for 95.1% (2.406/2.5278) of the variation in the separate analysis of the R matrix, 57.3% (0.362/ $(0.398)^{1/2}$) in the separate analysis of the L matrix, and 90.9% (2.353/2.587) of the separate analysis of the Q matrix (Table 6). Similarly, the second RLQ axis accounted for 95.4% for the R matrix, 50.7% for the L matrix, and 74.6% for the Q matrix, respectively (Table 4.7).

The summer RLQ ordination results on the relationship between species abundance, environmental variables, and traits revealed that the resilient species such as *Wahlenbergia* sp, *Berkheya* sp, *Hypoxis acuminate, Ornithogalum* sp, and *Senecio specious* were clustered together and were dominant in highly eroded sites (HE1, HE3 and HE4). The species were strongly correlated with traits such as leaf area, resprouting capacity and SLA. These species were also associated with two environmental disturbances: soil disturbance, and vegetation community quality and habitat alteration (Figure 4.6).

The highly vulnerable species, such as *Themeda triandra*, *Hemarthria altissima* and *Panicum maximum*, were closely clustered and associated with LDMC. These species were mostly found in the less eroded sites (LE1, LE3 and ME2) (Figure 4.6). *Paspalum dilatatum, Digitaria erientha* and *Paspalum distichum* were closely clustered and associated with palatability. These species were found in LE2 and ME2 sites (Figure 4.6).

Species such as *Senecio coronatus, Conyza scabrida* and *Miscanthus capensis* were classified as highly vulnerable and were found in ME1, ME4 and HE2 sites. These species were correlated with plant height, lifecycle traits and environmental and biological metrics such as VC, slope, and hydrological alteration (Figure 4.6).

Table 4. 7: **Eigenvalues, percentage of variance (%) and correlation of plant species, traits, and environmental metrics explained by the first two axes of the RLQ analysis during the summer season.**

RLQ properties	**Axis 1**	**Axis 2**
	Separate ordinations	
Variance (R/Hill-Smith) %	41.2	27.3
Eigenvalue	2.52	1.6
Variance (L/Canonical Analysis)%	26.8	16.2
Eigenvalue	0.39	0.25
Variance (Q/Principal Component Analysis)%	36.9	21.9
Eigenvalue	2.5	1.5
Combined RLQ analysis		
Variance (RLQ)%	87.5	8.3
Eigenvalue	0.74	0.07
Covariance	0.86	0.26
Correlation	0.36	0.24
Variance (R/RLQ) %	95.1	95.4
Variance (L/RLQ) %	57.3	50.7
Variance (Q/RLQ) %	90.9	74.6

Fourth-corner analysis was used to determine the relationship between an individual trait and an environmental metric. There were eight significant associations between individual plant traits and environmental stress: i) SLA, correlated positively with soil disturbance, habitat alteration and hydrological alteration; ii) LDMC was negatively correlated with vegetation community quality; iii) leaf area was positively associated with habitat alteration and hydrological alteration; iv) plant height was positively associated with VC, and v) palatability was negatively associated with hydrological alteration (Figure 4.7)

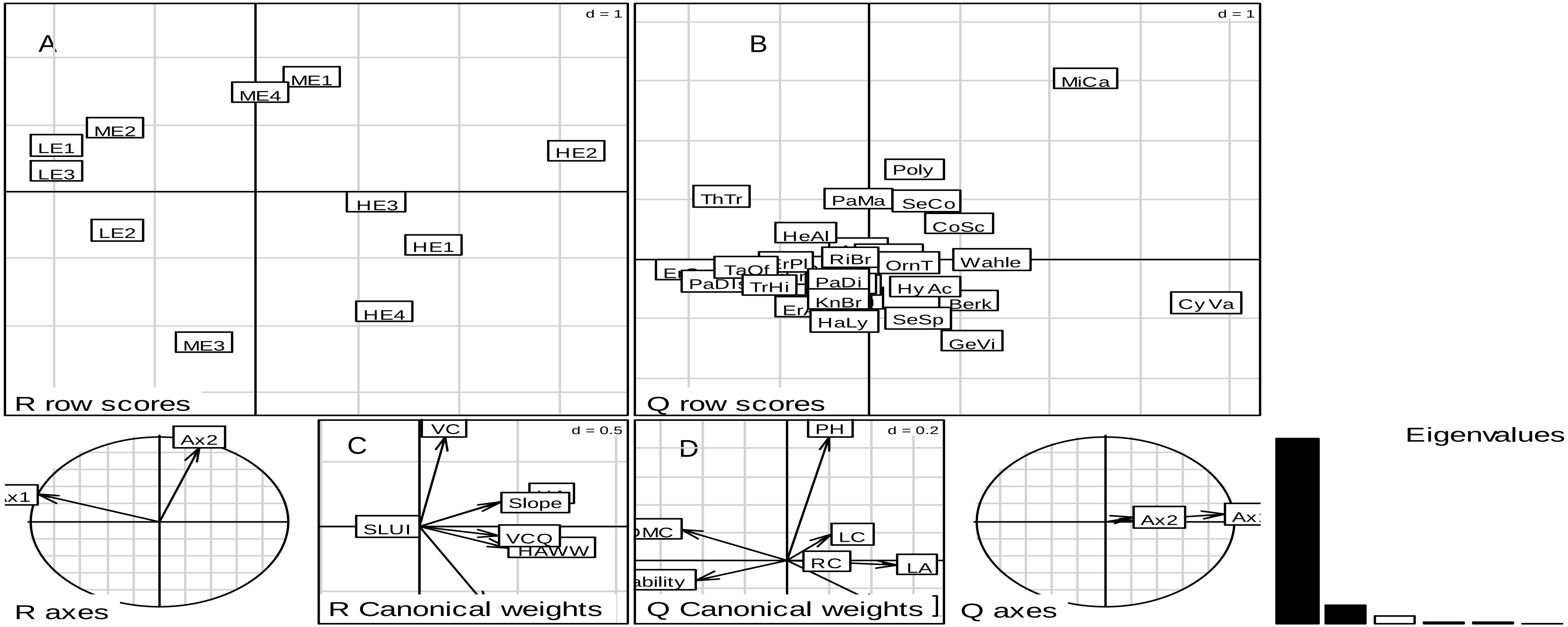
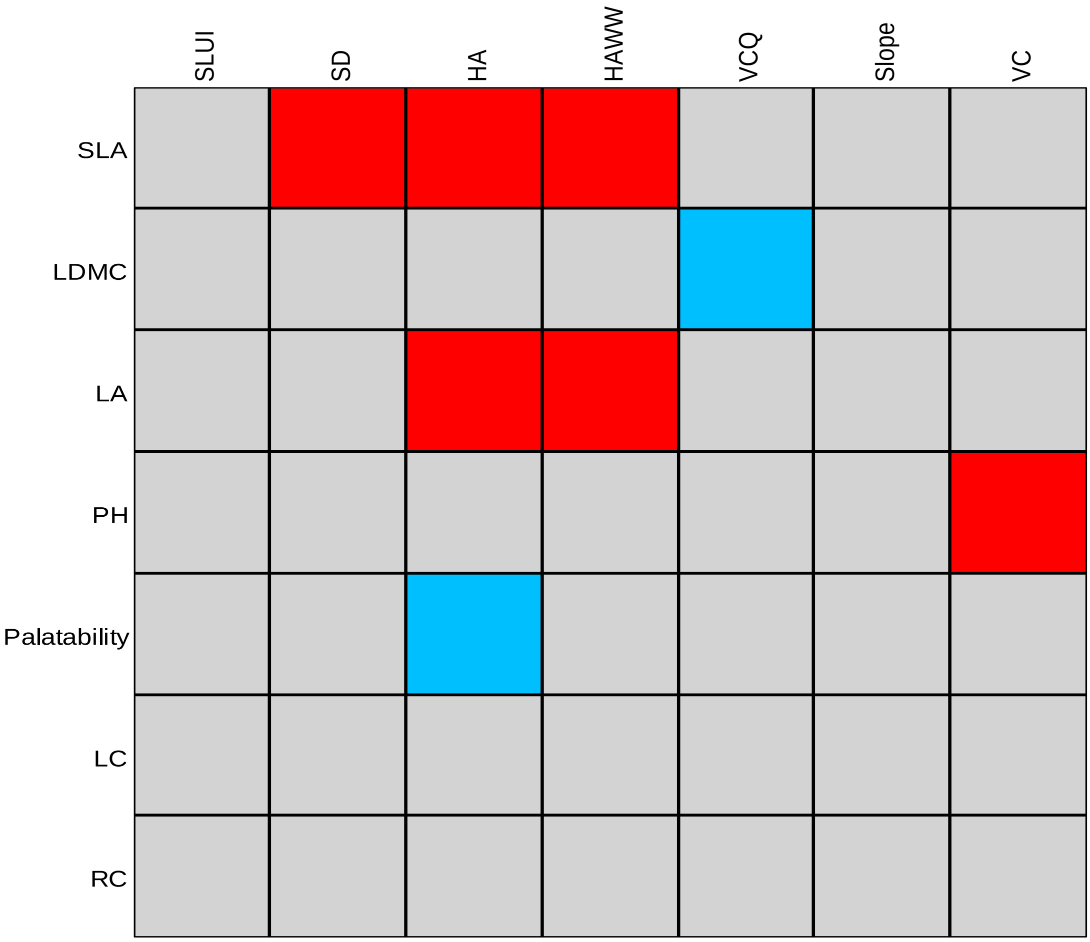


Figure 4. 6: **Ordination diagrams of the first two axes of the RLQ analysis during summer showing the results of the association between species, traits, and environmental metrics. (A) sites, (B) species abundance, (C) environmental metrics, and (D) plant trait scores. Abbreviations for species are reported in Appendix B. Plant trait abbreviations: PH=Plant height, SLA=Specific Leaf area, LA=Leaf area, LC=Life cycle, LDMC=Leaf dry matter content, RC=Resprouting capability and palatability. Abbreviations for environmental metrics: VC=Vegetation cover, SD=Soil disturbance, HA=Hydrological alteration, HAWW=Habitat alteration within the wetland, VCQ=Vegetation community quality and SLUI=Surrounding land-use intensity.**



	SLUI	SD	HA	HAWW	VCQ	Slope	VC
SLA	⬜	🟥	🟥	🟥	⬜	⬜	⬜
LDMC	⬜	⬜	⬜	⬜	🟦	⬜	⬜
LA	⬜	⬜	🟥	🟥	⬜	⬜	⬜
PH	⬜	⬜	⬜	⬜	⬜	⬜	🟥
Palatability	⬜	⬜	🟦	⬜	⬜	⬜	⬜
LC	⬜	⬜	⬜	⬜	⬜	⬜	⬜
RC	⬜	⬜	⬜	⬜	⬜	⬜	⬜

Figure 4. 7: **Fourth-corner analysis illustrating the association between individual plant traits and environmental metrics during summer season. Red cells correspond to positive significant relationships while blue cells correspond to negative significant relationships and grey are neutral (no significant correlation). The environmental metrics are along the horizontal axis and the traits on the vertical axis. Plant trait abbreviations: PH=Plant height, SLA=Specific Leaf area, LA=Leaf area, LC=Life cycle, LDMC=Leaf dry matter content, RC=Resprouting capability and palatability. Abbreviations for environmental metrics: VC=Vegetation cover, SD=Soil disturbance, HA=Hydrological alteration, HAWW=Habitat alteration within the wetland, VCQ=Vegetation community quality and SLUI=Surrounding land-use intensity.**

4.4.7 Association between traits, sites, species and environmental metrics using the RLQ analysis for winter season

In the winter season, the first two RLQ axes explained 92.8% cumulative variance. The first axis with an eigenvalue 0.56 explained 83.6% variance, and the second axis with eigenvalue 0.06 explained 9.2% variance (Table 4.8)

Since the combined RLQ analysis contains environmental variables, species abundances and traits, the proportions of the variance attributed to each matrix of the final RLQ analysis were compared to those resulting from their separate analyses. In winter, the first RLQ axis (with an eigenvalue of 0.56, covariance of 0.75, and correlation of 0.28) accounted for 85% (2.699/3.175) of the variation in the separate analysis of the R matrix, 48.4% (0.289/ $(0.357)^{1/2}$) in the separate analysis of the L matrix, and 91.09 % (2.4922/2.7357) of the separate analysis of the Q matrix (Table 4.8). The second RLQ axis accounted for 87.8% for R matrix, 51.4% for L matrix, and 73.7% for Q matrix, respectively.

The winter RLQ ordination results on the relationship between species abundance, environmental variables, and traits revealed that the moderately vulnerable species such as *Cymbopogon validus* and *Paspalum distichum* were clustered together and were dominant in highly eroded sites (HE1, HE2, HE4 and ME1). The species were strongly correlated with traits such palatability, SLA, leaf area and resprouting capability. These species were also associated with three environmental stresses: soil disturbance, slope, and vegetation community quality (Figure 4.8).

Highly vulnerable species, such as *Themeda triandra* and *Paspalum dilatatum,* were clustered together and they were dominant in less eroded and moderately eroded sites (LE2 and ME3). The species were strongly correlated with the LDMC trait (Figure 4.8).

Species such as *Richardia brasiliensis* and *Helichrysum aureonitens* were clustered together and were dominant in less eroded sites (less eroded sites (LE1, LE3 and ME2). These species were also associated with only one environmental stress: VC. (Figure 4.8).

Species such as *Polygonum* sp, and *Miscanthus capensis* were clustered together and were found in moderately and highly eroded sites (ME4 and HE3). These species were also associated with only one plant height trait and one environmental stress hydrological alteration (Figure 4.8).

Table 4. 8: Eigenvalues, percentage of variance (%) and correlation of plant species, traits and environmental metrics explained by the first two axes of the RLQ analysis during the winter season.

RLQ properties	Axis 1	Axis 2
	Separate ordinations	
Variance (R/Hill-Smith) %	52.9	17.8
Eigenvalue	3.1	1.07
Variance (L/Canonical Analysis)%	27.9	25
Eigenvalue	0.35	0.31
Variance (Q/Principal Component Analysis)%	36.08	22.8
Eigenvalue	2.7	1.6
Combined RLQ analysis		
Variance (RLQ)%	83.6	9.2
Eigenvalue	0.56	0.06
Covariance	0.75	0.24
Correlation	0.28	0.29
Variance (R/RLQ) %	85	87.8
Variance (L/RLQ) %	48.4	51.4
Variance (Q/RLQ) %	91.09	73.7

With regard to the winter season, the fourth-corner analysis returned three significant associations between individual traits and environmental stress. A positive correlation was found between SLA and vegetation community quality; plant height and leaf area were positively correlated to hydrological alterations (Figure 4.9).

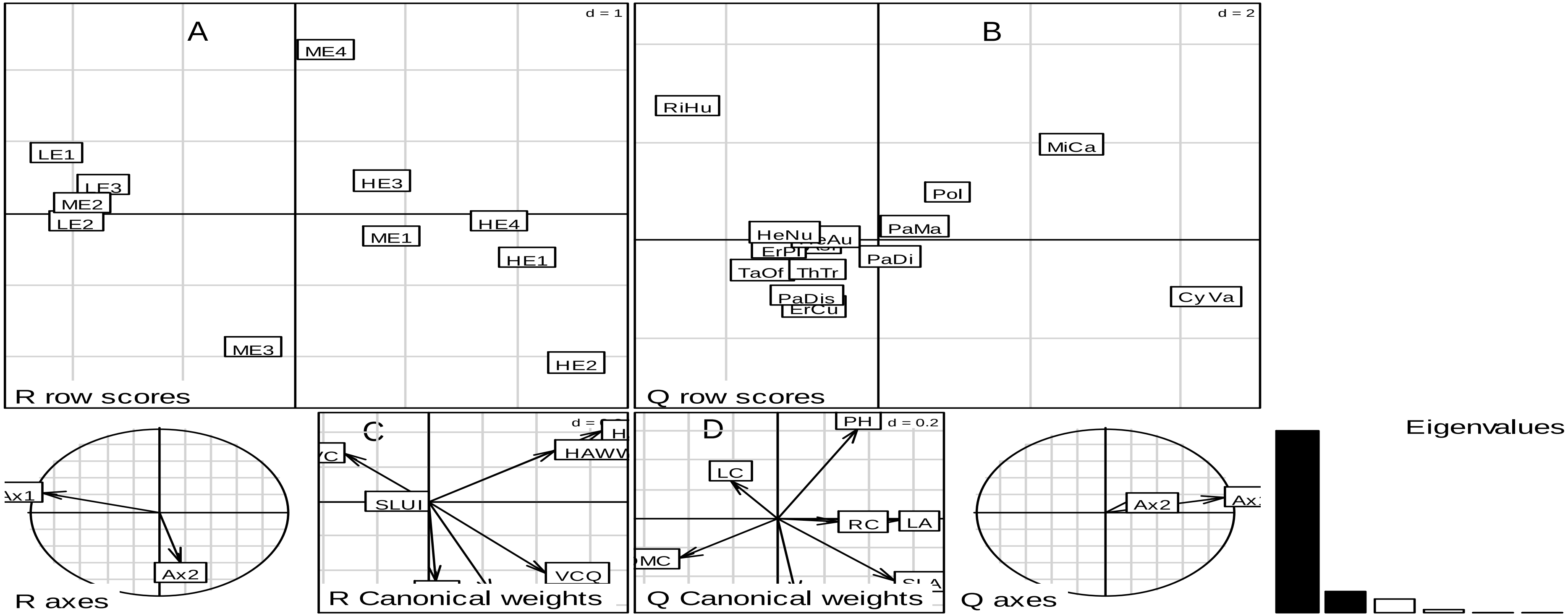
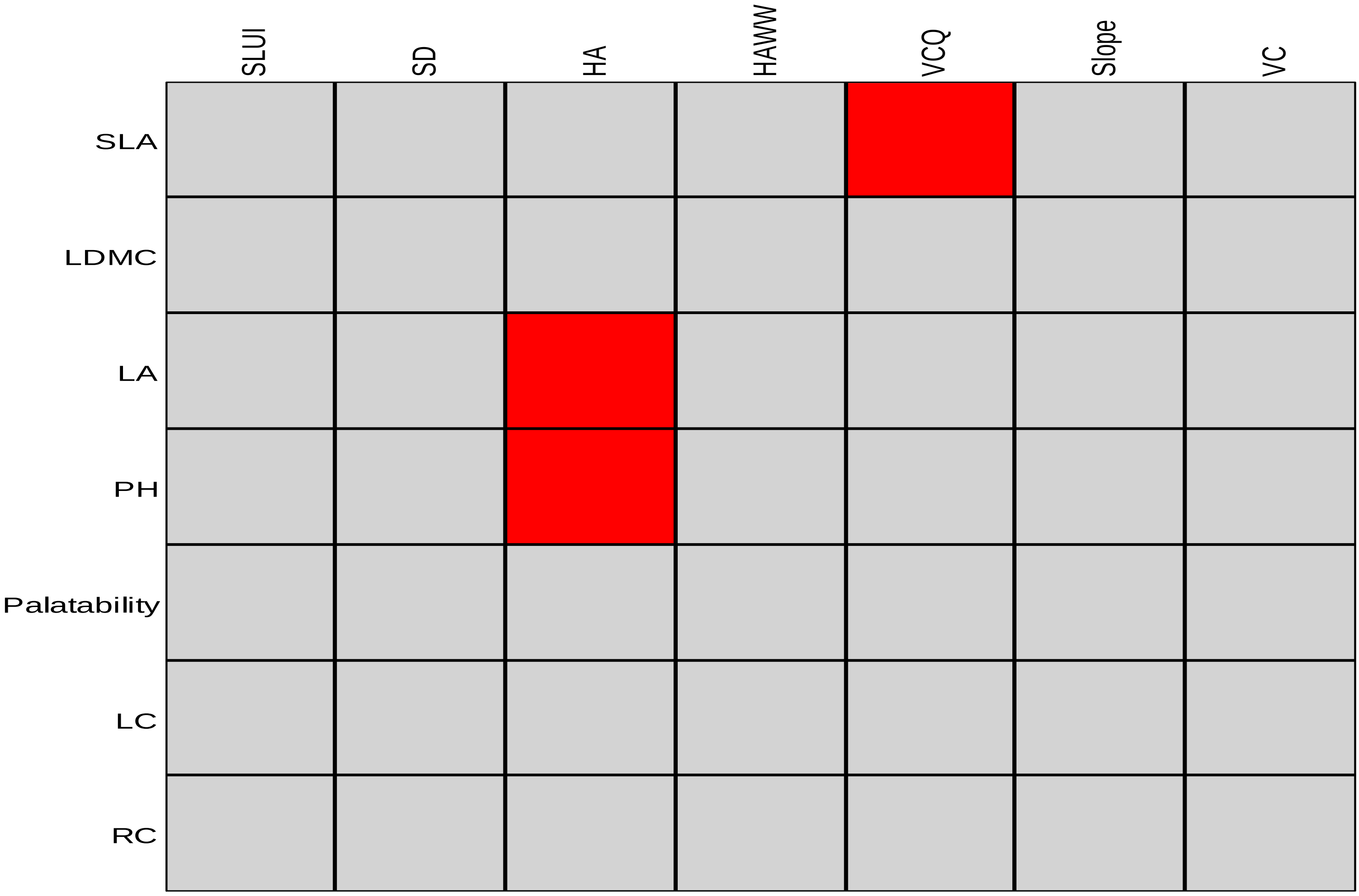


Figure 4. 8: **Ordination diagrams of the first two axes of the RLQ analysis during winter, showing the results of the association between species, traits and environmental metrics. (A) Shows the sites, (B) species abundance, (C) environmental metrics, and (D) plant traits. Abbreviations for species are reported in Appendix B. Plant trait abbreviations: PH=Plant height, SLA=Specific Leaf area, LA=Leaf area, LC=Life cycle, LDMC= Leaf dry matter content, RC=Resprouting capability and palatability. Abbreviations for environmental metrics: VC=Vegetation cover, SD=Soil disturbance, HA=Hydrological alteration, HAWW=Habitat alteration within the wetland, VCQ=Vegetation community quality and SLUI=Surrounding land-use intensity.**



	SLUI	SD	HA	HAWW	VCQ	Slope	VC
SLA					🟥		
LDMC							
LA			🟥				
PH			🟥				
Palatability							
LC							
RC							

Figure 4. 9: Fourth-corner analysis illustrating the association between individual plant traits and environmental metrics during the winter season. Red cells correspond to positive significant relationships and grey are neutral (no significant correlation). The environmental metrics are along the horizontal axis and the traits on the vertical axis. Plant trait abbreviations: PH=Plant height, SLA=Specific Leaf area, LA=Leaf area, LC=Life cycle, LDMC=Leaf dry matter content, RC=Resprouting capability and palatability. Abbreviations for environmental metrics: VC=Vegetation cover, SD=Soil disturbance, HA=Hydrological alteration, HAWW=Habitat alteration within the wetland, VCQ=Vegetation community quality and SLUI=Surrounding land-use intensity.

4.5 Discussion

4.5.1 The use of a trait-based approach to assess plant species response to grazing disturbances

The trait-based approach (TBA) has been used widely to develop mechanistic models that predict the potential responses of biological assemblages to abiotic and biotic perturbations (Funk et al., 2016). Some of these studies have been conducted on the impact of livestock grazing on vegetation patterns, based on the assumption that plant traits are useful in predicting species' responses to grazing (Díaz et al., 2007). Traits have also been found useful for conservation studies and for identifying species vulnerability to land-use changes (Cingolani et al., 2005; de Bello et al., 2005; Pillar et al., 2009; Zheng et al., 2015). However, in South Africa, not much has been done in using traits as a mechanistic basis for understanding species-environment interactions. This is particularly true for grazing pressure in hillslope seep wetlands. Given the degradation status of hillslope seep wetland in the Tsitsa River Catchment (see Chapter 3); there is an urgent need to develop an approach that enables the prediction of the effects of disturbance on vegetation patterns to guide conservation and management efforts.

In the present study, plant species were grouped into three potentially vulnerable groups in relation to grazing pressure. It was then predicted that species belonging to the highly vulnerable group would be less dominant at the highly disturbed sites, as well as in the winter season when grazing pressure is at its highest. The result corresponds with seasonal prediction as highly vulnerable group species were less dominant in winter compared to summer. However, looking at the sites within winter, the results show very clearly that the most vulnerable species are more abundant at the highly eroded compared to the less eroded sites and this clearly runs counter to what was predicted. The measurements of relative abundance of the different species groups at the different sites in winter are different from what was predicted. This lack of correspondence might be attributed to method used in assessing vegetation cover in the study. The category approach used is subjective and produces less accurate measures compared to a more objective measure (e.g. point quadrat or step point method). It also has the potential to result in quite different cover estimates between summer and winter because it uses canopy cover rather than basal cover (point quadrat and step point methods estimate basal cover). Also the vegetation cover results in winter indicated that there was no clear trend within sites, the cover was almost the same (low) in all sites. In line with the results of the study researchers also acknowledge that in using TBA there are limitation, strengths and weaknesses, Van den Brink et al. (2011) suggested a list of TBA strengths and these include: that traits are transferrable across geographies, add mechanistic and diagnostic potential to community ecology, requires no new sampling methodology, have an old tradition, and can supplement taxonomic analysis. Weaknesses include autocorrelation, redundancy, and inability to protect biodiversity directly, although if the outcome of trait analysis is the taxon as in the case of the vulnerability approach developed in this study, then trait can offer insights into biodiversity protection. Therefore based on the above factors, there would seem to be the question of whether or not a traits-based approach to monitoring and management would necessarily lead to protection of biodiversity in general.

The classification of vulnerable species in this study was successful; species designated as highly vulnerable were less associated with the highly disturbed sites, particularly in winter. These species include *Panicum maximum*, *Themeda triandra*, and *Paspalum dilatatum*. These species are generally highly palatable, tall with large leaves, thus exhibiting traits that reflect vulnerability. Because highly eroded sites in the study area are open access for livestock grazing, the lower association of these species with highly disturbed sites is attributed to high grazing pressure. Several studies have reported similar findings, for example, Díaz et al. (2007) demonstrate that grazing favours species with resilient traits such as annual over perennial species, short plants over tall ones, prostrate over erect plants, stoloniferous and rosette architecture over tussock architecture. Cingolani et al. (2005) report short species with high SLA were abundant in most intensively grazed areas. Jones et al. (2011) found that tall and medium-height species decreased with grazing intensity. The results also indicate that moderately vulnerable and resilient species show no pattern across sites, because resilient species are able to survive in all wetlands, since they have traits that avoid grazing disturbance. The results of this study suggest that when species possess traits that are resilient, they tolerate grazing pressure better than species that possess traits that are vulnerable. Therefore, management and sustainable conservation of hillslope seep wetlands may benefit from a trait-based approach; it is clearly important to take into account the classification of species into vulnerable groups based on plant traits when managing hillslope seep wetlands.

Regarding the degree of disturbance and grazing pressure in the studied hillslope seep wetlands, the VC and the AAI results showed that, in both winter and summer, the less eroded sites were least disturbed compared to the highly eroded sites, indicating that the grazing pressure was lower in the less eroded sites than on the other sites. The less eroded sites were on privately-owned land, which may have contributed to reduced grazing pressure. By contrast, the moderately and highly eroded sites were in communal areas. A study conducted by Bella et al. (2018) indicates that communal wetlands were in poor ecological status while wetlands in privately-owned lands were in excellent or good ecological status. Bella et al. (2018) indicated that overgrazing was a contributing factor to the poor ecological condition of wetlands in communal areas. The results of the present study are thus in agreement with those of Bella et al. (2018).

With regard to seasonality, grazing pressure on the wetlands seemed to be highest during winter as the AAI and VC were lower. A possible explanation is that, in winter, hillslope seep wetlands offers the only available green vegetation for grazing as the surrounding grasslands become less attractive for grazing. Cattle may therefore be enticed to enter the wetland to obtain good quality grass for grazing (Hughes et al., 2013). These results agree with those of Wondie (2018) who reported wetlands that were highly degraded by overgrazing, particularly during the dry season. Although there was a lack of significant relationship between species vulnerable groups and AAI/VC, the results showed that in winter highly vulnerable species decreased with an increase in stress, while resilient group was not affected by the stressor.

4.5.2 Individual plant traits response to grazing

In this study, the RLQ ordination analysis was used to assess the relationship between traits and environmental stress, while fourth-corner analysis was used to test the significance of relationships between individual traits and environmental metrics. The results showed that in both the winter and summer seasons, the highly eroded sites were clustered together and associated with environmental stresses such as soil disturbance, vegetation community quality, and slope. A possible explanation of the association between the highly eroded sites with soil disturbance could be high grazing intensity in these sites. The fourth-corner analysis showed that, in summer, plant height was correlated with VC; SLA correlated positively with soil disturbance, habitat alteration within wetland, and hydrological alteration. These results could be attributed to the fact that plant height and SLA are known to be the best predictors of grazing response compared to other traits. In winter, plant height and leaf area correlated with hydrologic alterations, whereas SLA correlated with vegetation community quality, signifying that these three traits (plant height, leaf area and specific leaf area) were the best predictors of grazing in winter. Similar findings are reported by Díaz et al. (20 01), de Bello (2005), and Dubey (2011) where plant height and leaf traits were the best predictors of grazing responses. The fourth-corner analysis results show that the individual trait responses to grazing were less clear. The results indicate only three out of 49 associations between species traits and environmental stress. Both analyses – the RLQ and the fourth-corner analysis – are influenced by the selection of traits which are constrained by their response towards grazing.

4.6 Conclusion

A trait-based approach was developed using a combination of multiple traits. Plant species were then classified into three vulnerability groups in relation to grazing pressure. Based on the results of the study two concluding remarks can be drawn. Firstly, the prediction made was true for comparing seasons, where the result indicates that the majority of species designated as potentially vulnerable were less associated with the winter season because of high grazing pressure. Therefore based on these findings it seems TBA worked and was useful for predicting the potential responses of plant species in hillslope seep wetlands to grazing pressure. Secondly, the prediction did not correspond well when comparing sites within the winter season and the less correspondence recorded can be attributed to the difficulty in accurate estimation of vegetation cover during winter. Therefore, this can be effectively built on to produce working field protocol for further testing using more accurate measures of vegetation cover. Further, the RLQ results showed that the relative abundance of species belonging to the highly vulnerable groups reduced in the highly disturbed sites compared to the relative abundances of the resilient plant species. Species such as *Panicum maximum*, *Themeda triandra,* and *Paspalum dilatatum,* identified as potentially vulnerable to grazing pressure, are less associated with the disturbed sites than species such as *Tristachya hispida, Centella asiatica, Senecio speciosus,* which are regarded as less vulnerable.

CHAPTER 5: ENGAGING WITH COMMUNITIES TO DEVELOP AN UNDERSTANDING OF LIVESTOCK GRAZING PRACTICES IN RELATION TO ECOSYSTEM SERVICES PROVIDED BY HILLSLOPE SEEP WETLANDS

5.1 Introduction

Livestock play a significant role in the livelihoods of people globally (Shackleton et al., 2005; Herrero et al., 2013; Bettencourt et al., 2013). They provide several benefits to society: they are a source of income, they provide cultural services, and they generate employment, especially for people living in rural communities in the developing world. Livestock sustainability relies heavily on wetland ecosystems because wetlands provide biomass for livestock grazing. According to Palmer et al. (2002) the main value of wetlands for livestock grazing is a six-week period towards the end of winter, when wetlands provide the best available grazing. Wetland vegetation concerns arise when wetland landscape has low VC and year-round grazing impacts wetland condition. Generally, hillslope seep wetlands are among the most commonly grazed wetlands type and the amount of forage produced by these wetlands is estimated to be about twice as productive as natural dryland veld (Palmer et al., 2002). The estimated annual value of seep wetland grazing is R1800 per ha for natural seepage systems, and between R1800 per ha and R2400 per ha for seeded seepage systems (Palmer et al., 2002).

African wetlands make an important contribution to people's livelihood (Wood et al., 2013). For example, wetland services in the Gulu municipality in Uganda provide >50% of the monthly income to the communities within the area (Opio et al., 2011). Obiero et al. (2012) also report that, in Kenya, wetlands are used by people for exploitation of plant resources, for subsistence and commercial farming, and livestock grazing.

Despite the benefits wetlands provide to people, currently half the wetlands in South Africa have been lost or degraded (Drayer and Richter, 2016). Wetland degradation and loss is attributed mainly to overgrazing, to forestry, and to invasion by exotic plant species (Drayer and Richter, 2016). Most communal lands in South Africa are open-access systems for grazing, with little or no active livestock management; as a result, lack of active grazing management practices gives livestock uncontrolled access to wetlands, leading to degradation. The degraded status of wetlands affects not only livestock production, but also the well-being of people who both value and depend on livestock.

In the Tsitsa River Catchment, livestock farming and subsistence crop production are the main economic activities for the majority of residents, especially older men and women, providing enough income to sustain family members (van Tol et al., 2014). Catchment soils are naturally erosive, but livestock trampling may aggravate the situation, and entire hillslope seep wetlands vanish into erosion gullies. Hillslope seep wetlands in the Tsitsa River Catchment are valuable and vulnerable keystone habitats because communities use them for livestock grazing. The demand for and importance of wetlands indicate that livestock and wetland issues have social, ecological, and economic consequences, and thus require a CSES approach to address (Pollard et al., 2010; Palmer and Munnik, 2018).

The need for community engagement in protecting and managing wetland resources is understood globally (Shrestha, 2013; Martini et al., 2017). The engagement of local community members is crucial in rural projects because it encourages community members to participate and take responsibility for sustaining and managing their natural resources (Pollard et al., 2010). Engagement also promotes a better understanding of any research or development project by both researchers and local communities through knowledge exchange (Palmer and Munnik, 2018). To date, the South African government implementers of natural resources have not recognised the value of participation by rural people in protecting grasslands and avoiding degradation (Vetter, 2013). This neglect of local people has led to the failure of several projects (Pimbert, 2004). It is therefore important to involve communities so that wetlands can be collectively protected and sustained**.** This study aimed to engage with livestock owners in communities within the Tsitsa River Catchment to elicit information regarding their knowledge of hillslope seep wetlands, and their understanding of the importance of these wetlands as systems that should be protected because of the services they offer. A further step would be evidence of the kinds of protection interventions that would be acceptable and supported by local residents – for example, active livestock herding. This chapter therefore fulfils objective three (Chapter 1, section 1.8) of the overall study.

5.2 METHODOLOGY

5.2.1 Research approach

Qualitative research approach

Qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena by observing feelings, thoughts, behaviours, and the beliefs of individuals and groups of people (Babu, 2008). Qualitative methods enable the exploration of phenomena using more flexible and semi-structured instruments, such as workshops, in-depth interviews, focus groups and participant observations (Mack et al., 2005). Creswell (2007, p. 40) describes qualitative research as a means to "*empower individuals to share their stories, hear their voices, and minimise the power relationships that often exist between a researcher and the participants in a study*". Qualitative methods, such as interviews, are believed to provide a deeper understanding of social phenomena than would be obtained from purely quantitative methods (Gill et al., 2008). A qualitative research design was used in the present study to explore the understanding and knowledge of rural people about the importance of seep wetlands, the contributions of hillslope seep to their livelihood, and the need for their protection. Because ecosystem services are the keys components of the study, part of the questionnaire was about ecosystem services provided by hill slope seep wetlands. These include: provisioning, e.g. livestock grazing and water for domestic use; and cultural, e.g. recreational and spiritual. The main focus research design was qualitative, but complemented by quantitative analysis where necessary.

5.2.2 Research design

Case study

A central feature of the case study method used in this study was the detailed and in-depth analysis of a single case over time, through the use of multiple sources (interviews, observations, audio-visual materials) (Creswell, 2003). Yin (2009) describes case study research as a method that is used when the boundaries between phenomenon and context are not clear enough, and multiple sources of evidence are used to investigate a contemporary phenomenon within its real-life context. The role of the case study method in research becomes more prominent when dealing with community-based problems (Johnson, 2006), including poverty, unemployment, drug addiction, and illiteracy (Zainal, 2007). The community problem in the current study is the lack of grazing management strategies, a lack that contributes to the degradation of hillslope seep wetlands, ultimately affecting livestock production. According to Creswell (2007), a case study approach involves an exploratory analysis of a bounded system over a sustained period of time. In the context of this study, the bounded system of the three selected villages was used to explore community perceptions about the importance of hillslope seep wetlands to livestock, and the benefits and ecological health of the systems. This exploration occurred using structured, semi-structured interviews, and recordings. The whole study was conducted over three years; the villages were part of a larger Tsitsa project and knew the Tsitsa project field co-ordinator. There was active engagement of the villages in this study. In the quaternary catchment where interviews concerning seep wetlands were conducted, there are 63 villages. From these, three were purposively chosen, based on their proximity to seep wetlands. We used Google Earth to estimate that 49 households owned livestock in the three small villages, based on the number of livestock kraals (enclosures) (Mtati, pers comm, 2014).

5.2.3 An application of Cultural Historical Activity Theory (CHAT)

Kuutti (1996) defined CHAT as a "*theoretical framework for analysing different forms of human practices as development processes, with both individual and social levels interlinked at the same time*". CHAT was originally developed by the historical philosopher Alexei Leont'ev', during the 1960s, and it is based on Lev Vygotsky's particular theories of cognition and learning (Vygotsky, 1978). Cultural Historical Activity Theory (CHAT) enables researchers to analyse complex, evolving professional practices, and practitioners to engage in reflective research (Foot, 2014).

Cultural Historical Activity Theory provides researchers with a holistic explanatory framework for the relationships between elements of an activity system. Elements of an activity influence each other and are influenced by social, cultural and historical factors such as background knowledge, personal bias, and availability of tools (Koszalka, 2004). An activity system has six core elements, each of which holds cultural and historical dimensions (Foot, 2014). The first three elements of the theory were developed by Vygotsky in the first generation of activity centred on the concept of mediated action, which suggests that human interactions with their environment are not direct ones, but are mediated through the use of artefacts (Fleer, 2010). Vygotsky's idea is expressed as the triad of **object** (the purpose or the reason of an activity), **subject** (an individual or a group of people involved in the activity) and the **tools** (resources used in the activity). However, because Vygotsky's model mainly focuses on the development of the individual, Engeström (1987) created a collective activity, developing Vygotskian activity by adding three elements provided in second-generation activity theory (Figure 5.1).The three added elements include: **community** members who set **rules** and norms under which the subject operates and establish how the community members organise (**division of labour**) to meet their goals. This theory has been developed as a driver for understanding transformative learning processes associated with changes in the activity system (Engeström, 2001).

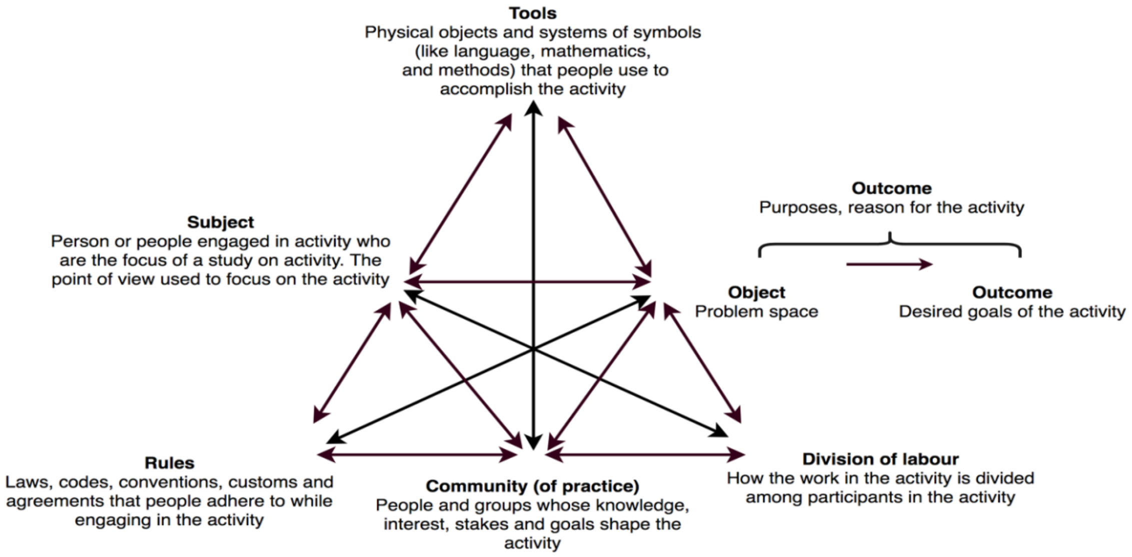


Figure 5. 1: **The triangular model, second-generation activity theory and primary unit of analysis of Cultural Historical Activity (Adapted from Engeström, 1987).**

In this study, the social activities of landscape restoration and sustainable management, and the livelihood activity of livestock ownership in relation to hillslope seep wetlands, constituted the activity systems of interest. Therefore, it was appropriate to use CHAT as a guide to understand seep wetland importance in relation to grazing and communities, livestock grazing management practices, seep wetland protection, and both the constraints to and benefits of livestock production. In this study, CHAT was not used as the basis of activity analysis, rather, it was used as a guide to formulate questions, based on the six elements of the activity system, developed for the interviews (Appendix 3c).). In several pure social science studied CHAT is used in detailed as an analytic framework, however, the currently study is based on both natural and social sciences, and the there is already an in-depth analysis on natural science aspect. It was therefore apposite to use CHAT as a basic guide in this study.

- **The object of the activity**

  The object of the activity in this study is the need to balance livestock production for livelihood and cultural purposes, with hillslope seep wetland protection. The anticipated outcomes of shifting activities to influence the sustainability of the object could include increased income generation for the livestock owners, improved livestock production, and better condition of seep and grazing land.

- **The subject of the activity**

  Livestock owners and herders are the focus subjects of the activity. Livestock owners and herders play a role in owning and controlling the movement of livestock, and benefit from increasing and/or improving livestock production. Owners depend on livestock for food (meat and milk), ritual, and income; herders benefit through employment.
- **Tools**

  Tools in the context of this study include farmers' knowledge and experience of about livestock and landscape: pasture/rangeland; dipping facilities for livestock care; community knowledge of grazing practices; kraals for security of livestock; livestock record-keeping materials; skills for breeding livestock, and water points for livestock.
- **Rules**

  These are customary or other formal and informal agreements that people adhere to when engaging in pastoralism. Agreements could include contracts signed by both livestock owners and herders on the norms and rules to follow while growing livestock, or historical patterns of livestock movement, and adherence to grazing management practices.
- **Community**

  In the activity system for the present study, six key groups/individuals form the community. These are i) local community members, ii) researchers, iii) livestock buyers, iv) the Department of Agriculture, v) traditional authorities, and vi) the DEA. Local community members are those members of the community who are interested in shaping, and willing to shape the system goal of engaging in pastoralism. Researchers are members of academic institutions who are working with the communities to involve people in facilitating organisation structure, such as land and water forums, that will deal with water and grazing land issues. Livestock buyers are community or commercial farmers that buy livestock from owners. The Department of Agriculture are the providers of health services for livestock to the communities. Traditional authorities are responsible for getting the initial information from researchers and government stakeholders and passing it on to the whole community.

The Department of Environmental Affairs is engaged in landscape restoration and are the lead agents of the Tsitsa Project (Chapter 2: Study area description).

- **Division of labour**
  Division of work among participants towards reaching a goal. Livestock owners provide employment for the herders. Herders are responsible for herding livestock to grasslands and for taking the livestock to water sources for drinking after grazing. DEA-EPWP programmes such as Working for Water deal with the restoration of the grazing land to improve livestock production.

Questionnaires framed using CHAT elements are provided in Appendix 3d

5.2.4 Sampling method

Sampling strategy

All the participants were purposively sampled from Caba, Luxeni and Manditshe villages. Singleton et al. (1988:153) define purposive sampling as an approach that consists of aspects that contain the most characteristic, representative or typical attributes of the population. Purposive sampling is a non-probability strategy in which the investigator intentionally selects certain people in a study based on defined characteristics, which may be exposed to a particular phenomenon. In the context of this study, the participants were engaged because they were livestock owners or herders, or family members in a household that owns livestock.

5.2.5 Data collection methods

Participant selection

Of the 63 villages in T35E quaternary catchment, respondents were chosen from three purposively selected villages. The three villages are the upper Caba, Manditshe and Luxeni (Table 5.1) villages. The villages were chosen because they are surrounded by seep wetlands and local livestock have easy access to these ecosystems. Households with kraals were chosen whenever a livestock owner could be found and agreed to participate.

Thirty-one “participants” were interviewed. A participant in the context of this study is one or more people who were in the household and participated in the interview (for example, a resident woman may have been assisted by a herder in answering some questions). Household interviews were conducted to gather information on seep wetland benefits, their degradation status, livestock grazing, importance of raising cattle, constraints and grazing practices (Interview data collection sheets in Appendix 3d).

Table 5. 1: **Villages selected for the study and the number of households sampled.**

Villages	No. of households	Sampled households
Upper Caba (Mafusini-local name)	32	10
Luxeni	44	6
Manditshe (Emrholweni local name)	30	15
TOTAL	**106**	**31**

Household interviews

Structured and semi-structured interviews were used as the data-gathering method. In the study area, isiXhosa is the first language so interviews were translated into isiXhosa. Semi-structured interviews were organised around a set of pre-determined open-ended questions, with other questions emerging from the dialogue between the interviewer and the respondent (DiCicco-Bloom and Crabtree, 2006). Field interviewing in research serves multiple purposes. It is a specific form of interviewing carried out by asking mostly open-ended questions. Singleton and Straits (2005) postulate that field interviewing is an efficient way of obtaining in-depth information insofar as it enables the investigator to probe deeply into social and personal experiences. In this way, interviews are an effective way of obtaining in-depth data (De Vos et al., 1995).

Kobo collect

Kobo Collect is free software that allows users to collect, transmit, store and use data easily and cheaply using mobile phones and tablets (Bannatyne et al., 2017). In the present study, interview questions were created in word document, transferred into a Kobo Collect form and saved.

5.2.6 Ethical considerations

Prior to data collection, traditional leaders were contacted to discuss and give clarity about the survey and make appointments for the interviews. Ethical clearance was obtained from the Rhodes University Ethics Committee. A consent form requesting authorisation was provided to interviewees (Appendix 3c) who signed the form before the researcher proceeded with the interview. The consent form served as proof that the participant agreed to be interviewed and that they had the right to withdraw their participation at any time if they were not comfortable. The outcomes of ethical clearance from the University are provided in Appendix 3a.

5.3 DATA ANALYSIS

5.3.1 Descriptive statistics

Descriptive statistics were used to analyse data through frequencies and percentages. These quantitative findings are presented in the form of graphs and tables.

5.3.2 Thematic analysis

Thematic analysis is a data analysis method that includes identifying reporting patterns (themes) within data, and establishing a framework for presenting the meaning of data collected (Creswell, 1998; Braun and Clarke, 2006). Thematic analysis was used to analyse the semi-structured interviews. Themes that emerged in the whole or sub-set of interviews were identified in order to create a framework for making contrasts and comparisons between the different participants (Gomm, 2008).

The thematic analysis used in this study was based on the six phases of thematic analysis developed by Braun and Clarke (2006):

- **Familiarising yourself with your data:** Transcribing data (Appendix 4), reading and re-reading the data, noting down initial ideas.

- **Generating initial codes**: Coding interesting features of the data in a systematic fashion across the entire data set, combining data relevant to each code.

- **Searching for themes**: Combining codes into potential themes, gathering all data relevant to each potential theme.

- **Reviewing themes:** Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2); generating a thematic ‘map’ of the analysis.

- **Defining and naming themes**: Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells; generating clear definitions and names for each theme.

- **Producing the report:** Final analysis of selected extracts, relating back to the analysis to the research question and literature, producing a scholarly report of the analysis.

5.4 Results

5.4.1 Demographic information

A total number of 31 respondents were interviewed for the study. About 80.1% of the respondents were heads of households and each had lived in their village for more than five years. A household usually includes an adult man as a head of the family, and/or his wife, their children and other dependants. A wife or a widow is the head of the household in the absence of a husband. About 55% of the respondents were male; female respondents made up 45%. The respondents' ages ranged from younger than 30 to older than 70 years of age. The majority of the respondents were more than 50 years of age (80.1%). The youth were the least represented age group (16.1%).

5.4.2 Livestock numbers

All respondents were willing to divulge their livestock numbers. Sheep numbered the highest with 753, followed by goats (323) and cattle (286). Of the 286 cattle, about 49.3% were cows, 25.5% oxen and 25.2% calves. Of 753 sheep, ewes contributed the highest percentage of 43.8%, followed by lambs at 33.7% and rams at 22.3%. (Table 5.2).

Table 5. 2: **Total livestock numbers in the studied communities.**

Livestock	Cows	Oxen	Calves	Total
Cattle	141	73	72	286
Sheep	Ewes	Rams	Lambs	
	330	168	255	753
Goats	-	-	-	323

5.4.3 Themes and sub-themes

Results presented in this section highlight how people perceive the importance/benefits of seep wetlands, wetlands and rangeland degradation status, problems associated with hillslope seep wetlands, changes in grazing land quality, causes and impacts of these changes on livestock production, and hillslope seep protection. Eight main themes were identified as the key perceptions of participants.

Seep wetlands

- Provide fresh green grass and water (importance)
- Seep dongas are dangerous to livestock (degradation)
- Seep wetland protection

Grazing management practices

- Camp division and fencing
- Rotational grazing and resting
- Employed rangers

Climatic conditions

- Drought
- Lack of rain

Grazing land problems

- Donga expansion and erosion
- Unexpected fires
- Wattle invasion
- Livestock theft
- Camp fence theft

Lack of institutional structure and enthusiasm for developing institutions

- No rules in the community
- Livestock graze anywhere

- Only people with herders have rules
- For community development
- To get help for fixing dongas and wattle removal
- For government to get close to rural people

Discussions around grassland and livestock issues and governmental factors

- With other community members
- With chief
- With neighbours
- With animal health technicians when livestock are sick
- Government is far from rural people
- Only government can help with resources
- No trust in government

Benefits of owning livestock

- Income
- Food
- Wealth status
- Ritual
- Other

Challenges in raising livestock

- Grazing and feeding
- Water scarcity
- Animal diseases
- Drought

Seep wetlands importance and condition

Most participants (45%) perceive seep wetlands as very important ecosystems for livestock grazing (Figure 5.2), reasoning that in winter, seep wetlands assist in maintaining livestock grazing by providing fresh green grass that is not available in other ecosystems. These ecosystems are not only important for grazing but the participants also recognise other ecosystem services provided by these wetlands, such as water for their livestock. About 19.3% of the participants felt that hillslope seep wetlands were not important, because livestock get stuck in the mud and die. If 'very important' and 'important' responses were combined as a category that says "yes", the overall percentage would be 64.5%, while 'probably' and 'unimportant' as a "no" category gives an overall result of 35.4%. Although 45% of the participants perceived seep wetlands as important ecosystems, there was no statistical significance in importance between the four groups. Some explanations with respect to the importance of the wetlands included the following:

"*Seeps are the only place with fresh grass. We don't have any choice; we are forced to take livestock up there during dry season."* P 17 lines: 282-283.

"*Seeps are very important because when livestock come home from seeps they come back full in their stomach because the grass that is there is soft and fresh.*" P 19 lines: 306-307.

"*Seeps are important because they always have water so when livestock done grazing they drink water without going far looking for water.*" P 28 lines: 434-435

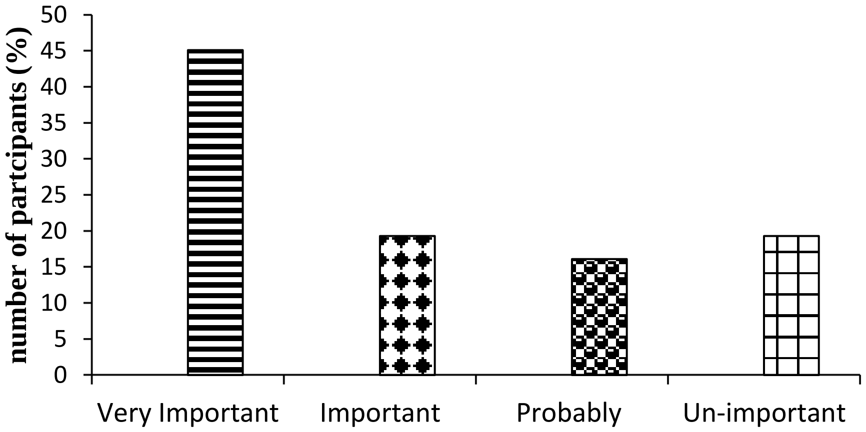


Figure 5. 2: **Percent of participants indicating the importance of hillslope seep wetlands for livestock grazing.**

Although seep wetlands were perceived as important ecosystems for livestock grazing, there was a consensus among the participants that the majority of the seep wetlands are degraded, some with dongas that are dangerous to livestock. The participants further indicated that seeps with dongas represent traps for livestock into which they easily fall, which may lead to death. About 54% of the participants indicated that hillslope seep wetlands are highly eroded; 40% felt that seep wetlands are moderately eroded, while only 6% mentioned less eroded (Figure 5.3). However, there was no statistical significant observed between the three groups. Livestock getting stuck in mud was mentioned several times as a problem. Typical responses included the following:

"*Cattle go to seeps because they are attracted by the green grass, but most of these seeps are degraded and there is dongas in the seeps, they are dangerous because cattle fall and sometimes no one is close by to help the cattle.*" P 30 lines: 466- 468.

"*They sometimes graze more on seeps to the extent that there is no grass covering surface that's when they get stuck in the mud.*" P15 lines: 251-252.

"*We used to have this seep as you can see it was big but we have lost it now, it is a gully.*" P2 lines: 33-34

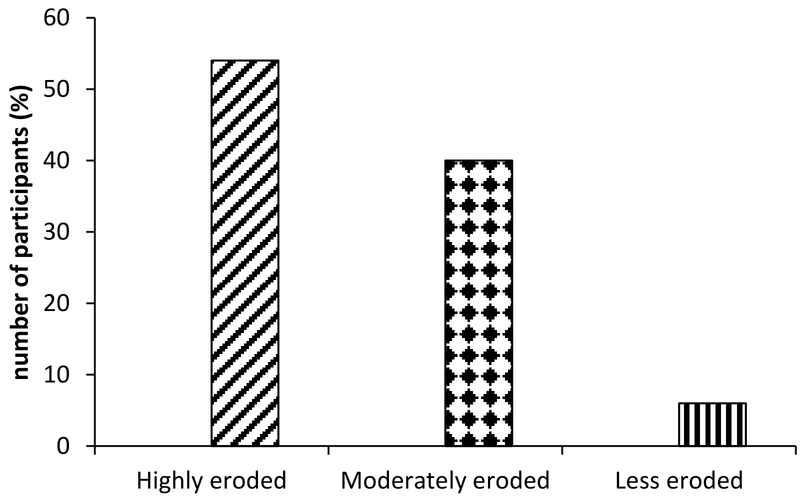


Figure 5. 3: **Percent of participants indicating the ecological condition of hillslope seep wetlands for livestock grazing.**

Hillslope seep wetland protection

With regard to protection of hillslope seep wetlands, the majority of participants (81%) suggested fencing as a better way of protecting seep wetlands (Figure 5.4), while 13% suggested gabion construction. There was no statistical significant observed between the three groups. Some participants suggested avoiding overgrazing and trampling by livestock, and dividing camps for rotational grazing as strategies for wetland protection. Responses include the following:

"*Livestock have open access to these seeps since they are not protected.*" P2 line: 19

"*We need to divide camps like commercial famers, what they do is to divide camps and put livestock in other camps and rest others.*" P 11 lines: 198-199

"Protection of grassland is better by fencing, so that we get enough grass for livestock." P 12 line: 214.

"If we protect the seeps it means they will produce more grass for our livestock and that we will also protect them from grazing too much and trampling, since they will not spend too much time on seeps." P 24 lines: 374-376.

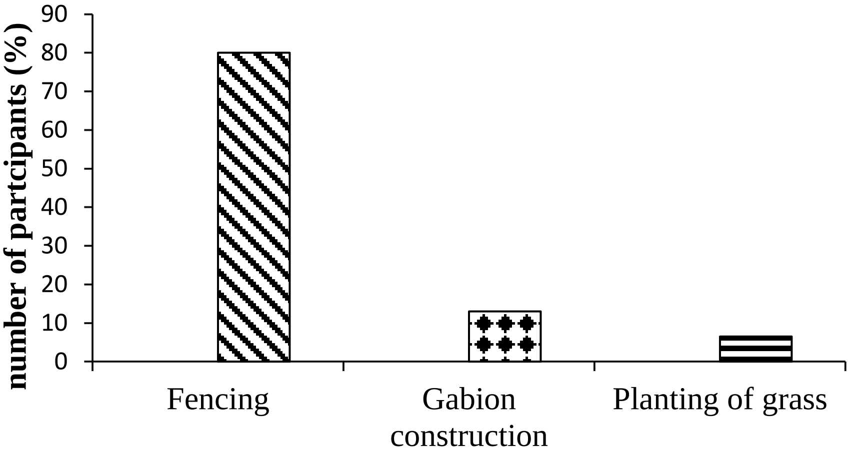


Figure 5. 4: **Percent of participants indicating possible ways to protect erosion in seep wetlands.**

Grazing management practices

Lack of grazing management practices in the studied communities emerged as the perceived cause of changes in grassland condition. A number of participants perceived that currently there are no grazing management practices. When comparing the current situation with previous years, participants were not happy about the current condition of the grazing landscape. Participants recalled that in times past, there were rangers employed by government to look after grazing lands; they recalled that at that time they had fenced grazing camps that were divided into dry and wet season camps. The camps were divided for rotational and resting purposes. During that time the condition of grassland was good with corresponding good condition of livestock. Responses included the following:

"*Our cattle go and graze anywhere around catchment.*" P5 line: 97

"*Long time ago when I was young we had rules, where we had one camp closed and one open, we usually use the one open for grazing for a particular season, and rest the other piece, but now we don't have any rules.*" P 12 lines: 206-208.

"*It used to be there long time ago, where we use to open one camp and rest the other, and rangers were looking after these but the trust disappeared now.*" P25 lines: 384-385.

Climatic conditions

Climatic factors, including drought and changing rainfall patterns, were mentioned by the majority of participants as factors that contribute to grassland erosion. Participants from the studied areas reported that they have noted that, over the past two years, changes in rainfall pattern affecting the condition of the grassland. Responses included the following:

"*This area is not the same, there is drought; we don't have grass this year at all."* P 19 lines: 307-308.

"*Last year we had no rain, it usually rains in summer but it is not; hey our cattle were hungry and thin, just like now there is no rain, no grass.*" P11 lines: 197-198.

Grazing land problems

Donga expansion and erosion, fires, wattle invasion, theft of fenced camps in the past, and livestock overgrazing emerged as the main grazing land problems that communities faced. Donga expansion and erosion were perceived as the biggest challenges in these communities. The challenges were attributed to the absence of controlled grazing practices. A participant from Caba village observed that the erosion in the community is caused by livestock coming from neighbouring communities. Wattle invasion was mentioned by the majority of the participants as the problem that destroys grasses. Participants also indicated that criminals hide within the wattle forest, escalating livestock theft. Some participants recognised that livestock theft is linked to the absence of camps and the fact that livestock graze far away from home. In addition, participants shared their concern about unexpected fires, mostly connected to drunken people with a tendency to throw out live cigarettes. Some participants felt that fires are not caused by the people in their community, but from people in other communities. Responses included the following:

"These dongas are expanding every year." P 3 line: 64

"*We get fires out of nowhere.*" P2 line: 29

"*Wattle is invading the whole grassland, you see this area, and we used to have our grazing land clean without wattle, but look at it now.*" P7 lines: 132-134.

"The main problem is that our livestock graze up close to that forest up there and now they get stolen." P11 lines: 196-197.

Lack of institutional structure and enthusiasm for developing institutions

Participants indicated that there are no generally accepted livestock management rules in the communities. This lack of livestock management rules has contributed to many of the challenges, including stock and fence theft, veld fires, and landscape degradation. Some participants mentioned that only people with herders have rules and this has helped to reduce stock theft, because herders stay with livestock in the veld. Participants maintained that people do as they please because they do not have to account to anyone for their actions, and this was also linked with the unexpected fires. Responses included the following:

"*We do our things separately, the way we want, sometimes we call the meetings but no one will come, sometimes people do wrong things and not being responsible because no one will ask why they do such things.*" P3 lines: 59-61

"*Our seeps (intlambo) are degraded because there is no structure in our community.*" P3 line: 70.

When participants were asked about joining organisational structures like a forum that could help them communicate with government about land and water issues, the majority of the participants said they are willing to join a Catchment Management Forum for various reasons. Some perceived that a forum would be good for community development in order to decide on some rules that are not currently in place. They also mentioned that a forum might help to improve their lives. Some participants recognised that there is a lack of communication between them and government, and therefore see the CMF as opportunity to bridge the communication gap. Responses included the following:

"I was going to join if I was a young person because I like to see development in our community." P4 lines: 92-93

"*I would join because I saw the benefit from the one we had, we were getting money from the sheep wool.*" P12 lines: 221-222.

"*I would join because in rural areas we really need help and our government is far away from us, there is a big difference between people in town and us here.*" P5 lines: 113-114.

Discussions around livestock issues, grazing land and governmental factors

There was a consensus among the participants that they do communicate and have discussions about their grazing land and livestock issues. The majority of the participants noted that they have contact details for their animal health technicians in Qumbu Town, a nearby town. Some mentioned that when livestock are sick, they quickly call the animal health technicians. Some, especially women who have less understanding about livestock, mentioned that they communicate with other community members. Responses included the following:

"*Yes, we do get some advices from each other as the community to the extent that when our livestock get sick, we call "abalimi" to come and vaccinate the livestock.*" P2 lines: 22-23

"*Yes, I do talk with my neighbours because I am a female, I seek advice from male for example when my cattle is too thin, I ask what can I do for it to gain weight and they give some advices."* P4 lines: 77-79.

Although participants acknowledged the provision of government veterinary services, there were general concerns regarding these services. These included issues such as a dwindling trust between the community and government. Participants further indicated that government officials only listen to people in towns, paying little attention to rural dwellers. Some participants mentioned that only government can assist with resources so that the grazing land could return to its original state.

"*If only our government can be reliable and bring services to us, because our government takes time to give us attention in rural areas.*" P28 lines: 438-439.

"In rural areas we really need help and our government is far away from us; there is a big difference between people in town and us here." P5 lines: 112-113.

Benefits of owning livestock

In the communities studied, livestock are primarily raised for ritual (39%) and generating income (32%), followed by food production (30%) which includes both milk and meat. About 87% of the participants mentioned that wealth status was the least important benefit for raising livestock (Figure 5.5.).

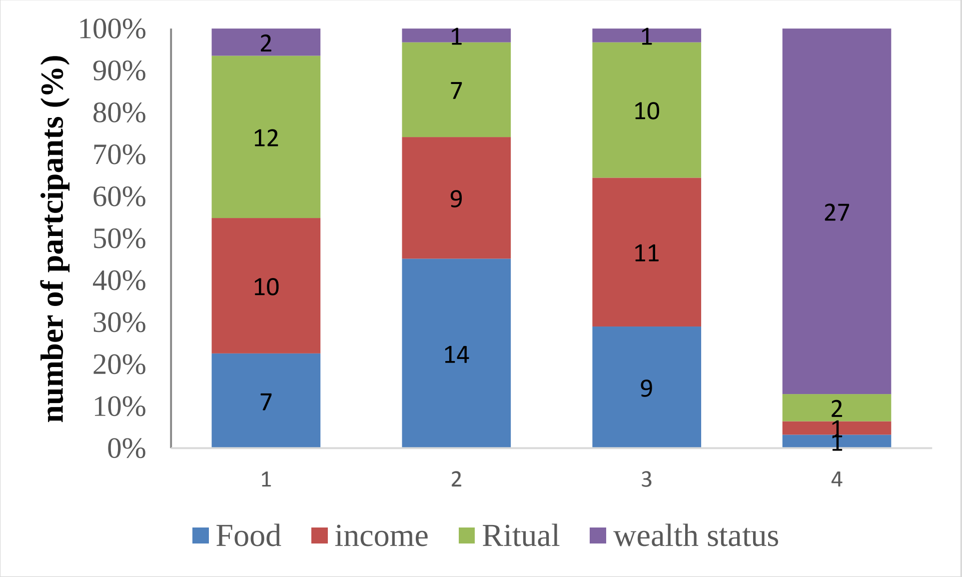


Figure 5. 5: Benefits of owning livestock ranked in order of importance from very important (1) to least important (4) by household respondents.

Challenges of raising livestock

Lack of grass for grazing, animal disease, and drought were ranked equally (29%) as the primary challenges mentioned by participants in raising livestock. Water scarcity was listed as the least important challenge in raising livestock in the catchment (Figure 5.6), but 71% of the participants mentioned livestock theft as the main challenge faced by the community in the category "other".

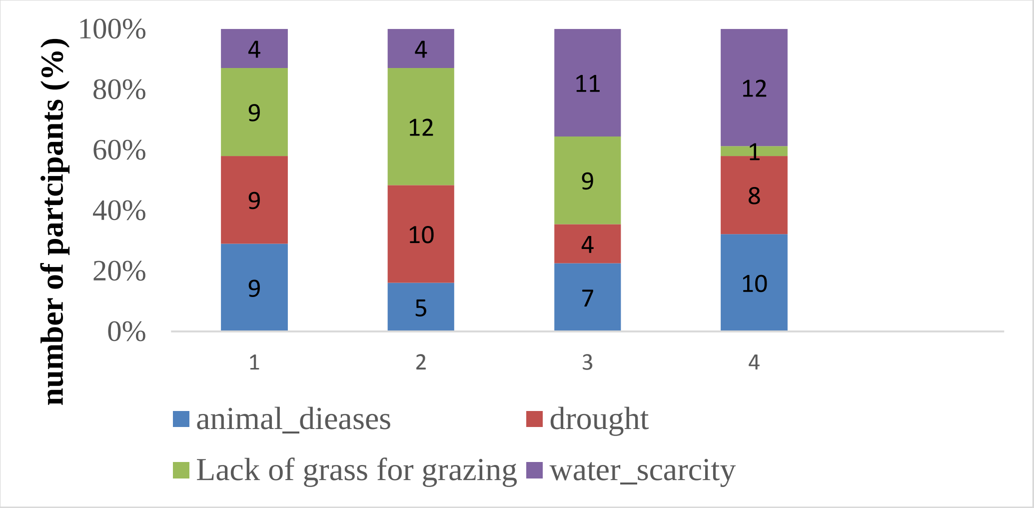


Figure 5. 6: **Challenges faced by communities in raising livestock from very important (1) to least important (4).**

Livestock feed

Approximately 55% of the participants reported that their livestock rely on grazing for feed, while the remaining 45% mentioned that with the current situation of inadequate grass especially in winter, and the drought, they are currently being forced to supplement with ruminant feed, salt Bran (ikhafu), lucerne, maize, and molasses meal (Figure 5.7).

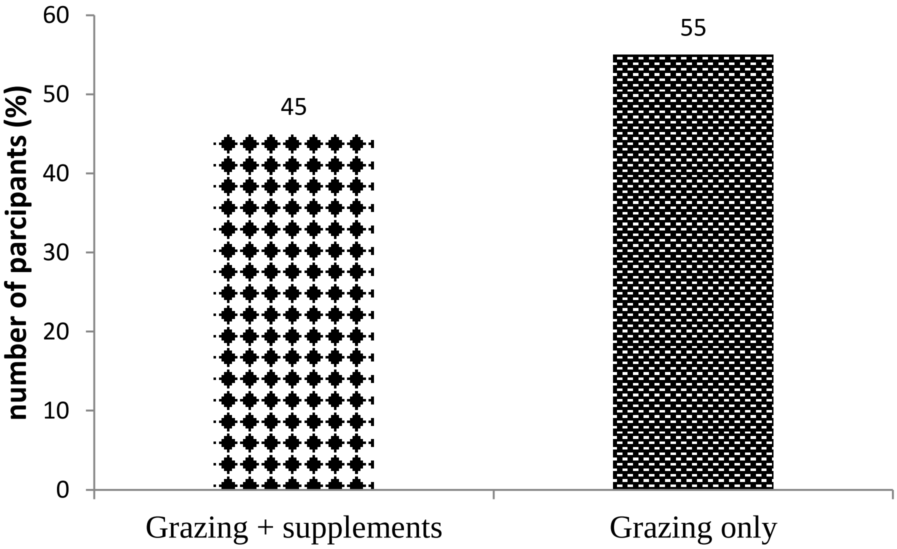


Figure 5. 7: **Participants' use of livestock grazing and supplements.**

5.5 Discussion

5.5.1 Seep wetland importance and condition

The aim of the study was to engage with livestock owners to elicit information regarding their knowledge and understanding of the importance of hillslope seep wetlands as systems that should be protected because of the services they offer. The issue of wetland importance and degradation has been the subject of many studies globally. South Africa, and particularly the Tsitsa River Catchment, is no exception to this global trend. In the current study, the results revealed that communities largely perceive hillslope seep wetlands as important ecosystems for their livelihoods. They recognise that the importance stems from services provided by the wetlands, particularly for livestock grazing during the dry season. Although hillslope seep wetlands are viewed as important ecosystems for livelihoods, the communities also perceive these wetlands as highly eroded ecosystems. South Africa has recently embarked on rehabilitating and protecting degraded wetlands due to the growing awareness of their importance (Dini, 2004). However, the South African rehabilitation has excluded local communities in decision-making and this has contributed to the lack of sustainability of such projects. It is therefore clear that the issue of hillslope seep wetland degradation and their importance to communities is complex, and has social, economic and ecological implications, thus requiring a holistic and integrated approach. A social-ecological systems approach used in this study is a holistic approach that provides an alternative in order to understand the complexity of hillslope seep wetlands, and allows communities and other related stakeholders to participate in improving the hillslope seep wetland condition. The results in this study are consistent with those of Pollard and Cousin (2008), who reported that more than 70% of Craigieburn village people depend on wetlands for their livelihoods in Mpumalanga province. Further, it is also suggested that it is crucial to understand the dynamics of the SES and take into consideration the interactions, feedbacks, thresholds and delayed responses of the system when managing wetlands (Hossain and Szabo, 2017). Other studies that report the importance of wetlands for livelihoods and degradation are those of Kotze e.t al., (1995), Drayer and Richter (2016) and Bhatta et al. (2016).

5.5.2 Lack of institutional structure and willingness to join Catchment Management Forums

Strong natural resource governance institutions, particularly at the community levels, are critical for sustainable management of natural resources, including hillslope seep wetlands. In South Africa, CMFs are envisaged as non-statutory bodies for democratising inclusive decision-making regarding natural resources (Munnik et al., 2016). In areas where CMFs are functional, there is evidence that natural resources are better supported as people collectively hold each other to account for the common good. In the present study, the results indicate participants' willingness to join a CMF if and when one comes into existence. Such willingness suggests the enthusiasm of community members to strengthen local natural resource governance, which could lead to better management of hillslope seep wetlands, so increasing the potential resilience of these systems to disturbances. Many studies have also recognised the importance of community involvement in natural resource management, such as wetlands, through the formation of local institutions and utilisation of local knowledge to improve management of natural resources (Pollard et al., 2010, Shrestha, 2013; Dixon and Carrie, 2015; Lamsal et al., 2015). Therefore, establishment of a forum in the study area, with a full participation of local communities, could help address the concern about rural people feeling excluded from natural resource management, as well as improve governance in wetland management.

5.5.3 Lack of grazing management practices in hillslope seep wetlands

Several studies have reported the lack of a management plan as the main driver in the decline of ecosystem services provided by wetlands (Bhatta et al., 2016). Most rural communities in South Africa still use open access for grazing, without any management. This approach poses a serious, negative threat to natural resources, especially hillslope seep wetlands which are vulnerable to disturbances. To ensure sustainable use of these natural resources, a holistic management approach is required. There are several grazing management practices that can be used to minimise erosion of natural resources and many of these require the cooperation of government and communities. In the current study, the results reveal the lack of grazing management practices as a contributing factor to the degradation of hillslope seep wetlands and grazing land. Communities suggested fencing as a solution. However, communities have also experienced theft of fence material in the past, and therefore only electric fencing of small mobile areas could work, but this would be expensive. Active herding might be a better option. A study conducted by Wang et al. (2014), comparing fenced conservation and grazed wetlands with similar environmental conditions, also found that livestock grazing and trampling increased soil compaction in the grazed wetland more significantly than in the fenced wetland, leading to the degradation of the grazed wetlands sites. In Australia, the Queensland Wetlands Programme lists overgrazing and trampling as impacts of poor wetland ecosystem management. Overgrazing can shift the vegetation community, reducing ground cover, creating bare areas and increasing erosion. Managing wetland areas as a separate paddock would allow the wetland pastures to be used as a drought or dry season resource (Wegscheidl and Layden, 2011). Wegscheidl and Layden (2011), demonstrates that fencing wetland areas as discrete paddocks and grazing smaller wetland paddocks for short periods (rotational grazing) reduces overgrazing, allows wetland plants to recover, and promotes evenness of grazing pressure in adjoining terrestrial pastures. Similarly, in the current study area, fencing or active herding, with the support of government and community members, would contribute to hillslope seep wetland resilience, the improved condition of hillslope seeps, better livestock production, and in turn, better livelihoods.

The weak institutional structures and lack of grazing management rules are clearly linked and one way to connect them would be by drawing on some of the basic ideas of common property theory. This suggests that what separates a common property regime from an open access situation is that the former specifies a defined resource, a defined user group that accesses the resource and a set of institutional arrangements that sets out how the resource is managed. Work has been done on this for the Eastern Cape e.g. Bennett et al. (2010) have suggested that one of the main problems in trying to implement grazing arrangements is inadequate institutional structures as the locus for defining boundaries and grazing management rules.

5.5.4 Livestock importance and challenges

Generating income and the importance of ritual have been reported by several researchers (Bettencourt et al., 2013; Magangana et al., 2015; Mhlobo, 2016) as the primary reason for raising livestock. This is particularly true for poor rural communities with a high rate of poverty and unemployment and a high affinity for traditional practices. In the Tsitsa River Catchment, livestock species play very important economic and socio-cultural roles in the well-being of rural households. The results of this study reveal that livestock in these communities are primarily important for income generation and rituals. Taking into consideration the poverty and unemployment in the rural areas, the results of this study suggest policy-makers and natural resource managers should protect and manage hillslope seep wetlands to sustain their deeply held traditions and rituals, and secure an income for people. The rituals include traditional ceremonies like circumcision, bride welcoming "Utsiki" and the first ceremony when the new baby is born "imbeleko" In the upper uMzimvubu River catchment in Matatiele, the South Africa government has cleared alien invasive and, with the rural communities, are practising rotational grazing through eco Rangers with the help of the uMzimvubu Catchment Partnership Programme (UCPP). The land restoration has improved livestock production and increased the prices livestock sell for at auctions, and thus had a positive impact on the rural economy.

Recurrent droughts still pose serious challenges to livestock farming in communal areas of South Africa (Maluleke and Mokwena, 2017) because droughts are associated with low forage supply and consequently animal weight loss and high mortality, findings reinforced by the results of this study. These results suggest that rural communities need to work collectively and use grazing practices, such as rotational resting, that will allow livestock owners to use one place in one season, and another in the next season.

5.6 Conclusion

The study concludes that local people are knowledgeable about hillslope seep wetlands and the ecosystem services they provide. Their hillslope seep wetland observations indicate that the majority of seep wetlands are degraded and the results of this project clearly indicate that deterioration of hillslope seep wetland systems in the Tsitsa river catchment is likely to have a negative effect on the livelihoods of those who depend on hillslope seep wetlands (livestock owners). Government intervention to manage the hillslope seep wetlands is needed to support restoration and protection of those wetlands. Therefore, in order to properly forestall and manage the degradation of hillslope seep wetlands, while at the same time maintaining livestock production, it is necessary to adopt a social-ecological systems approach that allows active participation of all users and actors. Developing participatory governance institutions that might balance the ecological condition of hillslope seep wetlands with human needs in the Tsitsa River Catchment will require active participation of different stakeholders such as government (DEA, DWS, and DAFF), research institutions, municipalities, NGOs, traditional authorities and local people. The lessons from UCPP approach in Matatiele, has a potential to be developed in the study area, so there is potential for the community taking control of the situation possibly assisted by UCPP and the governance team at Rhodes university is working with communities towards building an approach similar to that of the UCPP. Co-management between communities represented by CMFs is definitely the way forward to coordinate grazing over larger scales in the absence of fencing.

Chapter 6: GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter summarises the key findings of the study, integrating these findings within the broader literature. The first section of the chapter summarises the research contributions, and main findings of the study. The following section articulates policy and management recommendations, and outlines the limitations of the study.

Using an integrative social-ecological systems research methodology, this study aimed to assess the biological condition of hillslope seep wetlands and the value of the wetlands to the local community.

The focus of the study was on hillslope seep wetlands because: i) they are among the most poorly studied wetland systems; ii) they provide critical ecosystem services to people, particularly people relying on livestock for their livelihood; iii) they are vulnerable because of their small size and steep slope; iv) they are among the most degraded wetlands within the Tsitsa River Catchment, and v) they appeared to be a key livestock grazing resource, especially in the winter.

6.2 Research contributions

Understanding and managing complex interactions between people and nature is one of the central challenges faced by society (Hull et al., 2015). A social-ecological systems framework, offers an effective means of characterising such interactions by providing an integrative approach to studying complex systems (Liu et al., 2007; Ostrom, 2009; Cockburn et al., 2018). Considering hillslope seep wetlands as complex SESs, their sustainable management requires an integration of biophysical and social dimensions. The separate roles of the biophysical and social processes in natural resource management are relatively well recognised, but very little attention has been paid to integration so that both processes are concurrently taken into account in natural resource management strategies and plans.

Therefore, this study used an integration of social and ecological components, a SES framework, to assess the condition of hillslope seep wetlands. The integration of the social and ecological components provides a better understanding of the system involving people and natural resources than focusing only on the effect of people on the environment. This integrative research approach combines local and scientific knowledge on wetland management that can lead to the development of strategies for increased productivity of hillslope seep wetland and improve livelihood

CHAPTER 3 of the study was developed to evaluate the performance of various biological indices, and to identify those that provide the best assessment of hillslope seep wetland condition. Because hillslope seep wetlands are small and vulnerable to disturbances and there is yet no tool developed to assess their condition specifically, it was necessary to use a combination of FQAI, FQAWet and WET-Health in assessing hillslope seep wetland condition. Hargiss et al. (2017) indicate that wetland assessment is an important task in understanding the condition and function of wetlands, and the use of multi-tiered assessment indices is necessary. Using a combination of tools allows for in-depth assessments that provide enough evidence to verify that the assessment levels are in agreement. De Berry et al. (2015) maintain that any assessment of ecosystem integrity based on a single index is likely to provide insufficient results for wetland conditions. Ervin et al. (2006) and Yepsen et al. (2014) also recommend the use of FQAI together with other indices that use indicator status since CC scores are not available in most countries. The bioassessment tools used in this study to assess ecological condition showed that hillslope seep wetlands in the Tsitsa River Catchment are deteriorating due to human disturbances. The results from WET-Health reveal that the selected hillslope wetlands in the catchment are moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place, but the natural habitat remains predominantly intact. Although ten wetland sites were in category C, the less eroded sites which were in a privately-owned area had the lowest scores compared to the highly eroded sites that were situated in communal land. One of the highly eroded sites was in category D, signifying large modifications to the wetland condition. The results suggest that there is an urgent need for hillslope seep wetland protection.

The results also show that FQAI and FQAWet scores are lower in winter than in the summer season, indicating a higher grazing pressure in winter. Regarding the evaluation of indices, the findings reveal that FQAIall and WET-Health performed better in assessing hillslope seep wetlands than FQAWet and FQAIdom. Therefore, the study recommends FQAIall and WET-Health as useful indices of hillslope seep wetland ecological health. These findings are consistent with the results of Yepsen et al. (2014) who found that FQAI performed better than FQAWet for wetland assessment. However, the results contradict those of Ervin et al. (2006) who reported that the performance of FQAWet and FQAI was similar.

This study also developed a novel trait-based approach (TBA) to assess and predict the potential vulnerability and resilience of plant species in hillslope seep wetlands to human-induced (**CHAPTER 4**) (Figure 6.1). Research indicates that plant traits provide useful insights in community conservation. Sandel et al. (2011) proved that plant traits can be used to guide the restoration of degraded habitats. It was suggested that restoration ecology can benefit greatly from developments in trait-based ecology that enable improved predictions of how the composition of plant communities respond to changes in environmental conditions. In this study, the results of the AAI and VC used as surrogates for grazing intensity showed that the disturbances differ between seasons; species designated as highly vulnerable were less associated with the highly disturbed sites in winter. In winter there was more disturbance since hillslope seep wetlands are the focal point of grazing during dry season. This approach can aid restoration and protection programmes through predicting species vulnerability to disturbance in a site. Another study (Lavorel and Garnier, 2002) reports that trait-based community ecology theory can provide a basis for predicting the success of restoration treatment in a particular community. The results in the present study are in agreement with the above studies. The chapter focusing on the TBA contributes a novel perspective to hillslope seep ecology in South Africa, as no other study has applied a similar approach to predict and understand the potential vulnerability of hillslope plant species to disturbances.

It has been reported that projects that sustain ecosystems without community engagement are unlikely to be successful. Rural communities who derive their livelihood directly from hillslope seep wetlands may have a good knowledge about the value of the ecosystem services provided by wetlands, especially in the study area, where livestock owners use these wetlands for livestock grazing. Excluding this knowledge base in sustaining or conserving hillslope seep wetlands can lead to further degradation of wetlands and, in turn, no management. **CHAPTER 5** was developed to engage with communities on their understanding and value of hillslope seep wetlands (Figure 6.1). The findings of this engagement reveal that communities are aware of the values and benefits of wetlands in the catchment; they perceive hillslope seep wetlands as important ecosystems because of the ecosystem services they provide, such as livestock grazing and water during the dry season, as well as improving their livelihoods. Similarly, with bioassessment tools, community also observes degradation of hillslope seep wetlands in their catchment. The community knowledge on protecting hillslope seep wetlands and the need for a governance institution proves that local knowledge is important when addressing natural resource management such as hillslope seep wetlands. Because communities in the study area use hillslope seep wetlands without any sustainable grazing practice, livestock grazing needs to be actively managed to minimise degradation. The significant role played by community knowledge and local institutions in sustainable management and conservation of natural resources has also been recognised by several studies (e.g. Pollard et al, 2010; Dixon and Carrie, 2015; Siyaya, 2015).

The results of the study confirm that government has not sufficiently integrated the aspirations of the local communities into decision-making processes when dealing with natural resources management, and this has led to increased degradation of those resources. A study conducted by Dabo (2017) reports an increase in degradation of forest due to the increased exclusion of indigenous communities from their communal lands. Pimbert (2004) also reports that soil erosion, degradation of rangelands, loss of forests – all these problems appear because policy and practice continue to exclude people and so discourage all forms of local participation. The results of this study reveal that institutional structures that are in the study area, for example, local/traditional chiefs, are weak and this is a contributing factor to the degradation in the landscape. These results agree with those of Bhatta et al. (2016) who document a weak institutional structure as a contributor to wetlands ecosystem services degradation.

Based on the results of this study, there is evidence from multiple aspects for protecting hillslope seep wetland and management strategies. Chapter 3 provided the scientific evidence based on the ecological health of the selected hillslope seep wetland; Chapter 4 deepened the scientific evidence based on the trait approach for protecting hillslope seep wetlands in the catchment, and Chapter 5 enhanced the importance of a social science approach to developing evidence based on local values and knowledge of hillslope seep wetland as the motivation for integrating community aspirations into management strategies, including active livestock management. Hillslope seep wetlands need community involvement to protect them in the Tsitsa River Catchment. The Department of Environmental Affairs-Natural Resource Management is already restoring and rehabilitating the landscape in the catchment. This study recommends investing in the protection of hillslope seep wetlands and restoring highly degraded ones by DEA-NRM (Figure 6.1).

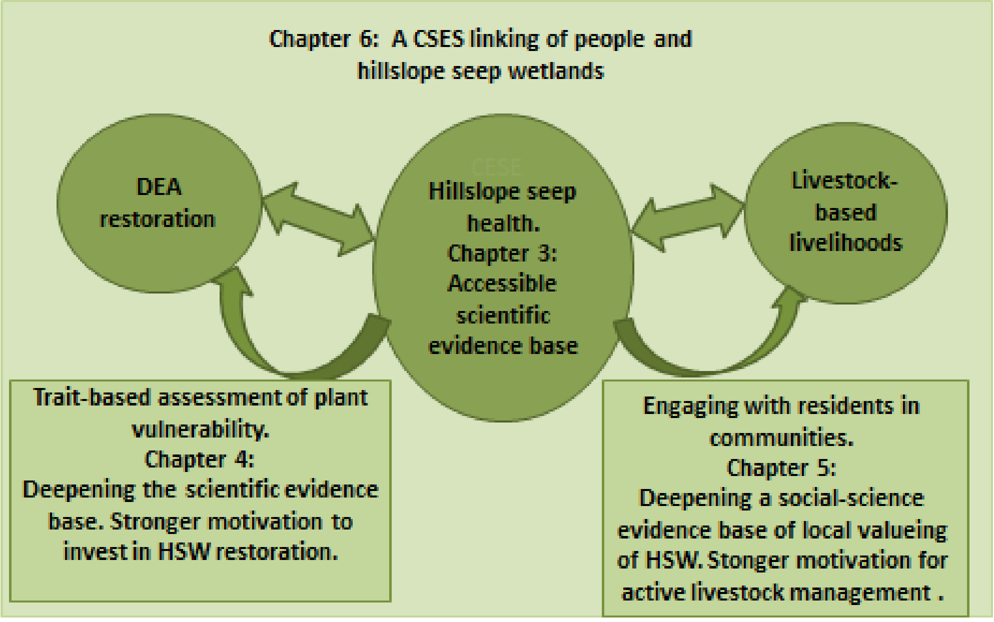


Figure 6. 1: **A complex social-ecological system linking people and hillslope seep wetlands.**

6.3 CSES – hillslope seep wetland systemic links and feed backs

One of the important components of a CSES framework involves examining feedbacks and links among people and natural systems (Berkes et al., 2017). In the current study, there were links and feedback loops between human activities (livestock grazing) and wetlands ecosystems. Because of the green vegetation provided by hillslope seep wetlands throughout the year, livestock owners use these wetlands to grow their livestock production and livelihood – especially in the winter when accessible grazing elsewhere on the landscape has been heavily used. However, because hillslope seep wetlands are located in the steep slope and they are small, they are highly vulnerable to overgrazing and trampling. Communities in the study area have been using seeps for grazing without active management practices, and without a framework for participatory governance that could guide grazing practices. This has contributed to the degradation of hillslope seep wetlands. In turn, the loss of hillslope seep wetlands has probably negatively affected the livelihoods of livestock owners. Developing participatory governance institutions that are able to balance the ecological condition of hillslope seep wetlands and human needs in the Tsitsa River Catchment will require the active participation of different stakeholders, such as government departments including DEA, Department of Water and Sanitation, and Department of Agriculture Forestry and Fisheries, and research institutions, municipalities, NGOs, traditional authorities and local people (Palmer and Wolff, 2018). The problems faced by livestock owners in managing wetlands and the value they perceive of wetlands is provided in Chapter 5. Chapters 3 and 4 highlight the ecological changes that are occurring in these wetland systems, one of them is seep wetland degradation which is connected to livestock grazing, because of the lack of control over grazing in space and time in the catchment. The wetlands constitute a key grazing resource for owners of livestock during winter. Although all livestock might use seep for grazing, the results of the study highlight that these are perceived of being of particular value to cattle compared to other livestock types. One of the factors in that affects wetlands is that livestock are not driven in the catchment it is free-ranging livestock.

6.4 Management and policy recommendations

The results of the study make it clear that hillslope seep wetlands are complex systems that require analysis from both biophysical and social aspects that underpin the dynamics of these resources. Excluding local communities in sustaining natural resources such as wetlands, results in poor, unsustainable wetland management. The findings of this study recommend an interdisciplinary, social-ecological systems approach to improve and sustain hillslope seep wetlands condition and people’s livelihoods.

It is evident from the results of the study that policy-makers and natural resource managers should acknowledge the role played by seep wetland ecosystem services in rural livelihoods and understand that our current policies on seep wetland management only emphasise sustainable wetland management without paying attention on the impoverished, rural people who depend on wetlands for their livelihood. Limiting community use of wetlands might well impact negatively on rural people as these are communities where poverty forces them to rely heavily on wetlands for their livelihood. Sustainable wetland management practices need to be developed to allow rural people to benefit from the ecosystem service provided by wetlands, without degrading those wetlands.

The bioassessment tools used in this study provide evidence that the selected hillslope seep wetlands are declining due to human disturbance. WET-Health and FQAIall were the best performing indices and the study suggests that these two indices be used for managing hillslope seep wetlands. The results from a TBA used in this study reveal that the approach is useful in predicting plant species response to grazing in winter. This approach can assist in guiding conservation and protection management of hillslope seep wetlands through predicting plant species vulnerability to disturbances.

The results of the study reveal that local people are aware of the benefits derived from hillslope seep wetlands, the dangers of degradation, and of possible solutions for managing these wetlands. This shows that local knowledge is important in management of hillslope seep wetlands and the knowledge base of local people is an influential component within a social-ecological system. The community interviews in the study indicated fencing of hillslope seep wetlands as better protection for sustainable management and, based on the ecological results, hillslope seep wetlands were found to be more vulnerable in winter than summer, and therefore, to enhance the resilience of hillslope seep wetlands and improve livestock production, the study suggests that protection should be carried out more extensively during winter. Fencing should be used in a way that moves livestock across the landscape, or so that livestock are moved from one camp to another to allow other camps or part of the wetlands to be rested.

The processes that affect wetland degradation in South Africa are tied to economic, social and agricultural policies (Adekola et al., 2010). Therefore, dealing with wetland degradation will require institutional structure with a combination of different stakeholders from the Department of Agriculture, DEA and the Department of Water and Sanitation, local and district municipalities, and communal people including traditional authorities. The Catchment Management Forum (CMF) process of DWS has already started in the Tsitsa River Catchment (Palmer and Wolff, 2018). These structures are meant to deal with community concerns, and land and water issues in the communities. As a part of sustaining hillslope seep wetlands, this study recommends empowering communities to engage in participatory natural resource governance through engaging effectively with existing formal governance structures. This is the best possible investment in sustainability of both livelihoods and the ecological infrastructure of the catchment (Palmer and Wolff, 2018).

Although the current study showed evidence that a lack of institutional structure in the study area contributed to the degradation of the landscape, this study did not engage with the establishment of a participatory forum. The DEA Tsitsa Project is attending to this, and a planned post-doctoral study will focus on the nexus between ecosystem services, livelihoods and governance. This study suggests that using the role of governance as a platform to assess key levers in effecting a trajectory of change towards improved human well-being would be effective in linking livelihoods to improved ecological infrastructure health and functionality.

6.5 Limitations of the research

A major limitation of the present study is that South Africa has no comprehensive list of species with assigned CC scores, indicating that research is needed to compile a database of regional wetland plant species with their coefficients of conservatism.

6.6 Recommendations for further study

- It is clear in the study that local knowledge is necessary for sustainable management of hillslope seep wetlands. Therefore, it is important that on-going ecological research continues to include local people and acknowledge the active role of local people in participating in natural resource management.

- Further research is also needed to establish participatory governance to improve sustainable management of hillslope seep wetlands.

- A new trait-based approach was developed and proved to be useful in predicting the effect of species response to grazing in the study area. It will be necessary to apply the approach across the other wetlands and grasslands in southern Africa and this still needs to be refined.

- Although, the FQAI index was one of the best performing indexes for hillslope for wetland management, the use of the index is limited in South Africa because of its requirement for a list of species with coefficients of conservatism (CC) scores. Further research is required to focus on the database for South African plant species with CC. This could also potentially lead to better results of Floristic Quality Assessment Index for only dominant species (FQAIdom) whose performance in the current study was weak.

REFERENCES

Adekola, O., Morardet, S., de Groot, R. and Grelot, F. 2010. The economic and livelihood value of provisioning services of the Ga-Mampa wetland , South Africa. 13th IWRA World Water Congress, Sep 2008, Montpellier, France.

Adekola, O., Morardet, S., de Groot, R. and Grelot, F. 2012. Contribution of provisioning services of the Ga- Mampa wetland , South Africa , to local livelihoods. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 8:3, 248-264.

Adger, N. 2000. Social and ecological resilience: are they related? Progress in Human Geography, 24(3): 347–64. http://doi.org/10.1191/030913200701540465.

Adler, P.B., Milchunas, D.G., Lauenroth, W.K., Sala, O.E. and Burke, I.C. 2004. Functional traits of graminoids in semi-arid steppes. *Journal of Applied Ecology*, 41: 653 – 663.

AgriLASA. 2004. Agri Laboratory Association of Southern Africa, AgriLASA Soil Handbook. , pp.1–109.

Allain, L., Smith, L., Allen, C., Vidrine, M.F. and Grace, J.B. 2004. North American Prairie Conference. A Floristic Quality Assessment System for the Coastal Prairie of Louisiana A Floristic Quality Assessment System for the Coastal Prairie of Louisiana. *In Proceedings of the 19th North American prairie conference (pp. 1–18).*

Babu, G.R. 2008. Research Methodology in Social Sciences (India: Concept Publishing Company).

Bannatyne, L.J., Rowntree, K.M, van der Waal, B.W. and Nyamela, N. 2017. Design and implementation of a citizen technician – based suspended sediment monitoring network : Lessons from the Tsitsa River catchment , South Africa. , 43(3): 365–377.

Bauer, J.T., Koziol, L. and Bever, J.D. 2018. Ecology of Floristic Quality Assessment : testing for correlations between coefficients of conservatism , species traits and mycorrhizal responsiveness. *AoB PLANTS* 10: plx073; doi: 10.1093/aobpla/plx073.

Baird, D. J., Rubach , M. N ., and Van den Brinkt, P. J. 2008. Trait-based ecological risk assessment (TERA): The new frontier?. *Integrated Environmental Assessment and*

Management, 4(1) , 2-3.

Bell, J., Boyer, J.N., Crystall, S.J., Nichols, W. F. and Pruyn, M. 2017. Floristic quality as an indicator of human disturbance in forested wetlands of northern New England. *Ecological Indicators* 83:227–231. doi: 10.1016/j.ecolind.2017.08.010.

Bella, J., Collins, N and Jordaan, A. 2018. Managing wetlands for disaster risk reduction : A case study of the eastern Free State , South Africa. *Jàmbá - Journal of Disaster Risk Studies*, 10(1), a400. https://doi. org/10.4102/jamba. v10i1.400.

Bennett, J., Ainslie, A. and Davis, J. 2010. Fenced in: Common prope1iy struggles in the management of communal rangelands in central Eastern Cape Province, South Africa. Land Use Policy 27(2): 340-350.

Berkes, F. 2017. Environmental Governance for the Anthropocene ? Social-Ecological Systems , Resilience , and Collaborative Learning. *Sustainability*. 9(7): 1232; doi:10.3390/su9071232

Berkes, F. Ibarra, M.A., Armitage, D., Charles, T., Loucks, L., Makino, M., Satria, A., Seixas, C. and Abraham, J. 2014. Guidelines for Analysis of Social-Ecological Systems.

Bernhardt-Reomermann, M., Gray, A., Vanbergen, A,J,, Berge`s, L,, Bohner, A., Brooker, R.W., De Bruyn, L., De Cinti, B., Dirnb€ock, T., Grandin, U., Hester, A.J., Kanka, R., Klotz, S., Loucougaray, G,, Lundin, L., Matteucci, G., Meszaroz, I., Olah, V., Preda, E., Prevosto, B., Pykala,¨ J., Schmidt, W., Taylor, M.E., Vadineanu, A., Waldmann, T. and Stadler, J. 2011. Functional traits and local environment predict vegetation responses to disturbance: a pan-European multi-site experiment. *Journal of Ecology*, 99:777–787.

Bettencourt, E.M.V., Tilman; Henriques, P.D.S., Narciso, V. and Carvalho, M.L.S. 2013. The Economic and Sociocultural role of livestock in the wellbeing of rural communities of Timor-Leste. , in SOBER (Orgs). Actas do 51º congresso da SOBER, Belém do Pará, Brasil pp. 93-110 (ISBN (978-85-98571-10-URI:http://icongresso.itarget.com.br/useradm/anais/?clt=ser.3

Bhatta, L.D., Chaudhary, S., Pandit, A., Baral , H., Das, P.J. and Stork , N.E. 2016. Ecosystem Service Changes and Livelihood Impacts in the Maguri-Motapung Wetlands of Assam, India. *Land* , 5(2): 15; doi:10.3390/land5020015.

Biggs, R., Schlüter, M. and Schoon, M. L. 2015. Principles for building resilience: sustaining ecosystem services in socialecological systems. Cambridge University Press, Cambridge, UK. http://dx.doi.org/10.1017/cbo978131601424.

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S., Cundill, G., Dakos, V., Daw, T.M., Evans, L. S., Kitschy, K., Leitch, A. M., Meek, C., Quinlan, A., Raudsepp-Hearne, C., Robarbs, M. D., Schoon, M. L., Schultz, L. and West, P. C. 2012. Toward principles for enhancing the resilience of ecosystem services. Annual Review of Environment and Resources 37:421-448. http:// dx.doi.org/10.1146/annurev-environ-051211-123836

Blackhurst, R., Spinks, A. and Rossouw, J. 2002. Mzimvubu to Keiskamma Water Management Area: Water Resources Situation Assessment. Eastern Cape: Department of Water Affairs and Forestry.

Blackhurst, R., Spinks, A. and Rossouw, J. 2002. Mzimvubu to Keiskamma Water Management Area: Water Resources Situation Assessment. Eastern Cape: Department of Water Affairs and Forestry.

Bourdaghs, M., Johnston, C.A. and Regal, R.R. 2006. Properties and performance of the floristic quality index in Great lakes coastal wetlands. *Wetlands* 26:718–735.

Braun, V. and Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3:2, 77-101.

Breen, C.M., Quinn, N.W. and Mander, J.J. (eds). 1997. Wetlands conservation and management in southern Africa: Challenges and Opportunities, Summary of the SADC wetlands conservation survey reports. IUCN Wetlands Programme.

Bried, J.T., Jog, S.K. and Matthews, J.W. 2013. Floristic quality assessment signals human disturbance over natural variability in a wetland system. *Ecological Indicators*, 34: 260–267. Available at: http://dx.doi.org/10.1016/j.ecolind.2013.05.012.

Brown, A. M., Warton, D. I., Andrew, N. R., Binns, M., Cassis, G. and Gibb, H. 2014. The fourth-corner solution–using predictive models to understand how species traits interact with the environment. *Methods in Ecology and Evolution*, 5: 344–352.

Bunning, S., McDonagh, J. and Rioux, J. 2011. Land degradation assessment in drylands land degradation. *manual for local level assessment of land degradation and sustainable land management*.

Carpenter, S.R. and Gunderson, L.H. 2001. Coping with collapse: Ecological and social dynamics in ecosystem management. *Bioscience,* 51:451-457.

Chamberlain, S.J. and Brooks, R.P. 2016. Testing a rapid Floristic Quality Index on headwater wetlands in central Pennsylvania , USA. *Ecological Indicators*, 60:1142–1149.

Chamberlain, S.J. and Ingram, H.M. 2012. Developing coefficients of conservatism to advance floristic quality assessment in the Mid-Atlantic region Your use of this PDF , the BioOne Web site , and all posted and associated content Developing coefficients of conservatism to advance floristic qual. *Journal of the Torrey Botanical Society* 139(4): 416–427.

Cingolani, A.M., Posse, G. and Collantes, M.B. 2005. Plant functional traits , herbivore selectivity and response to sheep grazing in Patagonian steppe grasslands. Journal of Applied Ecology, 42: 50 – 59.

Cockburn, J., Biggs, H., Rosenberg, E. and Palmer, C.G. 2018. Tsitsa Project Learning Report 2018. Learning through reflective praxis: Lessons from integrated sustainability research with a governance focus in a complex social-ecological system, Eastern Cape, South Africa. Tsitsa Project Internal Report. Rhodes University, Grahamstown.

Cockburn, J., Cundill, G., Shackleton, S. and Rouget, M. 2018. Towards Place-Based Research to Support Social – Ecological Stewardship. *Sustainability* , 10(5): 1434 doi:10.3390/su10051434.

Cohen, M.J., Carstenn, S. and Lane, C.R. 2004. Floristic quality indices for biotic assessment of depressional marsh condition in Florida. *Ecological Applications*, 14(3):784–794.

Cole, M. and Engeström, Y. 1993. A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), Distributed cognitions. Cambridge: Cambridge University Press.

Collins, N.B. 2005. Wetlands*: The basics and some more.*

Cornelissen, J.H.C.A., Lavorel, S. Garnier, E., Diaz, S., Buchmann, N., Gurvich D.E., Reich, P.B., ter Steege, H., Morgan, H.D., Van der Heijden, M.G.A., Pausas, J.G and Poorter, H. 2003. A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. *Australian Jornal of Botany*, 51: 335-380.

Cowden, C., Kotze, D.C., Ellery, W.N. and Sieben, E.J.J. 2014. Assessment of the long-term response to rehabilitation of two wetlands in KwaZulu-Natal, South Africa. *African Journal of Aquatic Science,* 39:237–247. doi: 10.2989/16085914.2014.954518.

Creswell J.W. 1998. Qualitative inquiry and research design: choosing among five traditions. Thousand Oaks: Sage.

Creswell, J. W. 2003. Research design: Qualitative, quantitative and mixed methods approaches. Thousand Oaks, CA: SAGE Publications, Inc.

Creswell, J. W. 2007. Qualitative Enquiry and Research Design: Choosing Among Five Approaches. Thousand Oaks, CA: Sage Publications.

Dabo, D. 2017. Community-Based Natural Resource Management: The case of Community Forest Management Areas in Pete, Zanzibar. Minor dissertation submitted in partial fulfilment of the requirements for the award of the degree of Master of Environmental Humanities. University of Cape Town.

de Bello, F., Lavorel, S., Diaz, S., Harrington, R., Cornelissen, J.H.C., Bardgett, R.D., Berg, M.P., Cipriotti, P., Feld, C.K., Hering, C.K., Silva ,P.M. Potts, S.G., Sandin, L., Sousa J.P., Storkey, J., Wardle, D.A. and Harrison P.A. 2010. Towards an assessment of multiple ecosystem processes and services via functional traits. *Biodiversity Conservation*, 19: 2873–2893.

de Bello, F., Leps, J. and Sebastià, M.T. 2005. Predictive value of plant traits to grazing along a climatic climatic gradient in the Mediterranean. *Journal of Applied Ecology* 42: 828-833.

de Bello, F., Lepš, J., and Sebastia, M. 2005. Predictive value of plant traits to grazing along a climatic gradient in the Mediterranean. *Jorunal of Applied Ecolology*, 42: 824–833. doi: 10.1111/j.1365-2664.2005.01079.x

De Caceres, M., Legendre, P., Wiser, S.K . and Brotons, L. 2012. Using species combinations in indicator value analyses. *Methods in Ecology and Evolution*, 3: 973–982.

De Vos, A., Strydom, H., Fouche, C.B . and Delport, C.S.L. 2005. Research at Grassroots: For the Social Sciences and Human Service Professions, Hartfield: JL van Schaik Publishers.

DeBerry, D.A., Chamberlain, S.J. and Matthews, J.W. 2015. Trends in Floristic Quality Assessment for Wetland Evaluation. *Wetlands Assessment*, 32(2):12–22.

Department of Agriculture Forestry and Fisheries- (DAFF). 2014. Visual veld assessment condition tool (version 1.1).

Department of Water Affairs and Forestry- (DWAF). 2005. A practical field procedure for identification and delineation of wetlands and riparian areas.

Departmnet of Water and Sanitation – (DWS). 2013.National Water Resource strategy. June 2013 Second edition.

Departmnet of Water and Sanitation – (DWS). 2014. Mzimvubu Water Project. Background information document (BID) Invitation to register and comment , 23 April 2014 - First Document for comment.

Díaz, S., Lavorel, S., McIntyre, S., Falczuk, V., Casanoves, F., Milchunas, D. G., Skarpe, Ch., Sternberg, G. R., Noy-Meir, I., Landsberg, J., Zhang, W., Clark, H. and Campbell, B. 2007. Plant trait responses to grazing: a global synthesis. *Global Change Biology* ,13: 313–341, doi: 10.1111/j.1365-2486.2006.01288.x.

Díaz, S., Noy-meir, I. and Cabido, M. 2001. Can grazing response of herbaceous plants be predicted from simple vegetative traits ? *Journal of Applied Ecology* , 38: 497–508.

Dicicco-Bloom, B. and Crabtree, B.F. 2006. The qualitative research interview. Med Educ. 40(4):314-21.

Dickens, C., Kotze, D. and Mashigo, S. 2003. Guidelines for Integrating the Protection , Conservation and Prepared for the Water Research Commission and WWF by Umgeni Water University of KwaZulu-Natal. WRC Report No . TT 220 / 03 December 2003.

Dini, J. 2004. Restoring wetlands and healing a nation: South Africa’s Working for Wetlands programme. South Africa's Working for Wetlands programme. South African National Biodiversity Institute, South Africa.

Dixon, A. and Carrie, R. 2015. Creating local institutional arrangements for sustainable wetland socio-ecological systems: lessons from the ‘Striking a Balance’ project in Malawi, *International Journal of Sustainable Development & World Ecology*, 23:1, 40-52, DOI: 10.1080/13504509.2015.1107861.

Dorrough, J., Ash, J. and Mcintyre, S. 2004. Plant responses to livestock grazing frequency in an Australian temperate grassland. *Ecography,* 27: 798-810.

Dray, S., Choler, P., Dolédec, S., Peres-Neto, P. R., Thuiller, W. and Pavoine, S. 2014. Combining the fourth-corner and the RLQ methods for assessing trait responses to environmental variation. *Ecology*, 95: 14–21. doi: 10.1890/13-0196.1.

Drayer, A.N. and Richter, S.C. 2016. Physical wetland characteristics influence amphibian community composition differently in constructed wetlands and natural wetlands. *Ecological Engineering,* 93:166–174. Available at: http://dx.doi.org/10.1016/j.ecoleng.2016.05.028.

Driver, A., Sink, K.J., Nel, J.N., Holness, S., Van Niekerk, L., Daniels, F., Jonas, Z., Majiedt, P.A., Harris, L. and Maze, K. 2012. *National Biodiversity Assessment 2011: An assessment of South Africa’s biodiversity and ecosystems. Synthesis Report.*

Drobnik, J., Römermann, C. and Bernhardt-Römermann, M. 2011. Adaptation of plant functional group composition to management changes in calcareous grassland. Agric *Ecosystem Environment*, 145: 29–37.

Dubey, P., Sharma, G.P., Raghubanshi, A.S. and Singh, J.S. 2011. Leaf traits and herbivory as indicators of ecosystem function. *Current Science*. 100(3):313-320.

Dunne, T., Western, D. and Dietrich, W.E. 2011. Effects of cattle trampling on vegetation, infiltration, and erosion in a tropical range land. *Journal of Arid Environments*, 75:58-69.

Eastern Cape Socio Economic Consultative Council- (ECSECC). 2017. Elundini local municipality socio economic review and outlook, 2017.

Ellery, W., Grenfell, M., Grenfell, S., Kotze, D., McCarthy, T., Tooth, S., Grundling, P., Beckedahl, H., le Maitre, D. and Ramsay, L. 2009. WET-Origins. Controls on the distribution and dynamics of wetlands in South Africa. Gezina: Water Research Commission.

Elundini Municipality. 2019. Integrated Development Plan: 2018-2019.

Engelhardtand, K A. M. and Kadle, C. J.A. 2001. Species Traits, Species Richness and the Resilience of Wetlands after Disturbance. *Journal of Aquatic Plant Management*, 39: 36-39

Engeström, Y. 1987. Learning by expanding: An activity-theoretical approach to developmental research. Helsinki, Finland: Orienta-Konsultit.

Engestrom, Y. 2000a. Activity theory as a framework for analysing and redesigning work. *Ergonomics*, 43(7): 960-974.

Engeström, Y. 2001. Expansive learning at work: Toward an activity theoretical

Environment and Rural Solutions- (ERS). 2011. Umzimvubu Catchment Overview. Matatiele: Environment and Rural Solutions.

Ervin, G.N., Herman, B.D., Bried, J.T. and Holly, D.C. 2006. Evaluating non-native species and wetland indicator status as components of wetlands floristic assessment. *Wetlands*, 26(4):1114–1129. Available at: http://link.springer.com/article/10.1672/0277-5212%282006%2926%5B1114%3AENSAWI%5D2.0.CO%3B2.

Evans, R. and Love, R.M. 1957. The Step-Point Method of Sampling: A Practical Tool in Range Research. *Journal of Range Management*, 10(5): 208–212. Available at: http://www.jstor.org/stable/3894015.

Feldman, A. and Weiss, T. 2010. Understanding change in teachers ' ways of being through collaborative action research : a cultural – historical activity theory analysis. ISSN: 0965-0792 (Print) 1747-5074 (Online) Journal homepage: http://www.tandfonline.com/loi/reac20, 792.

Fennessy, M.S., Jacobs, A.D. and Kentula, M.E. 2007. An evaluation of rapid methods for assessing the ecological condition of wetlands. *Wetlands*,27 (3): 543–560.

Fleer, M. 2010, Early Learning and Development: Cultural-historical concepts in play. Cambridge, England: Cambridge University Press.

Flombaum, P. and Sala, O. E. 2007. A non-destructive and rapid method to estimate biomass and aboveground net primary production in arid environments. *Journal of Arid Environments*, 69(2), 352-358. http://doi.org/10.1016/jjaridenv.2006.09.008.

Folke, C. 2007. Social-ecological systems and adaptive governance of the commons. Ecological Restoration, 22:14-15.

Folke, C., Biggs, R., Norström, A. V., Reyers, B. and J. Rockström. 2016. Social-ecological resilience and biosphere-based sustainability science. Ecology and Society 21(3):41.

Foot, K.A. 2014. Cultural-historical activity theory: Exploring a theory to inform practice and research. *Journal of Human Behavior in the Social Environment*, 24(3): 329–347.

Fortini, L. and Schubert, O. 2017. Beyond exposure, sensitivity and adaptive capacity: a response based ecological framework to assess species climate change vulnerability. Climate Change Responses, 4:2 DOI 10.1186/s40665-017-0030-y.

Freyman, W.A., Masters, L.A. and Packard, S. 2016. The Universal Floristic Quality Assessment (FQA) Calculator : an online tool for ecological assessment and monitoring. *Methods in Ecology and Evolution*, 7: 380–383.

Funk, J.L., Larson, J.E., Ames, G.M. and Butterfield, B.J. 2016. Revisiting the Holy Grail : using plant functional traits to understand ecological processes. *Biological. Reviews*, 92:1156 – 1173. doi: 10.1111/brv.12275

Gallopin, G. C. 2006. Linkages between vulnerability , resilience , and adaptive capacity, 16: 293–303.

Gardner, R.C, Barchiesi, S., Beltrame, C., Finlayson, C.M., Galewski, T., Harrison, I., Paganini, M., Perennou, C., Pritchard, D.E., Rosenqvist, A. and Walpole, M. 2015. State of the World ' s Wetlands and their Services to People : A compilation of recent analyses. *Ramsar Briefifing Note*.

Garnier, E. and Navas, M.L. 2012. A trait-based approach to comparative functional plant ecology: concepts, methods and applications for agroecology. Agronomy for Sustainable Development 32: 365–399.doi:10.1007/s13593-011-0036-y

Gernes, B.M.C. and Helgen, J.C. 2002. Indexes of Biological Integrity (IBI) for Large Depressional Wetlands in Minnesota.

Gill, P., Stewart, K., Treasure, E. and Chadwick, B. 2008. Methods of data collection in qualitative research: Interviews and focus groups. *British Dental Journal*, 204(6): 291-295.

Gianopulos, K. 2018. Performance of rapid floristic quality assessment indices for increasing cost- effectiveness of wetland condition evaluation. Ecological Indicators 95:502–508. doi: 10.1016/j.ecolind.2018.08.003

Gomm, R. 2008. Social Research Methodology, A Critical Introduction. New York, Palgrave MacMillan.

Grime, J.P., Hodgson, J.G., Hunt, R., Thompson, K., Hendry, G.A.F., Campbell, B.D., Jalili, A., Hillier, S.H., Díaz, S. and Burke, M.J.W. 1996. Functional types: Testing the concept in Northern England. In: Smith,T.M., Shugart, H.H. and Woodward, F.I. (eds.) Plant functional types, pp. 123- 131. Cambridge University Press, Cambridge.

Hargiss, C.L.M.. DeKeyser, E.D ., Norland , J.E. and Ell, M.J. 2017. Comparing tiers of a multi-tiered wetland assessment in the Prairie Pothole Region. *Wetlands Ecology and Management*, 25:639–647 DOI 10.1007/s11273-017-9540-4.

Hay, D., Kotze, D. and Breen, C. 2014. Well-wet. Wetlands and and Well-being : Getting more out of South Africa’s wetlands: An introductory handbook. Water Research Commission. TT 605/14.

Herman, D., Masters, L.A., Penskar , M.R., Reznicek, A.A., Wilhelm, G.S., Brodovich, W.W. and Gardiner , K.P. 2001. Floristic quality assessment with wetland categories and examples of computer applications for the state of Michigan.

Herrero, M., Grace, D., Njuki, J., Johnson, N., Enahoro, D., Silvestri, S. and Rufino, M. 2013.The roles of livestock in developing countries, *Animal*, vol. 7, no. 1:3-18.

Hodgson, D.L. 2017. Demographic Change in the Upper Tsitsa Catchment The Integration of Census and Land Cover Data for 2001 and 2011. Msc thesis. Rhodes University.

Hodgson, J.G., Wilson, P.J., Hunt, R., Grime, P. and Thompson, K. 1999. Allocating C-S-R plant functional types: a soft approach to a hard problem. *Oikos* 85: 282-294.

Holling, C. S. 2003. Foreward. In F. Berkes, J. Colding & C. Folke (Eds.), Navigating social-ecological systems: Building resilience for complexity and change (pp. xv-xxi). Cambridge: Cambridge University Press

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics. Vol. 4:1-23 (Volume publication date November 1973) https://doi.org/10.1146/annurev.es.04.110173.000245.

Hossain, M. and Szabo, S. 2017. Understanding the Social-ecological System of Wetlands. In: Prusty B., Chandra R., Azeez P. (eds) Wetland Science. Springer, New Delhi.

Hu, S., Niu, Z., Chen, Y., Li, L. and Zhang, H. 2017. Global wetlands: Potential distribution, wetland loss, and status. *Science of The Total Environment*, 586: 319–327. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0048969717302425.

Hughes, A., McKergow, L., Tanner, C. and Sukias, J. 2013. Influence of livestock grazing on wetland attenuation of diffuse pollutants in agricultural catchments.

Hull, V., Tuanmu, M. and Liu, J. 2015. Synthesis of human-nature feedbacks. *Ecology and Society*, 20(3): 17. http://dx.doi. org/10.5751/ES-07404-200317.

Jogo, W. 2010. Managing the trade-off between conservation and exploitation of wetland services for economic well-being : The case of the Limpopo wetland in southern Africa. PhD thesis Environmental Economics. University of Pretoria.

Johnson, M.P. 2006. Decision models for the location of community corrections centers. *Environment And Planning & Design*, 33 (3): 393-412 .

Jones, W.M., Fraser, L.H. and Curtis, P.J. 2010. Plant community functional shifts in response to livestock grazing in intermountain depressional wetlands in British Columbia. *Biological Conservation*, 144: 511–517.

Koch, E. 2004. Mafisa and member of friends of Makuleke. Johannesburg. Personal communication.

Koszalka, T.A. 2004. A cultural historical activity theory [CHAT] analysis of technology integration : Case study of two teachers.

Kotze, D.C., Hughs, J.C., Breen, C.M. and Klug, K.J. 1994. The Development of a Wetland Soils Classification System for KwaZulu-Natal. Water Research Commission, Pretoria, Report No 501/4/94.

Kotze, D.C., Breen, C.M. and Quinn, N. 1995. Wetland Losses in South Africa. In Cowan G. I. (Eds), Wetlands of South Africa, Department of Environmental Affairs and Tourism, Pretoria, 263-272

Kotze, D.C., Marneweck, G.C., Batchelor, A.L., Lindley, D.S. and Collins, N.B. 2008. WET-EcoServices: A technique fo rapidly assessing ecosystem services supplied by wetlands. WRC Report No. TT 339/09. Water Research Commission, Pretoria.

Kotze, D. and Malan, H. 2010. WET-Sustainable Use A System for Assessing the Sustainability of Wetland Use. Wetland health and importance research programme. WRC Report No. TT 438/09. Water Research Commission, Pretoria

Kotze, D.C., Ellery, W.N., Macfarlanec, D.M. and Jewittd, G.P.W. 2012. A rapid assessment method for coupling anthropogenic stressors and wetland ecological condition. Ecological Indicators, 13(1): 284–293. Available at:http://dx.doi.org/10.1016/j.ecolind.2011.06.023.

Kuutti, K. 1996. Activity Theory as a Potential Framework for Human- Computer Interaction Research. *English*, pp.9–22.

Lamsal, P., Pant, K. P., Kumar, L. and Atreya. K. 2015. Sustainable livelihoods through conservation of wetland resources: a case of economic benefits from Ghodaghodi Lake, western Nepal. *Ecology and Society*, 20(1): 10. http://dx.doi.org/10.5751/ES-07172-200110.

Lavorel, S. and Garnier, E. 2002. Predicting the effects of environmental changes on plant community composition and ecosystem functioning: revisiting the Holy Grail. *Functional Ecology*, 16, 545-556.

Le Roux, J.J., Barker, C.H., Weepener, H.L., Van den Berg, E.C., 2015. *S*ediment yield modelling in the mzimvubu river catchment. Water Research Commission. WRC report no. 2243/1/15.

Leont'ev, A. N. 1978. Activity, consciousness and personality. Englewood Cliffs, NJ: Prentice Hall.

Lichvar, R.W., Melvin, N.C., Butterwick, M.L. and Kirchner, W.N., 2012. National Wetland Plant List Indicator Rating Definitions. Wetland Regulatory Assistance Program U.S. Army Corps of Engineers Washington, DC! 20314-1000.

Liehr, S., Röhrig, J., Mehring, M. and Kluge, T. 2017. How the Social-Ecological Systems Concept Can Guide Transdisciplinary Research and Implementation : Addressing Water Challenges in Central Northern Namibia. *Sustainability*, 9, 1109; doi:10.3390/su9071109.

Liu , J., Dietz, T., Carpenter, S.R., Alberti, M . and Folke. C. 2007. Complexity of coupled human and natural systems. Science , 317: 1513–1516.

Macfarlane, D., Holness, S.D., Hase, A., Brownlie, S., Dini, J. and Kilian,V. 2016. Wetland offsets *: A best Practice Guideline for South Africa. Water Research Commission by South South African National Biodiversity Institute and the Department of Water and Sanitation.* WRC Report No. TT 660/16. Water Research Commission. Pretoria.

Macfarlane, D.M., Kotze, D.C., Ellery, W.N., Walters, D., Koopman, V., Goodman, P. and Goge, C. 2008. *WET-Health: A technique for rapidly assessing wetland health.* WRC Report TT 340/08. Water Research Commission. Pretoria.

Mack, J.J. 2001. Ohio Rapid Assessment Method for Wetlands, Manual for Using Version 5.0. Ohio EPA Technical Bulletin Wetland/2001-1-1. Ohio Environmental Protection Agency, Division of Surface Water, 401 Wetland Ecology Unit, Columbus, Ohio Forms.

Mack, N., Woodsong, C., Macqueen, K.M., Guest, G. and Namey, E. 2005. Qualitative research methods: a data collector's field guide. Family Health International, North Carolina.

Magangana, S., Gantsho, S., Mkhululi, V., Van Rooyen, T. and Palmer, O. 2015. The provisioning and cultural services of livestock in a small South African town.

Maire , V., Gross , N., Pontes, L, da, S., Picon-Cochard, C. and Soussana, J.F. 2009. Trade-off between root nitrogen acquisition and shoot nitrogen utilization across 13 co-occurring pasture grass species. *Functional Ecology*, 23:668–679.

Maluleke, W. and Mokwena R.J. 2017. The effect of climate change on rural livestock farming: case study of Giyani Policing Area, Republic of South Africa. *South African Journal of Agricultural Extension*, vol.45 n.1 Pretoria.

Martini, U., Buffa, F. and Nontaro, S. 2017. Community Participation , Natural Resource Management and the Creation of Innovative Tourism Products : Evidence from Italian Networks of Reserves in the Alps. *Sustainability* , 9: 2314.

Mavimbela, S.S.W. and Van Rensburg, D.L. 2015. In situ evaluation of internal drainage in duplex soils of the Tukulu , Sepane and Swartland forms In situ evaluation of internal drainage in duplex soils of the Tukulu , Sepane and Swartland forms.

McGill, B.J., Enquist, B.J., Weiher, E. and Westoby, M. 2006. Rebuilding community ecology from functional traits. *Trends in Ecology & Evolution*, 21: 178–185.

Mcintyre, S. and Lavorel, S. 2001. Livestock grazing in subtropical pastures : steps in the analysis of attribute response and plant functional types. *Journal of Ecology,* 89: 209 – 22.

Meng, W., He, M. and Hu, B. 2017. Status of wetlands in China: A review of extent, degradation, issues and recommendations for improvement. *Ocean and Coastal Management*,146:50–59.

Mhlobo, B.T. 2016. Multi–criteria livestock assessment for sustainability of smallholder farms in Kwa-Zulu Natal. Thesis presented in fulfilment of the requirements for the degree of Masters in Sustainable Agriculture (Animal Sciences) in the Faculty of AgriSciences at Stellenbosch University.

Millennium Ecosystem Assessment- (MEA). 2003. Ecosystems and Human Well- Being: A framework for assessment. Washington, D.C. World Resources Institute, Island press.

Miller, S.J. and Wardrop, D.H. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. *Ecological Indicators,* 6 (2): 313–326.

Morris, K. and Reich, P. 2013. Understanding the relationship between livestock grazing and wetland condition. Arthur Rylah Institute for Environmental Research Technical Report Series No. 252. Department of Environment and Primary Industry, Heidelberg, Victoria.

Mucina L, Rutherford MC, Phillips K, Rutherford MC (2006) The vegetation of South Africa, Lesotho and Swaziland.

Munnik, V., Burt, J., Price, L., Barnes, G., Ashe, B. and Motloung, S. 2016. Principled, pragmatic revitalisation of Catchment Management Forums in South Africa. Water Research Commission, Gezina, Pretoria.

Naidoo, S. 201. An investigation into the health status of the wetlands delineating the lower Umngeni river floodplain, Kwazulu-Natal, South Africa. Msc Thesis. School of Agricultural, Earth and Environmental Sciences University of KwaZulu-Natal.

Ngcaba, P. and Maroyi, A. 2017. Floristic composition and diversity in tsitsa river catchment area, the eastern cape province, South Africa. *Journal of Biological Sciences*, 17(6).

Nsor, C.A. and Obodai, E.A. 2014. Environmental determinants influencing seasonal variations of bird diversity and abundance in wetlands, Northern Region (Ghana). *Annals of Experimental Biology*, 2(3):17–30.

Obiero, K., Raburu, P., Okeyo-Owuor, J., Raburu, E. (2012). Community perceptions on the impact of the recession of lake Victoria waters on Nyando wetlands. *Scientific Research and Essays,* 7(16), 1647–1661.

Odume, O. N., Ntloko, P. and Akamagwuna, F.C. 2018. Development of macroinvertebrate trait-based approach for assessing and managing ecosystem health in South African Rivers – incoporating a case study in the Tsitsa River and its tributaries, Eastern Cape. WRC Report No: K1/7157.

Oksanen, J., Guillaume Blanchet, F., Friendly, M., Kindt, R., Legendre, P., McGlinn, D.and Wagner, H. 2017. Community Ecology Package, Package “ vegan .” http://doi.org/ISBN

0-387-95457-0

Ollis, D.J. and Malan, H.L. 2014. *Review of available methods for the assessment of the ecological condition of wetlands in South Africa*. Development of Decision-support Tools for Assessment of Wetland Present Ecological Status (PES). WRC Report No. TT 608/14. Water Research Commission. Pretoria.

Ollis, D.J., Snaddon, C.D., Job, N.M. and Mbona, N. 2013. Classification system for wetlands and other aquatic ecosystems in South Africa. User manual: Inland systems. SANBI Biodiversity Series 22. South African National Biodiversity Institute, Pretoria.

Opio, A., Lukale, J. K., Masaba, I. S. and Oryema , C. 2011. Socio – economic benefits and pollution levels of water resources , Pece Wetland , Gulu Municipality - Uganda.African *Journal of Environmental Science and Technology* Vol. 5(7): 535-54

Ostrom , E. 2009. A general framework for analyzing sustainability of socio-ecological systems. Science, 325: 419–422.

Pakeman, R.J. and Marriott, C.A. 2010. A functional assessment of the response of grassland vegetation to reduced grazing and abandonment. *Journal of Vegetation Science,* 21: 683–694, 2010DOI: 10.1111/j.1654-1103.2010.01176.x.

Palmer, C. G. and Munnik, V. 2018. Practising Adapative IWRM. Integrated Water Resources Management (IWRM) in South Africa: Towards Practising a New Paradigm. Water Research Commission, Gezina, Pretoria.

Palmer, C. G., Biggs, R. and Cumming, G. S. 2015. Applied research for enhancing human well-being and environmental stewardship : using complexity thinking in Southern Africa. Ecology and Society, 20(1). DOI: 10.5751/ES-07087-200153

Palmer, G.C. and Wolff M. 2018. Development of institutional structures, arrangements and processes. The Ntabelanga and Laleni Ecological Infrastructure Project report.

Palmer, R.W., Turpie, J. and Marnewick, G.C. 2002. Ecological and economic evaluation of wetlands in the upper Olifants river catchment, south africa. Water Research Commission. WRCreport no: 1162/1/02.

Parwada C, V. and vanTol, J. 2016. Soil properties influencing erodibility of soils in the Ntabelanga area , Eastern Cape Province , South Africa. , 4710.

Pausas, J.G., Pratt, R.B., Keeley, J.E. and Jacobsen, A.L. 2015. Towards understanding resprouting at the global scale. *New Phytologist*, 209:945–954 doi: 10.1111/nph.13644.

Pérez-Harguindeguy, A., Urcelay, N. and Garnier, E. 2013. New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany*, 61:167–234 http://dx.doi.org/10.1071/BT12225

Pescott, O.L. and Stewart, G.B. 2014. Assessing the impact of human trampling on vegetation : a systematic review and meta-analysis of experimental evidence. PeerJ 2:e360; DOI 10.7717/peerj.360.

Pilière, A.F.H., Verberk, W.C.E.P., Gräwe. M., Breure. A.M., Dyer. S.D., Posthuma. L., Zwart. D., Huijbregts, M.A.J and Schipper, A.M. 2016. On the importance of trait interrelationships for understanding environmental responses of stream macroinvertebrates. *Freshwater Biology*, 61: 181–194.

Pillar, V.D., Duarte, L.S., Sosinski, E.E. and Fernando, J. 2009. Discriminating trait-convergence and trait-divergence assembly patterns in ecological community gradients. *Journal of Vegetation Science*, 20: 334–348.

Pimbert, M. 2004. Natural resources, people and participation.

Pollard, S., du Toit, D., Cousins, T., Kotze, D., Riddell, E. and Davis, C. 2010. Sustainability indicators in communal wetlands and their catchments: Lessons from Craigieburn wetland, Mpumalanga. Water Research Commission. WRC Report No. 1709/1/10.

Pollard, S., and Cousins, T. 2008. Recognising community based governance of water resources in communal areas. Water Research Commission WRC Report, March(TT328/08)

Powell, M., Biggs, H. and Braack, M. 2017. A better world. Ntabelanga and Lalini ecological infrastructure project.

Pretorius, S.N. 2016. Sediment yield modelling in the upper Tsitsa Catchment, Eastern Cape, South Africa. Msc Thesis Thesis Environmental Management in the Faculty of Natural and Agricultural Sciences.

R Development Core Team. 2014. A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing. Available at: http://www.R-project.org.

Razaq, M., Zhang, P., Shen, H. and Salahuddin, I. 2017. Influence of nitrogen and phosphorous on the growth and root morphology of *Acer mono*. PLoS ONE 12(2): e0171321. https://doi.org/10.1371/journal.pone.017132

Reed, P.B., 1988. National List of Plant Species that occur in Wetlands: 1988, Nevada. *All U.S. Government Documents (Utah Regional Depository). Paper 508. https://digitalcommons.usu.edu/govdocs/508*.

Republic of South Africa. 1983. Conservation of Agricultural Resource (Act No 43 of 1983). Pretoria: Government Printers.

Republic of South Africa. 1996. The South African Constitution. Pretoria: Government Printers. http://www.infogov.za/gazette/acts.

Republic of South Africa. 1998. National Water (Act No 36 of 1998). Department of Water Affairs and Forestry, Pretoria: Government Printers.

Republic of South Africa. 1998. The National Environmental Management Act (Act 107 of 1998).

Rocchio, J., Anderson, D. and Buckner, D. 2007. Floristic Quality Assessment Indices for Colorado Plant Communities. *Colorado Natural Heritage Program, Colorado State University*.

Roy, K., Linstrom, A. and Otto, D. 2017. Wetland Ecological Assessment. Environmental Regulatory Processes relating to the Thubelisha, Trichardtsfontein and Vaalkop Mining Right Areas. Digby Wells Environmental.

Sandel, B., Corbin, J. and Krupa, M. 2011. Using plant functional traits to guide restoration: a case study in California coastal grassland. *Ecosphere*, 2: 1–16.

South Africa National Biodiversity Institut- (SANBI). 2006. 21 February 2006 Working for Wetlands Group. http://www.nbi.ac.za/research/wetlandprog.htm.

Schreiner, B. 2013. Viewpoint - Why has the South African national water act been so difficult to implement? Water Alternatives 6(2): 239-245.

Schuyt, K.D. 2005. Economic consequences of wetland degradation for local populations in Africa. *Ecological Economics*, Vol 53: 177 – 190.

Shackleton, C., Shacklton, S., Netshiluvhi, T. and Mathabela, F. 2005. The contribution and direct-use value of livestock to rural livelihoods in the Sand River catchment, South Africa. *African Journal of Range and Forage Science*, vol. 22, no. 2: 127-140.

Shrestha, U. 2013. Community Participation In Wetland Conservation In Nepal. *Journal of Agriculture and Environment*, 12: 140-147. https://doi.org/10.3126/aej.v12i0.7574.

Sieben, E.J.J., Collins, N.B., Corry, F.T.J., Kotze, D.C., Job, N., Muasyad, A.M., Venter, ,C.E., Mtshalie, H., Zondo, S.A., Janks, M. and Pretorius, L. 2016. The vegetation of grass lawn wetlands of floodplains and pans in semi-arid regions of South Africa: Description, classification and explanatory environmental factors. *South African Journal of Botany*, 104: 215–224. Available at: http://dx.doi.org/10.1016/j.sajb.2015.11.003.

Sieben, E.J.J., Kotze, D.C., Job, N.M. and Muasya, A.M. 2017. The sclerophyllous wetlands on quartzite substrates in South Africa: Floristic description, classification and explanatory environmental factors. *South African Journal of Botany*, 113: 54–61. Available at: http://dx.doi.org/10.1016/j.sajb.2017.07.008.

Sieben, E.J.J., Mtshali, H.and Janks, M. 2014. National Wetland Database: Classification and Analysis of the Wetland Vegetation Types for Conservation Planning and Monitoring.

Sigwela, A., Elbakidze, M., Powell, M and Angelstam, P. 2017. De fi ning core areas of ecological infrastructure to secure rural livelihoods in South Africa. *Ecosystem Services*, 27:272–280. Available at: http://dx.doi.org/10.1016/j.ecoser.2017.07.010.

Silima, V. 2007. A review of stakeholder interests and participation in the sustainable use of communal wetlands : The case of the Lake Fundudzi catchment in Limpopo Province , South Africa. *Thesis*. Rhodes university.

Singleton, R. and Straits, B. 2005. Approaches to Social Research. New York. Oxford University Press.

Singleton, R., Straits, B.C., Straits, M.M. and McAllister, R.J. 1988. Approaches to social research. New York, NY, US: Oxford University Press.

Sisitka, L., Ntshudu, M., Hamer, N. and de Vos, A. 2016. Ntabelanga (Laleni1) Stakeholder Report For the DEA: NRM Branch – Ntabelanga Lalini Ecological Infrastructure Project.

Siyaya, J.S. 2015. Review of local institutional arrangement for zone 3 community wetland in Sebokeng, Gauteng, South Africa. Msc thesis. Environment Department. University of South Africa.

Sun, D. and Liddle, M.J. 1993. A survey of trampling effects on vegetation and soil in eight tropical and subtropical sites. *Environmental Management*, 17(4):497-510.

Spyreas, G. 2016. Scale and Sampling Effects on Floristic Quality. doi: 10.1371/journal.pone.0160693

Swanepoel, C.M. and Barnard, R.O. 2007. Discussion paper : Wetlands in agriculture.

Swink, F. A, Wilhelm G.S. 1979 Plants of the Chicago Region, 3rd Ed. Morton Arboretum, Lisle, IL, USA.

Swink, F. A, Wilhelm GS. 1994. Plants of the Chicago Region, 4th Ed. Indiana Academy of Sciences, Indianapolis, IN, USA.

Taylor, A.R.D., Howard, G.W. and Begg, G.W. 1995. Developing wetland inventories in southern Africa: a review. *Vegetation*, 118 (1–2), 57–79.

Teixeira-Leite, A. and Macfarlane, D.M. 2012. Extension of East Central Arterial Road to Richards Bay Minerals: Specialist Wetland Assessment and Assessment of Aquatic Impacts. Unpublished report for Arcus Gibb.

ter Braak CJK, Smilauer P. 2002. CANOCO reference manual and Canoco draw for Windows user’s guide: software for canonical community ordination (Version 4.5).

Microcomputer Power, Ithaca, New York.

Turpie, J. and Malan, H. 2010. Wetland Health and Importance Research Programme. Wetland valuation. Vol II wetland valuation case studies. Water Research Commission. WRC Report No. TT 441/09.

U.S. EPA. 2006. Application of elements of a state water monitoring and assessment program for wetlands. Wetlands Division, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, DC. EPA 841-B-03-003.

Van Ginkel, C.E., Gordon-Gray, K.D., Cilliers, C.J., Muasya, M. and van Deventer, P.P. 2011. Easy identification of some South African Wetland Plants. Gezina: Water Research Commission.

Van Deventer, R., Teixeira-Leite, A. and Macfarlane, D. 2013. Specialist Wetland Assessment Report: Lions River-Howick Bulk Water Pipeline, KwaZulu-Natal. Availabllehttp://www.sahra.org.za/sahris/sites/default/files/additionaldocs/LionsRiverWaterPipeline_Wetland%20Assessment%20Report%20for%20Synergistics_Eco-Pulse.

Van den Brink, P. J ., Alexander, A. C., Desrosiers, M ., Goed koop, W., Goethals, P. L., Liess, M., and Dyer, S. D. 2011) Traits-based approaches in bioassessment and ecological risk assessment: Strengths, weaknesses, opportunities and threats. *Integrated enviro11111e11tal assessment and management,* 7(2), 198-208.

van Tol, J., Akpan, W., Kanuka, G., Ngesi, S., and Lange, D. (2014). Soil erosion and dam dividends: science facts and rural “fiction” around the Ntabelanga dam, Eastern Cape, South Africa. *South African Geographical Journal*, 1–13. DOI: 10.1080/03736245.2014.977814

Vesk, P. A., Leishman, M. R. and Westoby, M. 2004. Simple traits do not predict grazing response in Australian dry shrublands and woodlands. *Journal of Applied Ecology*, 41:22–31.

Vesk, P.A. and Westoby, M. 2001. Predicting plant species ’ responses to grazing. Journal of

Applied Ecology, 38: 897 – 909.

Vetter, S. 2013. Development and sustainable management of rangeland commons – aligning policy with the realities of South Africa's rural landscape. *African Journal of Range & Forage Science*, 30:1-2, 1-9, DOI: 10.2989/10220119.2012.750628

Violle, C. and Jiang, L. 2009. Towards a trait-based quantification of species niche. *Journal of Plant Ecology*, 2: 87–93.

Violle, C. Navas, M.N., Vile, D., Kazakou, E., Fortunel, C., Hummel, I. and Garnier, E. 2007. Let the concept of trait be functional ! Oikos 116: 882892, 2007doi: 10.1111/j.2007.0030-1299.15559.x,Oikos 2007, ISSN 0030-1299.

Vygotsky, L. 1978. Mind in society: the development of higher psychological processes. Cambridge: Harvard University Press.

Walker, B., Kinzig, A. and Langridge, J. 1999. Plant attribute diversity, resilience, and ecosystem function: The nature and significance of dominant and minor species. *Ecosystems*, 2:95-113.

Walters, D.J.J., Kotze, D.C. and O'Connor, T.G. 2006. Impact of land use on vegetation composition, diversity, and selected soil properties of wetlands in the southern Drakensberg mountains, South Africa. *Wetlands Ecology and Management*, 14:329–348.

Wang, L. Liu, H., Liu, Y., Li, J., Shao, H., Wang, W. and Liang, C. 2014. Soil Characteristic Comparison of Fenced and Grazed Riparian Floodplain Wetlands in the Typical Steppe Region of the Inner Mongolian Plateau , China. *The Scientific World Journal* Volume 2014, Article ID 765907, 10 pages http://dx.doi.org/10.1155/2014/765907.

Webb, C.T., Hoeting, J.A., Ames, G.M., Pyne, M.I. and Poff, N.L. 2010. Astructured and dynamic framework to advance traits-based theory and pre-diction in ecology.*Ecology Letters*,13: 267–283.

Wegscheidl, C. and Layden, I, 2011. Department of Employment, Economic Development and Innovation (DEEDI) for the Queensland Wetlands Program, with funding from the Queensland Government.

Westoby, M. 1998. A leaf-height-seed (LHS) plant ecology strategy scheme. *Plant Soil*, 199: 213–227.

Willby, N.J., Abernrthy, V.J. and Demars, B.O.L. 2000. Attribute-based classification of European hydrophytes and its relationship to habitat utilization. *Freshwater Biology*, 43, 43-74.

Wintola, O.A. and Afolayan, A.J. 2014. Alepidea amatymbica Eckl. & Zeyh: A Review of Its Traditional Uses, Phytochemistry, Pharmacology, and Toxicology. Hindawi Publishing Corporation Evidence-Based Complementary and Alternative Medicine://dx.doi.org/10.1155/2014/284517.

Wondie, A., 2018. Ecological conditions and ecosystem services of wetlands in the Lake Tana Area , Ethiopia. *Ecohydrology & Hydrobiology* , 18: 231–244.

Wood, A., Dixon, A. and McCartney, M. 2013. Wetland Management and Sustainable Livelihoods in Africa. Taylor and Francis. https://doi.org/10.4324/9780203128695.

Xu, L.. Freitas, S.M.A., Yu, F.H., Dong , M., Anten, N.P.R. and Werger, M.J.A. 2013. Effects of Trampling on Morphological and Mechanical Traits of Dryland Shrub Species Do Not Depend on Water Availability.PLoSONE 8(1):e53021. https://doi.org/10.1371/journal.pone.005302.

Yepsen, M., Baldwin, A.H. and Whigham, D.F. 2014. Agriculture , Ecosystems and Environment Agricultural wetland restorations on the USA Atlantic Coastal Plain achieve diverse native wetland plant communities but differ from natural wetlands. *Elsevier B.V.*, 197: 11–20. Available at: http://dx.doi.org/10.1016/j.agee.2014.07.007.

Yin, R. K. 2009. Case Study Research: Design and Methods (Vol. 5). Sage Publications. DOI: 10.1097/FCH.0b013e31822dda9e.

Zainal, Z. 2007. Case study as a research method. *Jurnal Kemanusiaan bil.9.*

Zheng, S., Li, W., Lan, Z., Ren, H. and Wang , K. 2015. Functional trait responses to grazing are mediated by soil moisture and plant functional group identity. Scientific Reports 5:18163 DOI: 10.1038/srep18163.

APPENDICES

Appendix 1a: Wetness zone and soil wetness indicators

Site number: 2	**Locality description:** In centre of wetland	
GPS position	**LAT:** -31,005552	**LONG:** 28,491725
Description of topographical position	On slope above tributary and below rock formation	
Vegetation	Predominately grasses	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** Low
	Colour: Light brown	**Abundance:** Low/Few
Matrix hue: 7.5yrs	**Matrix value:** 2.5	**Matrix chroma:** 1
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** High
	Colour : Orange	**Abundance:** High/Many
Matrix hue: 7.5yrs	**Matrix value:** 3	**Matrix chroma:** 1
Comments:		
Zone indicated by above: **Terrestrial** [✓ **Temporary**] **Seasonal** **Permanent**		

Site number: 3	**Locality description:** In centre of wetland, T35D	
GPS position	**LAT:** -31, 005168	**LONG:** 28,493321
Description of topographical position	On slope above tributary and below rock formation	
Vegetation	Grasses and sedges	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** Moderate
	Colour: Orange	**Abundance:** Moderate
Matrix hue: 7.5yrs	**Matrix value:** 4	**Matrix chroma:** 1
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** High
	Colour: Redish yellow	**Abundance:** High/Many
Matrix hue: 7.5yrs	**Matrix value:** 4	**Matrix chroma:** 1
Comments:		
Zone indicated by above: **Terrestrial** **Temporary** [✓ **Seasonal**] **Permanent**		

Site number: 4	**Locality description:** In centre of wetland, T35E	
GPS position	**LAT:** -31,056067	**LONG:** 28,600736
Description of topographical position	Below rock formation with forest buffer	
Vegetation	Predominantly grasses	

Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** Low
	Colour: Mustard yellow	**Abundance:** Low/Few
Matrix hue: 7.5yrs	**Matrix value:** 2.5	**Matrix chroma:** 1
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** Low
	Colour : Orange and yellow	**Abundance:** Moderate
Matrix hue: 7.5yrs	**Matrix value:** 2.5	**Matrix chroma:** 1
Comments:		
Zone indicated by above: **Terrestrial**	[✓ **Temporary**]	**Seasonal** **Permanent**

Site number: 5	**Locality description:** In centre of wetland, T35E	
GPS position	**LAT:** -31,056258	**LONG:** 28, 600044
Description of topographical position	On a slope above other site with forest buffer	
Vegetation	Sedges, grasses and rushes	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** High
	Colour: Orange and brown	**Abundance:** High/Many
Matrix hue: 7.5yrs	**Matrix value:** 1	**Matrix chroma:** 1
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** High
	Colour : Orange and brown	**Abundance:** High/Many
Matrix hue: 7.5yrs	**Matrix value:** 3	**Matrix chroma:** 1
Comments: Grazed vegetation and evidence of trampling		
Zone indicated by above: **Terrestrial**	**Temporary**	[✓ **Seasonal**] **Permanent**

Site number: 6	**Locality description:** In centre of wetland, T35E	
GPS position	**LAT:** -31,057310	**LONG:** 28,597433
Description of topographical position	Forest buffer	
Vegetation	Grasses, sedges and rushes	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** High
	Colour: Mustard and orange	**Abundance:** High
Matrix hue: 7.5yrs	**Matrix value:** 3	**Matrix chroma:**
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** Very high
	Colour : Mixture of colours	**Abundance:** High

Matrix hue: 7.5yrs	**Matrix value:** 3	**Matrix chroma:** 1
Comments: Trampling evident and grazed vegetation		
Zone indicated by above: Terrestrial Temporary [✓ Seasonal] Permanent		

Site number: 7	**Locality description:** In centre of wetland, T35E	
GPS position	**LAT:** -31,057985	**LONG:** 28,596455
Description of topographical position	Forest buffer	
Vegetation	Grasses and rushes	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** High
	Colour: Red, orange and yellow	**Abundance:** High/Many
Matrix hue:	**Matrix value:** 3	**Matrix chroma:** 1
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** High
	Colour : Strong brown and yellow	**Abundance:** High/Many
Matrix hue:	**Matrix value:** 3	**Matrix chroma:** 1
Comments:		
Zone indicated by above: Terrestrial Temporary [✓ Seasonal] Permanent		

Site number: 8	**Locality description:** In centre of wetland, T35E	
GPS position	**LAT:** -31,056017	**LONG:** 28,602859
Description of topographical position	Forest buffer Large gully and erosion present	
Vegetation	Grasses, sedges and rushes	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** High
	Colour: Maroon and yellow	**Abundance:** High/Many
Matrix hue: 7.5yrs	**Matrix value:** 4	**Matrix chroma:** 2
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** Moderate
	Colour: Yellow	**Abundance:** Moderate
Matrix hue: 7.5yrs	**Matrix value:** 3	**Matrix chroma:** 2
Comments: High OM		
Zone indicated by above: Terrestrial Temporary Seasonal [✓ Permanent]		

Site number: 9	**Locality description:** In centre of wetland, T35E	
GPS position	**LAT:** -31,056478	**LONG:** 28,599671
Description of topographical position	Forest buffer	
Vegetation	Sedges and grasses	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** Low
	Colour: Strong brown	**Abundance:** Low/Few
Matrix hue: 7.5yrs	**Matrix value:** 3	**Matrix chroma:** 1
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** Low
	Colour : Strong brown	**Abundance:** Low/Few
Matrix hue: 7.5yrs	**Matrix value:** 3	**Matrix chroma:** 1
Comments: High OM		
Zone indicated by above: **Terrestrial** **Temporary** **Seasonal** [✓ **Permanent**]		

Site number: 10	**Locality description:** In centre of wetland, T35E	
GPS position	**LAT:**	**LONG:** 28,
Description of topographical position		
Vegetation	**S**edges, grasses and rushes	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** Low
	Colour: Strong brown	**Abundance:** Low
Matrix hue: 7.5yrs	**Matrix value:** 2.5	**Matrix chroma:** 1
Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** X	**Contrast:** Moderate
	Colour : Rusty iron	**Abundance:** Moderate
Matrix hue: 7.5yrs	**Matrix value:** 3	**Matrix chroma:** 1
Comments: Trampling evident and high grazing area. High OM		
Zone indicated by above: **Terrestrial** **Temporary** **Seasonal** [✓ **Permanent**]		

Site number: 11	**Locality description:** In centre of wetland, T35E	
GPS position	**LAT:** -31,057661	**LONG:** 28,597150
Description of topographical position	Forest buffer	
Vegetation	Grasses, sedges and rushes	
Soil morphology 0-10cm		
Mottling	**Present:** X	**Contrast:** Low
	Colour: Strong reddish brown	**Abundance:** Low/Few
Matrix hue: 7.5yrs	**Matrix value:** 2.5	**Matrix chroma:** 1

Comments:		
Soil morphology 30-40cm		
Mottling	**Present:** No	**Contrast:**
	Colour :	**Abundance:**
Matrix hue: 7.5yrs	**Matrix value:** 2.5	**Matrix chroma:** 1
Comments: High trampling and grazing. High OM		
Zone indicated by above: **Terrestrial** **Temporary** **Seasonal** [✓ **Permanent**]		

Appendix 1b: WET-Health scores

SITES	HYDROLOGY	GEOMORPHOLOGY	VEGETATION	HEALTH	CATEGORY
LE1	5	0.2	0.2	2.257143	C
LE2	5	0.6	0.4	2.428571	C
LE3	5	0.5	1.5	2.714286	C
ME1	5	0.6	0.1	2.342857	C
ME2	5	0.8	1.2	2.714286	C
ME3	6.5	0.8	1.9	3.557143	C
ME4	5	0.8	0.3	2.457143	C
HE1	7	2.9	2.6	4.571429	D
HE2	6.5	1.6	2.1	3.842857	C
HE3	6.5	0.9	2	3.614286	C
HE4	6.5	0.7	1.8	3.5	C

Appendix 1c: Separate WET-Health scores for each modules in each site.

LE1

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	105.7:1692.6 = 0.06
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-3.8
Intensity of impact of factors potentially altering flow pattern	4
Overall magnitude of impact score: Canalization and stream channel modification	0
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	0.1
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	0.1
Combined magnitude score as a result of impacts on hydrological functioning	5
Present hydrological state	D
Vegetation module	
Extent of disturbance classes	12
Magnitude of impact score	0.2
Present vegetation state	A
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.2
Impacts of erosion	0
Impacts of deposition	0
Present geomorphic state	A

LE1: 2

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	105.7:1692.6 = 0.06
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-3.8
Intensity of impact of factors potentially altering flow pattern	4
Overall magnitude of impact score: Canalization and stream channel modification	0
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	0.2
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	0.2
Combined magnitude score as a result of impacts on hydrological functioning	5
Present hydrological state	D
Vegetation module	
Extent of disturbance classes	23
Magnitude of impact score	0.4
Present vegetation state	A
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.6
Impacts of erosion	0
Impacts of deposition	0
Present geomorphic state	A

LE1: 3

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	105.7:1692.6 = 0.06
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-3.8
Intensity of impact of factors potentially altering flow pattern	4
Overall magnitude of impact score: Canalization and stream channel modification	0
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	0.4
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	0.4
Combined magnitude score as a result of impacts on hydrological functioning	5
Present hydrological state	D
Vegetation module	
Extent of disturbance classes	50
Magnitude of impact score	1.5
Present vegetation state	B
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.5
Impacts of erosion	0
Impacts of deposition	0
Present geomorphic state	A

ME: 1

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	165.7:1682.2 = 0.1
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-4.2
Intensity of impact of factors potentially altering flow pattern	10
Overall magnitude of impact score: Canalization and stream channel modification	0
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	0
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	0
Combined magnitude score as a result of impacts on hydrological functioning	5
Present hydrological state	D
Vegetation module	
Extent of disturbance classes	5
Magnitude of impact score	0.1
Present vegetation state	A
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.6
Impacts of erosion	0
Impacts of deposition	0
Present geomorphic state	A

ME: 2

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	165.7:1682.2 = 0.1
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-4.2
Intensity of impact of factors potentially altering flow pattern	10
Overall magnitude of impact score: Canalization and stream channel modification	0
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	0.5
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	0.5
Combined magnitude score as a result of impacts on hydrological functioning	5
Present hydrological state	D
Vegetation module	
Extent of disturbance classes	40
Magnitude of impact score	1.2
Present vegetation state	B
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.8
Impacts of erosion	0
Impacts of deposition	0
Present geomorphic state	A

ME: 3

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	165.7:1682.2 = 0.1
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-4.2
Intensity of impact of factors potentially altering flow pattern	10
Overall magnitude of impact score: Canalization and stream channel modification	0
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	2
Impact of direct water losses	
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	2
Combined magnitude score as a result of impacts on hydrological functioning	6.5
Present hydrological state	E
Vegetation module	
Extent of disturbance classes	65
Magnitude of impact score	1.9
Present vegetation state	B
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.8
Impacts of erosion	0
Impacts of deposition	0
Present geomorphic state	A

ME: 4

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	165.7:1682.2 = 0.1
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-4.2
Intensity of impact of factors potentially altering flow pattern	10
Overall magnitude of impact score: Canalization and stream channel modification	0
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	0
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	0
Combined magnitude score as a result of impacts on hydrological functioning	5
Present hydrological state	D
Vegetation module	
Extent of disturbance classes	20
Magnitude of impact score	0.3
Present vegetation state	A
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.8
Impacts of erosion	0
Impacts of deposition	0
Present geomorphic state	A

HE: 1

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	165.7:1682.2 = 0.1
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-4.2
Intensity of impact of factors potentially altering flow pattern	10
Overall magnitude of impact score: Canalization and stream channel modification	4.3
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	1
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	5.3
Combined magnitude score as a result of impacts on hydrological functioning	7
Present hydrological state	E
Vegetation module	
Extent of disturbance classes	85
Magnitude of impact score	2.6
Present vegetation state	C
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	1.6
Impacts of erosion	1.3
Impacts of deposition	0
Present geomorphic state	C

HE: 2

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	165.7:1682.2 = 0.1
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-4.2
Intensity of impact of factors potentially altering flow pattern	10
Overall magnitude of impact score: Canalization and stream channel modification	1.1
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	0.8
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	2
Combined magnitude score as a result of impacts on hydrological functioning	6.5
Present hydrological state	E
Vegetation module	
Extent of disturbance classes	70
Magnitude of impact score	2.1
Present vegetation state	C
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	1.4
Impacts of erosion	0.2
Impacts of deposition	0
Present geomorphic state	B

HE: 3

Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	165.7:1682.2 = 0.1
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-4.2
Intensity of impact of factors potentially altering flow pattern	10
Overall magnitude of impact score: Canalization and stream channel modification	1
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	1.5
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	2.5
Combined magnitude score as a result of impacts on hydrological functioning	6.5
Present hydrological state	E
Vegetation module	
Extent of disturbance classes	65
Magnitude of impact score	2
Present vegetation state	C
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.8
Impacts of erosion	0.1
Impacts of deposition	0
Present geomorphic state	A

HE: 4

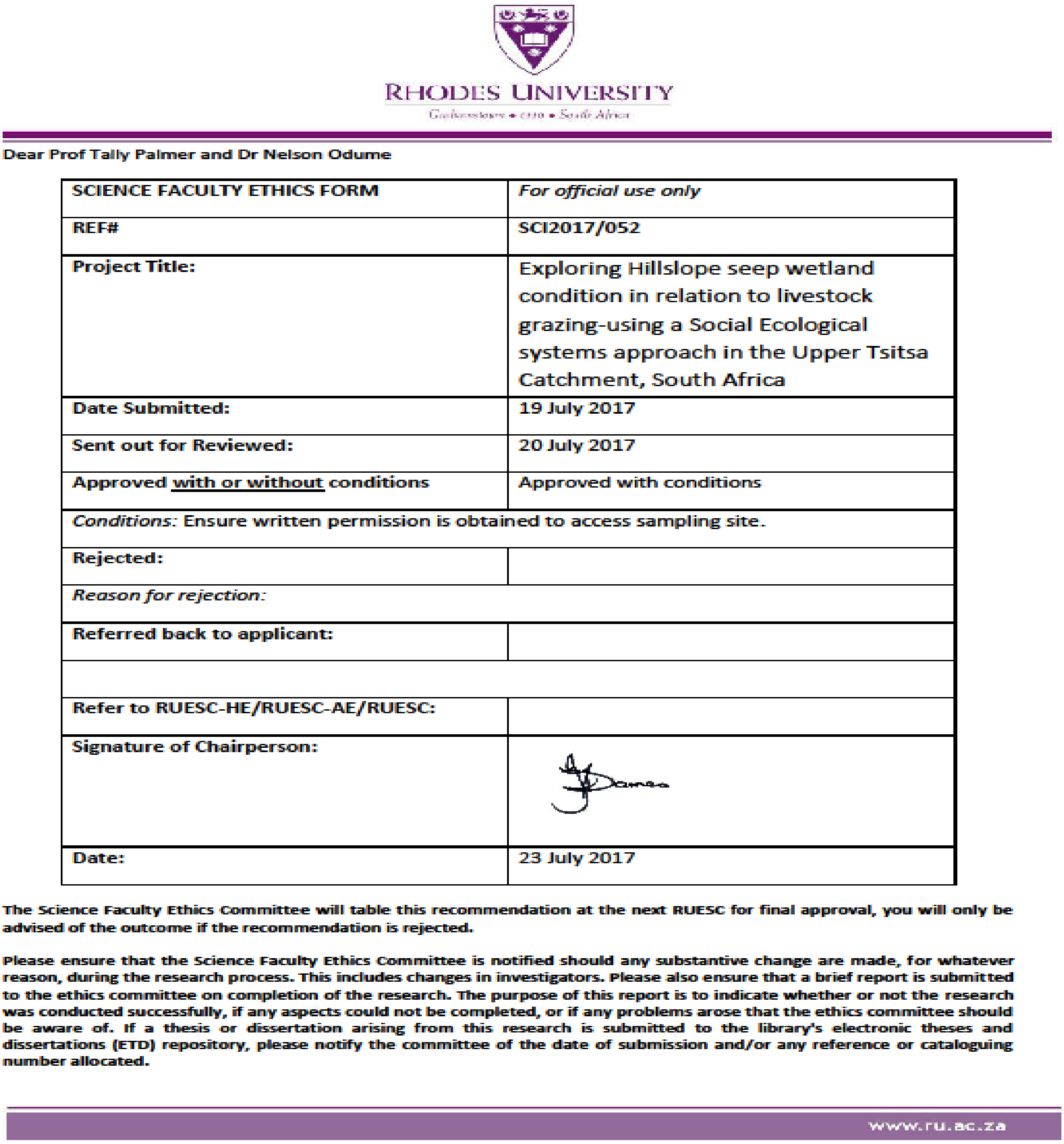
Hydrology module	**hillslope seepage (HGM unit)**
MAP:PET ratio	165.7:1682.2 = 0.1
Vulnerability factor	1.1
Combined score: Increased and decreased flows	-4.2
Intensity of impact of factors potentially altering flow pattern	10
Overall magnitude of impact score: Canalization and stream channel modification	1.7
Magnitude of impact score of impeding features	0
Magnitude of impact of altered surface roughness	0.8
Impact of direct water losses	0
Magnitude of impact of recent deposition, infilling or excavation	0
Combined magnitude of impact of on-site activities	2.5
Combined magnitude score as a result of impacts on hydrological functioning	6.5
Present hydrological state	E
Vegetation module	
Extent of disturbance classes	60
Magnitude of impact score	1.8
Present vegetation state	B
Geomorphology module	
Impacts of channel straightening	0
Extent of impact of infilling	0
Impacts of changes in runoff characteristics	0.5
Impacts of erosion	0.2
Impacts of deposition	0
Present geomorphic state	A

Appendix 2: Species and traits

Species	**abrev**	**SLA (mm mg)**	**LDMC (Mg)**	**LA (mm)**	**Height (cm)**	**Palatability**	**Life span**	**RC**	**WIS**	**Life span**
Alepidea amatymbica	AlAm	0.91875	500	147	30	Low	Perennial	20	4	annual
Alloteropsis semialata	AlSe	0.84625	400	135.4	90	Mod	Perennial	60	4	annual
Berkheya sp	Berk	3.705556	257.143	667	50	Mod	Perennial	40	4	annual
Centella asiatica	CeAsi	0.26	517.241	15.6	20	Mod	Perennial	40	4	creeper
Commelina africana	CoAf	0.823333	666.667	49.4	50	Low	Perennial	60	2	Perennial
Conyza scabrida	CoSc	1.4375	86.957	115	120	Low	Perennial	0	4	Perennial
Cymbopogon validus	CyVa	21.7	370.37	2170	100	Low	perennial	60	5	Perennial
Digitaria erientha	DiEr	2.63	615.385	210.4	70	High	perennial	60	4	Perennial
Eragrostis aspera	ErAs	1.229667	545.455	73.78	30	Mod	Perennial	60	4	Perennial
Eragrostis curvula	ErCu	0.213333	923.077	25.6	50	High	perennial	60	4	Perennial
Eragrostis plana	ErPl	0.5806	833.333	29.03	45	Low	perennial	40	4	perennial
Gerbera viridifolia	GeVi	5.9	31.746	118	30	Low	Perennial	20	4	perennial
Haplocarpha lyrata	HaLy	1.472143	608.696	412.2	6	Low	Perennial	20	4	Perennial
Helichrysum aureonitens	HeAu	0.10375	266.667	8.3	60	Mod	Perennial	20	2	perennial
Helichrysum nudifolium	HeNu	0.310625	524.59	99.4	40	Mod	Perennial	20	5	perennial
Hemarthria altissima	HeAl	0.3315	400	19.89	110	High	creeper	40	1	Perennial
Hypoxis acuminata	HyAc	0.464833	76.923	27.89	60	Low	Perennial	0	4	Perennial

Knowltonia bracteata	KnBr	1.375	500	27.5	30	Low	perennial	0	1	Perennial
Mentha aquatica	MeAq	1.78125	333.333	285	90	Mod	perennial herb	60	1	Perennial
Miscanthus capensis	MiCa	3.611111	318.584	1300	250	Low	perennial	60	2	Perennial
Ornithogalum sp	OrnT	0.40615	210.526	81.23	75	Low	perennial	0	5	perennial
Panicum maximum	PaMa	0.591	250	118.2	150	High	weak perennial	40	2	perennial
Paspalum dilatatum	PaDi	0.766	200	76.6	80	High	weak perennial	40	2	perennial
Paspalum distichum	PaDIs	0.36625	727.273	29.3	50	High	perennial	40	1	perennial
Polygonum sp	Poly	0.985	232.558	19.7	170	Mod	Perennial	60	3	Perennial
Richardia brasiliensis	RiBr	0.323	625	32.3	40	Mod	annual/perennial	100	4	perennial
Senecio coronatus	SeCo	0.076855	447.653	95.3	90	Low	annual	20	4	Perennial
Senecio speciosus	SeSp	0.346875	114.286	111	30	Low	perennial	20	4	perennial
Taraxicum officinale	TaOf	0.45475	800	72.76	50	Mod	Perennial	20	5	perennial
Themeda triandra	ThTr	0.351667	857.143	21.1	120	High	perennial	40	5	perennial herb
Tristachya hispida	TrHi	0.155714	666.667	21.8	40	Mod	perennial	40	5	weak perennial
Wahlenbergia sp	Wahle	3.35	181.818	134	60	Low	annual/perennial	20	4	weak perennial

Appendix3a: Ethical clearance



RHODES UNIVERSITY

Dear Prof Tally Palmer and Dr Nelson Odume

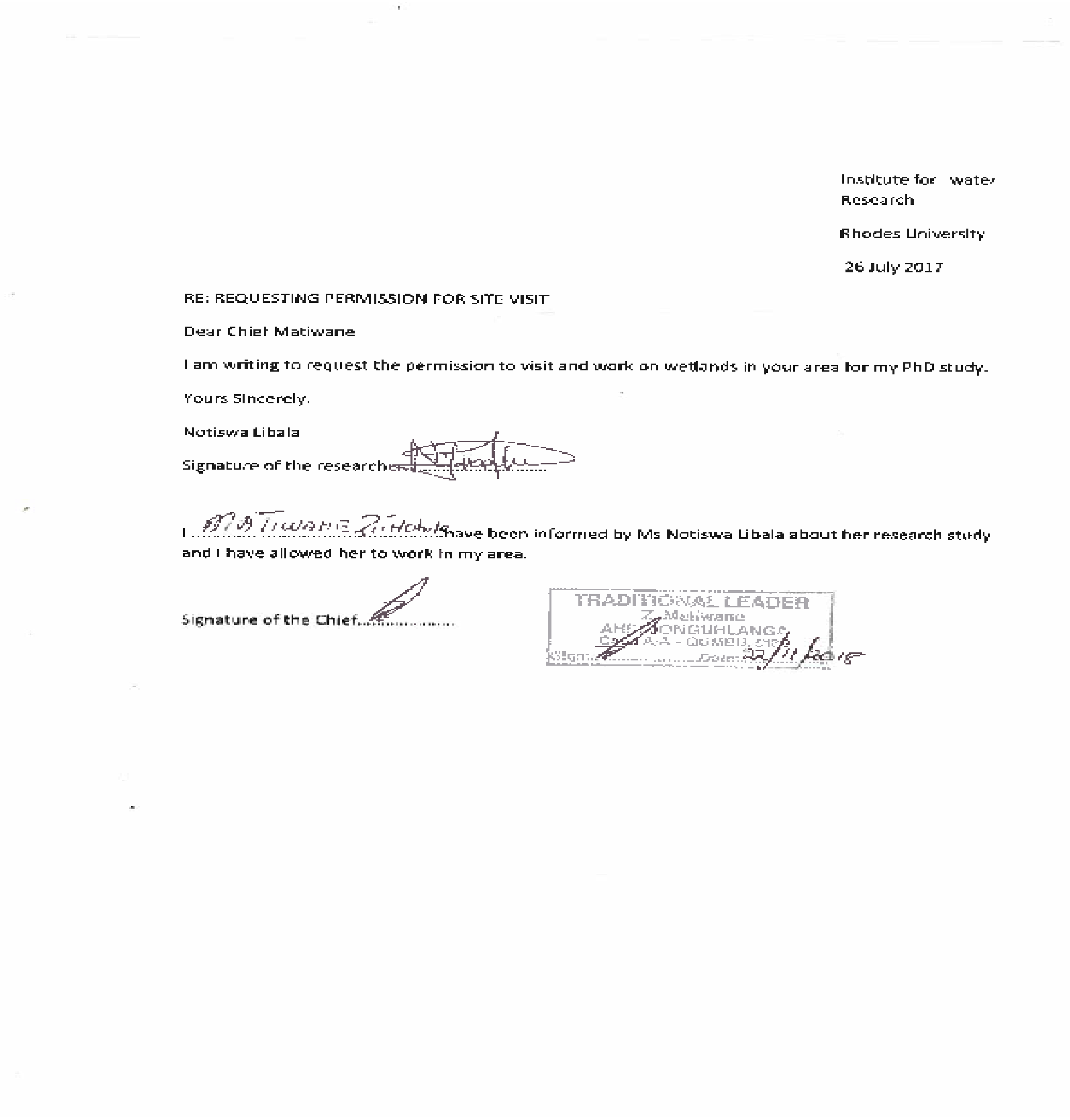
SCIENCE FACULTY ETHICS FORM	*For official use only*
REF#	SCI2017/052
Project Title:	Exploring Hillslope seep wetland condition in relation to livestock grazing-using a Social Ecological systems approach in the Upper Tsitsa Catchment, South Africa
Date Submitted:	19 July 2017
Sent out for Reviewed:	20 July 2017
Approved with or without conditions	Approved with conditions
Conditions: Ensure written permission is obtained to access sampling site.	
Rejected:	
Reason for rejection:	
Referred back to applicant:	
Refer to RUESC-HE/RUESC-AE/RUESC:	
Signature of Chairperson:	
Date:	23 July 2017

The Science Faculty Ethics Committee will table this recommendation at the next RUESC for final approval, you will only be advised of the outcome if the recommendation is rejected.

Please ensure that the Science Faculty Ethics Committee is notified should any substantive change are made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on completion of the research. The purpose of this report is to indicate whether or not the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the ethics committee should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloguing number allocated.

www.ru.ac.za

Appendix3b: Permission to access sampling sites



Institute for water
Research

Rhodes University

26 July 2017

RE: REQUESTING PERMISSION FOR SITE VISIT

Dear Chief Matiwane

I am writing to request the permission to visit and work on wetlands in your area for my PhD study.

Yours Sincerely.

Notiswa Libala

Signature of the researcher……………………………

I ……MATIWANE Z. Hobola……have been informed by Ms Notiswa Libala about her research study and I have allowed her to work in my area.

Signature of the Chief…………………

TRADITIONAL LEADER
Z. Matiwane
AHS[illegible]ONGUHLANGA
[illegible] A.A - QOMBE, [illegible]
Sign:………………… Date: 22/11/2018

Appendix 3c. Consent Form

RHODES UNIVERSITY
Where leaders learn

My name is Notiswa Libala, a registered PhD student in Water Resource Sciences at Rhodes University. I am conducting a study entitled: Exploring hillslope seep wetland condition in relation to livestock grazing-using a Social Ecological systems approach in the Upper Tsitsa Catchment, South Africa. The purpose of this research is to involve rural communities in protecting natural resources. The study is being funded by National Research Foundation and Department of Environmental Affairs. Any information that you provide will be kept confidential and be used in writing reports for my thesis and the DEA-Natural Resource Management, as this is government money, this report will also be used in publications and presented at conferences. The names of respondents will be kept confidential, and accordingly it will not be possible to trace the information back to the specific households. Participation is voluntary and you can decide to withdraw from the interview process at any time with no adverse consequences. Under these conditions all evidence of your participation in the study will be destroyed and omitted from the thesis and publications produced from the research. Data collected through this research process is the property of the Institute for Water Research (IWR) and will be stored securely within the IWR for a minimum of five years. At the end of this project the researcher will come back and give feedback to the participants.

Signature of the interviewer…………………………..........

I ....have been informed by Ms Notiswa Libala about the content of the study and I have agreed to participate. I confirm that the information I provide will be used towards a report in writing up of the Thesis and report for the DEA and NRF. I understand that I am free to withdraw from the research project at any time should I wish.

Signature of the Respondent…………………………..

Igama lam ndingu Notiswa Libala, ndingumfundi kwiYunivesithi yaseRhodes kwi-Institute for Research Water. Kupando lwam ndijonga imeko kunye nokubaluleka kwemigxobhozo malunga nemfuyo etya kulemigxobhozo, ndisebenzisa ulwazi olusuka kubahlali kunye ne sayenisi. Injongo yolupando kukubandakanya abahlali ekukhuseleni indalo yabo. Olu pando luxhaswa yimali esuka kwa National Research Foundation and Department of Environmental Affair. Kuba ndisebenzisa imali kaRhulumente, ulwazi okanye icazelo othe wasinika yona iyakugcinwa ngokufihlakeleyo, le ngxelo iyakusetyenziswa ngu National Research Foundation and Department of Environmental Affair. Olu pando luzakupinda lusetyenziswe kwikomfa nakwincwadi yam yapando. Amagama abathathi nxaxheba ayakugcinwa ngokufihlakeleyo, kwaye akuzobalula ukujonga icazelo yemizi ethile. Kolupando abantu bathatha inxaxheba ngokuzithandela, kwaye banelungelo lokurhoxa nani na befuna ngapandle kwemipumela emibi. Kwimeko ezinje, bonke ubungqina bokuba uthathe inxaxheba buyakutshatyalaliswa kwaye akuyi kuvela kwincwadi yolupando. Izipumo zolupando ziya kugcinwa ngokukhuselekileyo kwa IWR- eRhodes, iminyaka emihlanu. Ekupeleni kolupando Umphandi uzakubuya azonika ingxelo kubahlali.

Utyikityo lomphandi…………………………..........

Mna…………………… Ndiyifumene icazelo ku Notiswa Libala kwaye ndiyavuma, ndiyazinikezela ekubeni ndibengomnye wabantu abathatha inxaxheba. Ndiyazi ukuba ulwazi endizakuthi ndinikezele ngalo luyakusetyenziswa ekubhaleni I Thesisi, futhi luyakusetyenziswa kwi ngxelo yakwa National Research Foundation and Department of Environmental Affair. Ndiyazi ukuba ndivumelekile ukurhoxa kolupando nanini na xa ndingaziva mnandi.

Utyikityo lomthathi nxaxheba…………………………..

Appendix 3d: House hold interviews

Date.. Questionnaire number..

Observer's name.. Village... ....

DEMOGRAPHIC INFORMATION

1. Is the respondent the head of the household?

☐ **Yes**

☐ **No**

2. How long have you lived in the village?

☐ **0-1 year**

☐ **1-3 years**

☐ **3-5 years**

☐ **5-10 years**

☐ **>10years**

3. What is your gender?

☐ Male

☐ Female

4. What is your age?

☐ **<30 years**

☐ **30-40 years**

☐ **40- 50 years**

☐ **50 – 60 years**

☐ **60 – 70 years**

☐ **< 70 years**

5. What is the highest level of education/ qualification you have completed?

☐ **Primary**

☐

Secondary

☐ **Artisanal/ vocational study**

☐ **College graduate (FET)**

☐ **Some university certificate programme**

☐ **University degree**

☐ **Post-graduate degree**

☐ **None**

6. **Average household size?.................................**

LIVESTOCK OWNERSHIP

7. **Do you own any livestock?**

☐ Yes

☐ No

8. **Are you willing to divulge the numbers?**
9. **If yes, how many cattle are parts of homestead's herd…………**
10. **How many cows………..**
11. **How many oxen…………**
12. **How many calves…………**
13. **How many sheep are part of homestead's livestock holdings?...........**
14. **How many of the sheep are female…….**
15. **How many are rams………**
16. **How many are lambs**
17. **How many sheep are part of homestead's livestock…………**
18. **Do you keep livestock in the kraal at night?**

☐ Yes

☐ No

19. **If yes, is there a herder to take care of your livestock while grazing ?**

☐ **Yes**

☐ **No**

20. **Is the herder a member of the household/ hired herder?**
21. **On a scale of 1 – 5, where 1 is most important and 5 least important, rank the following in order of their importance to you, what are the benefit of owning livestock**

Benefits	**Rank (1-5)**
Income	
Wealth status	
Food (meat and milk)	
Ritual	
Others, please specify	

22. **Do your livestock rely on grazing for feed?**

☐ Yes

☐ No

23. **If No, what else do you provide them with as additional feed or supplements and how often?** **…………………………………………………..**
24. **What challenges do you face in raising livestock? Rank In the order of importance (1- most important; 5- least important.**

Challenges	**Rank (1-5)**
Grazing and Feeding	
Water scarcity	
Drought	
Animal disease	
Others, please specify	

25. **If you slaughtered, lost (through death and theft) or sold cattle in the last year, how many animals……………………………..?**

26. **If you slaughtered, lost (through death and theft) or sold cattle, what is the value of animals**

☐ **<3000**

☐ **3000-5000**

☐ **5000-8000**

☐ >8000

27. **If you slaughtered, lost (through death and theft) or sold sheep, what is the value of animals?**

☐ **<500**

☐ **500-1000**

☐ **1000-1500**

☐ **>1500**

28. **If you slaughtered, lost (through death and theft) or sold goats, what is the value of animals?**

☐ **<500**

☐ **500-1000**

☐ **1000-1500**

☐ **>1500**

29. **If you sold any skin during past years what was the approximate values of these items?**

☐ **<500**

☐ **500-1000**

☐ **1000-1500**

☐ **>1500**

LIVESTOCK GRAZING

30. **During winter, the grassland is often g dry with little green vegetation, do your livestock prefer grazing on wetter areas with green vegetation during winter?**

31. **Where your livestock do spent most of their time grazing during winter season?**

☐ Grasslands?

☐ Seep wetlands?

☐ Cultivated land?

☐ Other?

32. **Where your livestock do spent most of their time grazing during summer season?**

☐ Grasslands?

☐ Seep wetlands?

☐ Cultivated land?

☐ Other

33. **Are there any community rules that you need to adhere while grazing?**

☐ **Yes**

☐ **No**

34. **If yes, mention those rules………………………………………………………….**
35. **As a livestock owner or herder do you have other owner?/ community members that you discuss issues of livestock grazing with?**
36. **If yes, who are these people?........**
37. **Do you think that there are any problems in your village with the grazing land?..................**
38. **If yes, please elaborate more on the nature of the problem…………**
39. **Is there an understanding in your village of the problems associated the impact of livestock on the grazing lands and more especially seep?**

SEEP WETLANDS ECOSYSTEM SERVICES

40. **Do you know what seep wetlands are?**

☐ **Yes**

☐ **No**

41. **If yes, do you benefit from them?..................................**
42. **In your opinion, do you consider seep wetlands as important ecosystem for livestock grazing?**

a) Important

b) Very important

c) Probably important

d) Unimportant

e) Very unimportant

43. **Why? Would you like to elaborate on your response please?**

………

………

………

44 . On a scale of 1 – 5, where 1 is most important and 5 least important, rank the value of seep wetlands

Values	**Rank (1-4)**
Source of water	
Grazing for livestock	
Handcraft production	
Others, please specify	

45. In your village, what is the condition of seep wetlands?

☐ Less eroded
☐ Moderately eroded
☐ Highly eroded

46. If highly eroded what do you think are the causes?

☐ Overgrazing
☐ Under grazing
☐ Lack of grazing management practices
☐ Other

47. If less eroded what could be the causes?

☐ Overgrazing
☐ Under grazing
☐ Lack of grazing management practices
☐ Other

48. What grazing management practises are there to look after seep wetlands?

☐ Rotational grazing
☐

Continuous grazing

☐ Other

POSSIBLE SOLUTIONS OR RECOMMENDATIONS FOR SEEP PROTECTION.

49. Do you think we should protect seep wetlands?

☐ **Yes**

☐ **No**

50. What do you think could be done to protect erosion of seep wetlands?

☐ Fencing

☐ Gabion construction/ silt trapping

☐ Planting of grass

☐ Other specify

51. Would you agree to keep your livestock from grazing on seeps for six months (Jan – June) yearly, so that the seeps are only available for grazing other time of the year?

a) Definitely yes

b) Maybe

c) Probably not

52. Why? Would you like to elaborate please?...

53. Have you heard of Catchment Management Forum?...

a) Yes

b) No

c) Not sure

Appendix 4: Transcript

P1

We don’t have rules they graze everywhere/anywhere, people do what they think is right for their livestock no one ask anything to anyone, here we don’t have people discussing about livestock issues we just do what we think is right.

Problems

Is the lack of grasses for the livestock to eat to extent that, our sheep move around having nothing to graze and go as far to graze in other people’s garden and in far areas where they get stolen?

Because of the dirty water which is always not moving in seep wetlands, it affects animals they end up having worms and nyongo because of the water.

I don’t have enough understating

We don’t have things like that, because here people are not united, when there is something wrong no one calls everyone in one place to talk about what is wrong, people do as they want according to their way.

We can agree on that only if they will be a place where our cattle can graze in.

We never heard about CMF, we don’t know

We could agree because that would help us by proving water and food to our livestock, and the livestock would be safe.

P2

Livestock have open access to these seeps since they are not protected .We use to have camps divided, in the times where we use to plant maize but because we don’t plant anymore, we don’t have those camps; our cattle can go and graze anywhere

Yes we do get some advices from each other as the community to extent that when our livestock get sick, we call “abalimi” to come and vaccinate the livestock

We do communicate with the whole community, especially with the issues of draught and when they are fires we call the community to come and stop the fire, after that we call people to come and take livestock in places where there was no fire, so that the livestock won’t be impacted by what happened.

The problem that we have is the one I have mentioned already, we get fires out of nowhere from other areas, after the fire, we usually seat with other people and advise as the community that we should avoid grazing our livestock in the area that was burnt because after fire there is “ihlungu” that causes a disease called “Qilikwana” in livestock, this disease makes animals to lose energy.

We use to have this seep as you can see it was big but we have lost in now, it is a gully. This river down there is helping us with drinking.

Seep is not important in a way that sometimes when they grazing, they end up being stuck in the mud.

We use to plant here in the olden days, we had grass all over the land, but in these days we have a problem of wattle that is invading our land, we even stopped planting crops because of it. This wattle is a problem it destroys our grazing land, suck water from our seep wetlands and it also destroys the grass, for example if we you look beneath the tree you find that there is no grass cover there is just bare soil. Nothing grows under those trees, we have been talking about this as a community, that we need to talk to our government about this wattle it is a problem and we might get help from government. As you can see it is all over from up to the bottom this area use to be grassland only.

These seeps are important since they provide good grass to the livestock, on the other hand it is a problem when it's too wet because livestock get stuck in the mud, it would good if we can only use them when its dry/ in winter to avoid them being stuck.

Forum I know it as a group of people that deals with crime, because of high rate of crime people come together and decide that they need community people that will be the security for the community, that is the forum I know, we call it "police forum" and at the moment I can't say I might join or not because it is something that we communicate about and decide as the community.

Even though we have drought, but water is not really our problem, the main problems are the ones I told you about fire and wattle, and these fires are coming from other areas not ours.

P3

We used to have rules, and divide our grazing land by the time we were planting maize, but we no longer doing that, we don't rules now.

We do our things separately, the way we want, sometimes we call the meetings but no one will come, sometimes people do wrong things and not being responsible because no one will ask why they do such things

We have a problem of wattle that is invading the whole grassland, as you can see up there, we use to have our land without wattle, the wattle it affects the whole grazing land, another problem these dongas are expanding every year.

Sometimes when the cattle graze on seep, the get stuck in the mud/ fall in the dongas and die, so if we take them out sometimes I can do that

Seeps are important for livestock to graze because this is an area where you find (uhlaza)

We use to have rangers, where our grassland was divided by fence, but we no longer have rangers now that is why you see too much degradation, the time we had rangers we had a rules, our seeps (intlambo) are degraded because there is no structure, people are doing their things in their corners

My wish is to have those rangers back and fence/divide our grassland, so that it can go back to its state

I can join because I see this would be the only way to protect our livestock.

P4

We don’t have any rule that says they should/shouldn’t graze there

Yes I do talk with my neighbours because I am a female I seek advice from male for example when my cattle is too thin I ask what can I do for it to gain weight and they give some advices. I even ask them to vaccinate for it to be in a good condition and I usually give them R10.

We have more grassland now because we no longer planting, if you look up there we use to plant maize, by that time we use to force our livestock to go and graze in the mountains

During dry season I see that livestock eat a lot of grass in the seeps to extent that they leave those seeps bare, so seeps are important for our livestock to graze, however sometimes, they die there because when they graze too much they leave bare soil and they get stuck in the mud.

I would agree especially if we will take our cattle to the other side and leave the other grass to grow.

I heard about forum, when I was in Qumbu town, this lady told me she was a member of a forum, where at night they protect people and also have t shirts of the forum

I was going to join if I was a young person because I like to see development in our community

P5

Our cattle they go and graze anywhere around catchment, we use to have rules during trust the time we had rangers, there are no rules now

Yes we have people including our Nkosi, he recently suggested that we need to vaccinate our livestock

The wattles destroys our grazing land including seep, it grows fast and grass cannot grow with wattle, this mostly affecting those who have sheep, and when they graze in between wattle we cannot see them, some people even steal them since they are hidden from us. They get stolen

We also have animals that eat out livestock such as a jackal.

Cattle benefit more from the seep, by eating the green grass that is always fresh

That is government's responsibility maybe to give medicine to filter.. seep or try mhhhh…produce all kinds of crop so that people will have something to do.

This would help to fence those seeps so that livestock graze at certain times, for example during the time of lack of rain we can only open the seeps

I used to hear about it while I was staying in Cape Town, they will say we have a what what forum???

I would join because in rural areas we really need help and our government is far away from us there is a big difference between people in town and us here

P6

No we don't have rules here

There is no communication between people here

During dry period the livestock usually graze in the seep wetlands

So during winter the cattle look for greener areas, they graze more on seeps that's why they are important

I don't know, I am not sure,

No I know nothing about forum, but because you have explained it now I do have an interest

P7

We use to have rules, the time we had trust, but we no longer have it so there are no rules. Our livestock they graze anywhere around. Trust- is the fence that was used to divide the grazing and cultivated lands. That time we also had rangers. Like big farmers,

I talk with my family when there's a problem with my livestock

Yes there is a problem especially the wattle invasion it is a big problem, wattle is invading the whole grassland, you see this area, and we use to have our grazing land clean without wattle, but look at it now to extent that our livestock end up not having a place to graze. For example up there the government has a project of planting trees that will also help for job creation, so the livestock that used to graze there were taken to another area.

We have a problem especially this year our grasslands are patchy just like the front of my house including those seeps and areas where there is wattle,

Seep wetlands are dangerous, when too wet; cattle end up being stuck inside

We use to have the time of trust, where grasslands were divided for rotational grazing purposes, we use to protect our grassland, by shifting livestock from one camp to another. During trust our grasslands were in good condition

I heard about forum long time ago I don’t remember what was about

Only if I was young I would join, because the way you explain it, its like we might get help from government.

P8

We don’t have rules in this area

No discussion, but what I do is to buy medicine for my livestock when I get paid (grant)

I see there is a problem, especially the wattle it is invading the grasslands, the dongas are expanding every year

In my opinion, there is a problem; sometimes cattle graze in a way the they leave bare areas in those seeps

They are important since, they give green grass, but again they are not important when the cattle get stuck in in the dongas of the seep.

I would agree but again I can’t do that alone, we need to be one as the whole community and decide which areas need to be protected

I heard about it especially the time we had a high rate of crime, there were people who use to patrol around protecting the community.

If the forum is exactly the way you say, it is something that can develop our community, then there is no problem I would join.

P9

No at the moment I don’t know any rule

We do have people especially when our livestock are sick we contact our extension officers (abalimi)

Yes we do have a problem of erosion as well as wattle invasion as you can see it is all over

We also see erosion in seeps, where you found most of them are degraded to a point that cattle will no longer have good grazing

Seeps are important because, it is an area where the livestock get green fresh grass when its dry.

We would agree to keep them, because this will help the livestock, you know what is happening here, they burn the whole area to a point where livestock has nothing to graze, but if we can work like this, keeping them away for certain time, we will definitely improve grasslands and burn some while protection some.

I hear about it but I do not have enough understating about forum

It will help us to have the rules for the community, especially on how we prevent things like erosion, we can decide as the community which area we will use for our livestock for that season and burn the other area

P10

No we don’t have rules

We do seek advice from other people, but most importantly we contact the extension officers when we experience some problems, they always give us some advices

Yes this area was not like this before as you can see the wattle

We have a lot of livestock here even people who are not from here send their animals to this side and I think that’s why we have erosion in these seeps

Seeps are important especially if we can protect them, because they are the source of food for our livestock

I am not sure about forum, but the way you explain it I would join I love livestock and I like to see it in good condition.

P11

We don’t have strict rules; I think its only government who can help us with the resources for those rules.

No there are no people I just buy medicine for my cattle in Maclear

The main problem is that our livestock graze up to close to that forest up there and now they get stolen

This year is worse, last year we had a no rain, it usually rain in summer but it is not; hey our cattle were hungry and thin, just like now there is no rain no grass

I would say seeps are very important since they give our cattle fresh feed

We need to divide camps like commercial famers, what they do is to divide camps and put livestock in other camps and rest others.

I didn’t go to school I know nothing about forum

No I don’t think I would join, you want us to give government our livestock no no.

P12

Long time ago when I was young we had rules, where we had one piece of veld closed and one open we used use the one open for grazing for a particular season, and rest the other piece, but now we don’t have any rules

I talk with extension officers I go straight to department of agriculture Qumbu offices to meet them whenever I have problems

Our livestock get stolen here, because we don’t have people following them (herders)

It happens, for example we have a big seep here but its clean there is no grass, it is too grazed by livestock, to a point where they get in without that grass cover they stuck in the mud because there is no grass to cover the mud.

I can say yes seep is important but because of this problem they are not that important for killing our cattle even horses.

Protecting grassland is better by fencing, so that we will get enough grass for livestock

I would be so happy even if we can start that by tomorrow; this would help us a lot, to use other camps and close others for grazing I would be happy

We use to have something like that, we joined it here in Caba, we were taking our sheep wool and sell in East London, and we were also exchange our sheep, for example if you want a bull but you have females.

I would join because I saw the benefit from the one we had, we were getting money from the sheep wool

P13

I know nothing about rules

No we don’t have rules

In most dongas here are our livestock get stuck in them and die

It is good to protect the seeps

I would agree because that would be the decision for the whole community, it is something that will help us and our livestock

I know forum as people in the community that are solving the problems in the community

I would join, as a member in this community I would love to see the development

P14

We don’t have rules, No structure we just do

We don’t discuss things, people do what they think is good for them we do talk but its not a serious thing

We don’t have problems here in our grazing land, when there is no grass in other areas we take livestock in areas where there is grass, there are places that we avoid we don’t take our livestock to places like close to dongas

I don’t know.

I would like because that will help me as well

I hear people talking about it

I would join if we agree on that as a community but I can’t do it if others are not joining

P15

We don’t have rules as results cattle from our neighbours are grazing the other side while ours are grazing up there in the mountains

We do discuss with other people when our livestock is sick

There is a problem since livestock graze up in the mountains; there is a lack of water

The other problem is when the livestock graze in an area that is recently burned that grass is dangerous to cattle

Seep are helping us with water, in terms of grazing it is good, they sometimes graze more on seeps to extent that there is no grass covering surface that’s when they get stuck in the mud. Sometimes in winter the river get dry and seeps are the source of water

I would agree because that is protecting the grassland to help us as the community

I never about forum

I would join because that forum can help in protecting grassland and remove the wattle which is another problem here.

P16

There are no rules here as a results one of our cow died up the in the forest no one told us we saw it after a long time

We don’t really discuss with community people, my father was a member in department of agriculture, we use to see the things he would use such as teramicine, vaccinating, so we still doing that. We also contact department of agriculture (EO) when we have problems. Even when we cut sheep EOS tells us the best way to do that.

I don’t see any problem that we have except for drought that we have this year

Seeps are important for grazing but they are also dangerous, and livestock love to go there

I would agree because its means cattle will only graze in seep when there is no too much wetness and this will also reduce the chances of cattle being stuck in seeps. Because the grass would be too much to cover the surface. People are not united

I hear about forum

I would join because this would be a platform for us to take our problems to government

P17

We don’t have rules, we just graze anywhere

I discuss my livestock problems with amalimi, for example I had a problem when 3 of my calves died, but after applying the advice I got from abalimi, I never experienced that again

The wattle is a big problem as you can see it is all over and it hide the jackal which kills our livestock even during the day.

Erosion is a problem as well there are dongas everywhere here

People here they also burn the grassland anytime and this destroys the livestock

Seeps are the only place with fresh grass we don’t have any choice we are forced to take livestock up there during dry season

I think if we can protect these seeps for certain time and keep away our livestock it can go back to their natural state where there is no trampling, then cattle can graze without being in danger.

Forum used to be people who are looking for people who steal our livestock

I would join, because this would help me as a farmer to gain more livestock

P18

Here we do have some rules, for example in winter we burn and take cattle to graze somewhere where we didn't burn

I don't discuss with anyone

The problem is the erosion as you can see; also the wattle is invading the whole area,

Seeps are important because in winter livestock have somewhere to graze

I would agree so that we protect the seeps and prevent the erosion that will lead to dongas

I hear those forums are the people that guarding the community, yes I can join only if I will get paid

P19

We don't have rules, it's those households with herders that will be following livestock and direct them on where to graze

I don't discuss with anyone I only go to kwaWhitey in town to buy medicine for my livestock

The big problem is the erosion in this area, there are dongas everywhere, this is the year that is worse because of drought, this area is not the same, there is drought; we don't have grass this year at all.

Seeps are very important because when livestock come home from seeps they come back full in their stomach because the grass that is there is soft and fresh

I would do that look these are our land we use to plant maize and have other veld for grazing only, by that time we had our livestock in good condition even the grassland

I hear about it, if my community is joining I would join too

P20

We use to have trust in this area previous years, we use to have rangers-people who will move livestock from one camp to other, we were doing what you call rotational grazing, but we no longer have rules and we don't even trust

I do discuss with some people around but as for me when my cattle get sick I used my Xhosa medicines

Dongas plus (dwabasi) are the biggest problem in this area when we were young this area was not like this. There was no Dongas no erosion no wattle. Some times our grassland are grazed to a point where there is just bare patches but again we don’t know what to do because we don’t have any plan.

Seeps are very important in a way that the grass that grows there is different form the one in the surrounding grasslands it is too fresh and green, particularly during this winter time the grass there is very important for the livestock. Remember there is also water there that is not available in other ecosystems. Most time our livestock survive from these seeps

I would agree if we have plan to take them somewhere else where they will get feed and water

I just hear about it, I would join if it’s something that we will benefit from as the community, if government can help us to get these dongas fixed and removing this wattle.

P21

We don’t really have strict rules, but when it’s time to plant maize in the gardens and when the veld is burnt we take them to graze up there in the mountains (for example the time of planting)

Heyy.. Here we don’t talk, we don’t help each other, it is difficult

We have big problems for example these dongas, they were not here before and they are getting worse, livestock are even falling and dying in these dongas

Seeps are very important for the livestock since they always have that saturated grass that doesn’t get dry

We don’t even have plan on protecting them, especially during drought, livestock graze more on these seeps leaving them eroded, because they have nowhere else to go.

I hear about police forum, I would join forum because I like seeing my livestock health.

P22

We have some rules

We do get some advices from the neighbours about where should we take the livestock to for grazing, and what to do during draught or when there is lack of food

Yes there are some problems you find that cattle graze too much on these seeps leaving bare area or mud that will also damage them when there is no grass cover or too much trampling.

I would say they are important when it comes to the grass that gives to livestock, but again when livestock are getting stuck it becomes difficult

Yes I would agree to keep them, so that our cattle only use it when there is too much grass cover

I don’t know about forum, I would join but it will depend

P23

We don’t have rules

People are not united; they are doing their own thing, only abalimi who are helping us when livestock are sick.

We don’t have problems except the dongas that are increasing everyday

Seeps are important because from there cattle come back home full, they do really help us

I would do that just to get our cattle good feed from seeps

I hear about it, I would only join if there is trust otherwise I wouldn’t

P24

No not now because the fence that was used to divide camps was old and it got stolen, by then we use to have rules about where we taking livestock to graze for a certain period of time

We don’t discuss with the community, we only get help from someone from Tsolo who is our person that usually vaccinate our livestock when they thin

Last year we had a lack of rain; hey our cattle were hungry and thin, just like now there is no grass, if you can burn now, the fire will go straight to the soil, when they graze in these seeps they become healthy and thick

It is important in that time of winter, to eat the green grass, but sometimes we give them maize

I would agree if we protect the seeps it means they will produce more grass for our livestock and that we will also protect them from grazing too much and trampling, since they will not spend too much time on seeps

I never heard about it, but I would join if government can provide us with fence so that our cattle will have good graze

P25

It used to be there long time ago, where we use to open one camp and rest the other, and rangers were looking after these but the trust disappeared now.

We only get help from abalimi, when experiencing some outbreak

The problem we have is these dongas and the fires that people just do, sometime when they drunk to extent that cattle don't have a place to graze, we also do see the damage that sometimes cattle do to the seeps but because we don't have alternative we want good feed for our livestock they graze anyway

They are important because our cattle cannot survive without them during dry season, they are of great help

We don't do anything to try and protect them

I would agree if we can talk with one word as the community because they are people who are outliers even community is coming with good suggestions

I never heard, I don't I would join because people here are not trustworthy, they are not united

P26

No we just graze

Yes I do get advice from (males) as a female farmer there are things that I don't know, for example i don't know where we need to take our cattle to when the is no grass on the other side, so they advise on those.

This area is not the same, the draught; we don't have grass this year at all, the dongas were not like this. Even in seep wetlands I was up there close to the seeps last week its worse, there are dongas in those seeps, there is no grass, and cattle finished it.

I would say seeps are not really important in a way that they get stuck in there, but there is nothing we can do because cattle go up there every day.

We don't do anything, now here they stole the fence that was up there in seeps, if we can have fence now it would good if there are people who will look up.

I hear when they say it, if I see that it will help me with my livestock I would join

P27

We don't have rules

We do discuss, especially we get help from abalimi, and we give each other advices as well

Not really except this dongas, even the herders they do tell us that maybe in July you need to prepare yourself, they won’t be enough feed for livestock in grassland, so we do buy some feed.

It is important when they come from seep they have full energy because they eat and drink there

I would but not really because most of us are not united

I heard about it long time, we would join because we want to see our grazing land back to its normal state.

P28

No we don’t have strict rules, as results now it is going to time of planting maize we will have fights because there are no camps for livestock they will come and eat from the gardens

We would like to have our own camps as people in caba, because here cattle form gqukuqa and shukanxa they come and graze here.

We do discuss sometimes but gain because we have no resources to solve the problems we have

In the olden day, there was no erosion no dongas here but look now this is not good

The problem is there are so many cattle grazing in this area including in seeps, not only our cattle in caba but also from shukanxa and gqukunqa, that’s why you find that these seeps are degraded.

Seeps are important because they always have water so when livestock done grazing they drink water without going far looking for water. We cannot do anything on our own government is far from us and when we talk to government they say “okay”, but never come

I would agree because I have a lot of livestock

I know forum, for example if I have problem at home I call them so that they call policeman.

I would join, If only our government can be reliable and bring services to us, because our government takes time to give us attention in rural areas

P29

No because trust disappeared

We don’t discuss and advise each other, but sometimes we do for example when there is no grass on the mountains we decide where we taking the livestock (otata bokuhlala).

The problems are these dongas here sometimes cows fall and die between dongas, especially if cattle are not in good condition.

They graze more on seeps in winter and they graze too much to extent that there is no grass covering surface that's where they get broken/ or stuck.

Seeps are important in the winter time since it has that grass supported by water, it helps us more during winter time where there is dryness in other areas of the catchment

We don't do anything to stop or trying to fix these dongas, we even see from other places close to us where government is closing the dongas we would like to have that one day.

I would agree, because I know that seeps will provide good feed during the time of lack of feeds in other areas this will also provide more grass to grow in seep and reduce the degradation

No I never heard, I would join because these forums would help us to get close to government

P30

No, we don't have, they only thing I know later we bring them close to home because we running away from thieves

We do talk especially with males seeking advices because they know more about cattle

We have a big problem here of the dongas, you find that in the seep there is a big donga because cattle likes to go up there and graze but sometimes you find them lying down on these dongas that are in seeps, people they burn anytime

Cattle go to seeps because they attracted by the green grass, but most of these seeps are degraded and there is dongas in the seeps, they are dangerous because cattle fall and sometime no one is close by to help the cattle.

There is nothing we do to protect the dongas here

We would agree and be happy because that will our livestock.

No we don't, but would like to join especially something that will help us in this community.

P31

WE USE TO have RULES, but there are people who (savelelwa luhlaselo) were taking our livestock so now each and every one is protecting their stock in their own way

We only have a person(ongumlimi), we only discuss with him he in town

Our veld is not good people they burn anytime

There are dongas that should be protected but that would require us as a community to seat and decide.

Seeps they are not important because they are dangerous to cattle

We don’t have means to protect these dongas that are in wetlands

I would agree with people and keep them, so that the livestock are protected

I use to hear about forum, would join just to protect the wealth of my children who are not currently staying in the location but in towns