IMPACTS OF SUGARCANE FARMING ON COASTAL WETLANDS OF THE NORTH COAST OF ZULULAND, KWADUKUZA, SOUTH AFRICA

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Signature: Date: 11/12/2014

ABSTRACT

Wetlands are key to providing important ecosystem goods and services yet they are under threat from a number of anthropogenic activities. In particular, in this study area, agriculture in the form of sugarcane farming is a threat to wetlands as sugarcane is reliant on a good water supply. The impacts of sugarcane farming emanates from the fact that sugarcane is a mono crop that requires wetland resources and uses a lot of pesticides and fertilisers. Despite the assumed contribution of sugarcane farming to wetland loss and degradation, few studies have quantitatively assessed the spatio-temporal changes in wetland extent as well as changes in water quality because of this activity. This study assesses the impacts of sugarcane farming on wetland extent and water quality in two coastal wetlands of KwaDukuza, North coast of Zululand, South Africa. Specifically this study sought to (i) assess the impacts of sugarcane farming on the spatial extent of wetlands between 1959 and 2012, (ii) determine if sugarcane farming negatively affect water quality within the wetlands and (iii) evaluate the perceptions of local farmers regarding impacts of sugarcane farming on wetlands. Results of the study indicated an increase in the extent of Zinkwazi sugarcane fields from 62.3% to 67% between 1959 and 1989 and Nonoti sugarcane fields' extent increased from 50.5 % to 56.4% between 1959 and 2000. The last decade from the year 2000 showed gradual decrease in the area of wetland farmed by sugarcane due to the global sugar price remaining static while the cost of farming inputs increased and due to conversion of some farms to urban developments. Unfortunately, this has not lead to an increase in wetland area as the waterfront type developments, as well as a formal settlement have replace the sugarcane in the wetlands. Water was analysed for nitrogen (N), phosphorus (P) and potassium (K) and results for both Zinkwazi and Nonoti indicated an increasing trend of N and P from upstream to the middle region of the rivers and a decreasing trend of the N and P from the middle region to downstream. Sugarcane farming does not take place below the middle region and so does not provide fresh sources of these nutrients. The downstream area where the N and P decrease also coincides with the area of the river under tidal influence such that the N and P are being diluted by the incoming tidal seawater. K showed an increasing trend from upstream to downstream and its values were higher than N and P. Concentrations of N and P above the South African water quality guidelines for aquatic ecosystem were recorded in the middle region. Furthermore, farmers' perceived wetlands to have been transformed to agricultural land and related these changes to their sugarcane farming activities. It can thus, be concluded that sugarcane farming has resulted in wetland loss as well as deterioration of water quality within the Zinkwazi and Nonoti wetlands in KwaDukuza. In that regard, there is need to engage farmers in wetland management programs in order to reduce the negative environmental impacts associated with sugarcane farming in wetlands.

KEY WORDS AND PHRASES

Wetland extent, sugarcane fields, spatial and temporal changes, aerial photography, water sampling, farmers perceptions.

OPSOMMING

Vleilande is die sleutel tot die verskaffing van ‘n belangrike ekosisteem dienste, maar hulle is onder ‘n bedreiging deur 'n aantal menslike aktiwiteite. In besonder in hierdie studie area, is Argriculture in die vorm van suikerriet boerdery is bedraging vir vleilande, en suikerriet is afhanklik van 'n goeie watervoorraad. Ten spyte van die veronderstelde bydraes van suikerriet boerdery, is die vleiland aan die agteruitgang, 'n Paar studies het kwantitatief die tydruimtelike veranderinge in die vleiland, sowel as veranderinge in die gehalte van water as gevolg van hierdie aktiwiteit waargeneem. Spesifiek is hierdie studie gepoog om (i) te bepaal wat die impak van suikerriet boerdery op die ruimtelike omvang van die vleiland tussen 1959 en 2012 is, (ii) bepaal of suikerriet boerdery negatief beïnvloed is deur die gehalte van water in die vleilande en (iii) die persepsies van plaaslike boere rakende die evalueering en impak van suikerriet boerdery op die vleilande. Resultate van die studie het aangedui 'n toename in die omvang van Zinkwazi suikerriet velde van 62,3% tot 67% tussen 1959 en 1989, en die Nonoti suikerriet velde toegeneem het met 50,5% tot 56,4% tussen 1959 en 2000. Die laaste dekade van die jaar 2000 het geleidelike afname in die area van die vleilande getoon, omdat suikerriet as gevolg van die globale suiker prys die koste van boerdery-insette verhoog het, en dit het gelei tot die omskakeling van 'n paar plase na stedelike ontwikkelings. Ongelukkig het dit nie gelei tot 'n toename in die vleiland gebiede nie, met die gevolg die waterfront tipe ontwikkelings, asook 'n formele nedersetting, vervang die suikerriet in die vleilande. Water is ontleed vir N, P en K en resultate vir beide Zinkwazi en Nonoti, het aangedui 'n toenemende tendens van stikstof en Fosfor. Dit gaan stroomop na die middel-streek van die riviere en 'n dalende neiging van die N en P uit die middel streek stroomaf. Suikerriet boerdery vind nie plaas onder die middel streek nie, en so is daar nie vars bronne, wat van hierdie voedingstowwe verskaf nie. Die stroomaf gebied waar die N en P ‘n afname het, val ook saam met die gebied van die rivier onder die gety , en dit beinvloed sodanig dat die N en P se water verdun word deur die inkomende gety se seewater. K het 'n toenemende neiging van stroomop en stroomaf en sy waardes is hoër as van die N en P. Konsentrasies van N en P bo die Suid-Afrikaanse water standaard riglyne is in die middel streek aangeteken. Verder, beskou boere dat die vleilande behoort te verander om die landbougrond en verwante veranderinge aan hul suikerriet boerdery en aktiwiteite. Ons kan dus aflei dat suikerriet boerdery het gelei tot die vleiland se verlies asook die verandering in die watergehalte in die Zinkwazi en die Nonoti vleilande in KwaDukuza. In dié verband is dit nodig dat die boere in die vleiland by programme betrek word ten einde die negatiewe omgewingsimpakte wat met suikerriet boerdery gepaard gaan in vleilande te verminder.

TREFWOORDE EN -FRASES

vleiland mate, suikerriet velde, ruimtelike en temporale veranderinge lugfotografie, water monsters, boere persepsies

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ACRONYMS AND ABBREVIATIONS

AMT	Agrimark Trends
BMP	Better Management Practices
GIS	Geographic information systems
GLCF	Global Landcover Facility
GPS	Global positioning systems
DEM	Digital elevation model
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities
DRDLR	Department of Rural Development and Land Reform
DWAF	Department of Water Affairs and Forestry
DAFF	Department of Agriculture Forestry and Fisheries
FAO	Food and Agriculture Organisation of the United Nations
EPA	United States Environmental Protection Agency
K	Potassium
KZN	KwaZulu-Natal
Landsat MSS	Landsat Multi Spectral Scanner
Landsat TM	Landsat Thematic Mapper
N	Nitrogen
P	Phosphorus
SASA	South African Sugar Association
SASRI	South African Sugarcane Research Institute
SPOT	Satellite Pour l'Observation de la Terre
SUSFARMS	Sustainable farms
WESSA	Wildlife and Environmental Society of South Africa
WWF	World Wide Fund for Nature

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Sugarcane *(Saccharum afficinarum*) (Food and Agriculture organization of the United Nations / FAO 2003) is a perennial grass crop grown in most parts of the world as a mono-crop for commercial production (FAO 2003). It grows well in tropical and subtropical regions between 37^{o} north and 35^{o} south of the equator (FAO 2003). Sugarcane is planted as setts, these setts are laid horizontally in farrows or at an angle of 45^{0}and is lightly covered with soil until they sprout (Van Antwerpen & Meyer 1996). The crop cycle varies from 10 to 24 months and it is harvested after 12 to 18 months. However, harvesting varies between countries; for example, in Australia, it is harvested after 9 months due to improved mechanisation and in South Africa, it is harvested between 9 to 18 months depending on the variety, and lately due to the increase in *Eldana saccharina* attacks (Verheye 2011). The crop is primarily grown for sugar production and the provision of other related by-products such as molasses, ethanol and bagasse. These by-products are more useful for heat generation, bio-fertilizers and fuel production among other industrial purposes (Verheye 2011). Sugarcane is also a source of renewable energy and is important for the neutralization of atmospheric carbon activities (Cheesman 2004).

Additionally, sugarcane farming and processing employs millions of people, contributing a significant proportion of the Gross Domestic Product for many countries across the globe (Gers 2004). In South Africa, the sugarcane industry contributes a direct annual average income of R8 billion towards the country’s foreign exchange earnings and employs about 79 000 people directly and 350 000 indirectly, which constitutes approximately 2% of the South African population (Department of Agriculture, Forestry and Fisheries / DAFF 2011). In this regard, knowledge of sustainable production of sugarcane is important if humanity is to continue to benefit from sugarcane production (International Crops Research Institute for the Semi-Arid Tropics - World Wide Fund for Nature / ICRISAT-WWF 2009). Currently, sugarcane plantations occupy approximately 21.9 million ha across the globe. Brazil is the leading sugarcane producing country with 5343 million hectares of land under sugarcane farming (Fischer et al. 2008). South Africa has approximately 413 556 hectares of land for sugarcane cultivation (Agrimark Trends 2009).

While sugarcane is an invaluable crop for many economies, it has also contributed towards altering natural ecosystems the world over (Wiles 2006; Keddy 2010). Studies have shown that a number of wetlands in many parts of the world including South Africa, have been lost or replaced by the expansion of sugarcane plantations (Netondo et al. 2010; Thorburn et al. 2011; KwaDukuza Municipality 2013). The loss of wetlands creates environmental challenges such as water and soil pollution and erosion leading to wetland degradation (Wiles 2006; Fuggle & Rabie 2009; Netondo et al. 2010; Mesta et al. 2014). Identifying the threats that sugarcane causes on the wetlands is essential considering the role of wetlands in regulating atmospheric carbon content (Department of Sustainability, Environment, Water, Population and Communities 2012), habitat provision (Veeravaitaya 2008; Howarth 2008; Netondo et al. 2010; Scott, Gautheir & Mudie 2014), groundwater purification (Noller, Paker & Gao 2003), balancing biogeochemistry processes (Reddy & DeLaune 2008; Kadlec & Wallace 2009; Sekercioglu 2010) and in sustaining economies of most of the rural populace in South Africa (Working for Wetlands 2006; Borie 2009). Benefits provided by wetlands are extensively recognized yet these wetlands are being lost (Martinelli & Filoso 2008; Netondo 2010). It is therefore critical to make an inventory of both the historical and current changes of wetlands in terms of the extent to which sugarcane production poses threats to the sustainability and integrity of wetlands if humanity is to continue deriving wetland services and goods (Omwoma et al. 2012; Scott, Gautheir & Mudie 2014).

The key threats to wetland conservation lie in the intrinsic properties of wetlands that make them viable and priority areas for sugarcane production (FAO 2003; Cowden et al. 2014). In particular, the successful growth of sugarcane is dependent on optimal environmental conditions such as warm temperatures, high soil fertility, high water retention capacity, high rainfall (approximately 1500 mm per annum) and low acidic or neutral soils (Gers 2004). Wetlands found in tropical and subtropical areas such as South Africa are the prime areas capable of providing optimal conditions for sugarcane cultivation (Srivastava, Singh & Srivastava 2003).

The growth of sugarcane in wetlands results in excessive abstraction of crucial wetland and groundwater reservoirs, leading to severe wetland degradation (Nakiyembe et al. 2010). For instance, the marshland in Jamaica and parts of the Caribbean are no longer regarded as biologically functional due to the high levels of effluent and pesticides in the waters around the Caribbean (World Wide Fund 2013). In the United States, sugarcane growth and expansion has turned the Everglades wetlands from productive and diverse forests to lifeless landscapes (World Wide Fund 2013). Wetlands within the Great Barrier Reef of Australia’s coast suffer from nutrient enrichment from sugarcane plantations (Brodie & Mitchell 2005). In Kenya and Uganda, eutrophication in wetlands surrounding Lake Victoria has become a persistent problem, concomitant with implications for fish and other aquatic species (Cheesman 2004; Nakiyembe et al. 2010; Omwoma et al. 2012).

FAO (2003) also identified potential health risks associated with pollution from sugarcane fields to the wetlands. In some cases, wetlands have been left bare and abandoned and this has increased erosion rate, which have in turn affected wetland ecosystem functioning (Cheesman 2004 Scott, Gautheir & Mudie 2014). The above studies demonstrate that the loss of wetlands due to sugarcane farming is a global phenomenon. In order to inform sustainable management strategies in sugarcane producing areas, there is need to objectively and repeatedly investigate and quantify the loss of wetlands due to sugarcane farming.

South Africa is one of the countries experiencing significant losses in wetland area (Begg 1986; Turpie 2004; Grundling, Van den Berg & Price 2013). Approximately 85% of the coastal wetland area in KwaZulu-Natal has been transformed into sugarcane fields leaving a few scattered patches of the wetlands (Begg 1986). Eutrophication and sedimentation have been reported in areas close to these wetlands (Scotney & Mc Phee 1990;Omwoma et al. 2012; Cowden et al. 2014). When nutrients such as nitrogen and phosphorus are applied excessively, runoff from the sugarcane fields enters into rivers, sinks and lakes resulting in the pollution of these water sources (Reddy & DeLaan 2008; Kadlec & Wallace 2009; Kebede et al. 2014). This pollution ultimately affects aquatic species, which depend on these water sources as well as the adjacent wetlands (Omwoma et al. 2012; Kebede et al. 2014). The changes in wetlands are of concern considering the limited number of wetlands in South Africa, their role as habitats for important and rare species, and as a water supplier (Working for Wetlands 2006; Cowden et al. 2014).

South Africa is a signatory to the Ramsar Convention, which seeks to promote the sustainable use and protection of wetlands (Collins 2005). As a signatory of the Ramsar Convention, South Africa is expected to protect and sustainably use its wetlands with future generation, in mind (Burger 2010). Furthermore, population increase coupled with a rapid decrease of water resources in South Africa calls for a thorough assessment of the pressures of agricultural activities on wetlands and implementation of possible changes where possible for sustainability of the wetlands (Wessels, Reyers, Van Jaarsveld 2000; Walters & Koopman 2004; Burger 2010). Understanding the nature and the extent of sugarcane farming impact on wetland environments is therefore an important initial step towards ensuring sustainable sugarcane farming that aims to maximise sugarcane farming and promotes the productivity of wetlands at the same time (Omwoma et al. 2012).

A review of studies on sugarcane farming and wetlands indicates that much focus has been directed towards understanding soil degradation due to sugarcane production (eg, Qongqo & Van Antwerpen 2000; Barnes, Ellery & Kindness 2002; Meyer 2011). Some of these studies have focused on water quality and use in sugarcane areas (eg, Howarth 2008; Agnew, Rohde & Bush 2011; Van der Laan et al. 2011; Thorburn et al. 2011). Although these studies have clearly indicated how sugarcane production has negatively affected most wetlands, few studies have looked at the impact of sugarcane farming on wetland extent across large temporal and spatial scales.

The advent of remote sensing coupled with advances in geographic information system (GIS) provide practical and economical means for mapping and quantifying spatial changes in wetland coverage over time, making field sampling more focused and efficient (Allen, Wang & Gore 2011; Mesta et al. 2014). In addition, the ability of remote sensing to provide repeat coverage offers archive data for detection of change over time while this digital data can be easily integrated into a GIS for further analysis (Biggs & Scholes 2002; Dahl 2004; Allen, Wang & Gore 2011). Consequently, several studies have applied different remote sensing datasets such as aerial photographs (Gweon & Zhang 2008; Tuxen et al. 2009; Powell 2010), Landsat imagery (Muzein 2006; Cardoso, Souza & Souza-Filho 2013; Turyhabwe et al. 2013) and SPOT imagery (Alam et al. 2011; Mwita 2013) to identify changes in wetlands. These studies have yielded promising results that could aid in the creation of wetland inventories.

Nevertheless, the utility of remote sensing is as good in that it can be related to processes occurring on the ground (Mesta et al. 2014). For remote sensing products to be useful, they have to be validated and verified through ground truthing (Grundling, Van den Berg & Price 2013). Hence, remote sensing coupled with survey methods is critical for analysing changes in wetland extent due to anthropogenic activities such as agriculture (Turyhabwe et al. 2013). To supplement, remotely sensed data, biophysical and chemical indicators, specifically soil and water analyses are key in determining changes in wetland quality, changes that would otherwise not be identified using remote sensing (Cowan 1995).

A review of the literature shows that studies that have used remote sensing have only looked to changes in the wetlands because of agriculture (Mwita 2013; Turyahabwe et al. 2013; Obiefuna et al. 2013). These studies have not focused on specific contributions of each crop for example sugarcane, yet it is known that not all crops contribute equally to wetlands loss (World Wide Fund 2013). In addition, those that have used field survey techniques have only identified the impact of sugarcane on water quality (Barnes, Ellery & Kindness 2002; Southwick et al. 2002; Carminati 2008). Little has been done to identify the impact of the sugarcane farming on wetland extent. This emphasises the need to integrate different approaches. This study thus integrates different techniques to provide a more comprehensive picture regarding influence of sugarcane farming in wetlands. Furthermore, it contributes to existing knowledge of the impacts of agriculture on wetlands through original research and presents conceptual frameworks, evidence and arguments on how sugarcane farming has affected wetlands.

1.2 STATEMENT OF THE PROBLEM

Several studies have been carried out to determine the impact of sugarcane production on the biophysical and socio-economic environment. These studies have assessed the impact of sugarcane farming on soil quality (Meyer, Van Antwerpen & Meyer 1996; Qongqo & Van Antwerpen 2000; Meyer 2011;), water quality and consumption (Southwick et al. 2002; Carminati 2008; Shabalala, Combrinck & Mc Crindle 2013), human health (SASA 2002; Mapanda et al. 2005) and impact on air quality aspects (Chessman 2004; Scott, Gautheir & Mudie 2014). To the best of our knowledge, information concerning the effects of sugarcane farming in coastal wetlands is very limited. There is a need to identify the effects of sugarcane farming in coastal wetlands for restoration and conservation purposes.

1.3 RESEARCH AIM AND OBJECTIVES

The aim of this study is to assess the impact of sugarcane farming on wetland extent and water quality in two coastal wetlands in KwaDukuza, North coast of Zululand, South Africa. The specific objectives of the study are:

1. To assess the impact of sugarcane farming on the spatial extent of wetlands in KwaDukuza between 1959 and 2012.
2. To determine if sugarcane farming negatively impact on water quality within the wetlands.
3. To evaluate the perceptions of local farmers regarding the impact of sugarcane farming on wetlands.

1.4 RATIONALE FOR THE STUDY

The ability of wetland ecosystems to continue providing benefits and services is dependent on the maintenance of the wetland ecosystem integrity by reducing factors, which negatively affect the wetlands functioning (South Africa 1998; 2003; Millennium Ecosystem Assessment 2005; Ramsar Convention Secretariat 2010). The continuous decrease in wetlands is a persistent obstacle to successful attainment of the Millennium Developmental Goals (Millennium Ecosystem Assessment 2005), targeted by the Ramsar Convention on wetlands and ultimately the goals of the Environmental Management Act 107 of 1998 (South Africa 2003a). However, to manage these wetland ecosystems sustainably, there is need for continuous assessment of the state of the ecosystems and the processes affecting the ability of the wetlands to provide goods and services (Working for Wetlands 2006; Kuntonen van‘t Riet 2007; National Geographic Education 2013). Decisions on sustainable environmental management and policies are often influenced by the lack of information on distribution and quantity of the wetlands (Chakupa 2011). Therefore, research on the historical and current changes in wetland size and quality is thus, crucial to informing management and conservation of wetlands (Grundling, Van den Berg & Price 2013).

1.5 METHODOLOGY AND RESEARCH DESIGN

Methodology refers to the research structure and the use of different instruments by the researcher to come up with a reliable understanding of a phenomenon and a valid research (Creswell 2003). The research structure comprises of theoretical analsysis and principles to formulate knowledge of a certain field, and the field can either be qualitative or quantitative in nature (Creswell 2003). The methodology combines the research design, preparation, data collection, analysis and ethical considerations.

A research design according to Creswell (2003) is a systematic plan or stages of decision that is used by researchers to conduct and answer the main objective of the research. In this research study, the research design derives from the research objectives to be answered. A quantitative research design was applied. According to Creswell (2003) and Fox (2008), quantitative research derives its measurements from positivism. These Post-positive claims use observations and measurements as invaluable ways of identifying causes and effects (Walliman 2006; Fox 2008). Data collected is transformed into number values and analysed using statistical means in most cases (Fox 2008). The researcher used quantitative research in an attempt to come up with the impact of sugarcane farming in coastal wetlands. The approach entails collecting data using aerial photographs, water samples and close-ended questionnaires.

The study also has a survey component. A survey is a method where the researcher chooses a small group of the population to represent the whole population.A population refers to a group within the study area who meets the criteria that the researcher is looking for (Creswell 2003). According to Henry (1990), the population size is not as important as compared to the analysis and gathering of sufficient information for answering the research questions, hence the selection of a small group for this study. The research design used for this study is illustrated in Figure 1.1.

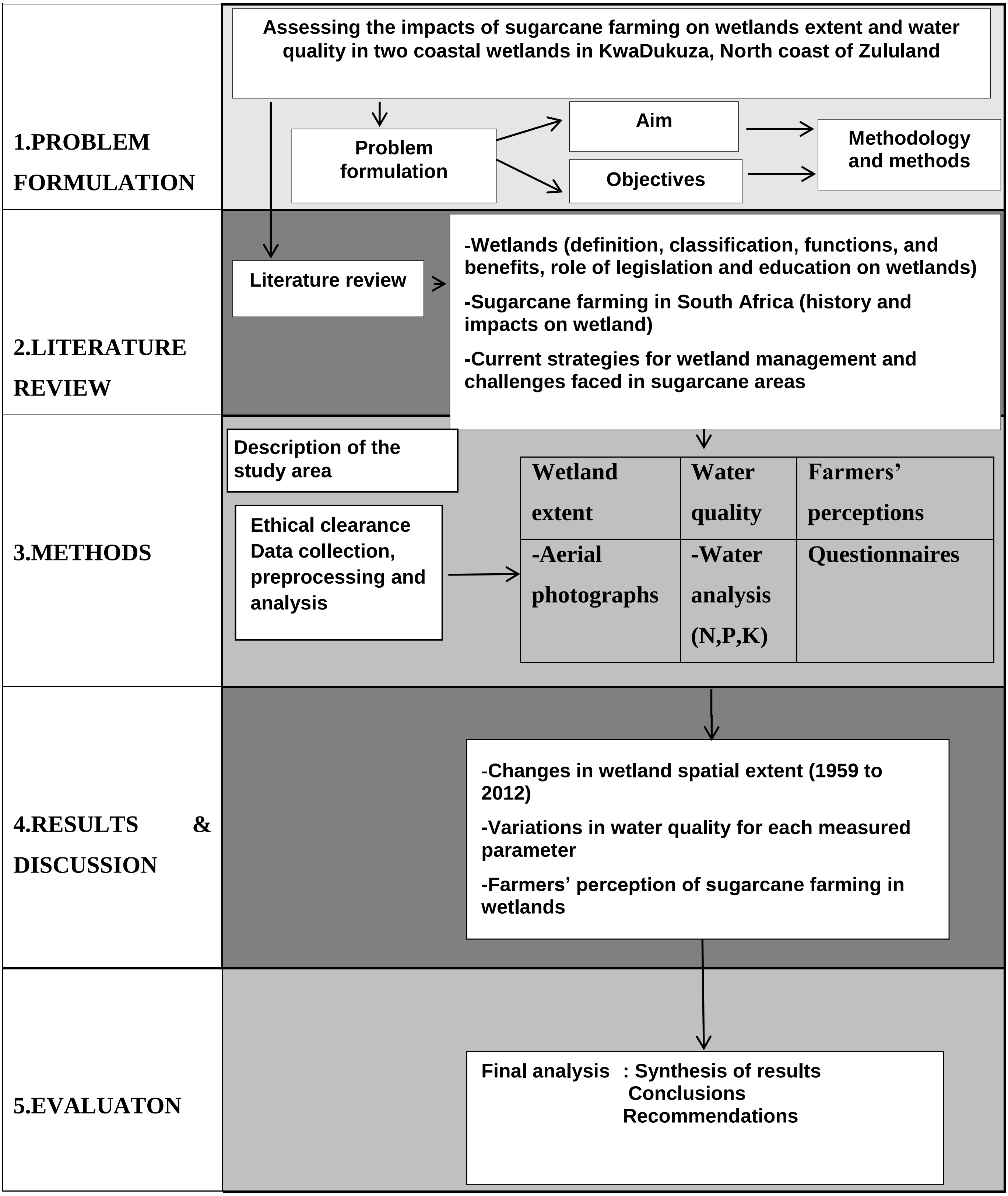


Figure 1.1 Research design showing the procedural study descriptions and methods

This study is sequentially outlined in Figure 1.1. It commenced with problem formulation and then a review of literature , followed by data collection, processing and analysis. The next step was to interprete and synthesize the data collected for the study and then finally to give recommendations that will direct future research on the impacts of sugarcane farming in wetlands.

1.6 ORGANISATION OF THE THESIS

This thesis is organized into five chapters. Chapter 1 provides a brief background of the impact of sugarcane farming on coastal wetlands and states the rationale, aim and objectives of the study. In Chapter two, literature on sugarcane farming in relation to wetlands loss is reviewed. Chapter 3 focuses on the materials and methods used in this study. The results are presented in Chapter 4, with a discussion of the results in Chapter 5. Conclusions of the study and recommendations for further research are presented in Chapter 6.

CHAPTER 2 AN OVERVIEW OF SUGARCANE FARMING AND WETLANDS

This chapter provides an overview of wetlands, namely their definition and classification. In addition, the values, functions and benefits of wetlands are highlighted. This chapter also provides an outline of the impacts of sugarcane farming and reviews the methods used to assess wetland condition around the world, particularly in South Africa. In the final section of this chapter, the role of government policies and legislation in sustainable management of wetlands in sugarcane regions are discussed.

2.1 DEFINITION AND CLASSIFICATION OF WETLANDS

Wetland refers to a group of different ecosystems and habitats that are characterized by a high water table (Williams 1991; Kotze, Klug & Breen 1996; Collins 2005). Spatially, these ecosystems are located between dry and wet lands and are thus ecologically at the transitional zone between terrestrial and aquatic ecosystems (Orme 1991). Temporally, wetlands are lands that ultimately change to dry lands due to a decrease in the water table or may become submerged because of a rise in the water table (Orme 1991). water is a key determinant of wetlands (Crosson & Fredrick 1999). The most recognized definition of wetlands is based on the Ramsar Convention Bureau (1997:1) which defines wetlands as:

> "wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres"

The definition is similar to that provided in the South African Water Act, Act 36 of 1998, that defines wetlands as:

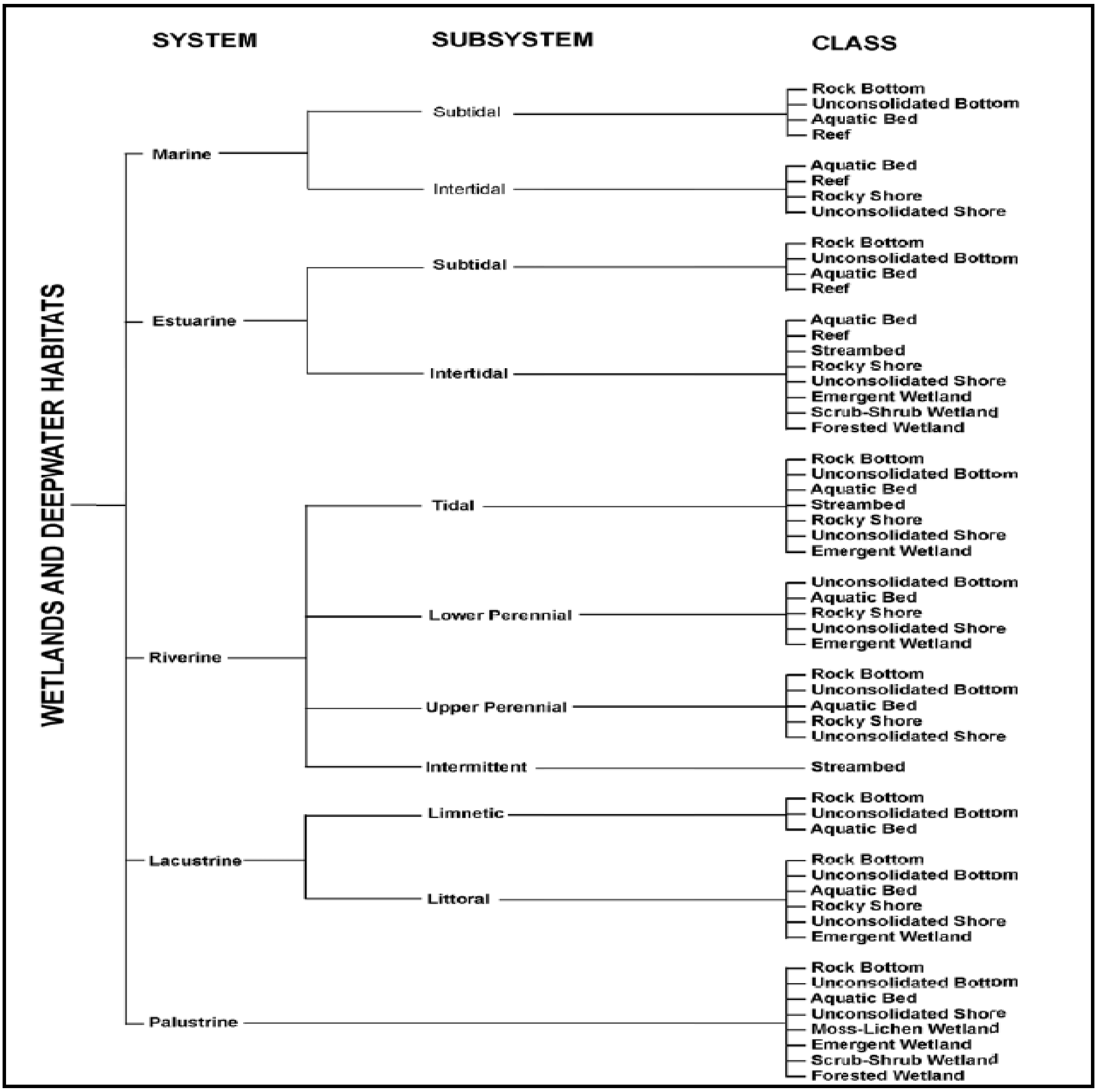
> " A wetland is defined as land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which under normal circumstances supports or would support vegetation typically adapted to life in saturated soil".

Coastal wetlands are defined as wetlands found in the coastal zone, along great lakes and rivers, which make up coastal drainage areas and these fall under the marine and estuarine wetlands in the Cowardian wetland system(Williams 1991) (Figure 2.1). These wetlands are adjacent to coastal waters and are usually waterlogged. Coastal wetlands can be characterised by intertidal sand, estuarine lagoons and lakes salt marshes, mangroves, mudflats and small streams regardless of whether they are fresh water or brackish (Grant 2003; Stedman & Dahl 2008). In some cases, estuaries can be composed of fresh water only and this happens when a river mixes with a lake (National Geographic Education 2013). Coastal wetlands are ecologically valuable and play a significant role in balancing the various processes thatoccur on Earth.

Various types of wetlands (Figure 2.1) can be identified using three important features, which are their hydrology, hydric soils and hydrophytic vegetation (Collins 2005). The hydrology of wetlands varies seasonally and over time. During the rainy season the water table is fully reached hence water is closer to the surface whereas in dry season, a decrease in ground water level occurs thus affecting the availability of water within the wetland depending with the area in which the wetland exist (DWAF 2003).

Wetland ecosystems occur in diverse environments across the globe except in Antarctica, given the extreme weather conditions (Hunter 1999; United States Environmental Protection Agency 2013). These wetland ecosystems occur in different geomorphologic, climatic, hydrologic, chemical and biological conditions and are named according to the conditions and local areas in which they occur (Hunter 1999; Mesta et al. 2014). Due to the diversity of wetlands, there is no consensus on a standard classification system of wetlands (Working for Wetlands 2006). However, organisations and scientists have subsequently developed a number of wetland classification systems (Cowardian et al. 1979; Brinson 1993). The most popular classification systems are the Ramsar Classification system (Dini, Cowan & Goodman 1999) commonly used by signatories to the Ramsar Convention (Ramsar Convention 1997) and the Cowardian System (Williams 1991). The Cowardian system is, however, considered to be one of the most extensive and detailed classification systems because of its broad focus on diverse wetlands as opposed to other classification systems which only focus on particular wetland types (Williams 1991).

South Africa adopted the Cowardian wetland classification system in 1997 because of its comprehensiveness and suitability to the South African wetland conditions (Dini 2004). However, Dini, Cowan & Goodman (1999), under the auspices of the Department of Environmental Affairs and Tourism modified the classification system to suit South African wetlands. Under the Cowardian classification system, wetlands are progressively refined from the broader classification systems to subsystems and finally to the classes as shown in Figure 2.1. There are five major systems which are; the marine, estuarine, riverine, lacustrine and palustrine (Dini, Cowan & Goodman 1999).



Source: Dugger (1997: 1)

Figure 2.1 Classification hierarchy of wetlands types that are found in South Africa

Of the five major systems (Figure 2.1), the estuarine and palustrine wetland systems occur everywhere in the world and constitute the most known types of wetlands, which are marshes and swamps (Williams 1991).

2.2 FUNCTIONS, VALUES AND BENEFITS OF WETLANDS

Wetlands are valuable systems that provide invaluable goods and services to the ecosystem and to human livelihoods (Kotze et al. 2005; Reddy & DeLaune 2008; Sekercioglu 2010). Wetlands regulate and maintain the biochemical processes that are significant for the ecological productivity of the global ecosystems (Reddy & DeLaune 2008). The most important biochemical processes that are maintained by the wetlands include the water and carbon cycles (Reddy & DeLaune 2008; Scott, Gautheir & Mudie 2014). These cycles are crucial to life because they transport and transform organic and inorganic matter into usable living entities that can be consumed by different organisms (Kadlec & Wallace 2009; Sekercioglu 2010). Additionally, wetlands provide habitat and food for various species especially the endangered species. This ultimately complements the biochemical processes by providing nutrients as well as the physico-chemical variables such as soil, water pH and anaerobiosis for the different species (Kotze et al. 2005; Collins 2005; Fuggle & Rabie 2009).

Wetlands provide a myriad of benefits and services to humans, these include the provision of improved water quality, water provision (Cheesman 2004; Kadlec & Wallace 2009), fertile land for agriculture (Turyahabwe et al. 2013) and urban development (Condon et al. 2010), food for local consumptions (Kotze et al. 2005; Working for Wetlands 2006), flood buffering (Crosson & Fredrick 1999; Collins 2001), recreational facilities (World Wide Fund 2013), employment to the country, (KwaDukuza Municipality 2013) and a platform for research (Mironga 2005; Luan & Zhou 2013). There is thus a need for knowledge on the loss of wetlands to ensure the continued derivation of goods and services by humans. Constanza et al. (1997) quantified wetland goods and services in monetary terms and found them to be worth more than 4.9 trillion United States Dollars per year. This proves the worth of wetland ecosystems to human beings worldwide and the need for more ecosystems to be protected (Mironga 2005).

Research has demonstrated that wetlands are key determinants of climate fluxes (Reddy & DeLaune 2008; Mesta et al. 2014). For instance, wetlands sequester and release a proportion of fixed carbon in the biosphere (Millennium Ecosystem Assessment Report 2005; Scott, Gautheir & Mudie 2014). The Millennium Ecosystem Assessment Report (2005) states that peat wetlands hold approximately 540 gigatons of carbon, which is about 1.5% of the total estimated global carbon storage. In South Africa, about 11 peat eco-regions have been identified and approximately 25% of these peat lands have been destroyed resulting in 300 000 tons of carbon being released in 2008 alone (Working for Wetlands Report 2003).

Wetlands have been regarded as flood buffers in regions that are prone to floods (Kebede et al. 2014). Wetlands reduce the occurrences of floods by absorbing some of the floodwater and slowing its movement and distribution (Mitsch & Gosselink 2000; Lui et al. 2008), thereby reducing potential human deaths as well as water logging of crop fields (Mesta et al. 2014). This has been reported to be effective mainly in developing countries such as South Africa where capital for building dam walls and other structures to mitigate floods is very low (Mitsch & Gosselink 2000). Wetlands also provide protection from the impact of sea level rise by subsiding water (Sekercioglu 2010; Mesta et al. 2014). According to Sikdar (2007), marshes reduce approximately 50% of the wave energy thereby protecting the shoreline and other lands adjacent to the sea where humans live.

In areas prone to water shortages, wetlands act as water storage reservoirs (Working for Wetland n.d.; Sheng, Lapetina & Ma 2012). Wetlands release water received from precipitation into surface and ground water during periods of water deficit (Keddy 2010; Grundling, Van den Berg & Price 2013). People who live in drought prone regions benefit from the water supplied by wetlands and by resorting to wetlands as a source of grazing and farming land (Working for Wetlands n.d.). The Mkuze wetlands system in the northern part of KwaZulu-Natal South Africa (Barnes, Ellery & Kindness 2002) are a source of fresh water to the Isimangaliso Wetland situated in the east coast of KwaZulu-Natal (Grundling, Van den Berg & Price 2013). The Pongola flood plains and pans that originate in Mpumalanga and stretch to the Maputaland coastal plain in the northern part of KwaZulu-Natal provide irrigation water to both small-scale and commercial agriculture activities, including 16 000 hectares of sugarcane fields (Van Antwerpen & Meyer 1996).

Wetlands are sometimes located on the transitional position between the land and water resources, they are situated between terrestrial and aquatic ecosystems (Kadlec & Wallace 2009). These wetlands assist in improving the quality of water in rivers, estuaries and streams (Collins 2005; Reddy & DeLaune 2008). They intercept pollutants from the uplands before they enter the rivers (Kebede et al. 2014). Thus, cleaner water leaves the wetlands into adjacent wetlands and water systems, providing humans and other species with a clean source of water (Fuggle & Rabie 2009; Verbruggen, Hermans & Schat 2009). Kadlec & Wallace (2009) stated the importance of wetlands in treating point and non-point pollution through different processes that occur within the wetlands. For example, plants within the wetlands absorb some of the pollutants such as nitrogen, phosphorus and sulphur (Omwoma et al. 2012). Some pollutants are removed through sedimentation and chemical precipitation (Mitsch & Gossilink 2000; Huising 2002; Kadlec & Wallace 2009).

Wetlands are regarded as cost effective measure of purification. In Gotland (Sweden), the restoration of wetlands was found to be less expensive in reducing nitrogen levels compared to expanding sewage treatment plants (Gren et al. 1994). In the Congaree Bottomland Hardwood Swamp in South Carolina, wetlands are estimated to be removing pollutants from the watershed that are equivalent to those that could be removed by a US $5 million treatment plant (United States Environmental Protection Agency 1995). In Uganda, the Nakivubo Swamp has been used for purification and waste treatment for more than thirty years (Kansiime & Nalubega 1999). In South Africa, studies have been done to determine the applicability of using wetlands as worst treatment plants. Turpie (2010) assessed the use of wetlands in the Fynbos biome for waste treatment and the results showed that it would cost less to use wetlands for water treatment compared to existing treatment processes that are being used now. Omwoma et al. (2012) reviewed studies done in Europe and concluded that wetlands are indeed viable for water processing especially peat lands. However, Williams (1991) noted that the use of wetlands for waste treatment is not reliable over long periods as many factors and priorities such as the sustainability of the wetland habitats within the wetland and local people who depend on the wetlands as water sources have to be considered before the treatment is put into place.

Metals flow into wetlands in aqueous or solid form from various sources such as agriculture, industry and mine runoff (Odinga et al. 2013). Unlike other pollutants which enter wetlands, metals are not degradable. Therefore, wetlands play a crucial role in the reduction and removal of these metals through various biotic and abiotic processes (Reddy & DeLaun 2008). The importance of the redox reactions of metals have long been identified especially in very poorly drained soils, alluvial soils and other types of soils in the wetland (Odinga et al. 2013).

In wetland soils, metals are either reduced or oxidized by different microorganism to different stable forms either that can be absorbed by plants or that are immobile (Chen et al. 2009). Examples of the most common metals found in wetlands are manganese and iron (Verbruggen, Hermans & Schat 2009). These two metals are mainly reduced through precipitation of sulphate in wetlands and through oxidation (Odinga et al. 2013). When oxidized, manganese and iron change to immobile solids and their movement to water systems are limited, thus, reducing their impact to the ecosystem in general and to human wellbeing (Nyquist & Greger 2009). In some cases, metals adsorb to different substrates such as carbon and nitrogen and transfer electrons, changing the metals to forms that plants can absorb and reduce the chances of metals contaminating water sources (Reddy & DeLaun 2008; Odinga et al. 2013).

Microorganisms within the wetlands also play a crucial role in stabilizing and maintaining levels of metals to tolerable values (Nyquist & Greger 2009). Fermentative microorganisms such as bacteria utilize metals in different chemical reactions within their bodies and ultimately affect the quantity and forms of metals (Verbruggen, Hermans & Schat 2009). Plants in wetlands specifically are hyper accumulators have a high tolerance of metals, hence they absorb some of the metals through their leaves and tissues (Chen et al. 2009). However, if the rate at which these metals flow into the wetlands exceeds the rate at which the biotic and abiotic processes within the wetlands absorbs and adsorb the metals, the metal ends up flowing into and out of the water systems within the wetlands (Nyquist & Greger 2009; Verbruggen, Hermans & Schat 2009).

According to Omwoma et al. (2012), the biological functions of wetlands are the most common appreciated values of wetlands. Inventories of these functions are kept at both national and local levels. Wetlands are a diverse community of endemic and endangered plants, migratory vertebrates and invertebrates species (Veeravaitaya 2008; Fuggle & Rabie 2009). Wetlands also act as breeding and nursery grounds for important species, such as the Sea Trout and Striped Bass that largely depend on estuaries for spawning and laying of eggs and the water migratory fowl (Stedman & Dahl 2008). The Isimangaliso wetlands along the east coast of KwaZulu-Natal are a well-known and documented habitat for various endangered bird, animal and fish species.

Drained wetlands produce immense yields for a variety of crops and fertile grazing lands for commercial and subsistence animal husbandry (Mesta et al. 2014). This is attributed to the high organic content of the soils, high rainfall amounts where wetlands are located and high nutrient supplies (Sikdar 2007). This richness in soil nutrients and water availability has been the main reason why wetlands have been degraded in many parts of the world (Collins 2005). Commercial crops are grown in wetlands and examples include sugarcane (Australia, Brazil, Thailand and South Africa) and rice has been grown in (China, India and Malawi). Subsistent farmers who live close to the wetlands have also benefited from wetland soils and grow their crops in and around wetlands as well. The Craigieburn Wetland along the Sandy River Catchment of Mpumalanga in South Africa supports about 100 subsistence farmers (Working for Wetlands 2006). Wetlands have provided a source of income to many nations and food for many rural livelihoods (Collins 2005).

Some wetland plants such as the waterblommetjies (*Aponogeton distachyos*) are even harvested for food. The River Pumpkin (*Gunnera perpensa*) has been harvested for medicines (Working for Wetlands 2006). Local people around wetlands also survive by making and selling some handcraft products from various plants such as the Sea Rush (*Juncus kraussii)* (Working for Wetland 2006).

Aquaculture is also practised in wetlands at both small and commercial scales. Aquaculture provides a source of income to the local people and proteins through fish and shrimp. For example, people around the Kosi Bay and Pongola estuaries in KwaZulu-Natal harvest fish to sell in these wetlands (Collins 2005). Wetlands also provide ideal damming sites. The Vaal dam and the Jozini dam are constructed in wetlands and largely support subsistence farming (Mitsch & Gossilink 2000).

Wetlands hold archaeological, historical, cultural, recreational and scientific values for many societies (Lui et al. 2008; Mesta et al. 2014). For example, the Louisiana Bayen State located in the southern region of United States and the Isimangaliso Wetland Park located on the eastern coast of KwaZulu-Natal were developed as a result of the wetlands (Collins 2001). Furthermore, several tourism resorts are established on wetlands and in some cases, they become backbone of the local economy (World Wide Fund 2003). Wetlands are aesthetic and provide leisure, recreation and scenic views for humans from all over the world (World Wide Fund 2003). In this way, wetlands have boosted tourism in many countries and indirectly contributed to employment and Gross Domestic Product. According to the United States Environmental Protection Agency (1995), observation photography of wetland birds by at least 50 million Americans generates 10 billion dollars per year. In 1996, the South African government justified a tourism-based economy in the Isimangaliso wetland region (World Wide Fund 2003) because of foreign currency inflow and employment opportunities it presented to the surrounding communities and the country at large (Fuggle & Rabie 2009).

Estuaries provide land for urban, industrial and agriculture developments in many countries (Collins 2001). The city Tokyo in Japan was established where the Sumida and Arakwa Rivers flows into the Pacific Ocean (National Geographic Education 2013). In South Africa, the town of Richards Bay developed along the Mhlatuze River lagoon and the Umgeni Catchment in KwaZulu–Natal are regarded as the biggest estuarine systems in the region (Kotze et al. 2005). The Knysa Lagoon in Western Cape Province and the Gqunube Estuary situated in the Eastern Cape Province are also considered the largest estuaries in South Africa where towns have developed (Collins 2001).

Wetlands have contributed significantly to livelihoods, particularly through provision of land for agriculture and urban development throughout the world (Mitsch & Gosselink 2000; Mc Cartney et al. 2010; Scott, Gautheir & Mudie 2014). The wetlands in KwaDukuza have provides fertile ground for sugarcane farming which employs many people and has led to the development of the KwaDukuza Town (KwaDukuza Municipality 2013). However, humans have threatened wetlands in so many ways and wetland loss is raging across the globe (Constanza et al. 1997; Mc Cartney et al. 2010).

2.3 THE ROLE OF LEGISLATION AND ENVIRONMENTAL EDUCATION ON THE PROTECTION OF WETLANDS

For decades, legislation did not consider the environmental effects of economic activities that were carried out in wetlands(Chakupa 2011). In fact, incentives were given to promote industry and agricultural production (Fuggle & Rabie 2009). The industrial and the green revolutions were initiated without any environmental concerns (United States Environmental Protection Agency EPA 2004). Wetlands were drained and cleared for agriculture lands (EPA 2004; Fuggle & Rabie 2009; Chakupa 2011). A notable example is the expansion of the Corn Belt in the United States of America that developed because of the Swamp Lands Acts of 1849-1860 (Crosson & Fredrick 1999). In South Africa, after the Second World War some departments even promoted the draining and destruction of the wetlands driven by the idea of economic growth (Fuggle & Rabie 2009). Notably, the Department of Agriculture and Fisheries in South Africa directly and indirectly modelled effective ways of draining wetlands. They also provided incentives and new technology for agriculture expansion in wetlands (Begg 1986; Fuggle & Rabie 2009).

Upon realization of the potential negative influences that human activities have on the environment, various governments including South Africa signed various conventions to help them frame laws and regulations to protect wetlands thereby abandoning some of the policies that promoted wetlands drainage (Fuggle & Rabie 2009). Thus, it is imperative to look into how Conventions and legislation protect wetlands. The next section describes the conventions and legislation that were signed by the South African Government and legislation formulated from the conventions. Finally, the selected environmental education approaches and projects are discussed.

There are two main conventions, which protect the wetlands in South Africa. These conventions are the Ramsar Convention and the Convention on Biological Diversity. The Ramsar Convention is an inter-governmental treaty encouraging its member countries to sustainably use and maintain the ecological functioning of their wetlands, specifically those of international importance (Ramsar Convention 1997). The Ramsar Convention was instituted in 1971 when people became aware of the loss of wetlands and the extinction of species within them, especially water birds (Collins 2005). The Ramsar Convention (1997), it was formulated with the aims of:

- Promoting sustainable use of all wetland types and protecting the ecological integrity of biodiversity that depends on the wetlands through local, regional, national and international management.
- Ensuring proper training and research for a better understanding of wetlands of international importance and promoting local participation as well as awareness of the importance of wetlands.
- Promoting local and international cooperation regarding trans-boundary wetlands and develop projects to sustainably manage these wetlands without promoting conflicts.

The Ramsar Convention brought a huge change to conservation of wetlands in many countries, including South Africa (Collins 2005). Countries signed the Convention to gain insight and develop frameworks to come up with policies, legislation and regulations for monitoring and protecting wetlands. Since April 2007, 1669 sites totalling 151 071 270 hectares have been declared wetlands of importance (Collins 2005). South Africa became a signatory in 1975 and the Department of Environmental Affairs and Tourism is responsible of the Ramsar Convention. So far, South Africa has successful designated twenty sites as wetlands of international importance and it has helped in protecting the wetlands from human effects (Collins 2005).

The major objective of the Convention on Biological Diversity is to promote a fair share of different natural resources between different stakeholders and maximize sustainable utilization (DEAT 2005). South Africa became a signatory of the Convention on Biological Diversity in 1995. The convention has been used as a guide in formulating various legislation and policy framework concerning biodiversity management of water, forests, marine and coastal resources (DEAT 2005). The convention successfully led to the formulation of the National Environmental Management Biodiversity Act of 2004 which brings together different fragmented parts of legislation that protects biodiversity . Another example of legislation that emanates from the Convention on Biological Diversity is the National Environmental Management Act 107 of 1998 (Collins 2005).

2.3.1 Legislation

Wetland conservation largely depends on proper legislation, however, wetlands do not have full protection of the national policy level like other resources such as water which is fully protected by the National Water Act 36 of 1998 (Coetzee 1992). Wetlands protection in South Africa is largely influenced by ownership of the wetlands, as most of the wetlands are privately owned. Hence it was difficult to control and protect which has largely delayed the formulation of policies that fully protects wetlands (Coetzee 1992; Fuggle & Rabie 2009). This section looks into the legislations that protects wetlands in South Africa.

2.3.1.1 The National Environmental Management Act 107 of 1998

The DEAT (South Africa 1998) houses the National Environmental Management Act 107 of 1998. It replaced the Environmental Conservation Act 73 of 1989 (South Africa 1998). It is a general environmental policy which serves as a framework for decision formulation in sustainability and integrity of all natural resources (Kuntonen van‘t Riet 2007). It provides guidelines in the maintenance of natural systems at both local and national levels, such as ecological processes, species diversity, habitats and landforms processes (South Africa 1998). This policy also facilitates coordination and integration of various activities carried out by state organs concerning the environment (South Africa 1998). The Environmental Management Act 107 of 1998 protects wetlands from human activities, such as it prohibits the construction of jetties, slipways and buildings close to water sources, that is, these activities have to be carried 32 m away from the water sources and riparian zones (South Africa 1998). Furthermore, no activities are carried out within the wetlands without conducting an environmental impact assessment (Fuggle & Rabie 2009).

2.3.1.2 National Water Act 36 of 1998

The DWAF operates under the National Water Act and is responsible for the assessment, monitoring and management of all the water resources in the country (DWAF 2003). The National Water Act 36 of 1998 provides a framework for sustainable use of natural resources and promotes the integration of planning and management of all water resources (South Africa 1998). The Act also promotes cooperation of different water users for effective monitoring of all water resources within the country (Kuntonen van‘t Riet 2007). Riparian zones and species within them are protected under this Act (South Africa 1998).

2.3.1.3 The Integrated Coastal Management Act 24 of 2008

The Act operates under the National Environmental Management Act of 1998 (South Africa 2008). It aims to maintain international commitments dealing with conservation of coastal wetlands. The Act uses an integrated approach in sustainable management of natural attributes in coastal wetlands and enforces laws that protects and controls wetlands from human activities (Kuntonen van‘t Riet 2007).

2.3.1.4 The Conservation of Agriculture Resources Act 43 of 1983

This Act replaced the Soil Conservation Act 76 of 1969 and the Weeds Act 42 of 1969 that were based on preventive and compulsion approaches (Fuggle & Rabie 2009). These approaches did not work, thus, the formulation of the Conservation of Agriculture Resources Act of 1983, which is now based on the persuasion approach (South Africa 1983). The 1983 Act provides a significant basis for conservation of lands under agriculture (Fuggle & Rabie 2009). The aim of the Act is to protect the agriculture base, for example, through the protection of indigenous vegetation (Kuntonen van't Riet 2007).

The Act also protects water sources such as vleis, marshes, water sponges and watercourses against pollution and disturbances that may arise from poor farming practices (Fuggle & Rabie 2009). For instance, it prohibits channelling of water from one watercourse to another, draining of wetlands and cultivation or use of vegetation without permission from the Department of Agriculture (Collins 2005). Furthermore, no agricultural activity (in this case sugarcane) may occur within 30 meters of 1:50 year flood line of water resources such as rivers, streams, wetlands, lakes and dams unless authorized in terms of the National Water Act 36 of 1998 (Sustainable Farms SUSFARMS 2012). The Act also encourages the use of biological measures in controlling pests and diseases and not by chemical methods (SUSFARMS 2012). It is unfortunate that the Act does not apply to areas that had sugarcane plantations before the act was established (Collins 2005).

2.3.1.5 Free State Wetland Policy

The Free State Department of Tourism, in partnership with the Department of Tourism Environmental and Economic Affairs, came up with a wetland policy adapted from the Canadian Federal Government on wetland conservation (Collins 2005). The aims of these policies are to avoid wetland malfunctioning; promote wetland rehabilitation; incorporating wetlands functions and importance in policy making; protecting wetlands from the local to the international level; promote sustainable practices in sectors such as agriculture and mining and sustainable use with the future generation in mind (Collins 2005).

2.3.2 Environmental education approach and selected projects in South Africa

Legislation and policies guiding wetland management have been formulated and this has proven to be a success (Ewel et al. 1999). However, there is need for educational awareness and campaigns to educate people on the threats they pose to the wetlands so that they make informed decision on sustainable wetland use. Of late, different stakeholders such as Non-Governmental Organisations and government departments in South Africa have tried to formulate frameworks through legislation to assist landowners and the public to manage wetlands through different programs and projects (Williams 1991; Cowan 1995; Collins 2005). These groups include the Mondi Wetland Project, Working for Wetland Project, National Aquatic Ecosystem Bio-monitoring Program and the SUSFARMS (Sustainable farms). The programs and projects are discussed in the next section. It is important to note that this chapter will only discuss selected programs that relate to the management of wetlands in sugarcane regions. These programs have been a success where they have been implemented despite some few challenges. For them to be a complete success there is need for more funding, adequate expertise and willingness of people to participate (Hurly 2013).

2.3.2.1 Mondi Wetlands Project

The Mondi Wetlands Project was formed in 1991. It is a joint initiative between government departments such as the DEAT and DWAF, Non-Governmental Organisations such as Wildlife and Environmental Society of South Africa (WESSA), South Africa World Wildlife Fund for Nature and private stakeholders such as Mondi Forestry and the South African sugar industry. The sugar and forestry industries are also part of the project (Dini 2004).

Mondi Wetlands Project facilitates research and awareness campaigns with different stakeholders in an effort to curb the environmental impacts of agriculture and other human impacts on wetlands (Mondi Wetlands Project 2009). The Mondi Wetland Project assisted the sugarcane industry in coming up with a sustainable sugarcane initiative which uses eco-agriculture approaches to manage sugarcane production in sensitive environments such as wetlands (Mondi Wetlands Project 2009). Pilot studies initiated in Noodsberg which is located in the southeast part of KwaZulu-Natal have been successful (Mondi Wetlands Project 2009).

2.3.2.2 Working for Wetlands Project

Working for Wetlands is a project that was developed and housed by the DEAT and the South African World Wild Fund for Nature in 2000 and became an independent organisation between 2002 and 2003. The program was developed as a result of an increase in wetland loss and degradation in the most important catchments in South Africa (Working for Wetlands 2013). Working for wetlands operates in all large catchments in South Africa and has been successfully implemented in fifteen catchments. Some of the catchments are in KwaZulu-Natal where sugarcane farming is practiced, such as, the Tugela, Nkomati and the Black Umfolozi Catchments. The main aim of the program is to initiate wetland management at the community level to the international level (Working for Wetlands 2013). Working for Wetlands facilitates rehabilitation of wetlands, promotes skills development and provides educational awareness to the local communities that base their livelihoods on wetlands.

2.3.2.3 South African River Health Program

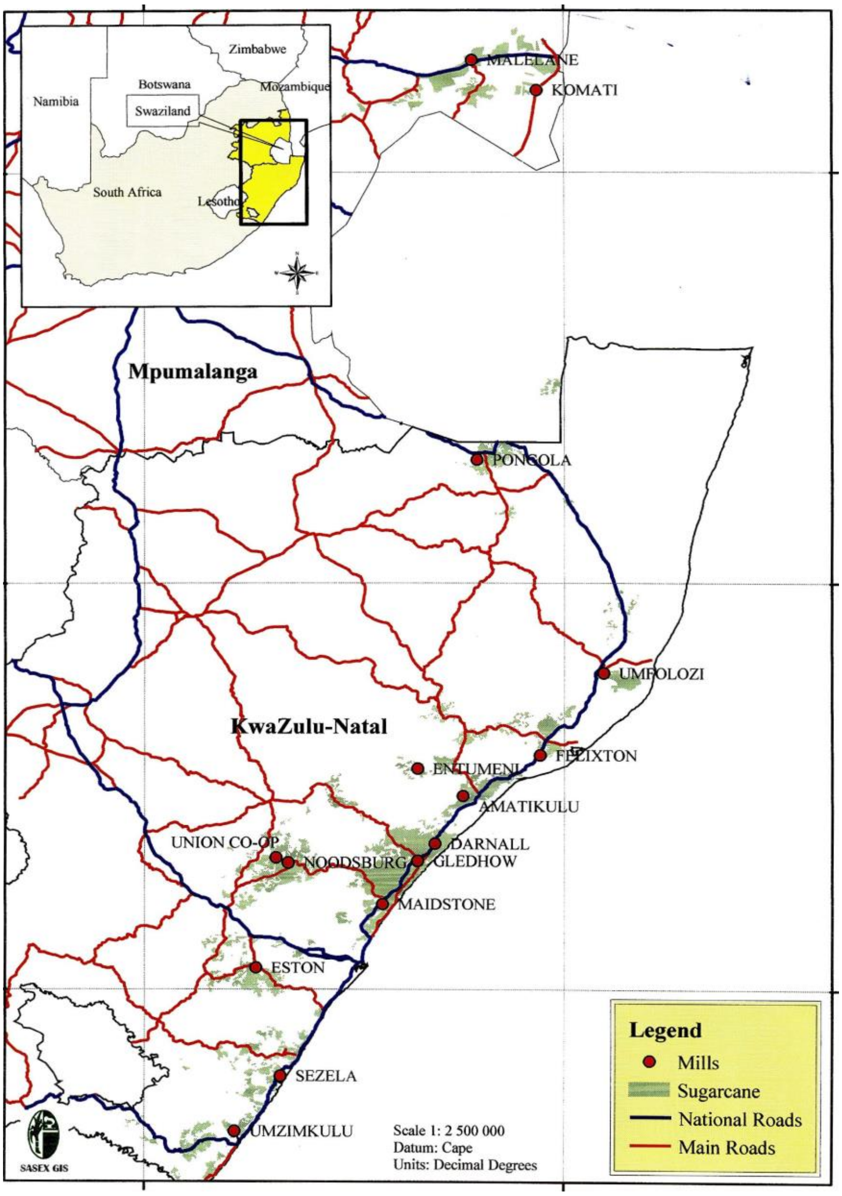
The South African River Health Program was initiated in 1994 by the Department of Water Affairs and Forestry (Dallas et al. 2006). The program generated information on the environmental health of water systems and the riparian areas in South Africa through research (Dallas et al. 2006). The major aim of the program was to come up with a database of the conditions of the riverine ecosystems that supports proper management of ecosystems. The South African River Health Program used biological indicators to assess the health and ecological status of water systems in South Africa, using in stream biota such as fish, benthic microinvertebrates and riparian vegetation to understand the response of the ecosystems to pollution and other human induced effects (Dallas et al. 2006; Odume 2011).

2.4 SUGARCANE FARMING IN SOUTH AFRICA

Before discussing the impacts of sugarcane farming in wetlands, it is imperative to discuss how sugarcane farming started and its distribution in South Africa. Sugarcane farming in South Africa dates back to 1847 where trials with some crops such as coffee, cotton, tobacco, indigo and arrowroot were made (Lewis 1991). From these trials, sugarcane farming was successful and, thus sugarcane was planted along the coastal belt of KwaZulu-Natal (Christopher 1961). Only 13 years later after the initial start-up in 1860, sugarcane fields covered approximately 4953 hectares. Another 50 years later, in 1910, about 23 658 hectares of land were under sugarcane production with most of the cane fields located in north coastal belt (Lewis 1990).

In response to market demand, land under sugarcane production continued to increase. In 1939 sugarcane fields covered approximately 95460 hectares and the area expanded to 129 485 hectares by 1950 (Lewis 1991). As sugarcane exports increased in the early 1950s, so did, the sugarcane fields and they expanded to the north coast. Around 1970, South Africa had become part of the eight leading producers of sugarcane in the world, exporting approximately 1.1 million tonnes of sugar (Christopher 1961). However, the introduction of quotas in 1978 reduced sugarcane exports first to 824 324 tonnes and later on to 754 283 tonnes, thus slowing sugar cane expansion for a while (Lewis 1990). Furthermore, sugarcane expansion was halted in some areas of Zululand between 1960 and 1971 due to expansion of human settlements (Christopher 1961). Nevertheless, sugarcane fields rapidly increased in some areas and even doubling the number of fields that existed prior 1970 (Lewis 1990). Currently, it is estimated that sugarcane production covers approximately 413 556 hectares of land in South Africa (Agrimark Trends 2009), with plantations stretching from Pondoland in the Eastern Cape through the coastal belt and the midlands of KwaZulu-Natal up to the lowveld of Mpumalanga (Gers 2004) as shown in Figure 2.2.

Approximately 68% of the sugarcane is grown within the coast of KwaZulu-Natal whilst 17% is grown in high rainfall areas of KwaZulu-Natal and the rest is grown under irrigation (Department of Agriculture, Forestry and Fisheries 2011). KwaZulu-Natal is the predominant sugarcane region (Figure 2.2).



Source: Gers (2004:2)

Figure 2.2 Distribution of sugarcane farming in South Africa

Fifteen mills use the raw cane and 14 of these are found in KwaZulu-Natal and Mpumalanga. These mills are distributed amoungst six companies including, Tongaat Hullets Limited, Illovo Sugar Limited, Transvaal Sugar limited, Union Cooperative Limited, Umvoti Transport Private Limited and Gledhow Sugar Company (Gers 2004). There are 47 000 registered cane growers in South Africa and these farmers are represented by South African Cane Growers Association which operates in KwaZulu-Natal (Maloa 2001). Commercial farmers produce approximately 90% of the sugarcane while small-scale farmers account for the remaining 10% (National Agricultural Marketing Council 2011).

The sugarcane industry is diverse and it combines several industries from sugarcane planting, refining and production of a variety of sugars and other important products (National Agricultural Marketing Council 2011). Sugarcane farming contributes significantly to the nation's gross domestic product as well as employment opportunities (Gers 2004). According to International Finance Cooperation (2011), sugarcane production in southern africa has tremendously increased over the years from 67% in 1998 to approximately 72% in 2010, with the top ten countries of the world increasing their share from 56% in 1980 to about 70% in 2010. Despite the economic benefits of sugarcane, it negatively affects ecosystems in different ways (Omwoma et al. 2012). Thus, there is a need to establish suitable ways that strike a balance between improved sugarcane yields for people's livelihoods and sustain the health of ecosystems that these sugarcane plantations thrive on.

2.5 ENVIRONMENTAL EFFECTS OF SUGARCANE FARMING IN WETLANDS

To understand how sugarcane affects wetlands, there is need to look into the negative impacts that sugarcane poses to the wetlands and these effects include as land degradation, biodiversity loss, pollution, water consumption and increase in nutrient levels. It is important to note that only the effects that are critical to wetlands are mentioned in this study.

Historically, sugarcane fields have expanded at the expense of natural ecosystems (Johnson et al. 1997; Cheesman 2004; Netondo 2010). Natural ecosystems have been cleared and replaced by various agriculture crops (Netondo 2010). This clearing of natural ecosystems has reduced the flora and fauna which depend on these ecosystems (Food and Agriculture Organisation 2003; Cheesman 2004; Turyhabwe et al. 2013). In some areas, species have become extinct or have been pushed to other areas where they have become invasive affecting the indigenous species of those areas (Primack 2000). Such loss of species has resulted in the fragmentation of linkages between vegetated riparian zones, the surrounding land, flood plains and adjacent marine environments (Meyer 2011). To make matters worse, sugarcane areas support fewer species compared to the natural environments (Cheesman 2004). In New Zealand, it is estimated that almost 95% of the wetland ecosystems have lost their productive capacity and species diversity to human activities such as agriculture and urban expansion (National Geographic Education 2013).

Furthermore, continuous monocropping has been reported to contribute to proliferation of harmful species which are very resistant to pesticides and herbicides (Cheesman 2004; Brodie & Mitchell 2005). Such damage is difficult to reverse (Mitsch & Gosselink 2000). In some cases, using pesticides to control pests affects non-targeted species (Netondo et al. 2010). There have been reports of these pesticides affect the embryos and larvae of anuran species that live within wetlands (Cowan 1995). These problems have also been reported in areas of KwaZulu-Natal in areas where sugarcane farming is the main agricultural activity (Du Preez, Van Huyssteen & Mnkeni 2011). Where biological means of controlling pests and diseases have been used, reports of damage to the ecosystem that surrounds the wetlands have been highlighted (Brodie & Mitchell 2005). For example in Australia, the introduction of the cane toad to control cane beetles ended up with the cane toad becoming one of the most invasive species (Cheesman 2004).

After harvesting and or during land preparation, land is left bare and exposed. This in turn leads to the drying out and crusting of the soil, which in the end affects the flow pattern of water facilitating soil and wind erosion (Van Antwepen & Meyer 1996; Cheesman 2004). Exposing the land has ripple effects on the microbial activities which take place in the soil and the ecosystem as a whole (Meyer, Tucker & Wood 1997). Erosion is part of land degradation and is a major issue in agriculture areas because of the effects it has on different ecosystems (Qongqo & Van Antwerpen 2000). Of late, soil erosion in major sugarcane regions has received attention (Meyer, Tucker & Wood 1997; Cheesman 2004; Qongqo & Van Antwerpen 2000). Soils are washed away into watercourses during the planting and harvesting periods. This poses an environmental hazard to the aquatic species as well as downstream users of the wetlands and watercourses (Scott, Gautheir & Mudie 2014).

In some cases, the top soil is blown off by the wind, especially on sloping land, a common trend in the undulating planes of KwaZulu-Natal (Omwoma et al. 2012). This loss of top soil leads to the leaching of organic matter and nutrients (Meyer, Tucker & Wood 1997; Thorburn et al. 2011). As the leaching process continues, the soil eventually loses its fertility, forcing farmers to increase fertilizer inputs for better sugarcane yields. Fertilization of the sugarcane crop is also regarded as one major source of metals and nutrients that pollute wetlands and water sources (Nakiyembe et al. 2010; Thorburn et al. 2011; Omwoma et al. 2012). The main fertilizers that are used in sugarcane farming are nitrogen, potassium and phosphorus (Cheesman 2004; Brodie & Mitchell 2005).Such practices continually, add excess nutrients which are be absorbed by the plants, or flow into water sources and promote algae and hyacinth growth and ultimately eutrophication. This in turn affects the oxygen balance in water systems leading to aquatic species deaths and in most cases the impact is felt in adjacent wetlands and water sources as well (Cheesman 2004; Yu et al. 2008; Meyer Tucker & Wood 1997).

Sugarcane farming is a cause of pollution in wetlands (Carminati 2008). Before harvesting, sugarcane is burnt to make harvesting easier, however, this burning process releases ash, soot, carbon dioxide, nitrous oxide and methane emissions. These emissions negatively affects the aesthetic value of the wetlands, kills and suffocates some of the animals living close to the sugarcane fields (Van Antwerpen & Meyer 1996), thereby upsetting the species richness of wetlands. Burning of the cane for harvesting also reduces organic matter and moisture levels of the soil (Meyer Tucker & Wood 1997). A reduction of organic matter and soil moisture levels has also been reported in Papua New Guinea, Fiji and the Philippines (Cheesman 2004). In South Africa, similar effects have been identified in KwaZulu-Natal (Meyer, Tucker & Wood 1997; Cowden et al 2014) and are associated with loss of proper soil structure in wetlands. This continuous loss of soil structure consequently contributes to a loss of productivity within the wetlands. When productivity of wetlands are affected, agriculture suffers as well (Mironga 2005). Moreover, harvesting sugarcane is usually done during the wet period and involves field haulage for loading cane (Cheesman 2004). This haulage cause compaction of the soil and ultimately affects the bulk density of the soil (Meyer , Tucker & Wood 1997; Cheesman 2004). This will in turn affect the root growth for some plants, soil permeability, porosity and increase the runoff rate, contributing further to erosion and nutrient deposition in water systems (Cheesman 2004).

Agricultural crops have a high water consumption rate. According to Clay (2004), they are responsible for about 70% of fresh water intake . Sugarcane is regarded as one of the crops that use a lot of water, particularly in areas where irrigation is used (International Finance Cooperation World Bank Group 2011). A cane crop consumes a lot of water. Hence, sugarcane is grown in wetlands because they provide easy access to water required by sugarcane (Cheesman 2004). Where rainfall amounts are too low to meet the water demands, irrigation is used leading to a reduction in ground water levels and degradation of some water systems in the wetlands. In India, excessive use of water has led to a depletion of ground water resources and this has been a concern (Cheesman 2004; World Bank 2005). According to Johnson et al. (1997), irrigation is regarded as water wastage and in some cases, the water is collected in the sugarcane fields and small pools of water are formed around the sugarcane fields harbouring pests and diseases (Carminati 2008). The pests and diseases affect animals and people who live in the wetlands and surrounding areas (Clay 2005). Poor irrigation strategies also increase salinization and affect the pH of the soil (Cheesman 2004). In areas like Pongola in South Africa, irrigation of sugarcane has also been a topical issue because of the rapid depletion of fresh water resources (Van der Laan, Van Antwerpen & Briston 2012). The Department of Water Affairs and Tourism is even considering the removal of sugarcane farms in areas where sugarcane depends on irrigation so that the water can be used elsewhere (Van der Laan, Van Antwerpen & Briston 2012). This is because South Africa is running out of water supplies and could have serious water scarcity by 2015 (SUSFARMS 2012).

This study is useful because it is investigating further some of the effects of sugarcane on wetlands. Although sugarcane is an important crop in terms of its benefits to the society, its effects are twofold in that it provides jobs and helps the economy, however, it has negatively affected wetlands (Agnew, Rohde & Bush 2011). It is therefore necessary to come up with suitable means which take into account an improved yield of sugarcane for the betterment of people without compromising and threatening the sustainability of wetlands (Collins 2005; Keddy 2010). Hence, the next section looks into different methods/approaches that have been used in identifying wetland changes.

2.6 METHODS USED TO DETERMINE WETLAND CHANGES

It is only now that people across the globe have started appreciating wetlands as productive lands that provides them with a vast range of services and as ‘laboratories’ of understanding various functions that occur within different ecosystems (Mitsch & Gosselink 2000). As a result, many studies have been carried out to identify, assess and quantify wetlands so as to come up with inventories and strategies to mitigate threats that humans pose on the wetlands (Peters 1994; Scott, Luan & Zhou 2013; Obiefuna et al. 2013; Turyhabwe et al. 2013; Gautheir & Mudie 2014). The studies have been informed by different methods suitable for identifying wetland boundaries and the intensity of the anthropogenic activities on the wetlands (Dini, Cowan & Goodman 1999; Kotze, Breen & Quin 1995; Dallas & Day 2004; Walters & Koopman 2004). This section presents literature on techniques which have been used to identify changes in wetlands.

Studies on wetlands inventories have been done (Peters 1994; Ozesmi & Bauer 2002) to identify the influence of human activities on the wetland ecosystem (Alam et al. 2011; Laun & Zhou 2013). Urban expansion and agriculture are regarded as the major causes of change within wetlands (Hoffman & Ashwell 2001; Syphard & Garcia 2001; Alam et al. 2011).Geographical information systems (GIS), coupled with some historical information and survey data have significantly contributed in identifying the intensity and spatio temporal extent of the impacts of urban and agriculture development in wetlands (Dahl 2004; Yaun et al. 2005). Various GIS models have been used in identifying wetland changes through vegetation indices, spatial autocorrelation and remote sensing based mapping (Ozesmi & Bauer 2002; Liu et al. 2008). This study uses the remote sensing approach hence this study will only focus on remote sensing based methods.

According to Ozesmi & Bauer (2002), Landsat MSS, Landsat TM and SPOT are the most used satellite systems for wetland change detection. However, aerial photographs have been used extensively in wetland change analysis (Dahl 2004; Morgan, Gergel & Coops 2010; Scott, Gautheir & Mudie 2014). Aerial photographs have proven to be more effective in wetland mapping, especially where there are many vegetation types because of its finer resolution which outweighs that of satellite imagery (Ozesmi & Bauer 2002). Biggs & Scholes (2002) mapped land cover changes using aerial photographs and Landsat images in South Africa as a result of agriculture expansion. Baker et al. (2007) used the change vector analysis to determine the changes in a wetland ecosystem. Alam et al. (2011) used supervised classification of the SPOT HRV, Landsat ETM and IRS-LISS III data sets for the same purpose. Luan & Zhou (2013) identified the impact of agriculture developments on marsh wetlands using Landsat MSS and TM. All these studies have yielded positive results.

Several projects for mapping wetlands have been conducted in KwaZulu-Natal. Grundling, Van den Berg & Price (2013) used remote sensing and historical data to map and identify wetland changes in the Maputaland coastal plain and Ezemvelo KZN Wildlife (2011) mapped different types of wetlands in KwaZulu-Natal, whilst Scott-Shaw & Escort (2011) created a wetland layer. However, these studies have not examined how sugarcane has expanded into wetlands

Biological and physicochemical techniques have been successfully used to assess wetlands health in many studies (Kashian & Burton 2000; Lillie 2003; Grobler & Ntsaba 2004). The studies on biological and physicochemical assessment use different biotic and abiotic variables as the basis of their research in determining the impacts of anthropogenic activities in wetlands (Kotze et al. 2005). According to the Department of Water Affairs and Forestry (2003), the most successful studies have used plants, soil and water quality to identify the various anthropogenic effects on wetlands. Studies that have used biological and physicochemical indicators to show the impacts of sugarcane farming include Barnes, Ellery & Kindness (2002); Simaika & Samways (2009); Omwoma et al. (2012); and Shabalala, Combrink & Mc Crindle (2013).

Biological techniques of assessing wetlands are used worldwide to measure the effects of agriculture and other human activities (Lillie 2003; Chinheya, Mabveni & Chinwada 2009; Ndebele & Mzime 2012). The biological indicators uses different indices such as the microinvertebrate metrics to identify toxicants on fish, reptiles, diatoms and vascular plants. Identifying how these microinvertebrates are affected by the toxicants helps to quantify the amount of toxicants that flows into the wetland ecosystems and how it impacts on the wetland ecosystem (South Africa 2003b). The quantity of toxicants on the species will in turn show how much the wetland is impacted on (Kashian & Burton 2000; Lillie 2003; Corry 2010). South Africa developed its own biological assessment methods that suits South African conditions. The biological assessment is referred to as the South African Scoring System. The South African scoring system uses aquatic benthic macroinvertebrates and fish indexes to assess wetlands health (Odume 2011). However, few studies have used biological indicators to determine how wetlands are anthropogenically impacted on in South Africa because of the lack of expertise (Grobler & Ntsaba 2004).

Physicochemical methods have been used to identify the impact of agriculture within wetlands. The physicochemical methods involve collecting soil, water and vegetation samples in wetlands. The samples are then checked for heavy metals hydrocarbons, excess nutrients, changes in colour and sediments (Collins 2005). Physicochemical methods also involve describing the ecological characteristics of wetlands (Dallas et al. 2006). Wetlands and their water systems are assessed and compared with the minimally damaged wetland systems in close proximity, however, it is very rare to find minimally demaged wetlands unless they are artificial wetlands (Grobler & Ntsaba 2004; Collins 2005; Dallas et al. 2006; Simaika & Samways 2009). Furthermore, due to the expenses and specifically expertise needed for the biological approach, many researchers use the physical aspects rather than the biological methods (Grobler & Ntsaba 2004).

Some researchers have identified and assessed wetlands through people who have their livelihoods based on wetlands and have yielded results (Mironga 2005; Turyahabwe et al. 2013). These studies have proven to be a success and have been integrated with other techniques to yield better results despite the expenses involved (Turyahabwe et al. 2013).

Since changes in wetland extent and functions occur at a large spatial scale. Traditional techniques such as field surveys are time consuming, tedious and site specific (Alam et al. 2011; Laun & Zhou 2013). These methods are therefore not suitable for assessing or monitoring the spatio-temporal changes over these extensive areas (Alam et al. 2011; Scott-Show & Escott 2011; Laun & Zhou

2013; Grundling & Van den Berg 2013; Turyhabwe et al. 2013). Such survey methods are therefore limited in extent and may fail to capture wetland changes occurring at the landscape scale (Laun & Zhou 2013). To this end, there is need to integrate the survey methods with other techniques that can objectively quantify changes in wetland extent and quality at large spatial scales as a first step towards sustainable management of wetlands (Ozesmi & Bauer 2002; Kashaigili et al. 2006).

2.7 CURRENT CONSERVATION STRATEGIES IN WETLANDS IN SUGARCANE REGIONS OF SOUTH AFRICA

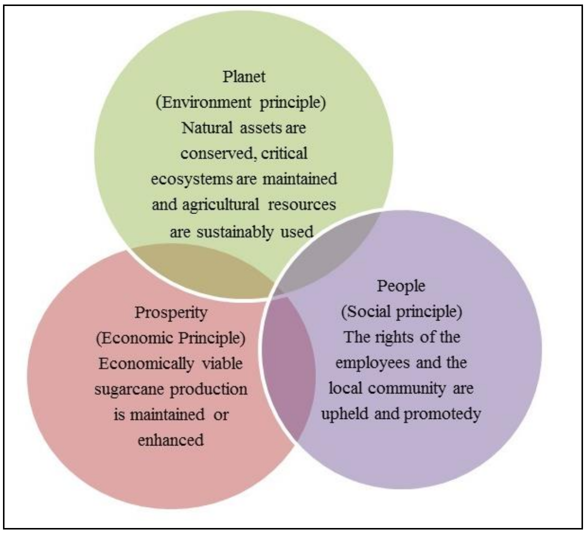
The South African sugar industry through the South African Sugar Association has been trying to promote sustainable farming in line with environmental legislation (Hurly 2013). These include trying to implement Better Management Practices (BMPs), defined as management practices that aim to maximize on quality and quantity without compromising the sustainability of the resources (SUSFARM 2012). Under this program, the South African Sugar Association (SASA) introduced extension officers and created partnerships with organisations such as Working for Wetlands, World Wild Fund for Nature, government departments such as the DEAT and the sugarcane farmers through South African Sugracane Research Institute (SASRI) to come up with better management of wetlands. SUSFARMS is the biggest project in the sugarcane industry that is promoting sustainable use of resources in sugarcane regions (Sibiya & Hurly 2011). SUSFARMS is a progress tracker based on BMPs and Legislation in Table 2.1 (SUSFARMS (2012). The main objective of SUSFARMS is to promotes sustainable sugarcane farming in South Africa (SUSFARMS 2008).

Table 2.1 South African legislation that corresponds to the SUSFARM guidelines of 2012

Legislation	Implications/ Guidelines
Water Act 36 of 1998	Regulation on fertilizer storage and disposing of containers.
	Planting 30 meters away from the flood line.
	Acquiring licenses for any water activities.
National Environmental Management Act 107 of 1998	Carrying out environmental impact assessments prior to construction of dams, levees and weirs.
Conservation of Agriculture Resources (Act 43 of 1983	Promoting conservation of soil using terraces, strip planting and grassed waterways.
	Regulating irrigation schemes
National Veld and Forest Fire Act 1998	Prohibiting burning of riparian and forested areas.

SUSFARMS aims to reduce the negative impacts of sugarcane farming on the environment whilst improving the economic and social stability of cane production (SUSFARMS 2008; 2012; Hurly 2013). The first version was developed in 2007 and it was reviewed in 2012. The 2012 version shifted its framework from a linear to a more integrated approach (Sibiya & Hurly 2011; Hurly

2013). SUSFARMS largely works in line with the Department of Agriculture Policy on Sustainable Development. It is based on three principles: prosperity, people and planet illustrated in Figure 2.3 (SUSFARMS 2012).



Source: Hurly 2013:5

Figure 2.3 An illustration of the integrated conceptual framework used in SUSFARMS 2012

This study will focus on the 'planet' principal, which is one of the principles of conserving natural ecosystems and agricultural lands. Better management practices are designed in such a way that farmers comply with legislation (see Table 2.1). When Sustainable farms (SUSFARMS) was first introduced, farmers ignored it because they thought it was meant to destabilize them from the world market and it would increase their farming costs (Hurly 2013). Furthermore, farmers have been facing many financial constraint such as increases in prices of fertilizers, herbicides and labour shortage. These constraints have been exceeding the profits they get, and as a result using the profits for wetland money to wetlands management is a challenge (Hurly 2013). Besides, there is confusion about the term sustainable management; farmers believe that SUSFARMS is about better yields and increasing profits. The farmers have not grasped SUSFARMS (2012) integrated approach, hence the sustainable management of the environment is left out many a times (Koopman 2012; Hurly 2013).

These programs and projects that have been put in place to manage wetlands have played a significant role in addressing the threats that sugarcane poses on the environment but cannot reverse the damages that have been done to most wetlands (Fuggle & Rabie 2009). This challenge coupled with other constraint makes it difficult to successfully manage wetlands in sugarcane areas. The next section deals with the challenges that affect conservation of wetlands in sugarcane areas specifically South Africa.

2.8 CHALLENGES IN ADDRESSING SUSTAINABLE MANAGEMENT IN THE SUGARCANE REGIONS

Whilst the sugarcane industry has contributed to successful environmental awareness programs, the changes that they have contributed to have not shown much significant differences (Hurly 2013). According to Benn (2013), the sugarcane industry has isolated itself from the environmental campaigns and activism, contributing less to sustainable management of the resources because of the assumptions that they are not making significant damage to the environment. Although the South African Sugar Industry has formulated local environmental committees comprising of extension officers deployed to assist in sustainable farming, the challenge remains that environmental management practices are voluntary, even in severely damaged environments (Cheesman 2004). There is no follow-up on legislation either (Hurly 2013). Moreover, farmers' education level, particularly small-scale farmers are very limited. They are already struggling with proper management of the farms and legislation is not a priority to them.

Some farmers have voluntarily to green farming methods, but this has been limited to financially stable farmers as it involves some costs, expertise and time (Eweg 2005; Sitas, Prozesky & Reyers 2014). This is in contrast to the resettled farmers, who in most cases are smallholder farmers with less or no experience at all. This trend indicates that these practices have been more feasible to the large-scale farmers compared to the small-scale farmers (Eweg 2005).

The other major constraint is that there is not much on legislation that governs wetlands, most of the legislation is dilute in nature (Fuggle & Rabie 2009). Wetlands do not have an independent policy that governs them and the existing legislation is not properly implemented (Coetzee 1992). Moreover, legislation is so fragmented and it is very difficult to integrate legislation from different ministries (Sitas, Prozesky & Reyers 2014). For example, the minister responsible for the environment in the Ministry of Water and Environmental Affairs cannot take action on activities relating to other ministries such as the Ministry of Mining and Energy yet all the departments have a bearing on the environment. The lack of integration between policies in different government departments and very low fines given as punishment make it difficult to achieve proper management results in wetlands (Fuggle & Rabie 2009). One other challenge in implementing legislation is that the people who are in direct control of the wetlands are excluded in decision-making. In the end, they fail to comprehend the legislation and lose interest to understand more about the legislation (Benn 2013; Hurly 2013). Hence, wetland degradation is perpetuated and wetland loss remains a threat.

For effective management and legislative controls, the government departments involved, should first have a clear understanding of how the sugarcane industry works, how the farmers relate to the surrounding wetlands and the constraint that they face in trying to conserve wetlands (Fuggle & Rabie 2009). This understanding is needed to formulate viable legislation which protects the environment specifically wetlands and at the same time maximize sustainable sugarcane farming.

2.9 CONCLUSION

Despite their significance, wetlands are threatened by extensive disturbances at both global and local scales . These wetlands remain the most indispensable ecosystems to both humans and various plant and animal species (Dini, Cowan & Goodman 1999; Scott, Gautheir & Mudie 2014). In the past, wetlands have been perceived to be wastelands and have been drained, waste dumped in them.Wetlands have been modified significantly inorder to suit human needs (Williams 1991). Sadly, these valuable wetlands only occupy six percent of the world's landscape and to make matters worse, they are only found in small portions and not in contiguous stretches.

Several studies have recognized agricultural expansion as the major source of disturbances and loses within the wetlands (Scott, Gautheir & Mudie 2014). Evidence suggests that many wetlands are increasingly overwhelmed by these human threats (Cowden et al. 2014). Sugarcane is one of the agricultural crops that have significantly altered many wetlands. Encroachment of sugarcane farming into wetlands has led to irreversible and very drastic changes the world over, and South Africa is not isolated in this case (Hoffman & Ashwell 2001; Syphard & Garcia 2001; Alam et al. 2011; Walters & Koopman 2004). Although various methodologies, policy frameworks and projects have been implemented to mitigate the impacts of agriculture activities, such as sugarcane farming on wetlands, they continue to decrease in extent and quality due to improper policy planning and lack of understanding on the part of the people who conduct activities in wetlands and those that utilise the wetlands. The next chapter looks at the methods and how these challenges can be addressed.

CHAPTER 3 METHODS

This chapter details the study area and the research approach that was used to answer the objectives of the study. It further explains in detail the steps that were taken in sequence for data collection, processing and analyses. The final section focuses on the ethical procedures that were taken in this study. To understand the effects of sugarcane farming in coastal wetlands, three main tools were used. These were:

a) Aerial photographical analyses to assess the effect of sugarcane farming on selected wetland extent over time.

b) Water quality analyses to determine the effect of sugarcane farming on water quality within the selected wetlands.

c) Questionnaire analyses to evaluate perceptions of farmers on the effects of sugarcane farming on wetlands.

3.1 DESCRIPTION OF THE STUDY AREA

KwaDukuza was chosen specifically for this study because (i) it is a good example of areas with wetlands where sugarcane farming is practiced and (ii) sugarcane farming in KwaDukuza dates back to 1910 (Lewis 1990). Therefore, KwaDukuza provides a platform to understand the impact of sugarcane farming on coastal wetlands. KwaDukuza is located between 29^{o} 20' 00" S and 31^{o} 17' 30" E in KwaZulu-Natal, South Africa, (Figure 3.1). KwaZulu-Natal is one of the major provinces in South Africa. The province is divided into 50 local municipalities with KwaDukuza located in the ILembe district municipality (KwaDukuza Municipality 2013; ILembe District Municipality 2012). The ILembe district municipality is about 3 260 km^2, along the east coast of KwaZulu-Natal, between EThekwini Metropolitan and the Tugela mouth. The district is comprised of 45 traditional authority areas and landholding is based on the traditional tenure system (KwaDukuza Municipality 2013).

KwaDukuza covers approximately 750 km^2 (KwaDukuza Municipality 2013). It stretches from Zinkwazi River in the north to the Tongaat River in the south. The major town in KwaDukuza is Stanger and is also known as KwaDukuza. The KwaDukuza municipality has a well-organised road network system which includes major roads such as the; N2 and R102 (KwaDukuza Municipality 2013). The well-developed road network is an important infrastructure for the various farming activities in KwaDukuza specifically sugarcane farming. It makes it easier to transport sugarcane from the fields to the mills.

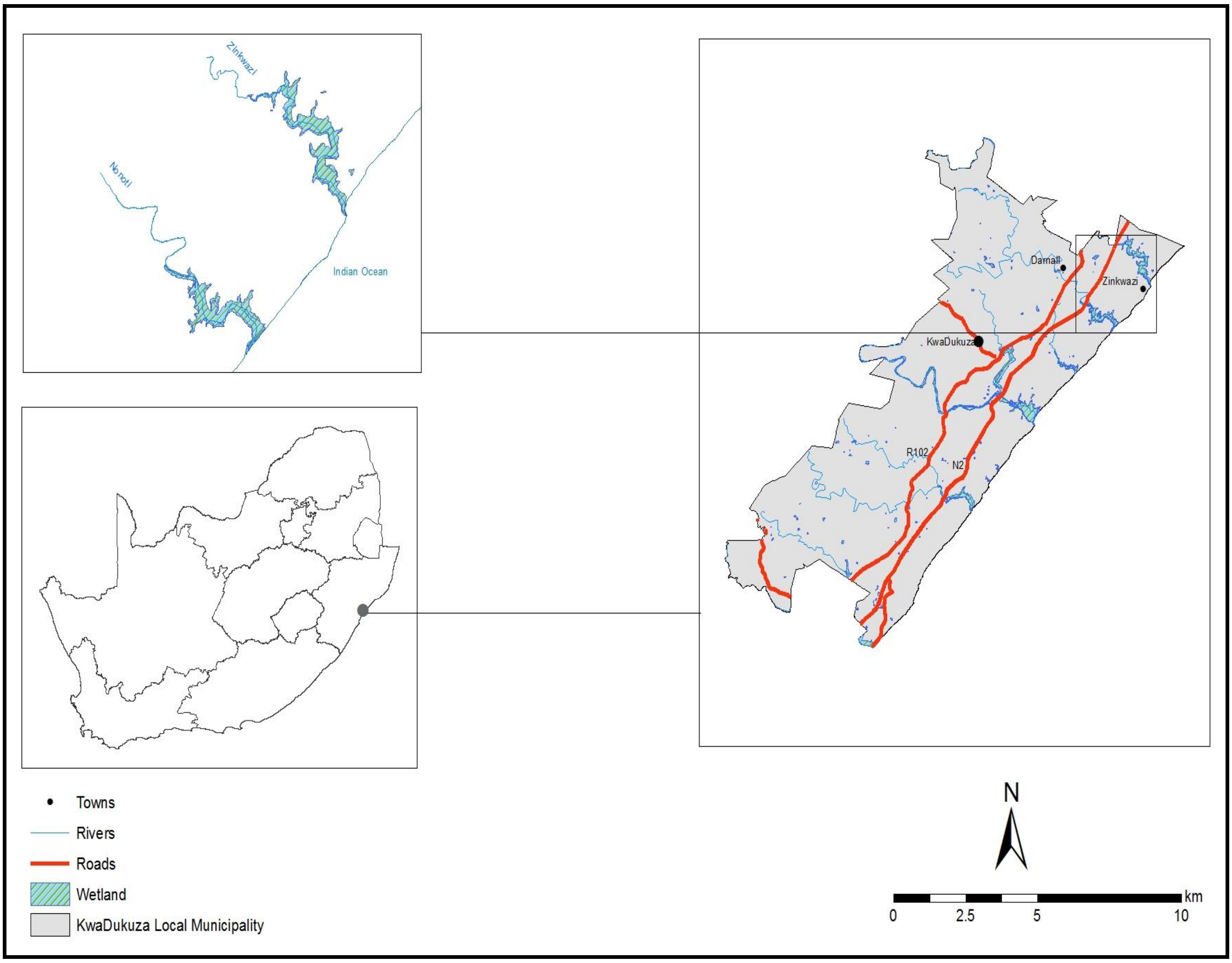


Figure 3.1 Location of the study area of KwaDukuza, KwaZulu-Natal, South Africa

3.1.1 Climate

The climate is mainly subtropical, with mean annual temperature varying from 21°C along the coast to 16°C inland (ILembe District Municipality 2012). However, these temperatures, can reach 30°C in summer because of the high humid conditions. These humid conditions are caused by inversions that usually rise above the escarpment (KwaDukuza Municipality 2013). Rainfall gradient varies as the distance from the coast increases (ILembe District Municipality 2012). Precipitation is from October to April and mainly in the summer months between December and February. Rainfall is higher along the coast than in the interior (Gers 2004). The average rainfall per annum ranges from 925 mm to 1059 mm per annum (Chetty & Loubser 2012). The climate is influenced by the Indian ocean anticyclones, which control the airflow extending through the region from the Indian Ocean (Singh 2009). Climate within the region varies with locality because of a number of undulating terrains within the region (Singh 2009).This climate is ideal for sugarcane farming and thus the reason why it dominates in the region (Chetty & Loubser 2012).

3.1.2 Geomorphology and hydrology

KwaDukuza is a slightly rugged and undulating coastal plain with the most dominant rock types being the siliciclastic type, extending from the coastal belt to non-coastal land (ILembe District Municipality 2012). The most common soil types in the study area are dystic regosols and the rhodic acrisols, with rhodic soils covering most of the area. The rhodic soils also provide vital nutrients for sugarcane cultivation in KwaDukuza. Thus, most of the sugarcane fields are found in the areas with rhodic soils (ILembe District Municipality 2012). Based on the classification by Dini, Cowan & Goodman 1999, most of the wetlands in KwaDukuza are estuarine systems. Estuarine systems are defined as being partially enclosed by land and partly connected to the ocean (KwaDukuza Municipality 2013). In estuarine wetlands, fresh water mixes with salty water during the occurrence of high tides (Dini, Cowan & Goodman 1999).There are eight estuaries connected to river systems within KwaDukuza and these includes the uThongathi, Zinkwasi, uMhlali, Seteni, Bob's stream, Mdlotane, uMvoti and Nonoti (KwaDukuza Municipality 2013).

3.1.3 Vegetation

Coastal rocks and soils, marine currents and climatic influences are the major dominant influence in the vegetation types found in KwaDukuza (Mucina & Rutherford 2006). The area is made up of three biomes which include the indian ocean Coastal belt and forests, grasslands and savannas. The major biome, however, is the grassland biome that is found inland of the coastal belt of KwaDukuza, which is covered by the subtropical grasslands biome and a few patches of indigenous forest (Gers 2004). In the grasslands of KwaDukuza, the dominant species of grass is the *Themeda triandra* and *Hyparrhenra hirta*. There are also a few patches of coastal thornveld and *Acacia sieberiana var woodii* in areas where natural vegetation has been destroyed (Mucina & Rutherford 2006). Furthermore, wetlands also influences species distribution in KwaDukuza, areas that lies along a gradient of wetness are composed of a higher species turn over, and most species are associated with the same wetness zones across different wetland sites (Donavan & Kotze 2000). *Eragrotis plana* is common in the least wet zone whilst *Pycreus macranthus* is found in the transitional zone and finally *Phragmites australis* is common in the wetzone (Donavan & Kotze 2000) However, most of the vegetation in KwaDukuza has been affected by anthropogenic activities such as dam construction and cultivation (KwaDukuza Municipality 2013).

3.1.4 Land use

Landuse patterns vary considerable in KwaDukuza, ranging from urban and infrastructure development to social facilities and agriculture (ILembe District Municipality 2012). The major activity in KwaDukuza is agriculture, specifically sugarcane farming (Chetty & Loubser 2012). Sugarcane farming in KwaDukuza is intensive and occupies approximately sixty percent of the land, stretching through to the coastal line (KwaDukuza Municipality 2013). Sugarcane contributes 23% to the local economy of KwaDukuza (Chetty & Loubser 2012). Industrial activities of ILembe are more concentrated in KwaDukuza and the dominant companies are Gledhow Sugar Milling Company and Darnall Sugar Milling Company, Sappi Paper Mills, Isithebe Industrial sites and the Uthongathi/Maidstone Mill (ILembe District Municipality 2012). There is also urban expansion that is happening in KwaDukuza.

3.2 DATA COLLECTION

This section describes the data collection procedures that were used for this study. The data collection procedures were derived from three fundamental approaches which involved the use of aerial photography, water quality analyses and questionnaires analyses.

3.2.1 Aerial photographs

Aerial photographs for the study sites were acquired from the National Geospatial Information housed by the Department of Rural Development and Land Reform in Mowbray, Cape Town. The aerial photographs were panchromatic ,black and white, taken with a single lens frame, film based camera to minimise distortion. These aerial photographs were captured at a scale of 1:50 000 and were taken at an altitude of 4750 m with a precision of 230 mm by 230 mm (DRDLR 2013).

In this study, aerial photographes were analysed to identify how sugarcane farming has affected the spatial extent of wetlands. Aerial photographs for the years 1959, 1989, 2000 and 2012 were used and two aerial photographs per year covered the study area. Aerial photographs are defined as the representation of the reflectance of an object (Morgan, Gergel & Coops 2010). Aerial photographs were used in this study due to their high geometric and spatial resolution (Ozesmi & Bauer 2002; Yongdae & Zhang 2008) and early temporal records (in this case since 1959). Aerial photographs are the only source of fine spatial resolution data that spans for more than 53 years and predates the advent of multispectral satellite images such as Landsat MSS which began around the 1970s (Yongdae & Zhang 2008). Aerial photographs also afford a stereoscopic outlook of the Earth's surface that lacks in other types of remote sensing images (Thomas 2012). Furthermore, the temporal resolution dates back to almost the initial land use of the wetland prior to the establishment of sugarcane farming and other activities as compared with other image sources. Aerial photographs are invaluable in determining changes on different landscapes over time (Thomas 2012). According to Scott, Gautheir & Mudie (2014), the use of aerial photographs is the most appropriate and relevant way to determine the existence of wetlands in areas that have been modified by both natural and man-made factors. The literature review provides ample evidence that most of the areas in the coastal belt of KwaZulu-Natal were wetlands (KwaDukuza Municipality 2013).

3.2.2 Water quality assessment

Water quality is defined as the physical, chemical and biological aesthetic properties of water that determines its suitability for a variety of uses, and the protection of the water resource together with its ecosystems (South Africa 1996). This study only assessed the chemical aspect of water quality because that was the major component affected by sugarcane farming (Cheesman 2004). Wetlands are part of the water resources and water resources are very difficult to separate since they exist in an integrated environment where they are interlinked and dependent on each other (DWAF 2003). Thus, water quality can indicate the impact of agriculture on wetlands (DWAF 2003).

3.2.2.1 Random probability sampling

To assess the effect of sugarcane farming on water quality, two wetlands in Zinkwazi and Nonoti were selected for this study. Stratified random sampling was used to select the sampling sites (Figure 3.2) whilst a presurvey was conducted to locate, familiarize with the study area and to locate and mark sampling points were samples would be taken. Also, see figure 3.2 for details.

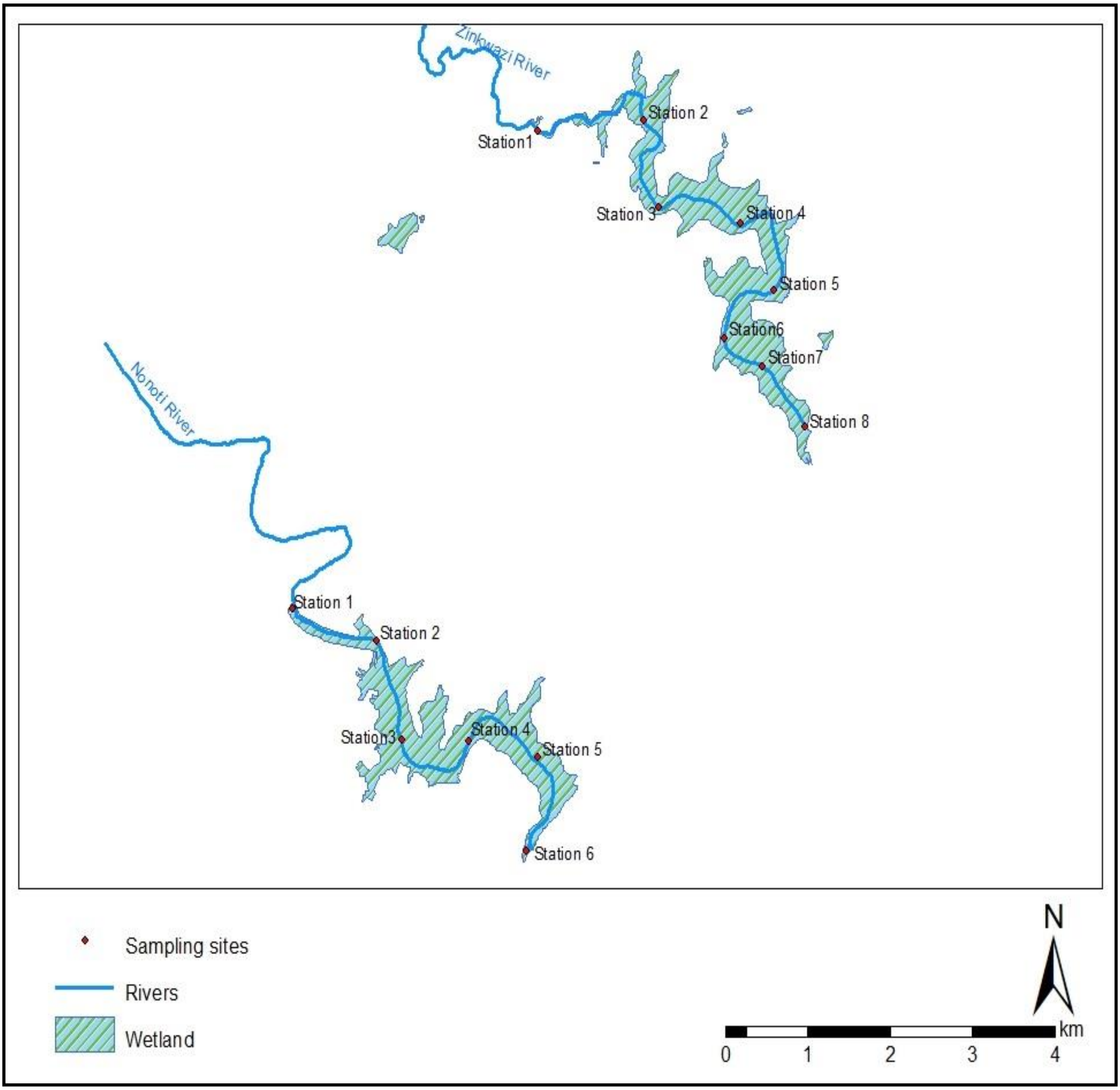


Figure 3.2 Points that were randomly selected in Zinkwazi and Nonoti wetlands using the Hawths Analysis Tools in Arc gis 10.1. (Red points show the sampling stations, 8 points for Zinkwazi and 6 points for Nonoti.

It is important to note that sampling sites were only established within the Zinkwazi and Nonoti wetlands since the major aim of this study focused on wetlands. The rivers were stratified into three sections or strata upon where sampling was conducted (upper, middle and lower watershed). There were fewer fields closer to the part of the river (Table 3.1 a and b). Sugarcane fields were concentrated and close to the middle sections of the rivers. The last section was downstream, where sugarcane fields were absent from the river.

Table 3.1 Coordinates representing the exact location where water samples were collected along Zinkwazi and Nonoti wetlands .

Wetland station	**Position**	**Latitude**	**Longitude**
Zinkwazi			
Station 1	Upstream	29.278663 º	31.442714 º
Station 2	Upstream	29.273113 º	31.437980 º
Station 3	Upstream	29.265703 º	31.439078 º
Station 4	Middle stream	29.258676 º	31.437004 º
Station 5	Middle stream	29.256651 º	31.423685 º
Station 6	Down stream	29.255712 º	31.423581 º
Station 7	Down stream	29.254259 º	31.422520 º
Station 8	Down stream	29.249532 º	31.423098 º
Nonoti			
Station 1	Upstream	29.318319 º	31.407326 º
Station 2	Upstream	29.309426 º	31.408880 º
Station 3	Middle stream	29.307763 º	31.400026 º
Station 4	Middle stream	29.307555 º	31.391862 º
Station 5	Down stream	29.298229 º	31.388857 º
Station 6	Down stream	29.294675 º	31.378542 º

The reason for dividing the rivers was that the chemical characteristics of water vary spatially as one moves downstream. Different activities occurring close to, within or adjacent the wetlands directly influence the water quality of rivers within the wetlands (Kebede et al. 2014). Using the GIS layer of rivers and the three strata, points were generated using the random point generator of the Hawths Analysis Tools in ArcGIS 10.1, which is used for spatial analyses (ESRI 2010). The coordinates of these points were then entered into a hand held GPS. The GPS was then used to locate those points along the Zinkwazi and Nonoti rivers. Zinkwazi wetland is approximately 8km in length and Nonoti is 6 km which is the reason why the number of sampling sites within the two rivers differed (Table 3.1).

3.2.2.2 Water quality indication

Most nutrients enter wetlands through runoff from agriculture, sediments and through ground water. The major nutrients entering the wetlands are inorganic nitrogen, phosphorus and potassium (Mitsch & Gosselink 2000; Fisher & Acreman 2004). Many processes occur in wetlands that reduce nutrients. These processes include absorption by plants, sedimentation, filtration, chemical precipitation and microbial interactions (Huising 2002). However, wetlands can reach a threshold, therefore, they will not be able to hold and convert more of the nutrients that are deposited (Reddy & DeLaune 2008).

One of the nutrients is nitrogen which is a vital and essential nutrient for sugarcane growth (Reddy & DeLaune 2008). Nitrogen exists in many forms, with the common ones being ammonium, nitrate, nitrite and nitrous oxide. Ammonium and nitrate are found in larger quantities and are mostly absorbed by plants as compared to nitrite and nitrous oxide which are toxic to plants (Reddy & DeLaune 2008). Nitrogen in wetlands is balanced through the nitrogen cycle, where nitrogen is transformed into different nitrogen types through different processes that includes mineralisation, leaching, plant assimilation, nitrification, denitrification and immobilization (Nikanorov & Brazhnikov 2011). According to Kebede et al. (2003), nitrates, nitrites, ammonium and ammonia are the measurable forms of nitrogen in wetlands. However, nitrate is the most common form in aquatic environments and it is highly soluble (Nikanorov & Brazhnikov 2011). Nitrogen increase is of major concern to the wetland ecosystem because if the levels of nitrogen are high, this can lead to nitrate toxicity and contamination of water bodies (Ngwenya 2006). High levels of nitrogen in wetland systems can be an indication of eutrophication (Ngwenya 2006; Mitsch & Gosselink 2000).

Phosphorus (organic and inorganic) is an invaluable constituent for (Reddy & DeLaune 2008). Organic phosphorus is the dominant source of phosphorus and is mainly found in form of phosphate (Sikdar 2007). Inorganic phosphorus is essential for the development of sugarcane roots, the ripening of the cane as well as purification of the sugarcane juice (Cheesman 2004). Phosphorus is applied on sugarcane plants in the form of a top dressing fertilizer (Cheesman 2004). It occurin a sedimentary or soluble form, and is found in wetlands as litter, peat and inorganic sediments (Mitsch & Gosselink 2000). Phosphorus in wetlands is regulated through cycling because of different ecological conditions within the wetland. Phosphorus is balanced through immobilization, precipitation, dissolution, weathering, and sorption (Reddy & DeLaune 2008). Sorption is regarded to be the main removal process of phosphorus in wetlands. It is not readily available in water systems under natural circumstances, however, human activities contributes to an increase of phosphorus in water systems (Nikanorov & Brazhnikov 2011). According to Ngwenya (2006), phosphorus increase is a problem compared to any other constituent in South Africa, and an increase in phosphorus exacerbates the growth and spread of algae blooms. Phosphorus is a major problem in still waters compared to natural flowing water.

Potassium is another essential element in the promotion of active growth, resistance to disease and increase in sucrose content of sugarcane (Van der Laan, Van Antwerpen & Briston 2012). Sources of potassium include silicate minerals, fertilizers, decaying plants and rain. Potassium has properties similar to sodium (Lennetech 2014) and is usually found in smaller soluble quantities in water systems due to its demand by different plants and micro organisms, and because of its inability to change to other forms (Chaudhuri, Clauer & Semhi 2007). However, potassium levels are usually high in agriculture and mining areas and can be easily washed to water systems.

3.2.3 Questionnaires

This section explains the questionnaire design and the sampling frame and size that was used to gather information on the perceptions of farmers concerning the expansion of sugarcane farming on wetlands.

3.2.3.1 Questionnaire design

The questionnaire was aimed to elicit information on the perceptions of farmers on the impact of sugarcane farming on coastal wetlands. The questionnaire consists of mainly close-ended questions to make it easy for the respondents as well as for analysis purposes (Krosnick & Presser 2009). Attention was given to limiting the number of open-ended questions because these are time consuming and in some cases produce missing data thereby affecting the study (Krosnick & Presser 2009). A copy of the questionnaire is given in Appendix A. Furthermore, the questionnaire was structured in a categorical scale design so that they would be exhaustive of all possible responses (Kent 2001). Respondents were requested to tick the category that was applicable.

Furthermore, the questionnaire was divided into three sections (see Table 3.2), for logical flow and for easy analysis (Kent 2001). The first section addressed demographical information. The reason for the section was to identify whether there was a relationship between demography and the farmers perceptions on wetlands. The second section was composed of the behavioural and management components, that is, the farmers' day-to-day activities in managing their farms. The third section delt with the cognitive variables. This section was concerned with perceptions of farmers regarding legislation that protects wetlands.

A pilot study was conducted with four agricultural extension officers and three farmers. These were selected on a convenience-sampling basis. According to Kent (2001), convenience sampling is the use of a readily available population chosen because of the need for quick and easy access to avoid respondents delays. A pilot study was done to achieve the following

- Identify questions that needed to be rephrased and use simpler terms.
- Gauge how farmers may react to the questionnaires.
- Determine whether the questions would be answered within the context of the study.
- Eliminate the researcher's bias.
- Suggestivefeedback to improve the questionnaire and gauge its efficacy as a data collection method.

Following the pilot study, the questionnaire was revised and a consent form with the description of the aim and significance of the study was attached to each questionnaire , see Appendix A for more information.

3.2.3.1 Questionnaire sampling frame and size

For this study, farmers were the only group of interest since they are in direct contact with the wetlands. They grow sugarcane and are the ones largely affected by the changes that may occur within the wetland. The farmers were stratified into small scale and commercial farmers. This was done to address the differences that may exist between the two categories of farmers. According to Robson (2011), stratified sampling gives meaningful comparisons and ensures representation of all groups.

Having stratified the farmers into small scale and commercial farmers, the researcher did purposive sampling to identify the farmers of interest. Purposive sampling was chosen because it was the best sampling frame that was applicable to the study and addressed the aims of the study. Furthermore, the applicability and contribution of the sampled population is more valuable compared to a mere representation of figures Hungwe 2014). Farmers who had farms close to or whose farms fell within the Zinkwazi and Nonoti wetlands were selected because these were the wetland sites selected for the study. A sampling frame has practically determined by the study aims (Figure 4.3) and a valid sampling frame is one that helps to answer the research questions derived from the study (Palinkas et al. 2013). According to the Gledhow Cane Supply office, there are 265 active farmers within the study area. Twenty-two (22) were purposively selected because of the geographical location of their farms are in proximity to or within the two study sites, (Table 3.3). A questionnaire was used to elicit these farmers' perceptions on effects of sugarcane farming on coastal wetlands.

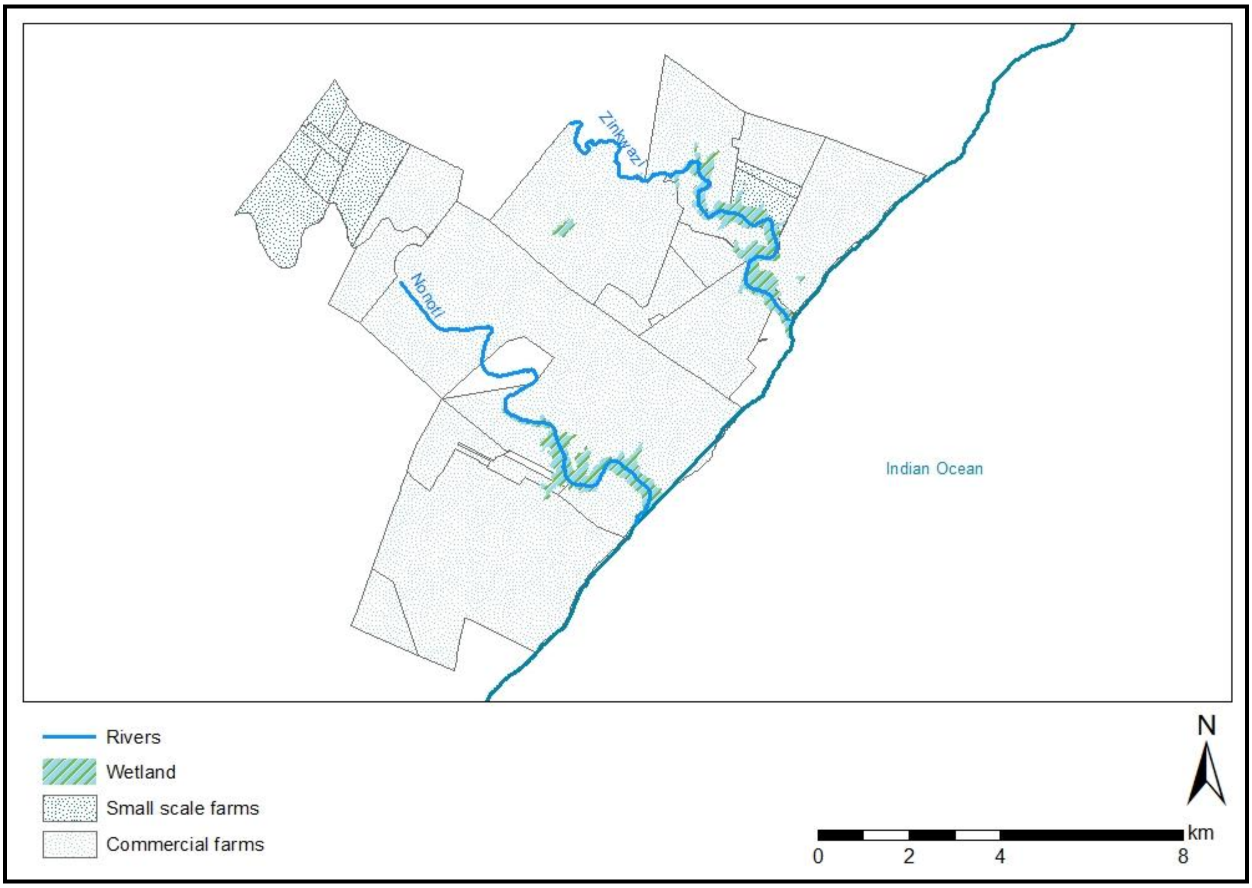


Figure 3.3 A sampling frame that was purposively selected for questionnaire distribution in Zinkwazi and Nonoti wetlands.

The reason for selecting only these farmers was that they had their farms within the wetlands of interest, and would know more about the wetlands changes and reasons behind the change. Generally, commercial farmers had larger farms compared to small-scale farmers whose farms ranged from 30 ha to 250 ha. Commercial farms had their farms along and more close to the rivers as compared to small-scale farmers. Overall, thirteen commercial and nine small-scale farmers were included (Table 3.3).

Table 3.2 Distribution of questionnaires to farmers in the two study areas namely Zinkwazi and Nonoti wetlands to gather information on their perceptions on the effects of sugarcane farming

	Category of farmers	
Farm location	Commercial	Small-scale
Zinkwazi wetland	7	2
Nonoti wetand	6	7
Total	13	9

Commercial and small-scale farmers were contacted through the South African Extension Officers who are constantly in touch with the farmers. South African Sugar Technologists' Association (SASTA) extension officers assisted with translation into Zulu, which is the local language of the area. The use of the extension officers was very beneficial because farmers are used to working with them.

3.3 DATA PREPARATION

Data collected was processed. The Sequence of how the data were prepared is reflected in the section below.

3.3.1 Aerial photographs

The acquired photos did not have a spatial reference hence they were first geometrically corrected to topographical maps and projected to WGS 84, Lo 31. As a pre-processing step, the aerial photographs were orthorectified since they did not have a spatial reference. Orthorectification involves assigning a spatial reference, and correcting for distortion that may have arisen because of relief displacement, lens distortion, camera tilt and scanning the aerial photographs (Mc Cloy 2006). Orthorectification was done using the Ortho Engine software package in Geomatica (Geomatica 2013) used to orthorectify aerial photographs and satellite imagery (Brostuen, Sutton & Siddiqui 2001). Ortho Engine was chosen because it allows for input of ground control points and digital elevation models (DEMs) in different projections compared to other software (Mc Cloy 2006). An orbital model was used to model the geometric errors in Ortho Engine because it does not use many ground control points (PCI Geomatica 2013). Hence, first additional steps required by some softwares at the beginning of the project were eliminated (Brostuen, Sutton & Siddiqui 2001). A 30m ASTER DEM was used for correcting for relief distortions. The ASTER DEM was used because of its high accuracy in representing elevation and it gives a 30m resolution (Global Land Cover Facility (GLCF) and Japan ASTER Program 2003 & Japan ASTER Program 2003). Finally resampling was done through weighted avarages of four nearest cells (Pauw 2012).

Several GIS datasets (shapefiles) were obtained from various organisations (Table 3.4). The shapefiles included rivers, roads, wards, wetland vegetation, districts and towns. These shapefiles were important for demarcating the study area and mapping the wetlands and areas occupied by sugarcane fields within the study area. All the shapefiles used in this study were re-projected to WGS 84, Lo 31coordinate system to avoid spatial errors due to inconsistencies in the mapping processes spatial characteristics (Madej 2001).

Table 3.3 Shapefiles that were used in the study and organisations that provided the shapefiles

Shapefiles	Source
Roads, rivers, towns, provinces	Department of Rural Development and Land Reform, Capetown
Wetlands boundaries, vegetation and types	Ezimvelo KZN Wildlife Conservancy and ILembe District Municipality

3.3.2 Water sampling

Fourteen water samples were collected at the depth of 300mm below the water surface of flowing water (Kebede et al. 2014; Shabalala, Combrink & Mc Crindle 2013). Eight of the samples were from Zinkwazi and six from Nonoti wetlands. Polythene bottles were washed with using acid and covered to prevent contact with air. These were used to collect the water samples. Water sample were differentiated by labelling them with coordinates where they had been sampled, date and time. The water samples were then sent to the laboratory in a cooler box to stop biological and chemical processes. Samples were analysed for nitrogen, phosphorus and potassium at b n Kirk (Natal) Water, Sewage and Industrial Effluent Testing Laboratory within 48 hours of collection. nitrogen, phosphorus and potassium were selected for analysis mainly because:

- The nutrients are applied as fertilisers for sugarcane growth. These are the primary nutrients for algae that lead to eutrophication (Van der Laan et al 2012).
- These macro elements are used for determining the water quality as well as the concentrations of nutrients that are within the river and can be used as indicators of water pollution.

3.3.3 Questionnaires

Kumar’s (2005) steps in data processing where used,these steps started with editing, followed by coding and finally developing a frame of analysis for the questionnaires. The returned questionnaires were first checked for errors and completeness and were coded after editing. Data coding is assigning variable attributes numbers to change them to a machine-readable format and prepare for statistical analysis (Kent 2001; Neuman 2011). Data coding is regarded to be invaluable and necessary for better interpretation of the results (Neuman 2011). Data coding in this study involved condensing the data into analysable groups using Statistical Package for Social Science (SPSS) through the creation of categories derived from the questionnaires (Lockyer 2004). Questions were selected to be the main headings whilst categories were the subheadings. Responses for every farmer were recorded under the headings formulated from the questionnaire. Responses were analysed individually and collectively to come up with meaningful conclusive results and discussions (Lockyer 2004).

3.4 DATA ANALYSIS

Following the processing of the data collected, data was analysed to draw meaning and conclusion and come up with recommendations to reduce wetland loss in the study area. Techniques used for data analysis in addressing to inform the objectives of the study are explained in this section.

3.4.1 Aerial photographs

After pre-processing the collected data, which included wetland shapefiles for Zinkwazi and Nonoti were overlaid with the orthorectified photographs for 1959, 1989, 2000 and 2012 years respectively. Sugarcane field portions that had encroached into the wetlands for each year were digitized on screen and combined into one polygon for each year to derive changes in wetland extent (sugarcane fields encroachment into wetlands) maps for the four different years. Consequently, the area occupied by sugarcane fields for each year was geometrically calculated in ArcGIS 10.1 (ESRI 2010). This process was followed for each of the aerial photographs used in this study to derive the area occupied by sugarcane fields at that specific time.

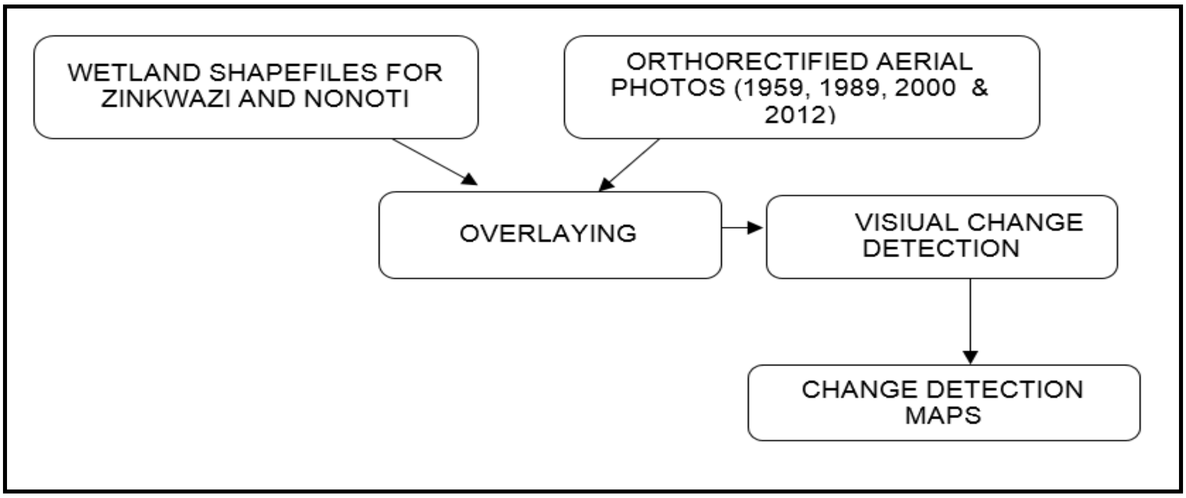


Figure 3.4 Schema for the steps that were taken in order to determine sugarcane fields' encroachment into wetlands using aerial photography.

The next step was to see if there were any significant differences in the area occupied by fields for the different periods. In this regard, the hypothesis was that an increase in sugarcane field extent suggests a reduction in the wetlands. On the other hand, a reduction in the sugarcane field extent indicates abandonment of fields, temporary or long-term due to low productivity of the wetlands.

3.4.2 Water quality

The collected water samples were analysed to ascertain whether sugarcane farming in KwaDukuza significantly contributes to an increase in N, P and K in water sources within the wetlands. The DR 2800 Hach Spectrophotometer was used to analyse the samples in the laboratory. Nitrate, nitrite and ammonia were analysed using the Hach Spectrophotometer methods 375, 353 and 371, respectively. Phosphorus and potassium were analysed using Hach Spectrophotometer method 536 and 905, respectively. See Appendix B for Zinkwazi wetland and Appendix C for Nonoti wetland water analysis results.

Nitrogen, phosphorus and potassium levels were then compared to the South African water quality guidelines for aquatic ecosystem (South Africa 1996). Water quality analyses were achieved through assessing certain parameters of water properties such as composition concentration of polluting substances (Nikanorov & Brazhnikov 2011; South Africa 1996). These were grouped into a harmful index and can be referred to as the standard guidelines. Every country has its own standard guidelines. The South African water quality guidelines for aquatic ecosystem were derived by using sensitive species representatives of important trophic groups occurring in aquatic ecosystems. This was done with the idea that protecting the most sensitive species within the ecosystem would ultimately protect all the species. The South African water quality guidelines for aquatic ecosystem consist of the Chronic effect value (CEV), Acute Effect Value (AEV) and the Target Water Quality Range (TWQR) (South Africa 1996). For this study, the identified constituents were compared to the South Africa aquatic ecosystem quality guidelines specifically to the TWQR (Table 3.5). The TWQR is used as an important measure to managed and maintain the integrity of different ecosystems (South Africa 1996).

Table 3.4 South African water quality guidelines for Aquatic Ecosystems for the three variables used for the study (N, P, K)

Variable	**Target water quality range range(mg/l)**
Ammonia	0.0-0.6
Nitrite	0.0-0.6
Nitrate	0.0-1.0
Phosphorus	<5
Potassium	N/A

Source: South Africa (1996)

The South African water quality guidelines for aquatic ecosystem were used in this case because wetlands are regarded as part of the aquatic ecosystems. The other reason for using the guidelines was that they are the only yardstick to determine whether sugarcane is polluting the water of and the adjacent wetlands and to what extent.

3.4.3 Questionnaires

Coded data that included questionnaires and responses were entered into Statistical Package for the Social Science (SPSS) data sheet. Descriptive statistics were calculated on independent variables to summarize the gathered data since most of the data was nominal. The data were analysed in terms of the two different categories of farmers, which are the commercial and the small-scale. It was also analysed according to the farming regions: Zinkwazi Region and Nonoti Region. This was done to compare the perceptions of these farmers by type and location. Graphs cross tabulations and pie charts were used to analyse and represent the data.

3.5 ETHICAL CONSIDERATIONS

Ethics are important to consider when one is dealing with research involving people because research can lead to the manipulation of people's behaviour and attitudes (Mouton 2001). Secondly, it is a requirement of Stellenbosch University that a researcher submits the questionnaire to the Departmental Ethics screening committee for review before engaging in the research; see (Appendix D). Obtaining informed consent was an important component of this study. Hence, the farmers were first informed about the nature of the research before participating. Participants were not forced to take part in the research and were constantly reminded that their participation in the research was voluntary. They were given informed consent forms to complete before they responded to the questionnaires (Appendix A). Confidentiality and anonymity was promised. They were left with a copy of the ethical form and the researcher's contact number as well as the departmental number in case they needed clarification on some issues. Codes were used to keep confidentiality and no names would be linked to the study. It was explained to them that the research was for academic purposes.

The researcher was also guided by moral principles in collecting water samples from the Zinkwazi and Nonoti rivers. To get samples from Zinkwazi and Nonoti Rivers the researcher had to get permission from the ILembe Department of Water Affairs to carry on with the research. Water samples were only collected after getting the permission was granted.

3.6 EXPERIMENTAL DESIGN

The experimental design for the study is illustrated in Figure 3.5. What is significant about the methodology used for this study is that it brings together three different approaches (aerial photographs, water quality and questionnaires). These three approaches covered the gaps that each cannot cover independently.

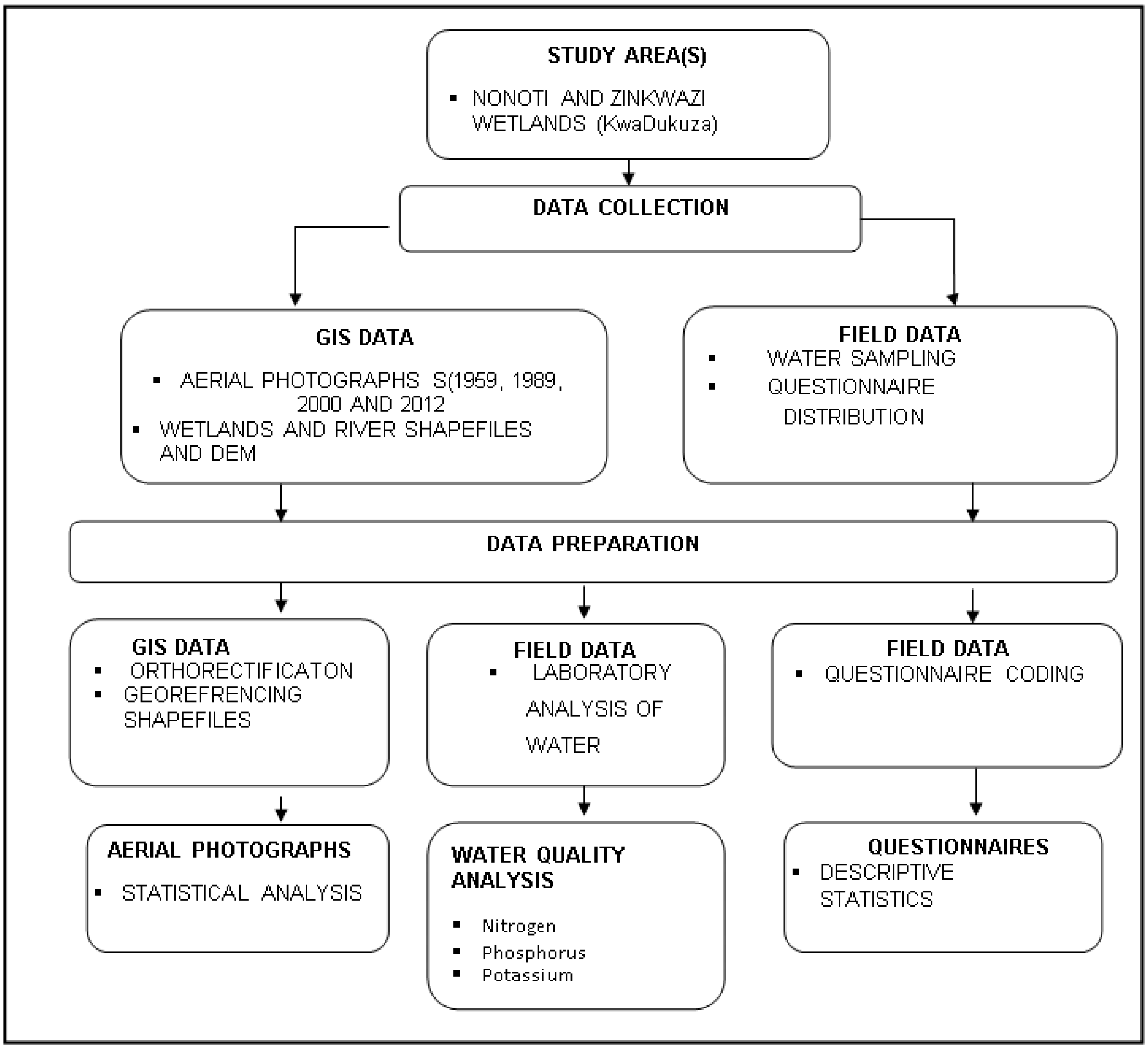


Figure 3.5 A schema of the methods used to obtain the results of the study by analysing aerial photography, water sampling and questionnaires

This chapter discussed the methods used to understand the impacts of sugarcane farming on coastal wetlands. As indicated earlier on the quantitative research design was employed to generate data that answers the objectives of the study. In the next chapter results obtained using methods described herein are presented and discussed.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 OVERVIEW OF RESULTS

Chapter 4 describes the results of the analysis of the data collected followed by discussion of the findings. Data were collected and processed through the methodology explained in Chapter 3 in response to the problem established in the study. The main aim is to determine the impacts of sugarcane farming in coastal wetlands. Results of the study are systematically detailed and linked to the results of the aerial photographs, water quality and questionnaire analysis. The first section deals with the impacts of sugarcane farming on the wetland extent. The second section deals with impacts of sugarcane farming on water quality. Finally, results of farmers' assumptions on the impacts of sugarcane farming are presented and discussed.

4.2 CHANGES IN WETLAND SPATIAL EXTENT (1959 TO 2012)

4.2.1 Zinkwazi wetland

Total area occupied by wetlands in Zinkwazi derived from the KwaZulu-Natal wetland shapefile (2011) obtained from Ezimvelo KZN Wildlife. The area occupied by the wetlands was 250.41 ha. Results of the aerial photographs analysis show that the spatial extent of sugarcane fields that encroached into wetlands has fluctuated over the 53 years under consideration. It has to be noted that since the sugarcane fields are within wetlands, an increase in sugarcane fields directly results in the reduction of wetland size. Sugarcane fields were characterized by an increase in extent from 1959 to 1989 and a decrease between 1989 and 2012 as shown in Figure 4.1.

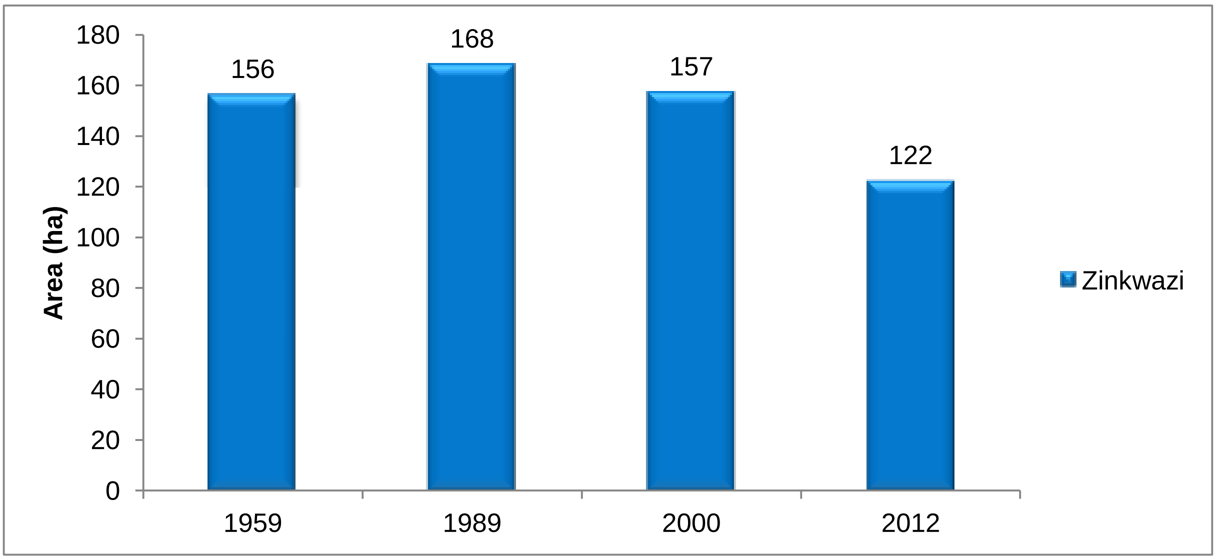


Figure 4.1 Changes in sugarcane field extent expressed in ha for Zinkwazi wetland for the period 1959 to 2012

Specifically, it can be observed that in 1959, sugarcane fields occupied an area of 156 ha in Zinkwazi, which translates to 62.3% of the wetland area and in 1989, the area under sugarcane increased to 67% (Figure 4.2). The area under sugarcane in Zinkwazi then decreased from 168 ha in 1989 to 157 ha in 2000 shown in Figure 4.2C, with a decline of 4.3% of the sugarcane fields within the wetland area. The area occupied by sugarcane fields further declined to 122 ha in 2012, (Figure 4.2 D) indicating a 14% decrease in the area under sugarcane fields.see

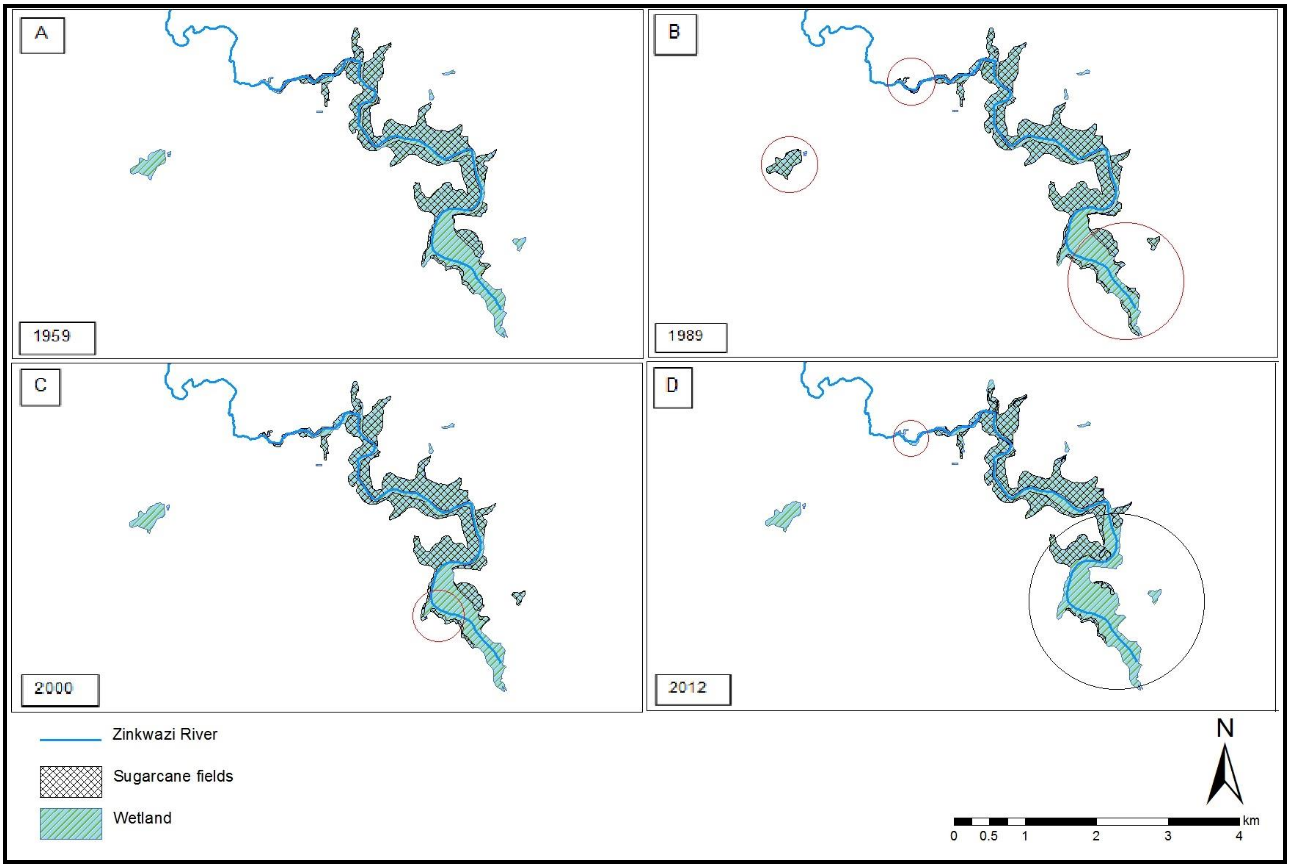


Figure 4.2 Changes in the extent of sugarcane fields in Zinkwazi between 1959 and 2012. Areas marked with red circles show wetland portions where sugarcane significantly increased and black circles show where sugarcane fields significantly decreased between 1959 and 2012.

4.2.2 Nonoti

Nonoti wetlands is 193.19 ha and was geometrically calculated from the 2011 wetland shapefile obtained from Ezimvelo KZN Wildlife Conservency. It is also observed that in Nonoti extent of sugarcane impact on wetlands fluctuated from 1959 to 1989. In 1959, sugarcane fields occupied 98 ha, which corresponds to 50.7% of the total wetland area (as shown in Figure 4.4 A). Sugarcane fields decreased by six ha between 1959 and 1989 (see Figures 4.4A and 4.4B).

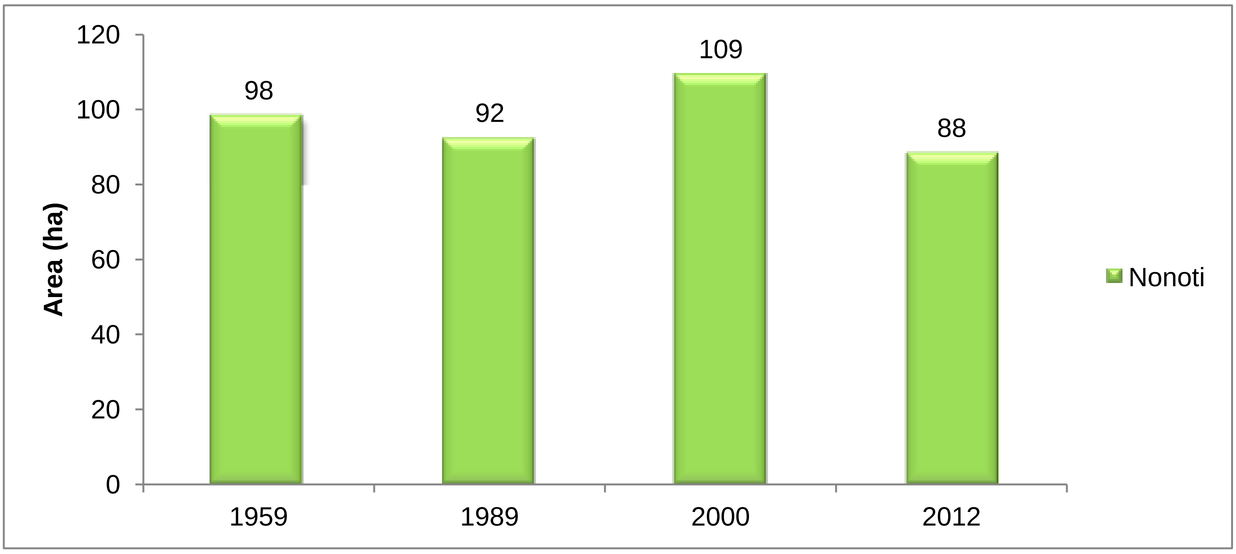


Figure 4.3 Changes in sugarcane field extent expressed in ha for Nonoti wetland for the period 1959 to 2012

In contrast, the period between 1989 and 2000 wetlands experienced an increase in aerial extent of sugarcane fields of 17 ha. During this period, sugarcane fields occupied approximately 56.4% of the total wetlands area. The period 2000 to 2012 is characterized by a 10% decrease in sugar cane fields. The increase in the spatial extent of sugarcane fields within the wetlands during the period 1959 to 1989 is greater compared with the period 1989 to 2000. Overall, the change within the wetlands is a decrease in the spatial extent of wetlands.

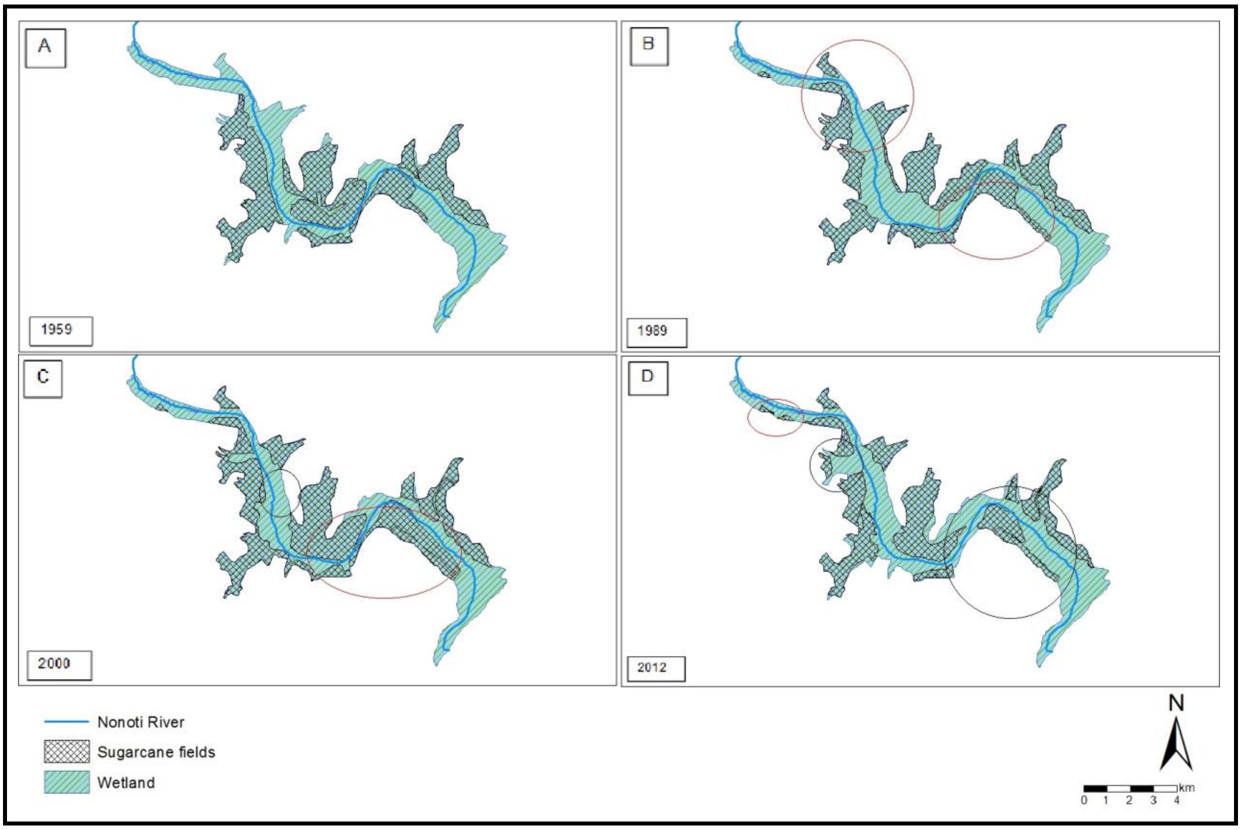


Figure 4.4 Changes in sugarcane fields extent in Zinkwazi using aerial photographs 1959, 1989, 2000 and 2012. Areas marked in red circles show wetland portions where sugarcane significantly increased and black circles show where sugarcane fields significantly decreased between 1959 and 2012.

4.2.3 Comparison of Zinkwazi and Nonoti changes in spatial extent

Results of Zinkwazi wetland (Figure 4.1) indicated a decrease of sugarcane field extent from 1959 to 2012 whilst Nonoti wetland results (Figure 4.3) showed fluctuations over the years. Both Zinkwazi and Nonoti results confirmed an increase between 1959 and 2000 and a decrease between 2000 and 2012 with Zinkwazi showing the higher percentage of decrease.

4.2.4 Discussion

In assessing the impacts of sugarcane farming on the spatial extent of the wetlands, results of this study revealed that there was a general increase in sugarcane fields between 1959 and 2000 that coincided with decrease in wetland extent between 2000 and 2012 in Zinkwazi wetland. According to Lewis (1990), sugarcane farming was still in its initial stages during 1959. This expansion of sugarcane fields into the wetlands observed in Zinkwazi can be explained by the fact that in South Africa, during that period, priority in the process of allocating land was given to sugarcane farming (Lewis 1990; Phillips 2013). The Zinkwazi wetland might have been one of the areas that was being expanded during that time. In addition, farmers were given incentives other than land that promoted sugarcane farming compared to other cash crops (Williams 1991; Fuggle & Rabie 2009). This in turn led to more land being cleared and some sugarcane fields encroaching into wetlands thereby increasing the area occupied by sugarcane fields in the wetlands.

Nonoti sugarcane fields fluctuated during the period under consideration. There was a decrease between 1959 and 1989 with an increase between 1989 and 2000. (See Figure 4.3). These patterns especially the period between 1989 and 2000 can be explained by the fact that, in 1995 the South African government and the South African sugar industry initiated the land reform programme that was aimed at redistributing at least 30% of land to the black farmers (Baiyegunhi & Arnold 2011). This initiative again resulted in an increase of the area occupied by sugarcane fields in the wetlands accommodating the new farmers (DAFF 2006). In a related study, Namaalwa et al. (2013) demonstrated that in the Namatala wetland in Eastern Uganda during the 1990s, small-scale farmland occupied the largest part of the wetland (44%) and it expanded to 62% of the area in 2005. This was attributed to the need for more agricultural land. Their results show a similar trend to the results of the present study. Similarly, Bayley, Wong & Thompson (2013) noted that agricultural activities were responsible for the reduction in the area covered by wetlands and shallow lakes in the Boreal Transition Zone of Canada.

In contrast, the area occupied by sugarcane fields in wetlands exhibited a gradual decrease in both Nonoti and Zinkwazi wetlands from 2000 to 2012 (shown in Figure 4.1 and 4.2). This decrease for land occupied by sugarcane fields can be explained by the rapid urban and infrastructural development along the coast during the year 2000 (AFF 2006; Phillips 2013). From 2000 onwards, many farmers sold their sugarcane farms to land developers drastically reducing the amount of land occupied by sugarcane fields within the wetlands. Currently, the Zinkwazi town, for example is expanding into former sugarcane farms, whilst in Nonoti there is a portion that was sold and allocated for expanding Rural Development Programme houses by the government.

In addition, high economic drivers could also explain the gradual decrease in the area occupied by sugarcane in Nonoti and Zinkwazi wetlands from 2000 to 2012. Similarly, Baiyegunhi & Arnold (2011) noted that the running costs of sugarcane farms have gone up since 2003 whilst the sugarcane prices remained stagnant on the world market. Specifically, the prices of the farm inputs such as fertilisers, machinery and implements increased by up to 45% (Baiyegunhi & Arnold 2011; Singels et al. 2011; Hurly 2013) such that developing land into residential areas was deemed more profitable than sugarcane farming. In some cases, sugarcane farming has been replaced by some other agricultural activities such as animal husbandry. However, urban expansion is the major cause that has limited sugarcane farming expansion into the wetlands and this is the case with South Africa, KwaZulu-Natal (Phillips 2013). Namaalwa et al. (2013) noted that the Namatala wetland in Eastern Uganda also had a gradual decreases of small scale agricultural land which was converted into commercial farmland.

Another possible driver of the reduction in sugarcane fields around 2012 is the drought that occurred between the period of 2010 and 2011 (Sibiya & Hurly 2011; Phillips 2013). Considering the fact that most of the sugarcane crops in the KwaDukuza municipal area are rainfed, the meagre rainfall could have affected water levels in some cases leaving the soils deficit of water for sugarcane supply (Phillips 2013). Sugarcane plants are dependent on water, more than other crops, and farmers could have abandoned portions of their fields due to the effects of droughts.

Moreover, there were no legal instruments and environmental impact assessments conducted to protect wetland resources when sugarcane farming started (Fuggle & Rabie 2009). In contrast, some policies promoted draining of wetlands for farming (Williams 1991; Kotze, Breen & Quinn 1995; Fuggle & Rabie 2009; Chakupa 2011) and this may explain the intensity of sugarcane field encroachment into wetlands between 1959 and 1989 for Zinkwazi which is illustrated by the results of this study. Legal instruments that protect the environment including wetlands were effected in the late 1990s specifically, the National Environmental Management Act 107, enacted in 1998, advocates for a thorough environmental impact assessment of proposed activities before they are carried out in wetlands (South Africa 1998). However, results of the study illustrated that few farmers were aware of the various forms of legislation that related to the protection of the environment and the majority of the farmers are still draining wetlands, cultivating closer to riverbanks and pumping irrigation water (Sibiya & Hurly 2011). Previously, the sugar industry did not incorporate environmental issues in their farming activities, as they perceived that their farming activities did not cause significant negative environmental impacts (Benn 2013). Considering the fact that the sugarcane industry was in denial of the impacts it pose to the environment, the farmers were not fully informed of the threats their activities had to the wetlands (Benn 2013). Therefore, the disregard of environmental issues by the sugar industry explains why Nonoti and Zinkwazi farmers were unaware of the threats posed by agricultural activities in the wetlands in the study.

It is only recently that the industry realised its adverse impacts and the threats that it poses not only to wetland, but also to the environment in general (Hurly 2013; Kebede et al. 2014). Considering the negative environmental impacts of sugarcane farming, the industry initiated joint programs with different government departments and some non-governmental organisations to train farmers on sustainable sugarcane farming. This saw the implementation of some programs such as the 2008

Phakamisa Project that aimed to educate and assist small-scale farmers in the Zululand area on sustainable management of their farms (Sibiya & Hurly 2011). SUSFARMS (Sustainable Farms) is also another initiative that was initiated in 2008 to guide farmers in sustainable management of their farms and this tool was formulated in line with legislation that supported sustainable use of farms (Hurly 2013).

The introduction of these sustainable management programs resulted in some farmers improving the way they manage their farms, for example, avoiding the draining of wetlands, and protecting the small fragmented remnants of wetlands as well as reclaiming and conserving them (Sibiya & Hurly 2011). In Nonoti and Zinkwazi, few farmers, mostly commercial farmers have implemented sustainable management on their farms which has contributed to the reduction of sugarcane field extent to riverbanks and wetlands between 2000 and 2012. Similar studies identified the same changes in farmers' behaviour towards wetlands protection and the environment in general (Qongqo & Van Antwerpen 2000; Cheesman 2004; Cowden et al. 2014). However, in some cases farmers believe that these programs are only there to assist them in maximising their yields.

Although the rate of sugarcane encroachment into wetlands has reduced and farmers have improved their farming practices, it has to be noted that the rich wetlands are irreplaceable (Mesta et al. 2014). They cannot recover to their original status with high species richness and diversity. Additionally, balanced biochemical cycles as well as good purification services will not be replaced (Kotze, Breen & Quinn 1995; Cheesman 2004; Cowden et al. 2014). Literature shows that permanent loss of wetlands due to agricultural activities have been noted in many parts of the world (Wiles 2006; Netondo 2010; Thorburn et al. 2011; Turyahabwe et al. 2013). In cases where wetlands have been rehabilitated, they have failed to recover to their initial state, as new non-original species have been introduced (Cowden et al. 2014).

4.3 VARIATIONS IN WATER QUALITY FOR EACH MEASURED PARAMETER

This section presents results of water analysis for the Zinkwazi and Nonoti wetlands. Water quality results for Zinkwazi and Nonoti (ammonia, nitrate, nitrite, phosphorus and potassium) are presented in Table 4.1 and 4.2 respectively.

4.3.1 Zinkwazi

Results obtained in Zinkwazi are presented below and discussed.

4.3.1.1 Ammonia

Table 4.1 shows results of water sampling analyses in Zinkwazi wetland. The ammonia concentrations in Zinkwazi River increased from 0.02 mg/l at Station 1 (upstream) to 4.835 mg/l at Station 5 (middle stream). The ammonia concentration at Station 5 (middle stream) was eight times more than the highest concentration levels recommended by the South African water quality guidelines for aquatic ecosystems (range: 0.0-0.6mg/l; highest 06mg/l) (South Africa 1996). Results showed a sharp decrease of ammonia from station 6 to 8 downstream from 4.625 mg/l to 0.3 mg/l respectively.

4.3.1.2 Nitrate

The nitrate concentration level prescribed by the aquatic ecosystems standard guidelines of South Africa ranges from 0.0 1.0 mg/l (South Africa 1996). The nitrate concentration levels were above the standard guidelines except for Stations 1 with 0.22mg/1 located upstream and Station 8 (last station downstream), which had 0.4 mg/1. The highest concentration recorded was 6.95 mg/l, which is approximately seven times more than the recommended levels at Station 5 (middle stream).

Table 4.1 Upstream, middle stream and downstream water nutrient values of samples taken from Zinkwazi wetland (with highlighted values showing highest nutrient concentration)

Upstream Stations	**Ammonia mg/l**	**Nitrate mg/l**	**Nitrite mg/l**	**Phosphorus mg/l**	**Potassium mg/l**
Station 1	0.02	0.22	0.03	1.423	21
Station 2	1.24	3.22	0.44	1.5	47
Station 3	3.432	5.231	1.32	2.13	60
Middle stream Stations					
Station 4	3.82	5.67	3.56	4.325	61
Station 5	**4.835**	**6.95**	4.532	**6.35**	71
Downstream Stations					
Station 6	4.625	5.83	**4.86**	5.678	63
Station 7	1.346	4.22	0.46	2.567	54
Station 8	0.3	0.4	0.413	1.5	**85**
Acceptable values	0.0-0.6	0.0-1.0	0.0-0.6	<5	N/A

4.3.1.3 Nitrite

Nitrite concentrations increased from 0.03 mg/1 for station 1 (upstream) to 4.86 mg/l for Station 6 (downstream) Zinkwazi wetland. Stations 5 and 6 (middle and the downstream) the highest nitrite concentration levels of 4.53 mg/l and 4.86 mg/l respectively. Nitrite values were generally lower compared to ammonia and nitrate concentration levels. Nitrite acceptable values ranges from 0.0 to 0.6 mg/l and the highest recommended value is 0.6mg/l (South Africa 1996).

4.3.1.4 Phosphorus

Phosphorus concentration in Zinkwazi River increased from Station 1 (upstream) (1.423 mg/l) to Station 5 (6.35 mg/l) ;(middle stream) and then decreased to Station 8 (1.5 mg/l) (downstream). Station 5 and 6 also (middle to downstream sections) recorded 6.5 mg/l and 5.68 mg/1, respectively. Only these two sites had phosphorous concentrations above the acceptable level of less than 5 mg/l (South Africa 1996).

4.3.1.5 Potassium

Potassium concentrations in the Zinkwazi wetland exhibited a progressive increase from 21 mg/l at station 1 upstream to 71 mg/l at Station 5 (middle stream). However, the concentration decreased at station 6 (63 mg/l) and decreased further at Station 7 (54 mg/l). Conversely, Station 8 in the downstream had the highest concentration (85 mg/l). However, there are no standard values to gauge whether Pottasium is higher or low within the South African Water Quality Standard guidelines for aquatic water systems.

4.3.2 Nonoti

Results for nitrate, nitrite, ammonia, phosphorus and potassium obtained in Nonoti wetland were analysed and results of the analysis are presented in the section below.

4.3.2.1 Ammonia

The ammonia concentrations increased from 0.16 mg/l at Station 1 (upstream) to 2.8 mg/l at Station 3 (middle stream). The middle stream section of the Nonoti wetland exhibited the highest ammonia concentrations of 2.8 mg/l and 2.3 mg/l for Stations 3 and 4 respectively. These two stations exceeded the recommended range of 0.0-0.6 mg/l and the highest value (0.6mg/l) (South Africa 1996). Furthermore, a sharp decrease from the middle stream to downstream, that is from Station 4, to Station 6 was observed (2.3 mg\l to 0.38 mg/l). The rest of the stations along the wetland had ammonia concentration levels that met the standard (0.0-0.6 mg/l) (South Africa 1996).

4.3.2.2 Nitrate

Nitrate concentration in Nonoti wetland increased from 0.2 mg/l at Station 1 (upstream) to a peak of 19 mg/l at station 3 in the (middle stream). The nitrate concentrations then dropped to 7.2 gm/l at Station 4, 0.5 mg/l at Station 5 and 0.11 mg/l at Station 6. The values recorded for the middle stream where above the standard guideline of South Africa (1 mg/l) (South Africa 1996).

4.3.2.3 Nitrite

Nitrite concentrations were lower and within the water quality standard guidelines (range: 0.0-0.6mg/l) in Nonoti wetland ranging from 0.03 mg/l at Station 1 (upstream) and peaked up to 0.25 mg/l at Station 4 (middle section) and dropped again to a 0.03 mg/l at Station 6 (downstream). Nitrite concentrations in Nonoti wetland were within the standard/ recommended range of 0.0 to 0.6 mg/l as per the South African water quality standard guidelines for aquatic ecosystems (South Africa 1996).

Table 4.2 Upstream, middle stream and downstream water nutrient values of samples taken from Nonoti River (with highlighted values showing highest nutrient concentration)

Upstream Stations	**Ammonia mg/l**	**Nitrate mg/l**	**Nitrite mg/l**	**Phosphorus mg/l**	**Potassium mg/l**
Station 1	0.16	0.2	0.03	2.7	2.9
Station 2	0.58	0.6	0.03	2.1	7.2
Middle stream Stations					
Station 3	**2.8**	**19**	0.07	**6**	**37**
Station 4	2.3	7.2	**0.25**	2.9	5.8
Downstream Stations					
Station 5	0.38	0.5	0.03	2.5	9.9
Station 6	0.19	0.11	0.03	1.6	3.9
Acceptable values	0.0-0.6	0.0-1.0	0.0-0.6	<5	**N/A**

4.3.2.4 Phosphorus

Phosphorus concentration in Nonoti wetland at Stations 1, 2, 4, 5 and 6 met the South African standard guidelines (5 mg/l). However, Station 3 (middle stream) had a concentration level above the standard guidelines (South Africa 1996). Station 1 (upstream) recorded a higher value than Station 2 Stations 5 and 6 (downstream), whilst station 3 in the middle stream recorded the highest concentrations of phosphorus (6 mg/l). There was a decrease of phosphorus concentration from the middle stream station 4 to downstream Stations 5, from 2.9 mg/l to 2.5 mg/l, respectively. Station 6 recorded the lowest value of 1.6 mg/l, which was within the standard guidelines (range <5) (South Africa 1996).

4.3.2.5 Potassium

The concentrations of potassium ranged from 2.9 mg/l at Station 1 (upstream) to 37 mg/l at Station 3 (midstream). Potassium concentrations increased from Station 2 in the upper stream (2.9 mg/l) to 37 mg/l at Station 3 in the middle stream. Then a sharp decrease was recorded at station 4 (5.8mg/l). Station 5 downstream recorded a value that was higher than station 4 (9.9 mg/l) and there was a decrease from station 5 to 6 (3.9 mg/l). There are no recommended values for potassium.

4.3.3 Comparison of Zinkwazi and Nonoti water quality

4.3.3.1 Ammonia

Generally, the ammonia concentration levels in the Zinkwazi wetland were higher than in Nonoti wetland, levels were higher at the middle stream but lower downstream. Four station in Zinkwazi (Stations 3, 4, 5 and 6) recorded higher values than the high Nonoti's highest recorded value which was recorded on Station 3.

4.3.3.2 Nitrate

Zinkwazi wetland recorded lower nitrate values as compared to Nonoti wetland. Although Nonoti wetland had higher concentrations of nitrate at two stations, Zinkwazi wetland five stations that were above the recommended guidelines of South Africa whilst Nonoti wetland had two stations that were above the standard guidelines. Zinkwazi and Nonoti wetlands had different values, however, the two wetlands had the similar pattern whereby nitrate levels increased from upstream to middle stream and then decreased from the middle stream to downstream.

4.3.3.3 Nitrite

The general trend in the levels of the nitrite concentration was the same for Zinkwazi and Nonoti. In addition, concentration levels of nitrite in Zinkwazi wetland were above the recommended thresholds, whilst all nitrite concentration levels in Nonoti wetland were within the standard guidelines (South Africa 1996).

4.3.3.4 Phosphorus

Generally phosphorous levels in Zinkwazi and Nonoti wetlands were lower (upstream) and higher (midstream). The two wetlands exhibited the same patterns with lower levels of phosphorous upstream, high levels at the middle part and lower levels again downstream. Zinkwazi had two stations, one in the middle stream and the other one downstream that were above the recommended standard, guidelines (range: <5) whilst Nonoti had only one station in the middle stream that recorded a value above threshold.

4.3.3.5 Potassium

Potassium concentrations differed in Zinkwazi and Nonoti. Zinkwazi had much higher levels of potassium compared to Nonoti. Five stations in Nonoti recorded values less than 10 mg/l while none of the values in Zinkwazi was below 10 mg/l. Potassium levels in Zinkwazi wetland increased from first station upstream through to the middle stream (Station 5), then dropped and peaked at Station 8. Nonoti did not show this trend, amount of potassium varied from upstream to downstream, there was a sharp peak at Station 3 and a major drop at Station 4 and another peak at Station 5 and finally a decrease at Station 6.

Generally, it was noted that the potassium values of both Zinkwazi and Nonoti wetland were higher than ammonia, nitrate, nitrite and phosphorus. Nitrite recorded less than all the other nutrients and was generally within the recommended standard guidelines (range 0.0-0.6 mg/l).

4.4 Discussion

4.4.1 Ammonia

Ammonia concentrations ranged between 0.02 mg/l to 4.8 mg/l in Zinkwazi. The high values recorded (station 2 to 6 station) above the recommended guidelines could be an indication of pollution in Zinkwazi wetland. There is a source of pollution that is emanating from somewhere within the Zinkwazi wetland and sugarcane is the main land use activity within the wetland. This suggests that sugarcane can be polluting the wetland especially at middle stream.

A similar pattern was noted in Nonoti Concentrations increased at the middle stream for example at Station 3. Downstream the values were lower, however, it can be noted that although the values decreased downstream they did not go below the initial values that were recorded at Station 1 and Station 2.

Zinkwazi wetland indicated a higher pollution level as can be noted by values from Station 2 through to Station 6, which were above the standard guidelines Nonoti wetland had only stations 3 and 4 above the standard guidelines (South Africa 1996). Ammonia values in Zinkwazi were higher as compared to those recorded in Nonoti. Zinkwazi is more polluted, and this can be explained by the proximity of the farms to the water sources. It was observed through field observations that sugarcane fields in Zinkwazi were much closer to the river as compared to those in Nonoti. Hence, this closeness facilitates easy movement of ammonia into water systems and increases the nutrient levels in the rivers (Reddy & DeLaune 2008).

Levels increased at the middle part of the river. Ammonia in both Zinkwazi and Nonoti increased up to the middle stream and started decreasing up to downstream. In some cases, ammonia concentrations were high above normal values of values of standard guidelines. An increased concentration of ammonia can be explained by the use of ammonia fertilisers. Ammonia fertilises increases the amount of ammonia in the soil and ground water. When the sugarcane is harvested, the soils containing higher amounts of ammonia are eroded into water sources leading to an elevation of ammonia within the water sources (Omwoma et al. 2012). As the ammonia, moves down the wetlands from the middle stream it is diluted such that when it reaches downstream the levels are lower as compared to those in the middle of the stream.

4.4.2 Nitrite

Nitrite levels in Zinkwazi wetland were above the standard guidelines (South Africa 1996) from Station 3 to Station 6. Results of this study indicated that there was a similar pattern between the levels of ammonia and nitrite in Zinkwazi wetland. Nitrite was higher where ammonia was higher as well. Nitrate values were higher where ammonia levels were higher as well. Nitrate values were identified on two stations (stations 5 and 6). This can indicate levels of pollution.

In Nonoti, nitrite levels were lower and all 6 stations were within the water quality standard guidelines for aquatic ecosystems (South Africa 1996). Results of the study confirmed that nitrite increased where ammonia increased and decreased respectively, there was a correlation between ammonia and nitrite.

Nitrite concentrations in Zinkwazi were higher than those recorded in Nonoti. This difference in the two wetlands can be explained by proximity to the water sources. Farmers in Nonoti have their farms further from the water sources. Another possible explanation can be that there are some patches of vegetation that were observed in Nonoti during field work which could be utilising some of the nitrite hence lower quantities in Nonoti as compared to Zinkwazi. Zinkwazi had more farmers as compared to Nonoti. More farmers are expected to increase fertiliser application and thus pollution.

The reason why nitrite levels were different between the upper stream, middle stream and lower stream could be explained by accumulation of nutrients from upstream to the middle stream. As the nutrient progresses from the middle stream to downstream dilution occurs. Another reason for the difference could be that wetland capacity to utilise nutrients could be impaired by high nutrient deposition and accumulation. According to Sikdar (2007), plants and microbial uptake remove phosphorus in wetlands during the start-up phase, however, as it progresses there is less net removal through uptake especially when the wetland is has been impaired. This could explain the high levels at the middle stream.

Zinkwazi had high amounts of nitrite as compared to Nonoti and nitrite levels in both rivers were lower than ammonia and nitrate. This lower level of nitrites can be explained by the nature of nitrite. Nitrite is unstable and is easily reduced through biological processes within the wetlands or it becomes oxidized to nitrate when it enters the water systems (see Equation A).

Equation A

$$2\ NO_2^- + O_2 \rightarrow 2\ NO_3^-$$

According to Qongqo & Van Antwerpen (2000), only 18% of the nitrogen that is applied to crops as fertilisers is utilised by the plants and the remaining 82% is unused. It is stored in the soils where it accumulates and eventually ends up in surface waters or volatilizes into the atmosphere. This can be one of the reasons for the high nitrogen content in the middle stream.

4.4.3 Nitrate

Zinkwazi wetland indicated higher values of nitrates at Station 5 to Station 6 than those of Nonoti wetland. The values were above the standard guidelines and were located between the upper stream through the middle stream and one point was located downstream. It can be noted that nitrate values were higher than those of ammonia and nitrite being elevated where ammonia and nitrite increased.

Nonoti had two stations at the middle stream that were above the water quality guidelines. nitrate values were above the ammonia values at all stations except for Station 6. Furthermore, the nitrate values were higher than the nitrite values for all stations.

Although nitrate values in Zinkwazi and Nonoti differed in some aspects, they showed the same pattern, having high values above the recommended standard guidelines (South Africa 1996). Zinkwazi had more stations that had higher amounts as compared to Nonoti and the different vegetation cover within the two wetlands can explain higher levels of nitrite. Nonoti might have plants that utilise nitrite more readily as compared to Zinkwazi. Pollution recorded on the stations can be because of the reduced capacity filtration capacity of the wetlands.

This coupled with the use of ammonia fertilisers increase the amount of ammonia in the soil and ground water. When the sugarcane is harvested the soils containing higher amounts of ammonia which are eroded into water sources leading to an elevation of ammonia within the water sources. Therefore, the portions of the river that are closer to the water sources will contain a high value of ammonia as indicated by the middle portion of the rivers. Furthermore, as the ammonia flows into the river it is transformed into nitrate and nitrite through oxidation.

4.4.4 Phosphorus

The recommended standard guidelines for phosphorus are <5 mg/l and only Stations 5 and 6 exceeded the guidelines in Zinkwazi. Nonoti had Station 3 above the recommended value as well. Although phosphorus concentrations were higher in the middle points of both wetlands, phosphorus was mostly within the recommended standard guidelines on the other stations. Plants and microbial uptake remove phosphorus in wetlands during the start-up phase, however, as it progresses there is less net removal through uptake. According to Sikdar (2007), plants can only remove 6% of the phosphorus. This can explain the decreasing values of phosphorus from the middle stream to downstream with distance from upstream to downstream.

High levels of phosphorus have also been attributed to sugarcane farming. Meyer et al. (1998) found phosphorus to be a problem in water systems that are close to sugarcane fields in KwaZulu-Natal. Under natural conditions, phosphorus originates from upstream and is filtered by wetlands as it moves downstream and when it reaches rivers, levels will be lower. However as the phosphorus continues to move within the wetlands it continuously increases and when the wetland reaches its threshold it accumulates thus leading to high nutrient gradients. According to Cheesman (2004), phosphorus found in water can be an indication of how the soils within the wetlands are loaded. Cultivation is one reason for the reduced ability of the wetland to retain phosphorus. When land is cultivated, the vegetation or crops that were utilising it are removed and this leads to the phosphorus flowing into water system (Kadlec & Wallace 2009).

Total phosphorus load in this study was high at the middle of the river due to an intensive use of chemical fertilisers such as superphosphate. In other related studies, phosphorus was also reported to be higher specifically in sugarcane regions of KwaZulu-Natal (Meyer, Tucker & Wood 1997; Qongqo & Van Antwerpen 2000). Under natural conditions phosphorus, originates from the uplands are filtered by wetlands as it moves to lowlands, and diluted when it reaches rivers (Reddy & De Laune 2008). However, these natural conditions are altered by sugarcane farming. Farmers have applied fertilizers to sugarcane crops in most cases without prior understanding and in some cases due to not following the general application guidelines, thus applying excess nutrients, which are then flushed into the drainage system (Thorburn et al. 2011; Van der Laan et al. 2011; Hurly 2013; Benn 2013). A decrease in the level of phosphorus and the rest of the nutrients downstream can also be explained by the meandering of the river. It was observed during fieldwork that the both the Zinkwazi and Nonoti Rivers meandered and this meandering structure slowed down nutrient movement. Thus, nutrients would be trapped at the middle of the stream for longer periods and lesser quantities flow downstream.

4.4.5 Potassium

Potassium values were higher above other nutrients it increased with distance from upstream to downstream in Zinkwazi. This increase could be a result of high inputs from sugarcane farms coupled with the fact that potassium occurs in various mineral forms. Different plants take up excess potassium from different sources in wetlands, however, removal of original plant cover may affect the potassium cycle thus resulting in an increase in potassium amounts in water sources (Kadlec & Wallace 2009). Accelerated amounts of potassium may increase high osmotic activities within fresh waters that can affect various aquatic species (Kadlec & Wallace 2009).

Potassium has a very high mobility rate and cannot be easily transformed (Van der Laan et al. 2011). Another source of potassium can be saline water from the Indian Ocean and fresh water mixing downstream, where the wetlands gets closer to the sea and they are about 50 m apart. Since seawater contains a higher amount of potassium because of the basalts and calcium rich granites contained in seawater. The other reason for higher potassium can be a result of some in stream processes such as carbon metabolism, sedimentation, bacteria mediated species transformations and denitrification all of which can affect variations of nutrients forms within the wetland (Kadlec & Wallace 2009). It has to be noted that there are no South African aquatic standard guidelines for potassium.

In contrast to other nutrients, potassium had different values across space. The findings of the study showed that Nonoti had lower levels of potassium compared to Zinkwazi. Potassium in Zinkwazi increased with distance from upstream to station 7 downstream as shown in Table 4.1. This increase could be a result of high inputs from sugarcane farms and the wetlands as well as incapacity of the wetland to purify the high potassium influx, resulting in an increase from upstream to downstream especially in Zinkwazi. The wetlands cannot purify the high influx of potassium (Reddy & DeLaune 2008; Kadlec & Wallace 2009). This could have accounted for the increase in the downstream values as opposed to other nutrients (Van der Laan, Van Antwerpen & Briston 2012).

4.4.6 General trends of nitrogen, phosphorus and potassium

Higher levels of macronutrients (nitrogen, phosphorus and potassium) in the wetland waters of Zinkwazi and Nonoti indicate the loss of the wetland capacity to purify and reticulate water due to high turnover of these three macronutrients into the drainage system. According to Hammer & Bastian (1989), wetlands are critical in the regulation of nutrient levels by absorbing nutrients that are drained by water systems connected to wetlands but can reach a threshold beyond which they fail to purify and regulate the nutrients as shown by the results of this study. A number of studies have also demonstrated the effect of high nutrients from agricultural activities entering into the drainage system and exceeding the capability threshold of reticulation by wetlands (Reddy & DeLaune 2008; Kebede et al. 2014; Omwoma et al. 2012). High levels of nutrients in the water systems could be attributed to land clearance during harvesting and land preparation. During harvesting and land preparation, land is left bare without any crops and this increases the rate at which nutrients leach out of the soil. The leached nutrients will then easily flow to the water systems. (Reddy & DeLaune 2008; Omwoma et al. 2012). High levels of nutrients indicate pollution (Reddy & DeLaune 2008). In that regard, it was observed that levels of pollution in Nonoti were low as compared to those of Zinkwazi, however, the fact remains that sugarcane farming is polluting both wetlands remains.

4.5 FARMERS' PERCEPTION OF SUGARCANE FARMING IN WETLANDS

This section interrogates perspectives on the effects of farming in wetlands expressed by the Zinkwazi and Nonoti small-scale and commercial farmers. In particular, the activities the farmers undertake which negatively affect the wetlands were identified. In addition, farmers' views on wetland legislation and management are examined. The objective was to identify changes and the associated causes in the wetlands from the farmers' understanding of the wetlands and their management. Twenty-two farmers (Nonoti 13 and Zinkwazi 9) responded to the questions and these were described in Chapter 3 (Table 3.4).

4.5.1 Existing farming practice

This inquiry was initiated by asking respondents to identify activities which negatively affect wetlands (see Figure 4.5).The predominant answers for Zinkwazi were construction of water division structures (3 respondents) and cultivation closer to wetlands/water resources (two respondents). Surprisingly, the results indicated that there was no planting of alien species, draining of wetlands and impoundment in Zinkwazi.

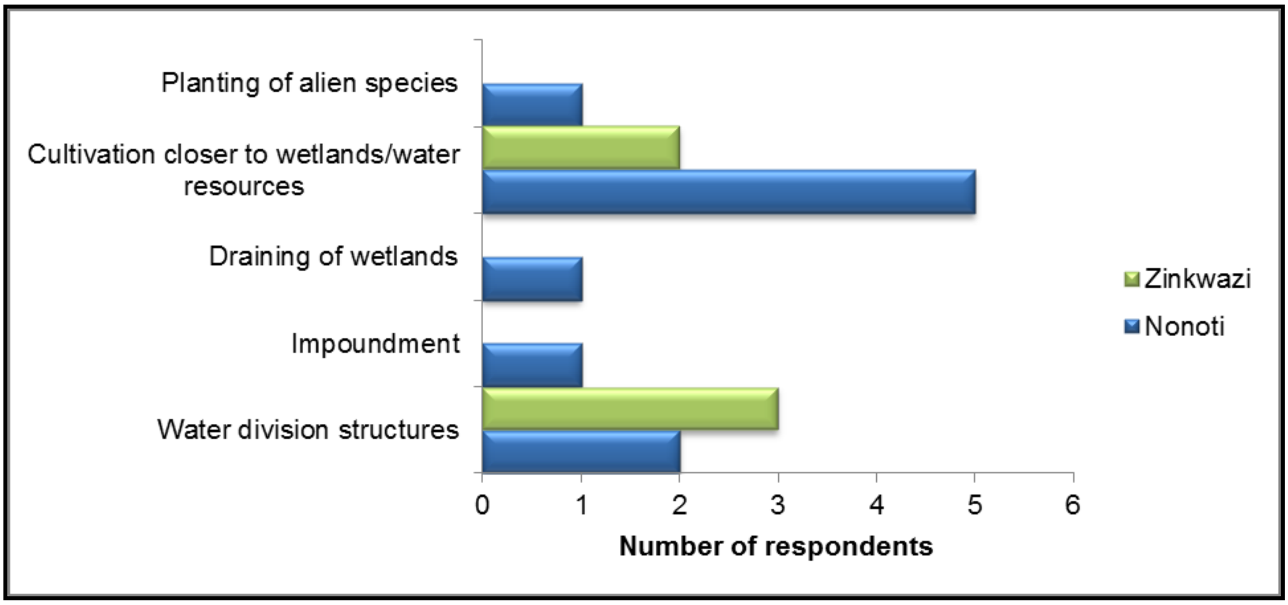


Figure 4.5 Responses to activities that farmers engage in that negatively affect wetlands in Zinkwazi and Nonoti wetlands.

The most common answers from respondents in the Nonoti wetland were cultivation closer to wetlands/water resources (five respondents) and construction of water division structures (two respondents). Planting alien species and draining wetlands were very common in the Nonoti area. Nevertheless, the responses about activities affecting wetlands are not different between Zinkwazi and Nonoti.

Consequently, respondents were asked why they conducted those tasks which negatively affect wetlands (see Figure 4.6). Five respondents from Zinkwazi wetland indicated the need for farming land as the main reason for engaging in activities which negatively affected wetlands. Two respondents identified lack of options as the reason why they engaged in activities that affected wetlands.

Seven respondents in Nonoti indicated the need for farming land. Four farmers in Nonoti indicated that they do not have other options. In each of the areas, two farmers indicated that they engaged in the activities that negatively affected wetlands because they were the cheapest means.

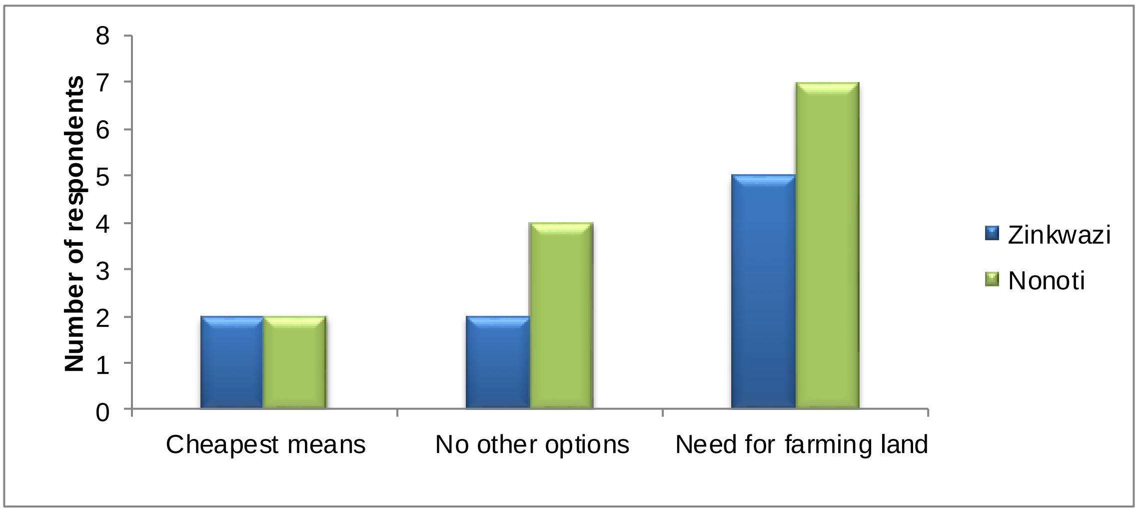


Figure 4.6 Reasons why farmers engaged in activities that affect wetlands.

The responses to this question were similar for both groups of farmers. They engaged in activities that affected the wetlands because of the need for farming land. However, they differed in that farmers in Nonoti considered lack of options as the second highest push factor as compared to Zinkwazi respondents who considered ‘cheapest means’ as their second highest reason. Overally farmers were in need for farming land, to support this, one farmer in Nonoti said:

> "My main aim is to farm, so I am mainly concerned about farmland and I end up cutting down trees and draining the wetlands because that's the only option I have, this however eventually leads to these wetlands being lost".

The response is a clear indication that the farmers are more concerned with farmland and do not care much what happens to the wetlands.

Having identified the perceived reasons for engaging in activities that degrade the wetlands, respondents were asked to identify the indicators of degraded wetlands within or in the surroundings of their farm. Respondents in Zinkwazi identified reduced productivity (five) and habitat loss (three) as the major indicators of wetland losses (Figure 4.7). The least perceived indication of wetland degradation was open lands and others. It has to be noted that not all farmers responded to the question.

A large number of respondents in Nonoti identified soil erosion (four), reduced productivity (three) and drainage channels (3) as the dominant features indicating degradation within the wetlands (see Figure 4.7). The respondents from both Zinkwazi and Nonoti did not indicate open lands as signs of degraded wetlands.

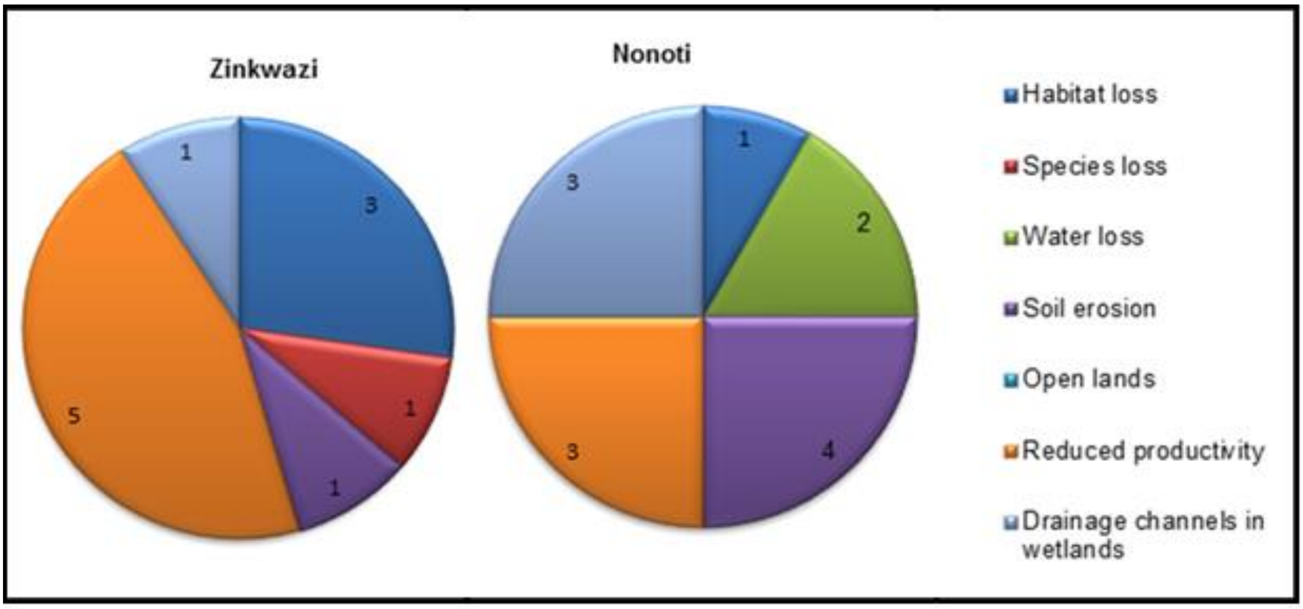


Figure 4.7 Signs/features that farmers perceived to indicate degraded wetlands within their farms or surroundings.

Respondents were also asked if they practice any restoration and reclamation of disturbed wetlands. Based on the results, commercial farmers are actively engaged in restoration and reclamation of wetlands and in Zinkwazi six commercial farmers and one small-scale farmer respondent that they practised restoration and reclamation (Figure 4.8). In Zinkwazi, farmers cited expense, lack of knowledge and limited labour force as the limiting factors in conserving the wetlands. Commercial farmers also indicated that expenses involved in reclamation was a challenge to them (Figure 4.9). It has to be noted that the question was a multi response question.

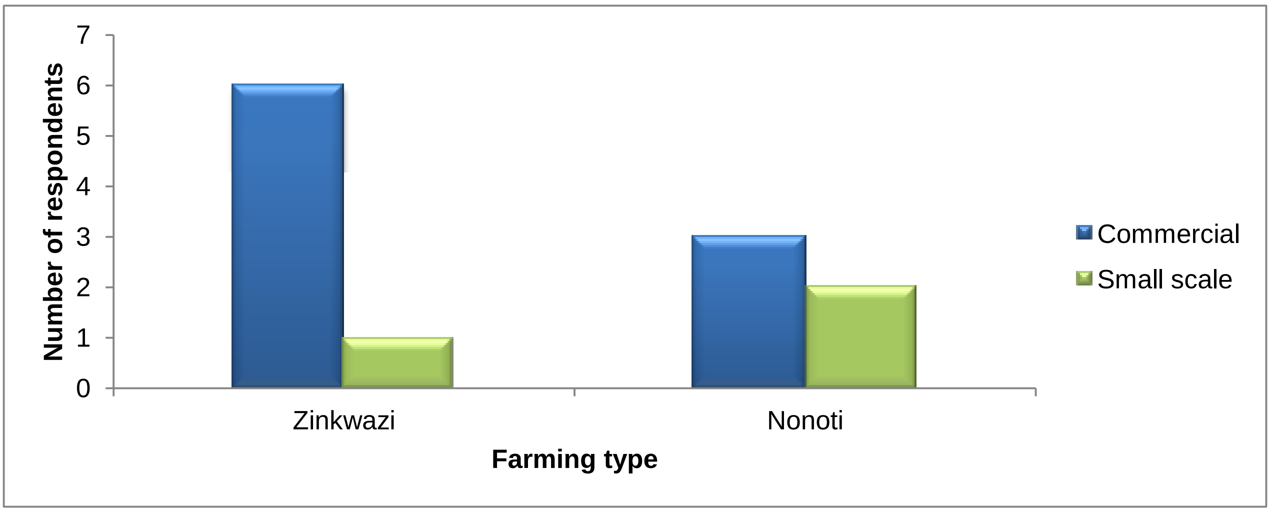


Figure 4.8 Farmers responses to whether they practised restoration and reclamation of wetlands within their farms

In Nonoti, more commercial farmers (three) than small-scale farmers responded that they practised restoration and reclamation. The farmers also indicated the reason why they did not practice restoration and reclamation. Commercial farmers were mainly limited by expenses involved in sugarcane farming whilst the small-scale farmers struggle with a myriad of problems such as the costs, labour force, and lack of knowledge. Small-scale farmers also indicated that they did not see any reason to practice restoration and reclamation because it was not mandatory (Figure 4.9).

Results of this study indicate that expenses involved in restoration and reclamation are the main cause of lack of interest in conserving the wetlands. A small-scale farmer in the Nonoti area pointed that: “Profit margin has been reducing over the years and if you focus on conserving you will fail to feed your family at the end of the day”. This was similar to what another commercial-scale farmer in Zinkwazi said: “You can only manage a small wetland portion in your farm, if you try to conserve all of them, then you are left with nothing for the family”. From the responses, it can be concluded that for these farmers, reclamation is deemed expensive (Figure 4.9).

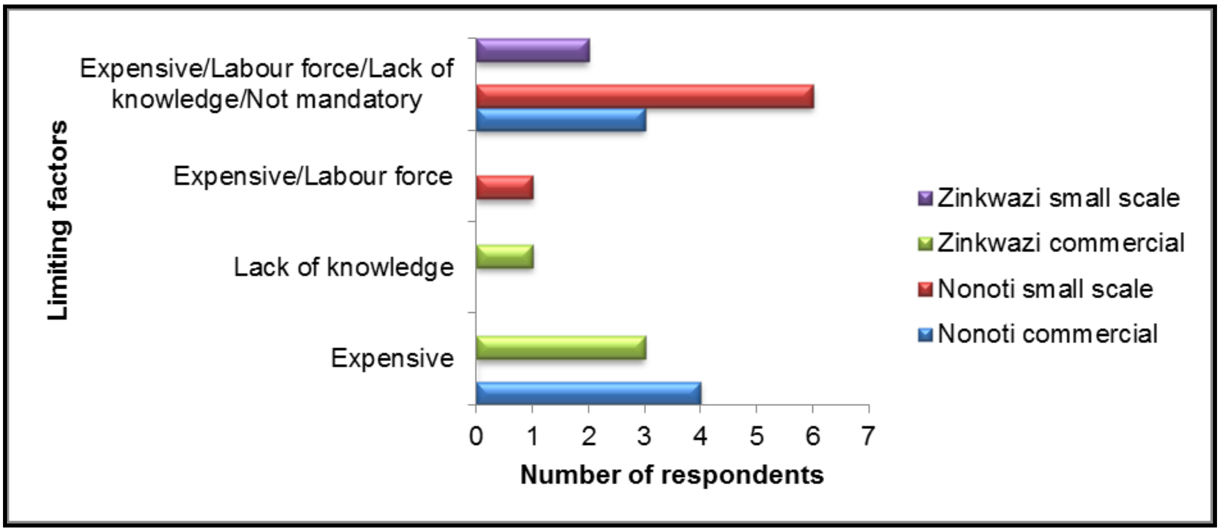


Figure 4.9 Farmers' reasons to why they did not practise restoration / reclamation of wetlands their farmers

4.5.2 Perceptions on Legislation

To determine the farmers' perception and knowledge of wetland legislation, the respondents were asked to indicate if they were aware of legislation which protected wetlands. The majority of the respondents who professed knowledge on wetland legislation in Zinkwazi were commercial farmers (six). The mostly commonly known legislation in Zinkwazi was the National Water Act 107 of 1998 (Table 4.3). Six farmers responded that they were aware of it. The National Environmental Management Act 107 of 1998 was also commonly known in Zinkwazi and five farmers responded that they were aware of it. Only one small-scale farmer indicated that they were aware of the National Environmental Management Act which is very common between all farmers. However, both commercial and small farmers in Zinkwazi were not very aware of the Environmental Conservation Act of 1989, only two commercial farmers' respondent that they were aware of it. Furthermore, small-scale farmers were not aware of the National Water Act 107 of 1998, none of the small scale farmers indicated that they were aware of the legislation

Table 4.3 South African legislation which protects wetlands, which farmers in Zinkwazi and Nonoti were aware of

Farm location	Farming type	NEMA Act 107 of 1998	National Water Act 36 of 1998	CARA 43 of 1983	ECA 73 of 1989
Zinkwazi	Commercial	5	6	3	2
	Small-scale	1		1	
Nonoti	Commercial	4	4	5	1
	Small-scale	3	2	2	

In Nonoti, five commercial scale farmers indicated that they were aware of legislation. The most common known legislation in Nonoti was the Conservation of Resources Act 43 of 1983 which had five responds. The National Environmental Management Act 107 of 1998 and National Water Act 107 of 1998 were the second common legislation in Nonoti. Small scale farmers were not very aware of the listed legislation, only three small scale farmers responded that they knew the legislation. Small-scale farmers in Nonoti were not well versed with legislation, however, the National Environmental Management Act 107 of 1998 was the most commonly known legislation, with three small-scale farmers indicated that they were aware of it.

It can therefore be concluded, based on the results that commercial farmers know more of the legislation and Zinkwazi farmers are more aware of legislation compared to those in Nonoti.

In assessing the perception of farmers with regards to the significance of legislation and environmental programs, a Likert scale was used. Results show that the bulk of the responses were neutral (Figure 4.10). Six farmers from Zinkwazi were not sure whether legislation and projects had helped in the management and conservation of wetlands. One farmer in Zinkwazi supported this observation on uncertainty when he said: “You cannot really tell because wetlands in many areas have already been lost and when farming started, there were no measures regulating sugarcane farming in wetlands”. Two of the farmers’ in Zinkwazi perceived legislation to have aid in the management and conservation of the wetlands and one farmer disagreed that legislation aids in the conservation of the wetlands.

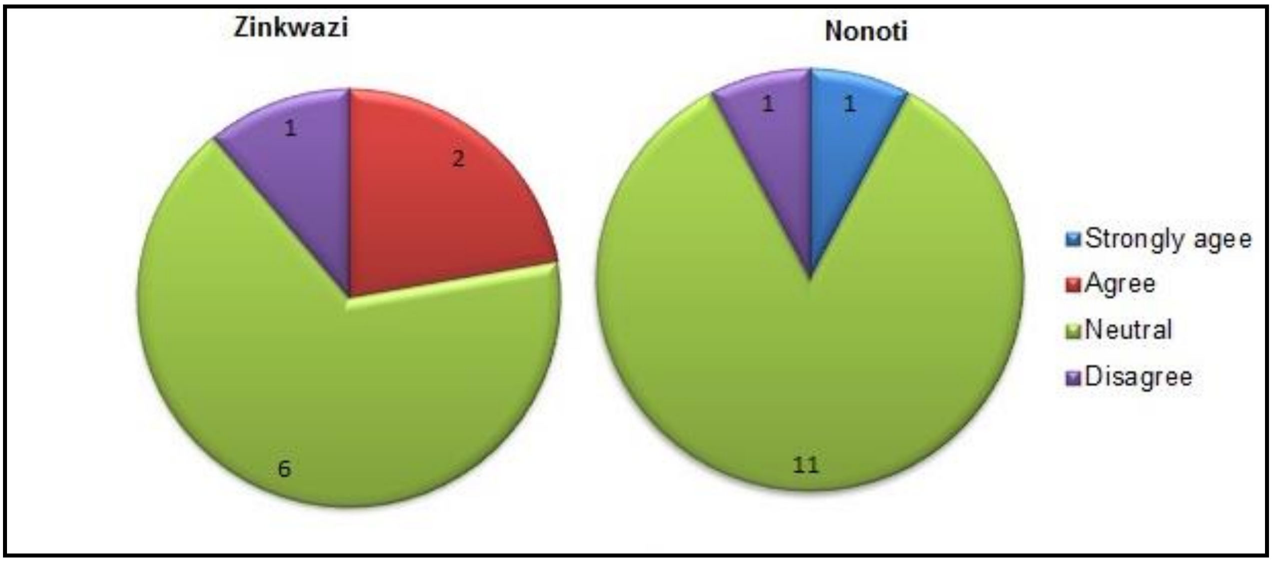


Figure 4.10 Number of farmers who responded that legislation and environmental programs have aided in wetland management

Majority of farmers (11 farmers) in Nonoti were not certain whether legislation had aided in the proper conservation and sustainable use of the wetlands (Figure 4.10). One farmer did not agree with the notion that legislation had improved wetland management, whilst another farmer strongly agreed that legislation had significantly aided in the protection and conservation of wetlands.

Only two respondents in Zinkwazi agreed that legislation plays a significant role in managing the wetlands while one respondent from Nonoti strongly agreed that legislation and environmental programs have aided in wetland management. One respondent in the Nonoti area differed with the view that legislation assisted in wetland conservation when he said:

> "These management programs are not so easy because most of us have private lands and it is difficult to tell someone to change their thinking when they have been doing it for lifetime. Therefore, I disagree that legislation has contributed to wetland management".

Perceptions on wetlands changes were captured using a Likert scale question. The results in Figure 4.11 illustrate that the majority of the respondents perceive wetlands close to them to have gone through changes spatially. Eight respondents from Zinkwazi strongly agreed that wetlands had changed over time and that they were being lost. Of the eight that strongly agreed to wetlands were being lost, six were commercial farmers and two were small-scale farmers.

Two respondents supported their choice: "My father told me that they used to catch fish in the Zinkwazi wetlands but now you cannot find them anymore". Because of these fertilizers and chemicals we use, they no longer exist". The second respondent said: "These soils are weary now, it has been years of intensive sugarcane farming and they produce less". From the statements, it can be concluded that farmers perceived that sugarcane farming has indeed affected wetlands.

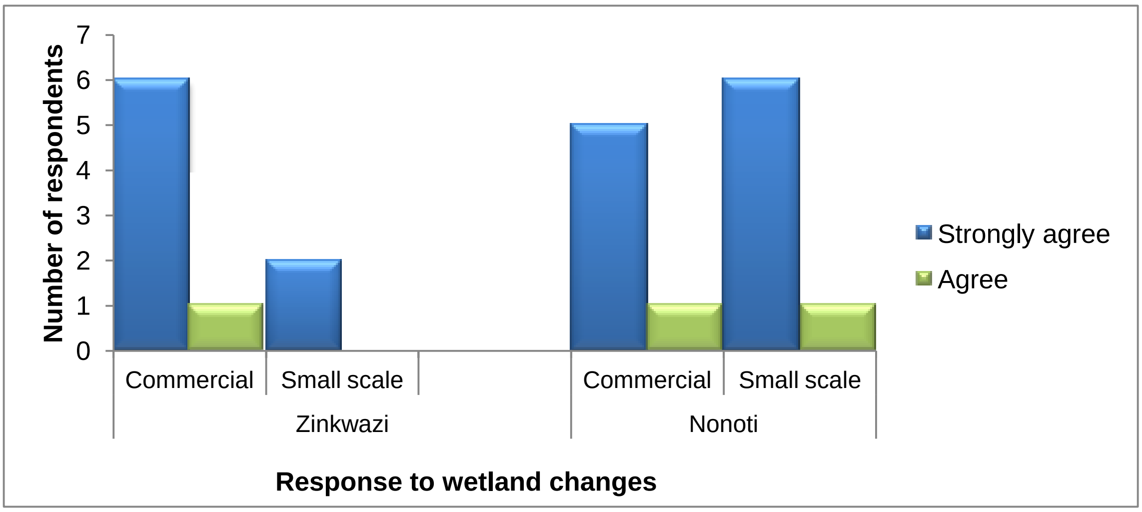


Figure 4.11 Commercial and small scale farmers' responses to whether they had observed a decrease in wetland extent with time

In Nonoti, five commercial farmers and six small-scale farmers strongly agreed that wetlands had been decreasing. Two of the commercial and two of the small scale farmers agreed that there were changes within the wetlands (Figure 4.11). All the farmers in Nonoti perceived the wetlands to be changing, and the change was negative.

It can be concluded that farmers in both Nonoti and Zinkwazi perceived wetlands to be lost because of sugarcane farming and different activities that were associated with their farming. Despite the farming type, farmers saw a loss of wetlands within their farms and in areas close to their wetlands.

4.5.1 Discussion

Results of this study confirmed similar results for Zinkwazi and Nonoti. Most farmers from both Nonoti and Zinkwazi cultivated closer to water sources and constructed water diversion structures that were threats to the wetlands, (Figure 4.5). The farmers perceived their activities to be contributing to wetland degradation and they could not change much in that regard, considering that sugarcane, farming was the mainstay of their livelihoods and their limited resources. This indicates that while farmers were aware of the consequences of their farming activities, but were forced to continue due to factors such as meagre rainfall, limited capital, as well as lack of access to other irrigation water sources (Turyahabwe et al. 2013).

Study results showed that experience of sugarcane farming is another factor contributing to the practices of agricultural activities which negatively affect wetlands. Commercial farmers have been in the sugarcane industry for some time compared to small-scale farmers (Sibiya & Hurly 2011). Most of the small-scale started farming after the land reform program in 1995 (Phillips 2013). Small-scale farmers are still trying to understand the processes of sugarcane farming whilst commercial scale farmers are now more stable, make relatively more profits, and have many investments. Therefore, they can use these other sources of income as backup in case they go through hardships whilst small-scale farmers are limited to their farms as the source of income because of the small profits.

Furthermore, education also emerged in this study as an important element that significantly affects the perceptions of people (Cliffton, Thompson & Thorley 2014). About three quarters of the commercial farmers had either a diploma or a degree whilst it was the opposite with small-scale farmers. In similar studies, Eweg (2005) & Hurly (2013) noted that small-scale farmers are ‘chancers’ mainly concerned with their livelihoods and technical know-how. Hence, most of them engage in activities that are detrimental to the environment. Eweg (2005) also noted that the transfer of information from extension workers to small-scale South African farmers is a challenge because they have limited education and capital to inject into their farming ventures. Thus, they revert into farming practices which are detrimental to wetlands.

The findings confirmed that small-scale farmers could not afford financing the reclamation and restoration process of wetlands within their farms (see Figure 4.8). Small-scale farmers had many challenges they faced in restoring and reclaiming wetlands, such as, lack of labour force and proper knowledge and skills to restore and reclaim the wetlands. On the other hand, a few commercial farmers indicated that expenses involved in the reclamation and restoration of wetlands was their only challenge. The majority of the commercial farmers can afford reclamation and restoration based on their knowledge and ability to hire qualified labour force, if sugarcane was selling well on the world market. However, considering the stagnant market prices of sugar since 2008 (Meyer & Nothard 2005), it has been difficult for a few commercial as well as the majority of small-scale farmers to invest in environmental conservation and protection. This is far more challenging for small-scale farmers who cannot access credit because of lack of sustainable money sources (Sibiya & Hurly 2011).

Commercial farmers in Zinkwazi and Nonoti were more aware of legal/ statutory instruments pertaining to wetlands as compared to the small-scale farmers (see Table 4.3). Very few small-scale farmers from both sites indicated that they were aware of legislation. It can be noted that small-scale farmers were not well informed about any statutory instruments on wetlands management and protection (Baiyegunhi & Arnold 2011) as compared to commercial scale farmers. The conclusion by Sibiya & Hurly's (2011) that there was a big difference in the understanding of legal instruments between the small and commercial scale farmers. The lack knowledge on the legal instruments that protects wetlands can be explained by the lack of awareness. This lack of knowledge emanates from lack of sufficient funds for capacity building on environmental awareness and sustainable means of managing sugarcane farms. Although the commercial farmers were well versed with legislation, they were more familiar with the National Environmental Management Act of 1998 and the Conservation of Agriculture Act 43 of 1983 as compared to the rest of the legislation. Results suggests that farmers who were aware of the listed legislation partially understood the legislation because they are not involved with the wetland management groups. The only knowledge concerning wetlands management and conservation that the farmers have is through the South African Cane Growers Association whose main aim is to help the farmers improve their yields, maintain their sugarcane, improve variety and maximize on their profits. Furthermore, most of the extension officers have agricultural backgrounds, not environmental backgrounds (Hurly 2013).

Despite the farmers' perceived loss of wetlands within their proximity, they continue to carry out activities, which affect the wetlands while conservation of wetlands remains insignificant. In cases where conservation of wetlands are practiced, it not on a large scale and it is done to increase the farmers' yield and not to specifically benefit the wetlands. To farmers, sustainability means getting as much profit as they can. It does not imply reducing the impacts of their farming activities on the wetlands environment around them and Benn (2013) and Hurly (2013) noted this similar trend. Farmers regard land as a base for food production and conserving the land is a way of depriving food stocks and opportunities (Sitas, Prozesky & Reyers 2014).

Furthermore, there is lack of integration between the department that protects the wetlands and the agriculture extension officers. Similarly, Sitas, Prozesky & Reyers (2014) found that lack of alignment between policies in environmental management in all three sectors of the government (national, provincial and local) in South Africa, contributed to the dilution of environmental legislation that protects all natural resources and in turn contributed to poor communication and participation across all the three sectors. Therefore, this lack of coordination could be contributing to the loss and pollution of wetlands in KwaDukuza.

4.6 CONCLUSION

This chapter provided results and discussion showing how sugarcane farming has affected the spatial extent and water quality of wetlands, KwaDukuza (South Africa) through the use of aerial photographs, water analyses and questionnaire analyses. The results of aerial photographs indicated encroachment of sugracane farms within the wetlands. Water analyses results also indicated pollution along some parts of Nonoti and Zinkwazi wetlands. Nutrients were above the water quality guidelines in some cases and this is an indication of excessive nutrient deposits contributing to pollution. Respondents perceived that the wetlands within their proximity were being lost due to sugarcane farming. Results of the study also indicate that there is little that has been done concerning conservation of the wetlands. In addition, farmers' perception seem to be consistent with the results of the aerial photographes and water quality analyses.

CHAPTER 5 EVALUATION AND CONCLUSION

5.1 SUMMARY OF THESIS

This study set out to assess the impact of sugarcane farming in coastal wetlands of KwaDukuza (South Africa). To achieve the main aim of the study three different approaches (aerial photographs, water sampling and questionnaires) were used. Results of the study showed the efficacy of incorporating the three approaches into understanding the severity of the impact of sugarcane farming on wetlands, water quality and how farmers perceive these impacts.

Results of the study have revealed that sugarcane extent fluctuated in the wetlands of KwaDukuza, between 1959 and 2000. Although sugarcane expansion into wetlands slowed down from 2000 to 2012 in both Zinkwazi and Nonoti due to factors such as urban expansion. The original wetland state will never be attained and the wetlands remain under threat from the existing sugarcane fields that are already within the wetlands. Water quality in these wetlands remains poor because of the use of nutrients such as nitrogen, phosphorus and potassium, in the form of fertilizer inputs for sugarcane cropping. The results of the study showed that nutrient concentrations were higher than the South African aquatic ecosystem standard guidelines at some points along the Zinkwazi and Nonoti rivers, specifically those at middle stream. Moreover, farmers continue to engage in activities that affect the remaining wetlands.

Despite the existing evidence of excessive wetland loss, there still appears to be a divergence and a gap between policy and practice about wetlands management and planning (Sitas, Prozesky & Reyers 2014). Lack of proper policy enforcement coupled with the farmers’ lack of interest in the conservation activities that protect the wetlands pose as a major drawback to proper wetland management and sustainability. Furthermore, these obstacles have increased by financial inadequacy coupled with the belief that farming is the farmers’ main goal. Therefore, farmers cannot divert their attention towards maintaining wetlands.

With the increase in reported cases of reduced water levels in some catchments, human population increase, climate change and limited extent of wetlands in South Africa (Kotze, Breen & Quinn 1995), there is need for long-term databases. The databases will aid in providing information on the remaining wetlands, especially in agricultural areas and will direct policy makers to the most important areas to focus on regarding wetlands management, to come up with proper measures, which are suitable for the sustainable management of different wetlands threatened by various agricultural activities. These wetlands are a critical base for agriculture.

5.2 REVISTING THE OBJECTIVES

First objective was established to assess the impacts of sugarcane farming extent on wetlands in KwaDukuza between 1959 and 2012. It was established that sugarcane fields expanded into wetlands between 1959 and 2000 and reduced between 2000 and 2012. Literature also showed that the same trends have been noted in some areas worldwide (Benn 2013).

The second objective was to determine the impacts of sugarcane farming on water quality within the wetlands. This was achieved through water quality analysis and results of this study confirmed that sugarcane farming might be the major cause of pollution in the Zinkwazi and Nonoti wetlands. Nitrogen and phosphorus as detailed in many studies was above the aquatic water standard guidelines of South Africa in some areas, especially the middle region of the wetlands.This implying that there is a source of pollution emanating from the middle stream.

Objective three was to evaluate the perceptions of the local farmers regarding the negative impacts of sugarcane farming on wetlands. Perceptions of farmers where assessed by conducting a questionnaire survey. The objective concluded that wetland degradation was an ongoing problem due to various factor such as financial means and lack of education and awareness on the importance of the wetlands. Furthermore, responses from farmers reflected that farmers prioritised sugarcane farming above conservation of the wetlands because farming was their main source of income.

5.3 LIMITATIONS OF THE STUDY

Although additional work has to be done, this study has generated important results on the impact of sugarcane farming on the coastal wetlands. The respondents of the study were specifically farmers that had farms in the Zinkwazi and Nonoti wetlands. This may cause the results to be less generalizable to the total population of people who live within or close to the wetlands. Future research should therefore increase and diversify the sampling frame. Questionnaire distribution to other people and not only farmers could generate more information. Furthermore, water analysis only focused on nitrogen, phosphorus and potassium. Future research should consider analysis of more constituents, for example, temperature, pH, watercolour and sediment loads within the river systems since this would yield more results to illustrate pollution levels caused by sugarcane farming. Overall, time was the major limiting factor, however, it was justified by time and financial limitations.

5.4 RECOMMENDATIONS

The recommendations are made with the intent of integrating the findings of this study in the implementation of proper planning for the management of wetlands in agricultural regions, especially where sugarcane farming is practiced.

Wetland loss is documented but there is no proper database providing the exact information on the contribution of each crop to wetland loss and degradation. Such information is crucial for the government departments and stakeholders concerned. It provides a baseline where critical measures should be taken and which crops to concentrate on. The information will assist in providing direction where future research needs to focus, to provide tangible results which will ultimately contribute to protecting the few remaining wetlands.

Results of the study have also shown lack of education is a challenge in wetland management for farmers, especially small-scale farmers. Consequently, promoting and providing basic knowledge of wetlands will effectively reduce impacts of sugarcane farming on wetlands and proper environmentalists who are fully aware of wetlands should do this. This education and awareness, coupled with incentives, can promote sustainable use and reclamation of the wetlands.

This study therefore revealed another possible means (aerial photographs, water quality analysis and questionnaires) for assessing impacts of sugarcane farming on coastal wetlands. Furthermore, the study contributes to the knowledge of how sugarcane farming has negatively influenced wetlands. The assessment of the impact of sugarcane farming in coastal wetlands can help in formulating a proper framework for the conservation of the wetlands, which are under threat from agricultural activities such as sugarcane farming. Remote sensing, combined with field surveys are critical in identifying threats that sugarcane farming pose to the wetlands. These methods can be used in future research to assess impact of different agricultural activities on the wetlands.

Formulation of legislation should consider a holistic approach, that is, information on wetlands should be acquired scientifically and directly from farmers. If farmers feel involved they commit to the sustainable use of the wetlands and become more aware of the need to conserve the wetlands within their farms. This approach also settles contradicting parts of the legislation. Furthermore, farmers perspectives can provide diverse and valuable experiences to help in tailor making a simplified version of legislation which is well understood by the farmers. Since farmers are meant to oblige to these rules and regulations. Legislation should be adhered to regardless of the type of land ownership.

Furthermore, there is need for a clear and stand-alone policy that specifically protects wetlands on a long-term basis especially in agricultural regions such as the KwaZulu-Natal coastal belt where sugarcane is grown. Policy that protects the wetlands should also be formulated in a way that it aligns with other policies that have a bearing on the environment to come up with practical and achievable solutions that benefits people and the environment from the national to the local level.

5.5 CONCLUSIONS

This study has successfully used aerial photographs, water quality and aerial photographs to assess the impacts of sugarcane farming on coastal wetlands. Through this study the impacts of farming, specifically sugarcane farming in KwaDukuza have been addressed. Results of the study confirmed loss of wetlands which is supported by various literature that was reviewed in Chapter 1 and Chapter 2. The study further highlighted recommendations derived from the findings of the study to improve wetlands management and key research aspects for the future.

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APPENDICES

APPENDIX A: CONSENT TO PARTICIPATE IN RESEARCH AND ADMINISTERED QUESTIONNAIRE

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STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

IMPACTS OF SUGARCANE FARMING IN COASTAL WETLANDS (Stanger to Tugela)

You are asked to participate in a research study being conducted by Melisa M Matavire and supervisor, Mr. N Poona from the department of Geography and Environmental Studies at Stellenbosch University. The research will provide a better understanding of the loss of wetlands caused by sugarcane farming.

You were selected as a possible participant in this study because:

- You are a farmer
- Your farm lies within the coastal wetlands (study area)
- You are familiar with the area because of many years of farming

PURPOSE OF THE STUDY

The aim of the study is to determine the impacts of sugarcane farming in coastal wetlands

1. PROCEDURES

If you volunteer to participate in this study, we will ask you to do the following things:

- Agree to fill in a questionnaire

This is divided into three sections the first section is for the demographic information the second is for the wetland changes and the last section is for the soil and water changes.

- Agree to participate in an interview

Exploring changes in coastal wetlands and the possible historical events that may have affected wetlands in some way and also to identify some effects posed by agrochemicals in wetlands.

2. POTENTIAL RISKS AND DISCOMFORTS

None

3. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The information acquired will be used to come up with recommendations that will call for better conservation and sustainable management as well as improved wetland legislation.

4. PAYMENT FOR PARTICIPATION

Not Applicable

5. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of pseudonyms to maintain anonymity. All the information gathered will be used for research purposes **only** at the University of Stellenbosch.

No information will be given to other parties

For the interviews that will be recoded one has the right to review and edit and these will be used for educational purposes **only** and they will be destroyed /erased after data analysis.

No publication is in the pipeline at the moment but should this be considered there will be the use of pseudonyms to maintain confidentiality and if there is need for names permission will be sought first before any publication.

6. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

7. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact my supervisor:

Mr. Nitesh Poona at:

University of Stellenbosch

Telephone +27(21)8089105

8. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

Melisa M. Matavire in [Zulu/English] described the information above to _______________ and I am in command of this language. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

Department of Geography & Environmental Studies, Stellenbosch University

Section A: Personal and farm-related information (Tick one box)

1. Age:

< 25	25 – 34	35 – 44	45 – 54	55 – 64	>65
1	2	3	4	5	6

2. Gender:

Female	1
Male	2

3. Highest educational qualification:

No education	1
Primary (Grade 7)	2
Secondary (Grade 12)	3
Diploma/certificate	4
Degree	5

4. Farming type:

Commercial scale	1
Small scale	2

5. Kindly indicate the tenure of your farm:

Tribal authority land	Lease rented	Private owned	Freehold	Other (specify)
1	2	3	4	5

____

Section B: Existing farming practices

6. What was the dominant/ original land cover type?

Forest	1
Floodplain	2
Grassland	3
Marsh	4
Swamp	5
Other (please specify)	6

____

7. Are there any farming activities that you do besides sugarcane farming?

Yes	1
No	0

7.1 .If 'yes', indicate the type of farming below

Forestry	1
Horticulture	2
Animal husbandry	3

Department of Geography & Environmental Studies, Stellenbosch University

8. What fertiliser types do you use for your sugarcane?

Superphosphate (Supers)	1
Diammonium phosphate (DAP)	2
Mono-Ammonium Phosphate (MAP)	3
Potassium Chloride (KCl)	4
Limestone Ammonium Nitrate (LAN)	5
Nitrogen Phosphate Potash (101(46))	6
Nitrogen Phosphate Potash (515(56))	7
Nitrogen Phosphate Potash (105)	8
Urea Ammonium Phosphate (UAP)	9
Urea	10
Potassium Nitrate	11
Triple Super Phosphate	12
Other (please specify)	

____

9. How many times do you apply fertiliser in each sugarcane season?

Once	1
Twice	2
Thrice	3
Other (please specify)	4

____

9.1 .Has the amount of fertiliser changed over time?

Yes	1
No	0

9.2. If 'Yes',what could be the reason for this change in the amount of fertiliser *(Multiple responses allowed)*

Early maturity/early harvesting	1
Decrease in soil fertility	2
Increase yield	3
To cover for loss through high evaporation	4
Other (please specify)	5

____

10. Has there been a decrease on yield with time?

Yes	1
No	0

10.1. If there has been a decrease in yield what could be the reason for this *(Multiple responses allowed)*

Loss of soil fertility	1
Pests and Diseases	2
Economic related issues	3
Drought	4
Other(please specify)	5

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11. How do you control / weeds/ pests / invasive species within your farm?

Chemical	1
Biological	2
Mechanical	3
Other (please specify)	4

____

12. Identify one activity within your farming that negatively affect wetlands (*Tick one only*)

Water division structures (Channels, ditches and levees that have been used to control floods, irrigation and mosquitos for example)	1
Construction of roads and bridges	2
Land division	3
Impoundment	4
Draining of the wetlands	5
Farming within 30m of the 1:50 year flood line	6
Burning of the wetlands	7
Cultivation closer to wetlands/water resources	8
Cutting down trees/deforestation	9
Planting of alien species	10
Other (please specify)	11

____

12.1. What is the reason for engaging in such practice? (*One answer only*)

They are the cheapest means	1
There are no other options	2
The need for farming land	3
Drought	4
Other (please specify)	5

____

12.2. What signs /features indicate degraded wetlands in your farm or surroundings of your farm?

Habitat loss	1
Species loss (wetland animals, birds, plants, trees, fish)	2
Water loss/reduction in water levels	3
Soil erosion	4
Open lands	5
Reduced productivity	6
Drainage channels in wetlands	7
Other (please specify)	8

____

Section C: Perception of legislation related to wetland management

Yes	1
No	0

13. Do you do any restoration/reclamation of disturbed lands and or conservation measures?

If your response to Q13 is 'yes' proceed to the next question. If 'no' then go to Q 13.3.

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13.1. If 'yes' which ones do you use? *(Multiple responses allowed)*

Minimum tillage	1
Eradication of alien species	2
Restoring wetlands and riverine vegetation	3
Strip planting	4
Trashing	5
Terracing	6
Other (please specify)	7

____

13.2. What are the reasons for restoration and reclamation/conservation? *(Multiple responses allowed)*

Improves yield	1
Flood protection	2
Indigenous species protection	3
Reducing soil loss	4
Maintaining water resources	5
Mandatory	6
Other (please specify)	7

____

13.3. What are the reasons for not practising restoration and reclamation/conservation? *(Multiple responses allowed)*

Expenses involved	1
Labour force is limited	2
Lack of knowledge	3
Not mandatory	4
Not my responsibility	5
No benefits	6
Other (please specify)	7

____

14. Are you aware of any legislation concerning wetlands management and conservation?

Yes	1
No	0

14.1.1 Tick the legislation that you are most aware of that protects wetlands *(Multiple responses allowed)*

National Environmental Management Act NEMA 107 of 1998	1
Conservation of Agriculture Resources Act 43 of 1983	2
National water Act 36 of 1998	3
Environmental Conservation Act 73 of 1989	4
Other (please specify)	5

____

15. Are there any follow-up on any of the legislation listed above?

Yes	1
No	0

15.1. Are they mandatory?

Yes	1
No	0

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16. Does these follow ups affect your farming in any way?

Yes	1
No	0

16.1. If 'yes' how do they affect your farming?

____

____

17. Which of the measures listed within the Agriculture Conservation Act 107 of 1983 are you aware of? *(Multiple responses allowed)*

Tick either' Yes' or 'No' for each item	
Cultivation of virgin soil	1
Protection of water sources against pollution on account of farming activities	2
Prevention and control of veld fires	3
Utilisation and protection of cultivated land	4
None	5
Other (please specify)	6

____

18. Do you have a Land Use Plan as required of you by the Agriculture Conservation Act 107 of 1983?

Yes	1
No	0

18.1. If 'yes', how have you benefited from the Land Use Plan *(Multiple responses allowed)*

In field work efficiency(proper location of cane extraction networks)	1
Provides guidelines for soil conservation works on the farm	2
Protection of natural resources such as wetlands, soil and water	3
Identification of rehabilitation of degraded wetlands and riparian areas	4
Ensuring long term sustainability on the farm	5
No benefits	6
Other (please specify)	7

____

19. Have you identified wetlands and riparian areas and included them in the land use plan?

Yes	1
No	0

20. Have you rehabilitated any degraded wetlands or riparian areas?

Yes	1
No	0

21. Are you aware of the distance that any farming activity may occur from water resources (river, spring, natural channel, lake, dam, or wetland)?

Yes	1
No	0

22. Legislation and environmental programmes have aided in wetland management

Strongly agree	1
Agree	2
Neutral	3
Disagree	4
Strongly disagree	5

23. Are you part of any environmental organisation/group?

Yes	1
No	0

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24.1. Select any of the environmental organisation/group that you are part of

South African Cane growers Association	1
Sustainable Sugarcane farmers (sus farms)	2
Working for wetlands	3
Sustainable farm management programme	4
Other (please specify)	5

____

24. There has been a decrease in wetlands

Strongly agree	1
Agree	2
Neutral	3
Disagree	4
Strongly disagree	5

25. Please feel free to provide any additional comments you feel are important on changes within the wetlands:

____
____
____

Thank you for your time and effort. Your cooperation is greatly appreciated.

For more information in relation to the research, please contact:

Melisa. M. Matavire Email: melmatavire@gmail.com Cell phone: 071 8955091

APPENDIX B : WATER ANALYSES RESULTS FOR ZINKWAZI

b.n. kirk (natal) cc
Reg.No. CK 1994/015428/23

Water, Sewage & Industrial Effluent Testing Laboratory

45 Eaton Road, Congella, Durban P.O. Box 30140, Mayville, 4058 RSA
Tel : (031) 205 1245 Fax : (031) 205 6904 E-mail: admin@bnkirk.co.za
Webpage: www.bnkirk.co.za

CERTIFICATE OF ANALYSIS - BN Kirk (Natal) cc

CLIENT:	Melisa Matavire	REF NO:	Lab/Misc/Ishmael Mavhenge/23-06-2014
ADDRESS:	Stellenbosch University	ORDER NO:	Cash sale
ATTENTION:	Melisa Matavire	DATE OF REPORT:	/03-07-2014
eMail:	melmatavire@gmail.com	DATE ANALYSED:	/02-7-2014
FAX No:	n/a	DATE RECEIVED:	23-06-2014

In accordance with the visit schedule and QP21

1	2	3	4	5							
Sample Origin											
Substance/Parameter	Test Method No.	SAGS 2004/GENERAL LIMIT VALUE: Units	General Limit	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Ammonia as N	P09/002	mg/L	6	0.02	1.24	3.432	3.82	4.835	4.625	1.346	0.3
Nitrite as N [d]	P09/019	mg/L	15	0.03	0.44	1.32	3.56	4.532	4.86	0.46	0.413
Nitrate as NO^3	P09/018	mg/L	ns	0.22	3.22	5.231	5.67	6.95	5.83	4.22	0.4
Phosphorous as PO_4	P09/075	mg/L	ns	1.423	1.5	2.13	4.325	6.35	5.678	2.567	1.5
Potassium as K	P09/047	mg/L	ns	21	47	60	61	71	63	54	85

Key: ns = not specified

for and on behalf of B.N. Kirk (Natal) cc

D.Bester - Laboratory Manager Technical Signatory	D. Subban - Chemistry Lab supervisor Technical Signatory	2014/03/07 Date

1. While every reasonable precaution is taken in obtaining these results the Company does not accept responsibility for any matters arising from the further use of these results.
2. In the case of sample/s submitted by or on behalf of the client, the results expressed in this certificate represent only the sample/s as received.
3. This certificate shall not be reproduced except in full, with out the written approval of the Company.

End of Report

APPENDIX C WATER ANALYSES RESULTS FOR NONOTI

b.n. kirk (natal) cc Reg.No. CK 1994/015428/23

Water, Sewage & Industrial Effluent Testing Laboratory

45 Eaton Road, Congella, Durban P.O. Box 30140, Mayville, 4058 RSA
Tel : (031) 205 1245 Fax : (031) 205 6904 E-mail: admin@bnkirk.co.za
Webpage: www.bnkirk.co.za

CERTIFICATE OF ANALYSIS - BN Kirk (Natal) cc

CLIENT:	Melisa Matavire	REF NO:	Lab/Misc/Ishmael Mavhenge/15-09-2014
ADDRESS:	Stellenbosch University	ORDER NO:	Cash sale
ATTENTION:	Melisa Matavire	DATE OF REPORT:	25-09-2014
eMail:	melmatavire@gmail.com	DATE ANALYSED:	23-09-2014
FAX No:	n/a	DATE RECEIVED:	15-09-2014

In accordance with the visit schedule and QP21

1	2	3	4	5					
Sample Origin									
Substance/Parameter	Test Method No.	SAGS 2004/GENERAL LIMIT VALUE		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
		Units	General Limit						
Ammonia as N	P09/002	mg/L	6	0.16	0.58	2.8	2.3	0.38	0.19
Nitrite as N [4]	P09/019	mg/L	15	0.03	0.03	0.07	0.25	0.03	0.03
Nitrate as NO^3	P09/018	mg/L	ns	0.2	0.6	19	7.2	0.5	0.11
Nitrate as N [4]	P09/018	mg/L	15	0.05	0.14	4.3	1.6	0.11	0.34
Phosphorous as PO_4	P09/075	mg/L	ns	2.7	2.1	6	2.9	2.5	1.6
Potassium as K	P09/047	mg/L	ns	2.9	7.2	37	5.8	9.9	3.9

Key: ns = not specified

for and on behalf of B.N. Kirk (Natal) cc

25 - 09 - 2014

D.Bester - Laboratory Manager	D. Subban - Chemistry Lab supervisor	Date
Technical Signatory	Technical Signatory	

1. While every reasonable precaution is taken in obtaining these results the Company does not accept responsibility for any matters arising from the further use of these results.
2. In the case of sample/s submitted by or on behalf of the client, the results expressed in this certificate represent only the sample/s as received.
3. This certificate shall not be reproduced except in full, with out the written approval of the Company.

End of Report

APPENDIX D: ETHICAL CLEARANCE

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jou kennisvennoot · your knowledge partner

Approval Notice
New Application

14-May-2014
Matavire, Melisa M

Proposal #: DESC/Matavire/May2014/9
Title: Impacts of sugarcane fields in coastal wetlands: a case of (KwaDukuza)KwaZulu-Natal.

Dear Ms Melisa Matavire,

Your **New Application** received on **08-May-2014**, was reviewed
Please note the following information about your approved research proposal:

Proposal Approval Period: **13-May-2014 -12-May-2015**

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**DESC/Matavire/May2014/9**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 0218089183.

Included Documents:
Research proposal
Informed consent form
DESC application
Questionnaire
Permission letter

Sincerely,

Clarissa GRAHAM
REC Coordinator
Research Ethics Committee: Human Research (Humanities)