

Evaluating the efficiency of management approaches for pompom weed control in the Free State

BY

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ABSTRACT

The focus of this study was to investigate the efficiency of Alien Invasive Species (AIS) management approaches, as employed by the South African National Biodiversity Institute (SANBI) through their Invasive Species Programme (ISP). Pom-pom weed was used as an indicator species and the Free State province as a study area. The indicator species was chosen because it is one of the most notorious invasive plants in South Africa, and the study area was consistently managed since ISP inception in 2009.

A literature study was conducted to document the importance of invasive species as threats to biodiversity and its components. Properties of the indicator species as well as possible management approaches were listed. The importance of having a functional environmental management system was advocated. Activity Based Costing (ABC) was introduced and its effectiveness in accurate monetary reporting stated. And finally, the importance of Environmental Management Accounting (EMA) and appropriate units for reporting on biodiversity were discussed.

An empirical study was conducted wherein species occurrence and abundance were recorded and species trends calculated. Efficiency of management approaches were investigated by performing spectral signature separability analysis, followed by pixel based classification on Landsat 7 and SPOT 5 satellite images. Monetary expenditure was recorded by employing ABC, as per identified activity centres and influenced by cost drivers.

Results obtained from this study indicated that pompom weed management approaches were successful in the Free State. These results however, should be interpreted with caution since the localised and fragmented nature of the invasion in Free State made it comparatively easy to manage the species. The result however, gives a good basis upon which modification may be made to accommodate different invasion patterns. Recommendations were made regarding the improvement of field work, the improvement of the accuracy of monetary reporting as well as on the establishment of a functional Environmental Management Accounting (EMA) system.

Keywords: Alien and Invasive Species (AIS), Environmental Management Accounting (EMA), Pompom weed, Biodiversity conservation.

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LIST OF ABBREVIATIONS

ABC	:	Activity Based Costing
AIS	:	Alien Invasive Species
CEMA	:	Conditional Environmental Management Accounting
DEA	:	Department of Environmental Affairs
Dec-Jan	:	December to January
EMA	:	Environmental Management Accounting
Feb-March	:	February to March
GAAP	:	Generally Accepted Accounting Principles
GIS	:	Geographic Information System
GPS	:	Global Positioning System
Ha	:	Hectors
ISP	:	Invasive Species Programme
KPI	:	Key Performance Indicators
m²	:	meter square
MEMA	:	Monetary Environmental Management Accounting
mg/l	:	Milligram per liter
NDVI	:	Normalised Differential Vegetation Index
NIR	:	Near Infra Red
NNPC	:	Nigeria National Petroleum Corporation
PEMA	:	Physical Environmental Management Accounting
QGIS	:	Quantum Geographic Information System
SANBI	:	South African National Biodiversity Institute
SEEA	:	Systems of Environmental-Economic Accounts
SNA	:	Systems of National Accounts
SWIR	:	Shortwave Infra Red

TCA : Traditional Costing Accounting
UNSD : United Nations Statistical Division
USGS : United State Geological Survey

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CHAPTER 1

INTRODUCTION

1.1 Background

In general, Biodiversity could be defined as the number, abundance, composition, spatial distribution and interaction of genotypes, species, populations and land scape units within an ecosystem (Diaz', Fargione, Chapin III & Tilman, 2006). With only 2% of the planet's land area, South Africa is home to 6% of the world's plant and mammal species, 8% of bird species and 5% of reptiles, many of which are found only in South Africa (Driver, Sink, Nel, Holness, Van Niekerk, Daniel, Jonas, Majiedt, Harris & Maze, 2011). The Southern African coast is home to almost 15% of known coastal marine species, including 270 marine fish out of a world's total of 325 (Driver *et al.*, 2011). South Africa is thus recognised as one of the only 17-megadiverse countries (Driver *et al.*, 2011). Despite its importance for human survival, biodiversity is threatened and experiences continuous pressures. These pressures are in the form of:

1. Overexploitation of resources by overgrazing and hunting;
2. Habitat alteration or loss mostly for infrastructure development;
3. Invasion by alien invasive species;
4. Pollution mostly by gas emission as by-products of mining, and
5. Climate change.

Second to habitat loss due to urbanisation and agricultural activity, invasion by alien species is the most serious threat to the invaded area's biodiversity, and poses serious concerns for all biomes and ecosystems (Driver *et al.*, 2011). Of all the known invasive plants in South Africa, pompom weed (*Campuloclinium macrocephalum*) is the most notorious and is an invader of the third largest biome, namely the grasslands. The greatest impact on biodiversity in Southern Africa has occurred in the grasslands, followed closely by fynbos (Scholes & Biggs, 2005). The South African grasslands are one of the country's most threatened biomes with only 2.5% formally protected and an estimated 60% irreversibly transformed (Endangered Wild Life Trust, n.d.). The importance of the grasslands is exaggerated by the services enjoyed, ranging from

grazing and management of domestic animals, to land conversion to crop, forest and urbanisation. In this study, Pompom weed will be used as an indicator species in accounting for biodiversity and consequent grasslands ecosystem services loss in the Free State.

As stated in the National Environmental Management: Biodiversity Act 10 of 2004, SANBI, an institute funded by the Department of Environmental Affairs (DEA), is mandated to monitor and report on the state of biodiversity, at species and ecosystems level. This is to ensure that our biodiversity is conserved, and where it is already transformed, measures are put into place for remediation. SANBI's ISP unit's role is to identify invasive species already present in the country; and act rapidly to eradicate them before they become widely established (Driver *et al.*, 2011), and alter the country land cover. Due to the importance of AIS invasion as a threat to biodiversity, the ISP is intrusted with millions of Rands annually to manage these species. Consequently, the ISP has to be accountable to its stakeholders namely the DEA and the broader South African community, on how funds allocated from the country's scarce resources are utilized. And most importantly, if the resources invested in AIS management are reflected in the state of biodiversity in the country. An Environmental Management System with accounting methods that supports proactive and prospective decision making, is the most effective tool that may be used for these purposes (Sroufe, Melnyk & Vastag, 1999). Moreover, it will help the organization in building and maintaining trust and confidence of its important stakeholder, DEA, and ensure that funding is not discontinued or reduced.

At the heart of any Environmental Management System is Environmental Accounting. According to Environmental Protection Agency in 2005, Environmental Accounting can be viewed in three contexts:

1. The National Income Accounting contexts, a macro-economic measure (for example Gross Domestic Product), where physical and monetary units refer to the consumption of the nation's natural resources.

2. Financial Accounting contexts, referring to estimates and public reporting of environmental liabilities and financially material environmental costs. The compiled financial reports are to be used by investors, lenders and other external stakeholders. Generally Accepted Accounting Principles (GAAP) is the basis for this reporting.
3. Environmental Management Accounting (EMA) which is defined as the identification, collection, analysis and the use of physical and monetary information for internal decision making (Abiola & Ashamu, 2012). According to Schaltegger and Burritt (2000) and International Federation of Accountants (2005) as reported by Möhr-Swart (2008), EMA focuses on information like cost drivers such as labour hours, quantities of materials purchased, that informs management decisions such as planning and budgeting. Unlike financial accounting which is governed by GAAP, management accounting practices and systems differ according to the needs of an organization or division.

In this study an Environmental Management tool, EMA, will be used to assess the efficiency of Pompom weed control in the Free State province. Although only a subset of Environmental Accounting and focusing only on information required for internal decision making, much of the information generated by EMA could be used for external reporting purposes. This information is particularly important in management initiatives with specific environmental focus like environmental life cycle assessment, costing or design, environmental preference purchasing and environmental performance evaluation and benchmarking (Tellus institute, n.d.).

Due to their difficult-to-quantify in nature, environmental costs are traditionally lumped into overhead accounts and are thus highly susceptible to disconnection from the processes and activities responsible for their creation (Tsai, Lin & Chou, 2010). ABC, a system where overhead costs are accumulated per organizational activity and then assigned to a service or product causing the activity, is the best tool in remedying distortions inherent in traditional cost-accounting systems (Cooper & Kaplan, 1988, Kaplan & Anderson, 2013). As reported by Emblemvåg in 2000, ABC is one of the most important management innovations in the last hundred years. This is mainly because ABC focuses attention on the activities required to achieve a said business objective and encourages managers to improve the efficiency of activities and reduce or

eliminate activities that do not add value (Northeast Waste Management Officials' Association, 1992, Mowen, Hansen & Heitger, 2014). In this study, ABC will be employed to help assess whether measures to remedy losses associated with pompom weed invasions in the Free State are economically worthwhile. This will be achieved in the following three steps:

1. Firstly, ABC principles will be applied to accurately quantify the cost of pompom weed management in the Free State;
2. Secondly, vegetation reflectance indicative of detectability of pompom weed will be assessed using remote sensing (Landsat 7) images, and
3. Thirdly, correlation between (1) the investment made in pompom weed management and (2) the state or pristineness of the area will be assessed.

The results obtained in this study are to be used to extrapolate effectiveness of AIS management, for biodiversity conservation purposes, in South Africa.

1.2. Literature review

In AIS management, it is important to ensure that biodiversity and subsequently ecosystem services, which are the primary reason for managing invasions, are accounted for (Ingram, Redford & Watson, 2012). Biodiversity can be accounted for at any level, however the higher levels, namely populations, species and ecosystem are more reasonable, more so that other users like Franklin in 1993, proposed landscapes, featuring multiple ecosystems, as appropriate scales for managing biodiversity. For purposes of this study, biodiversity is accounted for at ecosystem level. An ecosystem is a dynamic complex of plant, animal and microorganism communities as well as nonliving environment, interacting as a functional unit, with humans an integral part of the complex (Alcamo & Bennett, 2003). Decision-making concerning ecosystems and their services is difficult. This is mainly because disciplines, philosophical views and schools of thought often differs among decision makers in this regard (Alcamo & Bennett, 2003). Despite an increased interest in managing ecosystems and ecosystem services, to-date ecosystem science cannot provide the needed information to select management approaches capable of reliably providing a given service at a site, or even

to reliably measure the effects of management practices on some services. Commending the ISP for good strategic decisions made in AIS management to date (species-based strategies); it is however appreciated that the use of purpose-orientated data or information could assist the unit in making important broad scaled decisions (Schaltegger & Burritt, 2000).

Currently there are three broad accounting units for accounting for biodiversity, namely, Monetary Accounting Units, Physical Accounting Units and Condition Accounting Units (McDonald, 2011). Using Monetary Accounting Units, prices at which assets, goods and services are exchanged for value are directly employed, thus indicating environmental conservation costs. Using Physical Accounting Units, developed by Systems of Environmental-Economic Accounts (SEEA), assets, goods and services are described (United Nations Committee of Experts on Environmental-Economic Accounting, 2011) and provide a measuring mechanism where no monetary value applies. This is to measure environmental conservation benefit (Ministry of the Environment Government of Japan, 2005). Thirdly, using Conditional Accounting Units, metrics that describe the state or condition of environmental assets, using fit-for-purpose indicators against a set benchmark to create a scalable unit of measure are employed. The need for the later arose from recognizing that many environmental assets do not have monetary value, and physical units are non-compliant to aggregation (United Nations Committee of Experts on Environmental-Economic Accounting, 2011) and cannot measure the conditions necessary for accounting for the environment (Kinzig, Perrings, Chapin III, Polasky, Smith, Tilman, & Turner III, 2011, Weber, 2007). In this study, Monetary Accounting Units (MAU) as well as Condition Accounting Units (CAU) is used.

1.3. Motivation of topic actuality

To date, physical and monetary changes in the stock of biological resources (for example biodiversity) and the flows of goods and services arising from these assets

have not been recorded for South Africa. In 2005/2006, the National treasury released a policy paper on environmental fiscal reform, where the need to value environmental losses and remedies were highlighted. The government through ISP established measures to remedy losses associated with invasions by alien and invasive species. In this study, (1) interventions implemented in remedying losses associated with pompom weed invasions in the Free State will be assessed and (2) the efficacy of these interventions for biodiversity conservation will be evaluated by applying EMA and ABC principles.

It is often difficult to measure the extend of biodiversity loss (European Academies Science Advisory Council, 2009), with only a few available tools like Red Listing, showing that many of the threatened species are either endangered or critically endangered. Alien invasive plants are a major threat to the rich South African biodiversity and to sustained delivery of a wide range of ecosystem services (Le Maltre, Richardson & Chapman, 2004). Despite their importance, there is currently no standardised manner to account for losses associated with alien and invasive species and resources invested in their management. Though millions of Rands are annually spent on a national scale, the link between the resources and invasions has not been systematically established and reported. Due to time and money limitations however, this study only focuses on one invader, *Campuloclinium macrocephalum*, in the Free State, using ABC managerial costing and EMA principles.

1.4 Main objective

Evaluate the efficiency of AIS management approaches employed by ISP in the Free State, using pompom weed as an indicator species.

1.5 Secondary objectives

1.5.1 Literature objectives

1. Document the biology and behavioral patterns of pompom weed as an invader in South Africa.
2. State the importance of biodiversity management in South Africa.
3. Document Environmental Management Accounting (EMA) theory with particular emphasis to its importance in biodiversity management.
4. Explain the benefit of employing Activity-Based-Costing in EMA for biodiversity conservation purposes.

1.5.2 Empirical objectives

1. Assess the state of biodiversity as informed by pompom weed abundance in the Free State.
2. Collate historical abundance records for Pompom weed as well as resources invested in pompom weed management for the accounting period, 2009-2014, in the Free State.
3. Analyse the cost of AIS management versus the benefits obtained, and calculate the efficiency ratio(s) for pompom weed management in the Free State.

1.6 Literature review

Literature review is important for the researcher in familiarising himself or herself with a selected research area, current state of knowledge and the information gap; giving the researcher an opportunity to formulate a project, to generate new knowledge and/ or fill the gap (Fink, 2010). It is also helpful because one could learn from previous workers and build on or improve upon their work with the help of new technology and available resources. The resources to be utilized are relevant peer-reviewed journal articles, books, reports, Acts of parliament and discussions forums on the web.

1.7 Empirical research

1.7.1 Research setting (Study area)

This study took place in the Free State province of South Africa. In the Free State, pompom weed was first recorded in Kroonstad (27°13'60"E, 27°38'60"S). Kroonstad is a dry highveld grassland with a botanical composition dominated by *Eragrostis lehmanniana*, *Eragrostis obtusa*, *Panicum coloratum*, *Stipagrostis uniplumis* and *Pentzia globosa* (Solomons, Lehmann, Lobe, Martinez, Tveitnes, Du Preez & Amelung, 2005).

1.7.2 Sampling

Current and historical occurrence data for pompom weed including collection site description and Global Positioning System (GPS) coordinates, as well as the density of invasion was collated from ISP (Historical) and the study area (Current). Current and historical remote sensing data was retrieved from United State Geological Survey (USGS) EarthExplorer. Monetary data for the duration of the accounting period has been made available for this project by the ISP. This data was retrieved and analysed.

1.7.3 Data analysis

1.7.3.1. Data analysis: Condition Accounting Units (Remote sensing)

Free State Landsat 7 images for the flowering period 2009-2010, 2011-2012, 2011-2013 and 2013-2014 were retrieved from USGS EarthExplorer. From the retrieved images, images of the localities where pompom weed was recorded were extracted for further processing. Prior to processing, images were atmospherically corrected using Quantum Geographic Information System (QGIS) and spectral bands fused to create multispectral images using ArcGIS. Spectral fusion consists of the following bands:

Band 1 (blue 0.4 – 0.5), Band 2 (Green 0.5 – 0.6), Band 3 (blue 0.6 – 0.7), Band 4 (Near Infrared (NIR) 0.7 – 0.9), Band 5 (Shortwave Infrared (SWIR 1) 1.55 – 1.75) and Band 6 (Shortwave Infrared (SWIR 2) 2.08 – 2.35 μm). An algorithm used for calculating vegetation reflection called Normalised Differential Vegetation Index (NDVI) will be calculated using the formula: $(\text{NIR}-\text{Red})/(\text{NIR}+\text{Red})$, for the peak flowering phase (Dec-Jan) and the withering phase (Feb- Mar). The resulting NDVI images were compared for each flowering period and the difference in vegetation reflectance, as indicated by pixel values, was recorded.

1.7.3.2. Data analysis: Monetary Accounting Units

The monetary investment was calculated using ABC following the seven steps, as listed by Ben-Arieh and Qian in 2003:

1. Identifying a resource;
2. Analysing resource driver rates;
3. Identifying environmental activities;
4. Assigning resources to each environmental activity via resource driver spent;
5. Analysing the environmental cost for each activity;
6. Defining activity cost drivers for each activity and finding its activity driver rate, and
7. Calculating the total environmental cost for Pompom weed management based on the driver costs.

1.7.3.3. Study lay out

The study is laid out such that chapter 1 includes background information on the research topic, a brief introduction of South Africa's biodiversity, threats posed by pompom weed and the country's intervention through the ISP program are also provided in this chapter. The main and secondary aims of the study, as well as the problem statement and research methods are also stated in chapter 1. In chapter 2, the problem or threat posed by pompom weed is discussed in depth. This includes the biology of the species, key drivers of pompom weed invasions, as well as interventions implemented in pompom weed management. A detailed account of the study area,

including the ecosystem services enjoyed or potentially enjoyed from this area is also be given. Furthermore, EMA and ABC principles used in pompom weed managements are discussed in depth. In chapter 3, materials and method employed in the study are outlined and discussed. This includes a detailed discussion on data collection and analysis methods, as well as the reasons for choosing the method(s). In chapter 4, results and findings are reported. Finally, results reported in chapter 4 are critically discussed in chapter 5. Contributions of the study as well as conclusions and recommendations are also given in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The primary objective of this study is to evaluate the efficiency of AIS management processes, using pompom weed as an indicator species in the Free State province. Part of the study is to analyse the cost of managing AIS against the state of biodiversity in the managed area, and calculate the efficiency ratio(s) for managing pompom weed. A high efficiency ratio is indicative of a good investment, whereas a low efficiency ratio is indicative of a bad investment and/ or returns.

In order to achieve the above objectives and others listed in chapter 1, there should be a clear understanding of the importance of biodiversity as an asset, the importance of AIS as a threat to biodiversity and the tools available in assessing and monitoring AIS management. In this chapter, biodiversity, its economic and non-economic components, as well as its measures are listed. Properties of the notorious indicator species, pompom weed, are also listed. Furthermore, the importance of having a functional environmental management system is advocated; and one of the most effective tools in environmental management, ABC is introduced and explained. EMA is also discussed and appropriate accounting units for reporting on biodiversity are identified and discussed.

2.2 The importance of Biodiversity

Biodiversity interfaces with the economy in two ways, namely, biodiversity being depleted during economic activities, and the government investing in biodiversity

(McDonald, 2011). For accounting purposes, biodiversity is defined as genes, populations, species and ecosystems and the components of which they comprise as illustrated in Table 2.1 below.

Biodiversity is an environmental asset and should therefore be properly managed and accurately reported on. The System of National Accounts, 1993 (SNA93), defines an asset as a store of value representing a benefit or series of benefits accruing to an economic owner, that may be enjoyed by holding or using over a period of time. Walton (2007) defines an asset as a resource controlled by the entity as a result of past events and from which future economic benefits are expected to flow. Ecosystems, species, populations and genes can therefore be reported on as stock in the asset account, and their depletion and degradation should be measured. This asset account is to measure quantity, value and condition in order to record and explain variation in value over time. Changes in the stock of biodiversity may or may not be transacted in the economy (Walton, 2007). A proportion of positive and negative changes in species diversity as a result of economic activity, for example harvesting, will flow through the economy. On the contrary, a large proportion of the observed change in biodiversity will result in non-economic variables, for example invasions in this case study; and their flow will thus not be reflected in the economy. It is important to report on both the economy transacted and non-economy transacted flows, despite their interaction with the economy (McDonald, 2011). The said importance is one of the main motivations for the current study, which uses pompom weed as an indicator species for change in biodiversity in the Free State.

Table 2.1: Types of biodiversity and their components

Types of Biodiversity					
Biodiversity	Levels of Biodiversity	Components of Biodiversity	Examples of economics components	Examples of non-economics components	Measures of Biodiversity
	Ecosystems	-Diversity of ecosystems -Individual ecosystems -Other levels of biodiversity within the above stated levels (species, populations and genes)	-Harvested ecosystems (example: ecosystem services)	-Cleared ecosystems -Native forests -Rivers -Streams -Wetlands -Forests -Various ecosystem services	-Area of ecosystem -Condition of ecosystem (structure, composition, processes and functions and internal diversity)
	Species	-Diversity of species -Individual species -Other levels of biodiversity within this level (namely population and genes)	-Commercial species (example: fish and trees for timber)	-Non-commercial species -Species diversity -Threatened species	-Species richness -Abundance of individual species -Functional trait of species -Composition of species -Distribution
	Populations				
	Genes				

Source: McDonald 2011

2.3 Pompom weed

2.3.1 The Biology of Pompom weed

Pompom weed is a perennial, erect herb of South American origin that grows up to 1.5 m in height (Jaca, n.d.). The leaves are scattered along the length of the stem but forms a rosette at the base (Fig 2.1a). Showy pink flower heads are produced in dense clusters at the end of the aerial stems (Fig 2.1b). Each flower consists of numerous tiny, star-shaped florets surrounded by purple bracts (Fig 2.1c). Mature florets produce a single-seeded dry achene with tuft of hairs (Fig 2.1d), making wind dispersal definitely probable (Henderson, Goodall & Klein, 2003). The species had been declared a Category 1 weed according to the Conservation of Agricultural Resources Act, ACT 43 OF 1983. As stated in Regulation 15A of the Act about Category 1 weeds, pompom weed is illegal to plant, propagate, harbour or sell.

Figure 2.1: Pompom weed (*Campuloclinium macrocephalum*) (a) the entire plant, (b) flower heads, (c) florets, (d) mature florets susceptible to wind dispersal and (e) pompom weed seedling



Images: M. T. Sethusa

2.3.2 Pompom weed invasions

In South Africa, pompom weed was first recorded as an escapee from cultivations in the Fountains Valley in Pretoria (25°46'52"S, 28°11'37"E) in the 1960's and subsequently in Durban Westville (29°49'43"S, 30°55'58"E) in 1972 (McConnachie, Retif, Henderson & McKay, 2011). By the 1980's, the species had spread through Gauteng and spilled into Limpopo, followed by the North West and Mpumalanga Provinces in the 1990's (Manyama, Personal Communication, March 3, 2015) and Swaziland (McConnachie *et al.*, 2011). Pompom weed starts by invading disturbed sites such as roadsides or abandoned fields and then expands to natural Grasslands, open Savanna and Wetlands (McConnachie *et al.*, 2011), where it has a significant impact on biological diversity. The weed has been reported to increasingly disrupt conservation of grasslands in the country with a major threat of invading the entire Grassland biome.

This threat is exacerbated by (1) movement of cut-grass bails from infested roadsides, (2) members of the public unknowingly picking pompom weed flowers, (3) planting of pompom weed in private gardens and (3) most commonly, seeds collected on car radiators and scattered during driving (McConnachie *et al.*, 2011).

Pompom weed grossly invades the grassland biome of South Africa (Herderson, Goodall & Klein, 2006) which according to Richardson *et al.* (2004) is one most invaded by plant species in comparison to the other biomes in the country. The biome covers 30% of the country's land area and sustains major economic, agricultural, industrial and urban centres. These includes 6.4 million cattle and 13 million sheep grazing on the biome, provision of coal that feed power stations, 33.9% of the country's Gross Domestic Product (GDP) generated in Gauteng and the total output value of plantation forestry in grasslands being R5.4 billion (Grasslands, 2006). Grasslands provides for the following ecosystem services: (1) water production, wetlands functioning and flood attenuation; (2) good quality soil and forage for livestock; (3) culture, heritage and recreational amenities (support to livelihoods such as grasses for housing) and (5) weaving and medicinal plants (Grasslands, 2006). Based on the above mentioned, grassland invasions are associated with major economic losses, particularly because an estimated 60-80% of the grassland biome is already irreversibly transformed (Knobel & Bredenkamp, 2006). In this study, the invaded grasslands of the Free State will be used as a study area, with aims to use the study findings for improved AIS management and reporting at a national scale.

2.3.3 Pompom weed management

Keeping potential invaders out of the country is the most cost-effective way to deal with invasions. Once introduced, invasive species may be controlled and/ or eradicated by the four methods listed below (Simberloff, 2000):

1. Biological control, which entails introducing a natural enemy from the area of origin (for example an insect pest to control an invasive plant);
2. Chemical control, which entails administering herbicides (for plants) or insecticides (for insects);
3. Mechanical control, which entails hand pulling or employing various kinds of machinery to physically remove the species; and
4. Ecosystem management, which entails subjecting the entire ecosystem to regular treatment which is aimed at favouring the native species over invaders (for example simulated natural fire regime).

2.3.3.1 Controlling Pompom weed using biological control agents

For pompom weed, two potential biological control agents *Cochylis campuloclinium* (flower feeding lepidopteran) and *Liothrips tractabilis* (a stem-galling thrips) were identified. An ecological niche modelling study by Trethowan & co-workers in 2011 however, showed poor overlap between potential distribution of both *C. campuloclinium* and *L. tractabilis* and that of pompom weed under future climatic conditions. This suggest that in future, the agents would not survive climatic conditions were pompom weed would thrive, thus failing to control the weed. The sample size used in their study however is small and possible distortion cannot be out ruled. Further studies with more collection records will increase the confidence level of the results upon which decisions (i.e. reject or accept the agents) may be based. With the current knowledge, the tested agents will not be considered suitable for pompom weed control in future, making investing in them an unjustified expenditure.

2.3.3.2 Controlling Pompom weed using herbicides

Herbicidal control has a disadvantage in that it is expensive and is often also damaging to non-target plants (Pemberton, Goolsby & Wright, 2002). For pompom weed, Brush-

off by Du Pond is the recommended method, and it provides about 80% control. With the growth and expansion rate of pompom weed however, herbicide administration is becoming impractical and unaffordable (Agricultural Research Council, 2007).

2.3.3.3 Controlling Pompom weed mechanically

Physically removing the plants is labour intensive and causes too much soil disturbance and stimulates further vegetative growth (Mashiloane, 2011). Given the growth rate of pompom weed, mechanical control is also continuously becoming impractical and expensive (McKey & Oleiro, 2008).

2.3.3.4 Ecosystem management

This method also does not give favourable results. Burning, for example, is also ineffective in pompom weed because, as illustrated in Fig 2.2 below, the plant has an underground structure which stores nutrients and a more vigorous regrowth is likely in the following season (Mashiloane, 2011, Henderson *et al.*, 2006).

Figure 2.2: The Pompom weed roots used for storing nutrient, which helps the plant grow more vigorously post burning and/ or cutting



Image: SANBI-ISP

Currently as informed by past experiences, the best practice for this species is just containing the invasion (Manyama, Personal Communication, March 3, 2015), with major economic losses. Just as with most environmental expenditure, some resources consumed in pompom weed management are hidden in the overhead account using Traditional Costing Accounting (TCA). By using ABC, these costs will be revealed and pompom weed expenditure accurately reported.

2.4 Reporting on Pompom weed expenditure using Activity Based Costing (ABC)

Using traditional costing systems, costs are assigned based on easy to identify factors like direct labour hours, more often than not, with no relationship between cost pools and cost drivers. This result in managers receiving inaccurate ideas of amounts spent in each process or for each service, and thus making misinformed decisions. ABC on the other hand, is designed to assign costs to activities which enable more accurate cost information (Kumar & Mahto, 2013). According to Mitchell (2015), ABC accumulates overhead costs for each activity and then assigns them to cost objects causing the activity; by so doing, addressing the deficiencies of traditional accounting systems. The ABC overview holds that all activities that support the production and delivery of goods or services should be assigned to final cost objects (Franklin, 2013). The benefits of employing ABC includes: (1) increased cost awareness and understanding, (2) better tracing of costs to objects, (3) superior allocation of overheads to cost objects and (4) financial (cost driver rates) and non-financial (cost driver volumes) measures for cost management and operational decisions (Hopper & Major, 2007). Moreover, with ABC, an organization can estimate the cost elements of its services, separate value adding activities from non-value adding activities and make strategic decisions to eliminate waste and optimize processes.

One of the two ABC approaches listed below may be used in assigning costs (Society of Management Accountants of Canada, 1996; Mowen *et al.*, 2014):

Approach 1- sub-accounts are established in the general ledger, allocating costs to various activities in the appropriate proportions. Though resembling traditional accounting systems, this approach allows the organization to emphasize environmental costs.

Approach 2- emphasizes the relationship between activities and cost drivers. Using this approach, costs move from incurrence to cost objects in a series of steps, all based on a cause-and-effect relationship.

Approach 2 mirrors closely the actual flow of costs and will be adopted in the current study. Results obtained will be used to inform three management decision-making processes namely costing analysis, investment analysis and performance evaluation as part of the ISP's Environmental Management system using EMA.

2.5 Environmental Management Accounting

Environmental Management Accounting represents a combined approach providing for the transition of data from financial accounting and cost accounting to increase material efficiency, reduce environmental impact and risk and reduce costs of environmental protection (Domil, Peres & Peres, 2010). According to Schaltegger, Hahn & Burritt (2000), EMA is a generic term that includes Monetary Environmental Management Accounting (MEMA), using Monetary Accounting Units and Physical Environmental Management Accounting (PEMA), using Physical Accounting Units. MEMA forms part of the conventional management accounting dealing with environmentally-driven impacts expressed in monetary terms. As reported by Schaltegger & Burritt (2000) in Schaltegger *et al.*, (2000), MEMA is the basis upon which internal management decisions including tracking, tracing and treating environmentally driven costs are based. Following this decisions, strategic and operational plans as well as environmental Key Performance Indicators (KPI's) and targets may be set. Contrarily, PEMA is used to collect environmental impact information in physical terms (for example, hectors), for internal management purposes (Schaltegger *et al.*, 2000). The two may be integrated by following the framework of Environmental Management Account as proposed by Schaltegger and co-workers in 2000. Table 2.2 below shows details of the proposed framework.

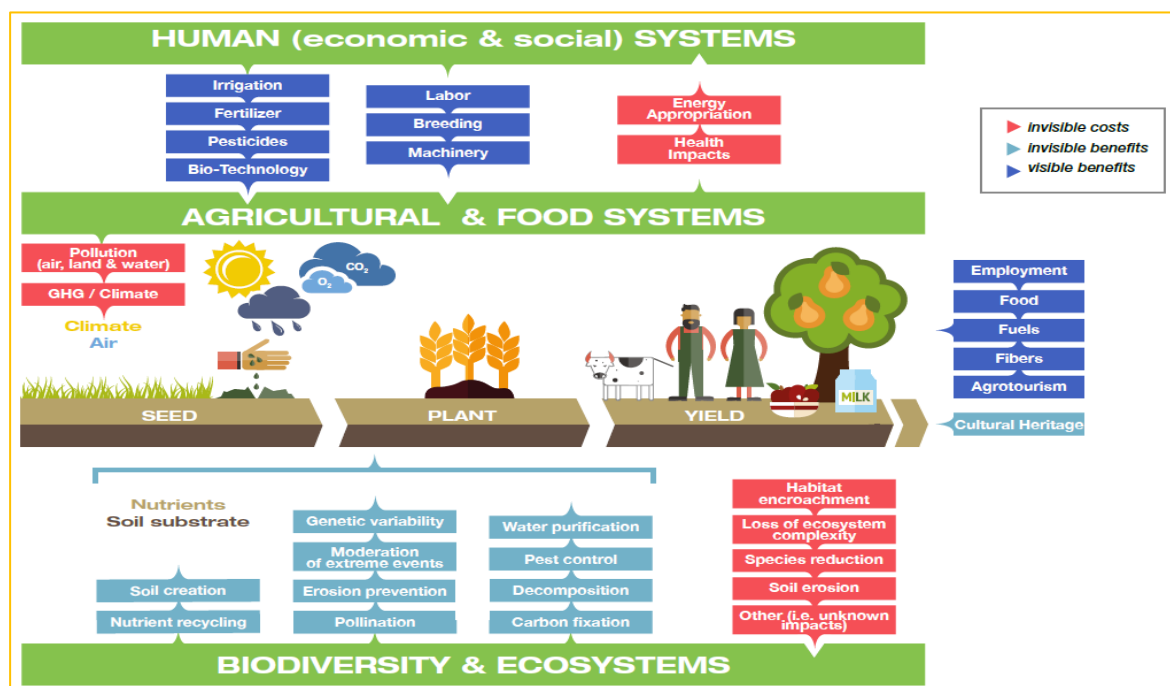
Table 2.2: Framework of Environmental Management Accounting

		Environmental Management Accounting (EMA)			
		MEMA		PEMA	
		Short Term Focus	Long Term Focus	Short Term Focus	Long Term Focus
Past Orientation	Routinely generated information	Environmental cost accounting (example: variable costing, absorption costing and Activity Based Costing)	Environmentally induced capital expenditure and revenues	Material and energy flow accounting (short term impact on the environment- product, site, division and company levels)	Environmental (or natural) capital accounting
	Ad hoc information	Ex post assessment of environmental costing decisions	Environmental life cycle (and target) costing Post investment assessment of individual projects	Ex post assessment of short term environmental impacts (example: of a site or product)	Life cycle investment Post investment assessment of physical environmental investment appraisal
Future Orientation	Routinely generated information	Monetary environmental operational budgeting (flows) Monetary environmental capital budget (stocks)	Environmental long term financial planning	Physical environmental budgeting (flows and stocks) (Example: activity based budgeting)	Long term physical environmental planning
	Ad hoc information	Relevant environmental costing (example: special orders, products mix with capital constraint)	Monetary environmental project investment appraisal Environmental life cycle budgeting and target pricing.	Relevant environmental impacts (example: given short run constraints on activities)	Physical environmental investment appraisal Life cycle analysis of specific project

Source: Schaltegger, Hahn and Burritt 2000

Although PEMA is generally straight forward and easy to understand, physical units are not easy to aggregate and do not provide a condition measure necessary in environmental accounting (Kinzig *et al.*, 2011, Weber, 2007). For those reasons, Condition Accounting Units, using fit-for-purpose indicators to describe the state of an environmental asset, for example biodiversity, are more favourable. In this study remote sensing (Landsat 7 images, which was operational in the time periods focused on in this study) is the method of choice for detecting pompom weed range shift as well as changes in abundance, in response to management approaches implemented. The use of time series satellite image analysis such as remote sensing, have been successful in monitoring vegetation trends (Yin, Udelhoven, Fensholt, Pflugmacher & Hostert, 2012). Detecting shrubs of small stature like pompom weed from Landsat 7 images is spatially challenging. This is because of their very low spatial resolution, with single or small scattered herbs not readily detectable. For pompom weed however, which invades the grasslands in large numbers and forms a pink sheet during peak flowering periods, the species may be indirectly detected using Landsat 7 images analysis. For the analysis, Normalised Difference Vegetation Index (NDVI) was used to contrast the peak light reflectance and decrease of vegetation in the areas heavily invaded by pompom weed. An increase in vegetation reflectance in the period December- January (Dec-Jan) and subsequent decrease in February- March (Feb-Mar) is the expected pattern. This pattern is in line with pompom weed flowering which is at its peak in Dec-Jan and withers around Feb-Mar. The time frames limits ambiguity in interpreting results since the invaded grasslands does not bloom and wither at the same times as pompom weed. Further analysis of image pixels generates vegetation reflectance values per pixel (Sah, Honji, Kubo & Senthil, *et al.*, 2012). Pixel values, confirming the observed reflectance for each invaded cell was then recorded and a trend analysis undertaken for the different flowering periods. This is referred to, in this study, as Conditional Environmental Management Accounting (CEMA). It is important because biodiversity pressures are inevitably transferred to ecosystem services and humans (Fig 2.3).

Figure 2.3: A multilayer relationship between Biodiversity, Ecosystem Services and Human well-being



Source: TEEB n.d.

In terms of biodiversity heritage, as reported by the government's Working-Group-6 for ecosystem services, South Africa is rated as one of the richest countries in the world. Not surprisingly, South Africa is one of the seven pilot countries selected by the United Nations Statistics Division (UNSD), to showcase the Systems of Environmental-Economic Accounting (SEEA), Experimental Ecosystem Accounting. Phase one of the project commenced in August 2014, and was scheduled to be completed in June 2015 (Environmental Economic Accounts Compendium, 2015). In the Experimental Ecosystem Accounting projects, assessment of ecosystem assets involves the measurement of:

1. Ecosystem condition and extent: land cover determining area and changes in areas
2. Expected ecosystem services flow: the ability of an ecosystem asset to generate an expected combination of provisioning, regulating and cultural services

3. Assessing changes in ecosystem flows: measuring changes in ecosystem assets, particularly degradation and enhancement

The compendium approach is similar to the approach followed in the current study, were (1) a study area has been identified, as guided by historical pompom weed records, (2) the weed's presence and absence data is used as an indicator of the change or state of the study area and finally (3) services flow are extrapolated from the remote sensing analysis to be discussed in detail in the materials and methods section in Chapter 3.

2.6 Summary

AIS are an important threat to Biodiversity and all its attributes. Managing AIS effectively and reporting on the state of the invaded area pre- and post- management interventions, as well as monetary investments made, is an important step in monitoring the efficiency of the applied methods. Furthermore, a strong link between biodiversity and human being makes it mandatory for this important asset to be closely monitored and protected.

The indicator species used in the current study is one of the most difficult to manage. Accurately measuring efficiency in management approaches applied will therefore be of much value to ISP and the methods will then be easily applied for other AIS in the programme. Despite well- known biodiversity threats associated with AIS, this group of species is not included in the Experimental Ecosystem Accounting projects (Driver, Personal Communication, February 3, 2015). This study therefore fills in an important gap in biodiversity management. A discussion of the empirical study conducted in this study will follow in Chapter 3.

CHAPTER 3

EMPIRICAL STUDY

3.1 Introduction

The primary goal of this chapter is to assess the condition of the study area as influenced by pompom weed invasions, and also to analyse financial investment in pompom weed management in the Free State province to date. In order to achieve these goals, current and historical pompom weed occurrence records were collected, cleaned and used to guide condition assessment of the land using satellite images. The same data was also used in tracking the species' range shift in the province.

Biodiversity loss as a result of pompom weed invasions was calculated based on Landsat 7 remote sensing images. A decrease in reflectance, following management interventions, indicates that the interventions were successful, whereas an increase in reflectance indicates intervention failure. Monetary investments are reported using ABC. This is to reveal the true cost of pompom weed management by reflecting costs traditionally hidden in the overhead account.

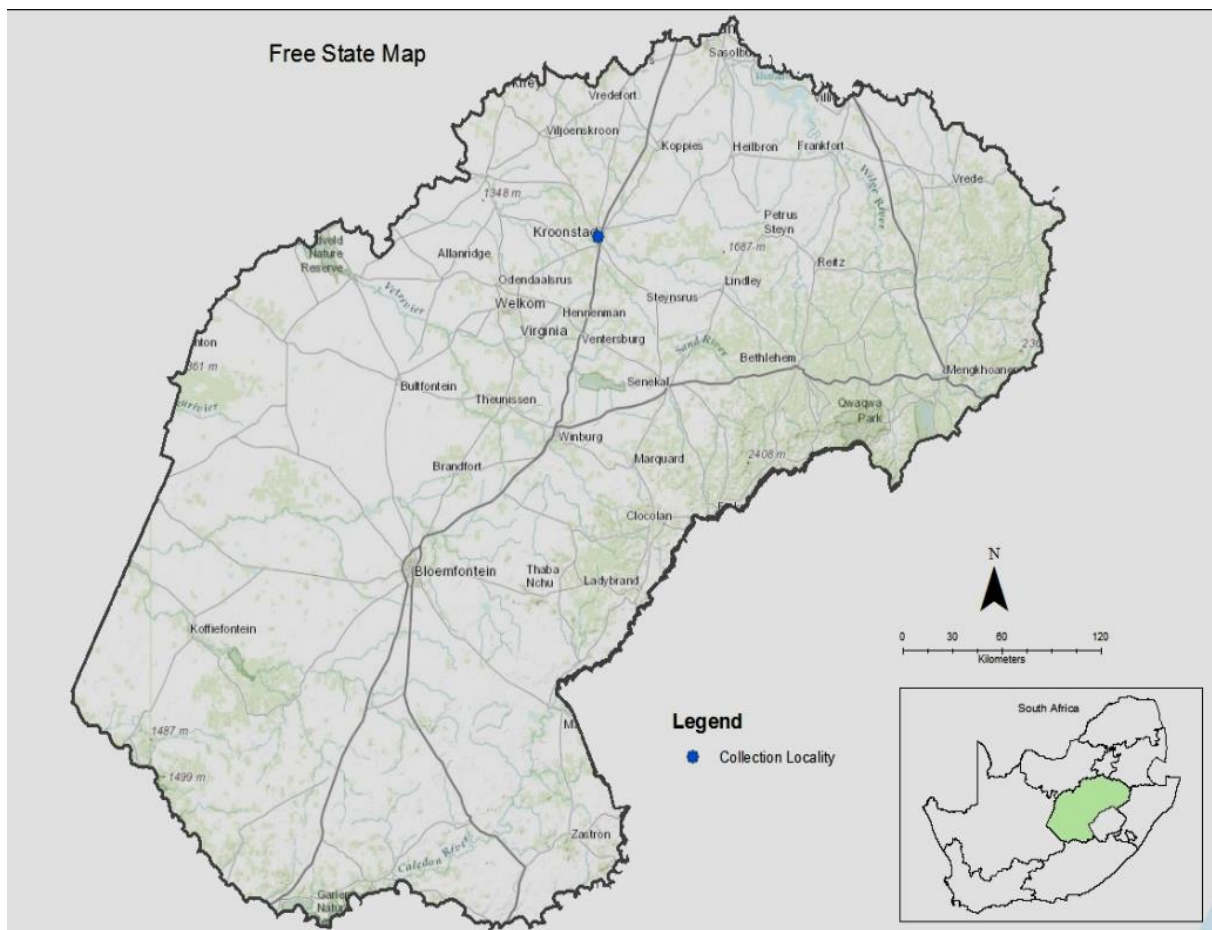
3.2 Research Ethics

No animals or humans were used in this study.

3.3 Study area

This study was conducted in the Free State province of South Africa. According to pompom weed collection records retrieved from SANBI's South African Plant Invader Atlas (SAPIA) list as well as the ISP section, pompom weed was first recorded from Kroonstad in the Free State, as indicated in the study area map below (Fig 3.1). Surveys following the initial reporting show pompom weed records to follow major roads connecting Kroonstad with important towns both in and out of the Free State province.

Figure 3.1: Map of the Free State showing Kroonstad as a locality where pompom weed was recorded.



Map generated in ArcGIS 10 with Topographic base map layer used as a background

3.4 Occurrence data collection, processing and analysis

3.4.1 Collating historical data

The collated historical occurrence data was collected by ISP appointed contractors for the flowering periods 2010-2011, 2011-2012, 2012-2013 and 2013-2014. These data sets include collection date, locality description, GPS coordinates as well as the number of plants observed per area and/ or species abundance.

3.4.2 Collecting current data

Current occurrence data, 2014-2015, was collected following the methods used for collecting historical data. This was to ensure direct comparison of the different datasets and to also ensure continuity. Field images of the surveyed areas were also captured.

3.4.3 Data processing and analysis

All GPS coordinates were Geo-referenced according to standard Geo-referencing procedures as followed in SANBI's Threatened Species Programme. The generated data was then mapped using ArcGIS software version 10. The produced maps as well as the GPS coordinates were used to guide the remote sensing procedures explained in section 3.5.1 below.

3.5 Environmental Management Accounting (EMA)

3.5.1 Conditional Environmental Management Accounting using Remote Sensing

Landsat 7 and SPOT 5 satellites images for South Africa were acquired from the US Geological Survey and Department of Environmental Affairs respectively. The acquired satellite images were first pre-processed to ensure that (1) there is 100% overlap between satellite images and respective areas they are representing and (2) environment factor like top of atmosphere corrections are taken into consideration. Multispectral images were then created by fusing the six bands; Red, Green, Blue, Near Infrared and two Middle infrared bands; Using Erdas Imagine 2014 software. The study area was then extracted through sub-setting in Erdas and prepared for further analysis as described below.

GPS coordinates from section 3.4.1 and 3.4.2 were overlaid over both satellite images, thus showing the exact location where pompom weed was recorded. Spectral signature was extracted on both Landsat 7 and SPOT 5 satellite images as guided by the GPS coordinates. Several spectral signatures of non-invaded grasslands were also extracted as control sites. Spectral signature separability analysis was then conducted. A pixel based classification then followed.

The above described analysis was conducted for the flowering periods 2009-2010, 2010-2011, 2011-2012, 2012-2013, 2013-2014 and 2014-2015. The condition of the study area in relation to pompom weed invasion for each period was recorded. Changes in Pompom weed abundance as well as range expansion and contraction was also recorded. A negative and positive control was included to avoid misinterpretations.

3.5.2 Monetary Environmental Management Accounting

In this section, ABC was used to report on pompom weed expenditure as invested in the Free State province. For reporting purposes as influenced by the current ISP reporting system, the activities were grouped per activity centre as illustrated in Table 3.1 below.

3.6 Summary

A trend analysis wherein the relationship between species prevalence and abundance; and management interventions in terms resources invested, was conducted. This was achieved by using both remote sensing and EMA with the two sub divisions Conditional Environmental Management Accounting and Monetary Environmental Management Accounting.

Results obtained in this respect are reported in the next chapter. Discussion, Conclusions and recommendation on efficient AIS management will be made in Chapter 5.

Table 3.1: Resource and Activity driver for Pompom weed management

Activity Centre	Activity	Resources	Activity Cost Driver
Invasion Detection	General surveys (actively searching for invasive species)	Labour, Equipment	Volume of surveyed land (in ha)
Environmental remediation	Activity for land rehabilitation (mechanical and bio- control)	Labour, Equipment	Volume of ground restored (in m ²)
	Purchasing herbicides	Consumable	Volume of herbicides used (in mg/l)
	Medical examinations	Field workers	Number of field workers
Monitoring and Evaluation	Site visits and action-plan formulation	Labour, Equipment	Volume of ground monitored (in ha)
Research and Development	Activity to train and develop future Conservationists and Ecosystem scientists (Scholarships and bursaries for Hons, MSc, PhD and Post- doctoral fellows)	Funding	Number of graduates
	Activity for Environmental training of employees/ field workers	Labour, Equipment	Number of employees/ field workers trained
Social Activity	Activity to educate the public about Pompom weed	Labour, Materials	Number of pamphlets distributed Number of Indaba's held
Administration Activity	Activity for environmental improvement activities i.e. remediation	Labour	Time (distributed proportionally per species-per-area)
	Activity for implementation and maintenance of an environmental management system	Labour	Time (distributed proportionally per species-per-team)

CHAPTER 4

RESULTS

4.1 Introduction

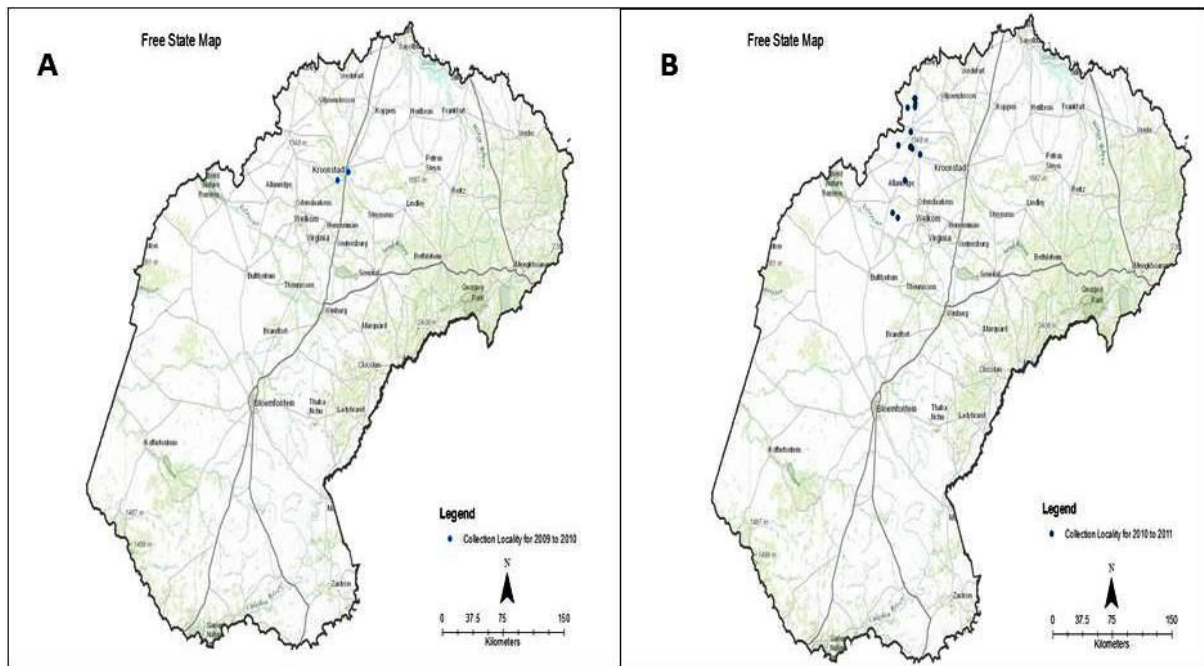
Results of this study which are presented in this chapter are reported in two sections, namely, the Occurrence data collection section as well as the EMA section. The EMA section is further subdivided into CEMA and MEMA sections respectively. Trend analysis for occurrence data collections as well as EMA is also reported.

4.2 Results

4.2.1 Occurrence data collections

In the Free State, pompom weed was first recorded in Kroonstad, as reported to the ISP in 2009 (Fig 4.1A). In 2010, the species was detected further west of Kroonstad as indicated in Fig 4.1B below.

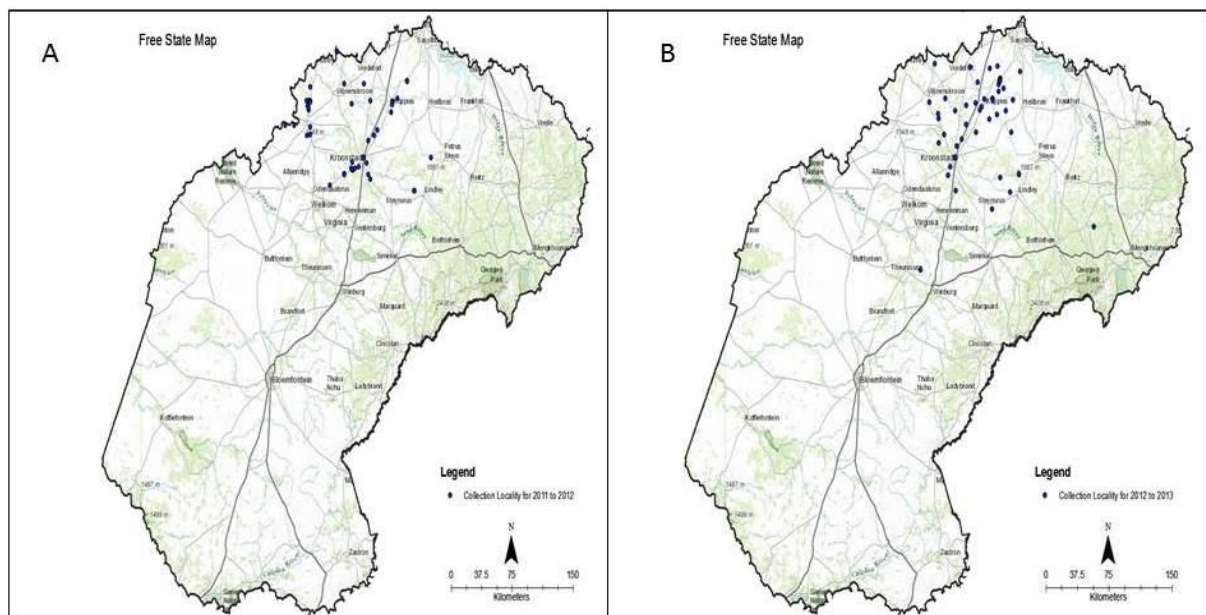
Figure 4.1: Pompom weed distribution records for the flowering period (A) 2009-2010 and (B) 2010-2011



Maps generated in ArcGIS 10 with Topographic base map layer used as a background

Records for the flowering period 2011-2012 indicates a broader species range, with pompom weed also recorded in the east of Kroonstad towards Lindley, and further in a south easterly direction past Bethlehem in 2012-2013 (Fig 4.2 A and B). More collection localities were also recorded towards Gauteng on the N1 road (Fig 4.2B).

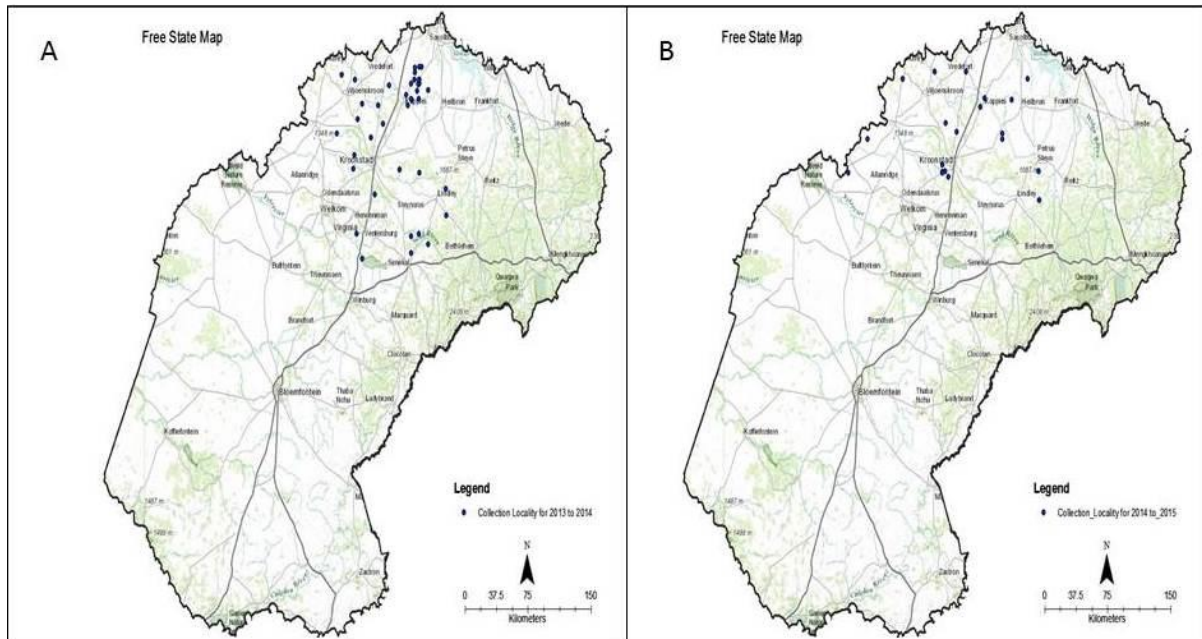
Figure 4.2: Pompom weed distribution records for the flowering period (A) 2011-2012 and (B) 2012-2013



Maps generated in ArcGIS 10 with Topographic base map layer used as a background

Although a small decrease in the total extent of pompom weed occurrence was observed in 2013- 2014 and 2014- 2015, a significant continued decline in the number of localities was reported (Figure 4.3 A and B).

Figure 4.3: Pompom weed distribution records for the flowering period (A) 2013-2014 and (B) 2014-2015



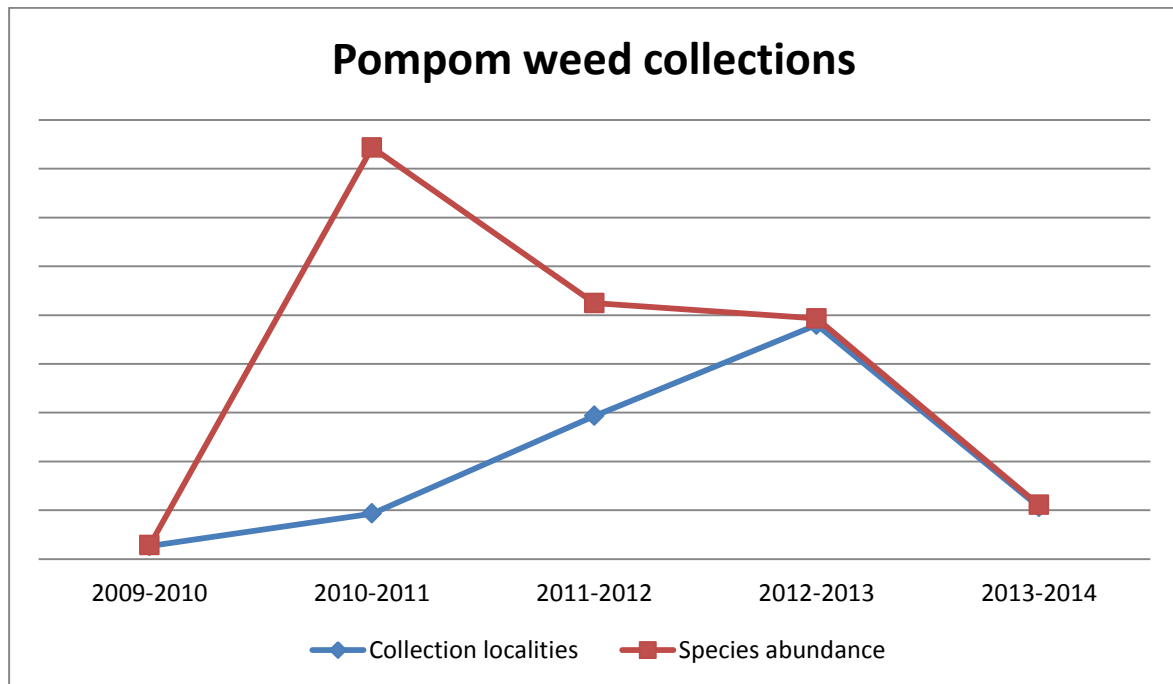
Maps generated in ArcGIS 10 with Topographic base map layer used as a background

4.2.1.1 Occurrence data collection: Trend analysis

An increase in the number of collection locality was observed from the first occurrence reporting in 2009, reaching its highest in the flowering period 2012-2013 (Fig 4.4). As also indicated in Fig 4.4 below, a decline was observed in 2013-2014. On the contrary, species abundance records reached their peak in the flowering period 2010-2011, with a steady but definite decline observed from 2011-2012 through to 2013-2014 (Fig 4.4).

The period 2014-2015 is not included in this analysis because not all species abundance data was submitted at the date of compilation of this document; hence distortion could not be out ruled.

Figure 4.4: Trend analysis of Pompom weed collections from 2009 to 2014



4.2.2 Environmental Management Accounting

In this study, condition and monetary accounting units were used and the results in this regard are reported below.

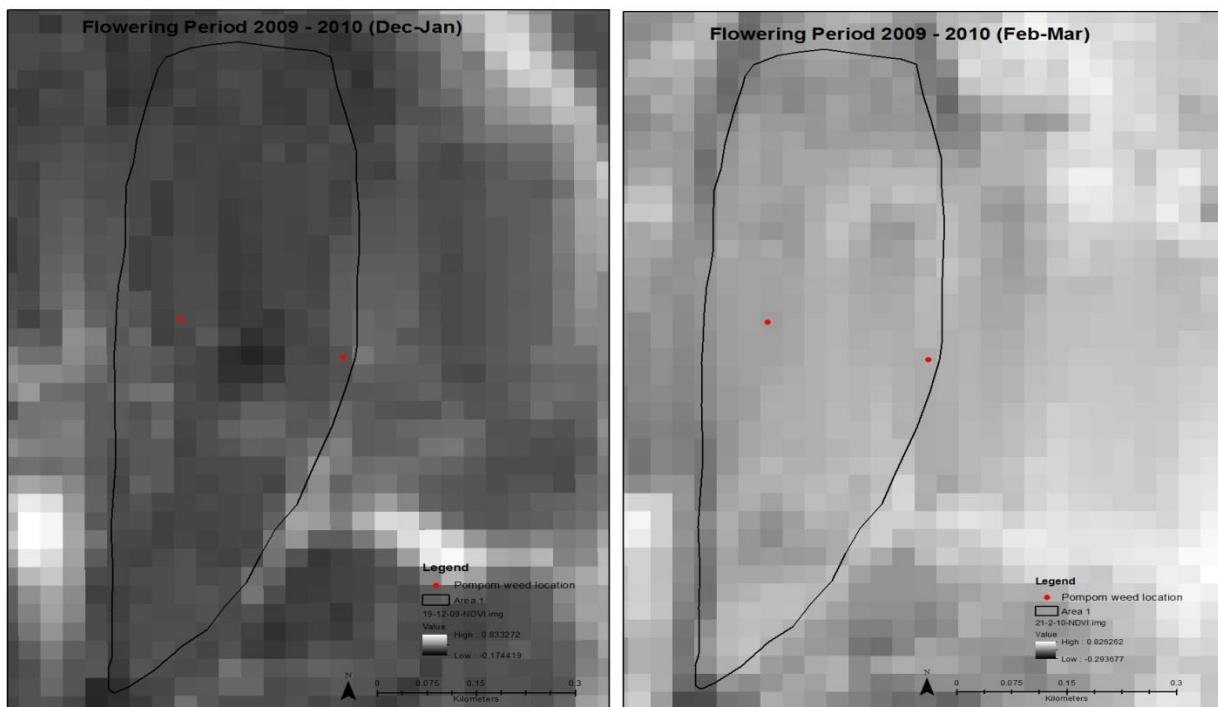
4.2.2.1 Conditional Environmental Management Accounting using Remote Sensing

In order to report on the condition of the study area in response to AIS management initiatives, one needs to go back in time and categorically record changes and patterns. One of the tools instrumental for this purpose is Remote Sensing which was used in this study. The one locality for which presence data was consistently recorded through the studied flowering periods is Locality 1 (Opposite Kroonstad Military base on the N1 to Bloemfontein). Furthermore, this locality is one of the two worked on since the inception

of the ISP, and the number of plants has reached remote sensing detectable levels. The locality was therefore used in this section of the study, to assess the success of pompom weed management approaches employed by ISP.

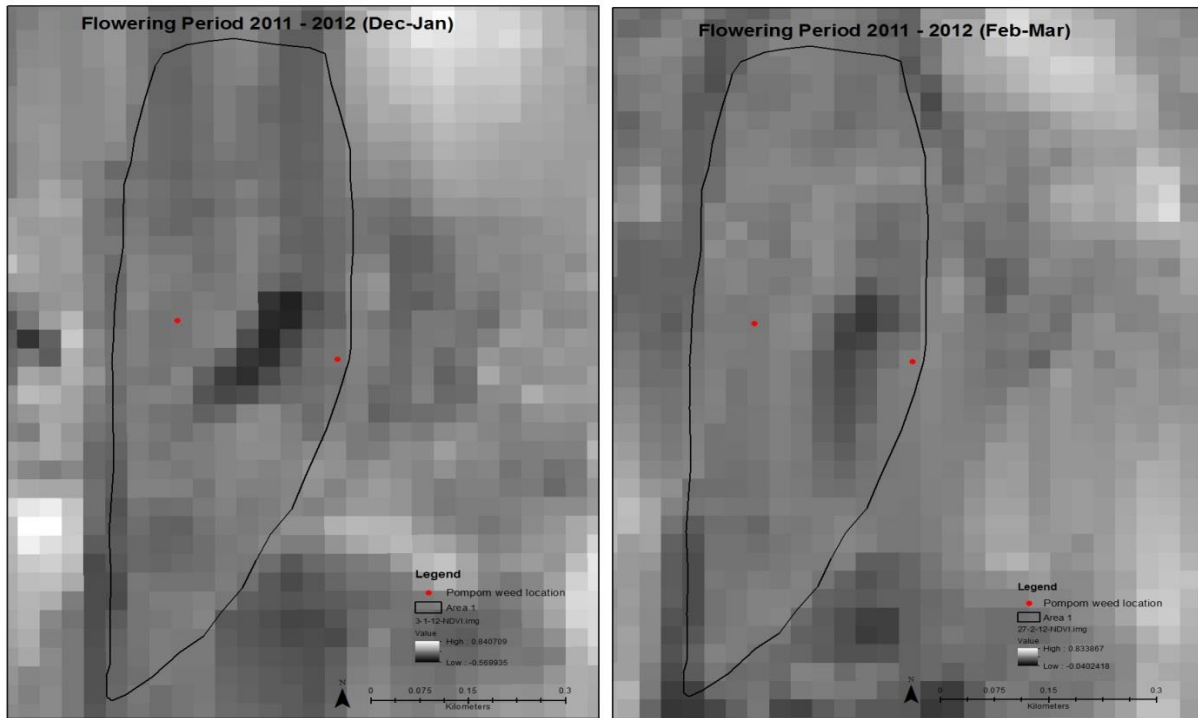
For the flowering period 2009-2010, an increase in vegetation reflectance was recorded from Dec-Jan to Feb-Mar (Fig 4.5). This pattern is opposing that of pompom weed, where the species withers in Feb-Mar and is at its peak in Dec-Jan.

Figure 4.5: Vegetation reflectance for the flowering period 2009-2010, with peak (Dec-Jan) and withering (Feb-Mar) seasons separated.



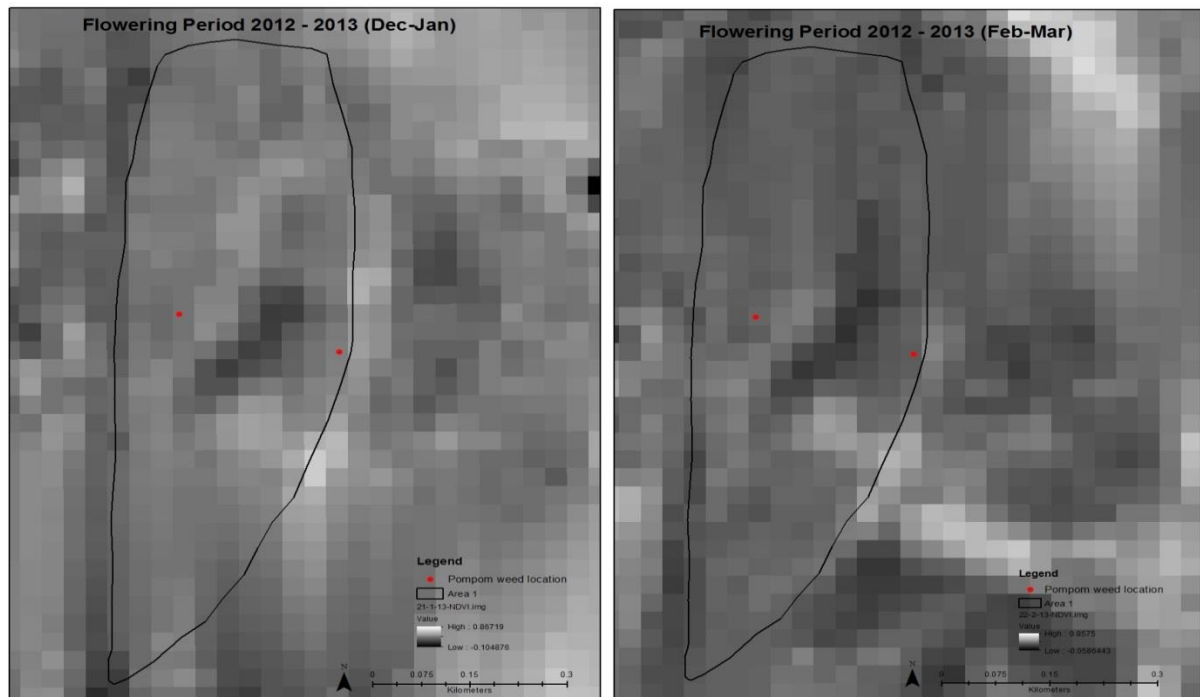
For the flowering period 2010-2011, no usable images could be retrieved; hence analysis for the period could not be performed. For the flowering period 2011-2012 however, there was a decrease in vegetation reflectance from Dec-Jan to Feb-Mar (Fig 4.6). This is indicative of Dec-Jan being the peak season for pompom weed and Jan-Feb its withering season. The record is in line with the species behaviour.

Figure 4.6: Vegetation reflectance for the flowering period 2011-2012, with peak (Dec-Jan) and withering (Feb-Mar) seasons separated.



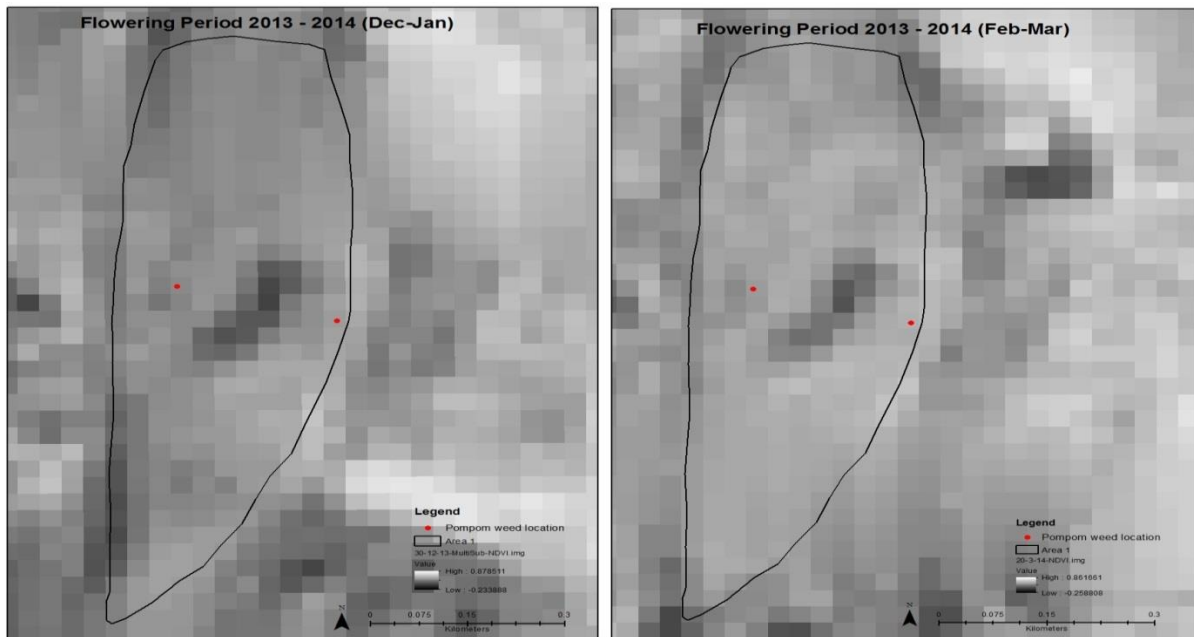
Similarly, for the flowering period 2012-2013, there was a decrease in vegetation reflectance from Dec-Jan to Feb-Mar, a pattern agreeing with flowering and withering periods for pompom weed (Fig 4.7 below).

Figure 4.7: Vegetation reflectance for the flowering period 2012-2013, with peak (Dec-Jan) and withering (Feb-Mar) seasons separated.



For the flowering period 2013-2014, an increase in vegetation reflectance was recorded from Dec-Jan to Feb-Mar (Fig 4.8 below). This pattern is opposing that of pompom weed, similar to that reported for 2009-2010.

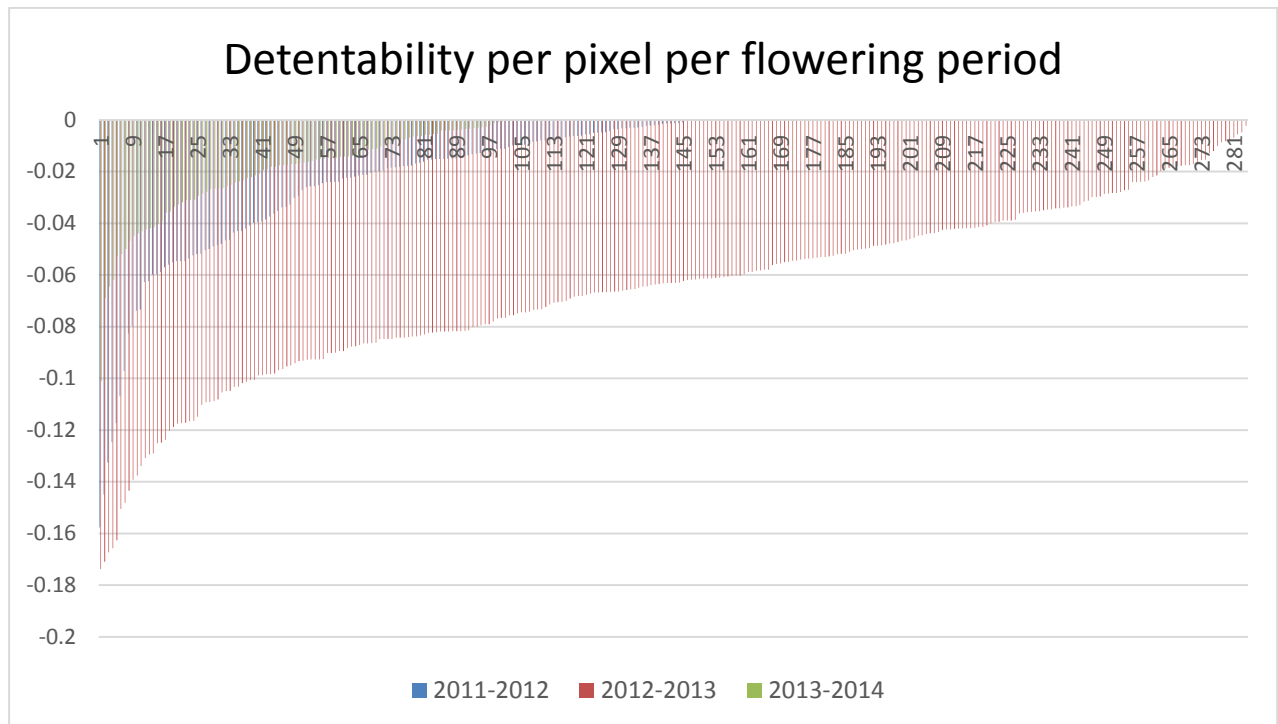
Figure 4.8: Vegetation reflectance for the flowering period 2012-2013, with peak (Dec-Jan) and withering (Feb-Mar) seasons separated.



4.2.2.2 Conditional Environmental Management Accounting, Trend Analysis

For trend analysis, NDVI algorithm, which highlights healthy vegetation with high photosynthesis activity, was used. Since the species pattern was correlating with vegetation reflectance for the flowering 2011-2012, 2012-2013 and 2013-2014, the three were used for trend analysis. Results obtained indicate higher detectability and subsequent drop in reflectance (Peak and withering phase) for the flowering period 2012-2013 (Fig 4.9 below). An increase in change reflectance is indicated from 2011-2012 to 2012-2013 while a decreased is indicated from 2012-2013 to 2013-2014. This suggests that pompom weed management initiatives were successful in this locality.

Figure 4.9: Trend analysis of pompom weed detectability in Kroonstad, Locality 1



4.2.3 Monetary Environmental Management Accounting

Expenditure reporting was conducted per financial year or pompom weed flowering season. The total costs for the entire five year was then collated and an expenditure trend analysis performed.

The ISP manages species by appointing and training contractors on species identification and treatment. Following a tendering process, an appointed contractor is contracted for one season. ISP is responsible for monitoring and evaluation, and subsequent reporting to the funding body, DEA.

For the flowering period 2009-2010, a total amount of R54 422.00 was approved for management of pompom weed in the Free State, here-in referred to as Approved Plan

of Operations (APO) cost. This amount was paid out to the appointed contractor, for the then flowering period. The APO cost however only accounted for 76% of the total costs for pompom weed management, with the remaining 24% hidden in overhead accounts (Table 4.1).

A reported 70% of pompom weed management costs were for Activity for land rehabilitation (Table 4.1 below). This was distantly followed by costs for Site visits and action-plan formulation at 9% and then Activity for environmental training for employees and contract workers, together with Activity for implementation and maintenance of an Environmental Management System at 5%. The least expenditure was for General surveys and Activity to educate the public about pompom weed each at 3% (Table 4.1).

Table 4.1: Costs per activity centre for the flowering period 2009-2010

Activity Centre	Activity	Cost per activity	Cost per activity centre	Percentage cost per activity
Invasion detection	General Surveys	R2 489.00	R2 489.00	3%
Environmental remediation	Activity for land rehabilitation	R50 157.00	R53 457.00	70%
	Activity to purchase herbicides	0		0
	Activity for medical examinations	R3 300.00		5%
Monitoring and evaluation	Site visits and action plan formulation	R6 504.00	R6 504.00	9%
Research and development	Activity to train and develop future conservationists and ecosystem scientists	0	R3 404.00	0
	Activity for environmental training of employees/ field workers	R3 404.00		5%
Social activities	Activity to activate the public about pompom weed	R1 868.00	R1 868.00	3%
Administrative activities	Activity for environmental improvement activities	0	R3 864.00	0
	Activity for implementation and maintenance of an environmental management system	R3 864.00		5%
Total cost accounted for			R71 586.00	100%
Approved Plan of Operations costs			R54 422.00	76%
Pompom weed costs hidden in the overhead account			R17 144.00	24%

For the flowering period 2010-2011, a total amount R48 600.00 was approved as a budgeted APO cost for the period. This amount was paid out to the appointed contractor on two intervals as stipulated in the deliverable contract agreed upon by the ISP and the contractor. As indicated in Table 4.2, this amount accounts for only 63% of costs incurred for pompom weed management for this reporting period. The remaining 37% was hidden in overheads accounts, and is revealed in this study as indicated by Table 4.2. No costs were incurred for activity centre Invasion detection in this reporting period, as general surveys and reporting on detections forms part of the deliverables for the contractor.

A reported 55% of pompom weed management costs were for Activity for land rehabilitation (Table 4.2). This was distantly followed by costs for Activity for environmental training for employees and contract workers at 16%; and then Site visits and action-plan formulation at 14%. Activity for implementation and maintenance of an Environmental Management System on the other hand, accounted for 6% of the total cost incurred. Disregarding General surveys, Activity to train future conservationists and ecosystem scientists and Activity for environmental improvement, the least amount was spent on educating the public about pompom weed at a 2% in this reporting period (Table 4.2).

Table 4.2: Cost per activity centre for the flowering period 2010- 2011

Activity Centre	Activity	Cost per activity	Cost per activity centre	Percentage cost per activity
Invasion detection	General Surveys	0	0	0
Environmental remediation	Activity for land rehabilitation	R42 317.00	R47 615.00	55%
	Activity to purchase herbicides	R1 998.00		3%
	Activity for medical examinations	R3 300.00		4%
Monitoring and evaluation	Site visits and action plan formulation	R11 102.00	R11 102.00	14%
Research and development	Activity to train and develop future conservationists and ecosystem scientists	0	R12 435.00	0
	Activity for environmental training of employees and field workers	R12 435.00		16%
Social activities	Activity to activate the public about pompom weed	R1 495.00	R1 495.00	2%
Administrative activities	Activity for environmental improvement activities	0	R4 264.00	0
	Activity for implementation and maintenance of an environmental management system	R4 264.00		6%
Total cost accounted for			R76 911.00	100%
Approved Plan of Operations costs			R48 600.00	63%
Pompom weed costs hidden in the overhead account			R28 111.00	37%

A total amount of R222 755.00 was approved for operations for the flowering period 2011-2012. The amount accounts for 84% of the total costs of pompom weed management in the Free State (Table 4.3). The remaining 16% is for costs traditionally hidden in the overhead account. Table 4.3 below also shows the percentage cost breakdown per activity.

Similar to the previous reporting period, a highest percentage of costs incurred were for Activity for land rehabilitation (79%), followed by Site visits and action-plan implementation (10%) and then Activity to purchase herbicides (4%). Second to General surveys, Activity for medical examinations and Activity for training employees/ field workers accounted for the least percentage cost, each at 1% (Table 4.3).

Table 4.3: Cost per activity centre for the flowering period 2011- 2012

Activity Centre	Activity	Cost per activity	Cost per activity centre	Percentage cost per activity
Invasion detection	General Surveys	0	0	0
Environmental remediation	Activity for land rehabilitation	R208 715.00	R221 770.00	79%
	Activity to purchase herbicides	R9 205.00		4%
	Activity for medical examinations	R3 850.00		1%
Monitoring and evaluation	Site visits and action plan formulation	R26 311.00	R26 311.00	10%
Research and development	Activity to train and develop future conservationists and ecosystem scientists	0	R3 781.00	0
	Activity for environmental training of employees/ field workers	R3 781.00		1%
Social activities	Activity to activate the public about pompom weed	R6 921.00	R6 921.00	3%
Administrative activities	Activity for environmental improvement activities	0	R4 874.00	0
	Activity for implementation and maintenance of an environmental management system	R4 874.00		2%
Total cost accounted for			R263 657.00	100%
Approved Plan of Operations costs			R222 755.00	84%
Pompom weed costs hidden in the overhead account			R40 902.00	16%

For the flowering period 2012-2013, a total amount of R369 757.00 was approved for operations. This amount accounts for 96% of the total costs of pompom weed management for the flowering period in the Free State (Table 4.4). The remaining 4% is for costs traditionally hidden in the overhead account. Table 4.4 below also shows the final cost percentage breakdown per activity.

Similar to the previous flowering period, no cost were directly allocated to the activity General survey. The cost for Activity for land rehabilitation was highest at 94%, followed by Site visits and action-plan implementation 2%. About 0.1% was spent on herbicides and the remaining Activity for medical examinations, Activity for environmental training of employees/ field workers, Activity to educate the public on pompom weed and Activity for implementation and maintenance of an environmental management system accounted for 1% each of the total cost for the flowering period 2012-2013 (Table 4.4).

Table 4.4: Cost per activity centre for the flowering period 2012- 2013

Activity Centre	Activity	Cost per activity	Cost per activity centre	Percentage cost per activity
Invasion detection	General Surveys	0	0	0
Environmental remediation	Activity for land rehabilitation	R364 007.00	R368 772.00	94%
	Activity to purchase herbicides	R365.00		0.1%
	Activity for medical examinations	R4 400.00		1%
Monitoring and evaluation	Site visits and action plan formulation	R6 351.00	R6 372.00	2%
Research and development	Activity to train and develop future conservationists and ecosystem scientists	0	R3 539.00	0
	Activity for environmental training of employees/ field workers	R3 539.00		0.9%
Social activities	Activity to activate the public about pompom weed	R3 155.00	R3 155.00	0.8%
Administrative activities	Activity for environmental improvement activities	0	R4 944.00	0
	Activity for implementation and maintenance of an environmental management system	R4 944.00		1%
Total cost accounted for			R386 781.00	100%
Approved Plan of Operations costs			R369 757.00	96%
Pompom weed costs hidden in the overhead account			R17 025.00	4%

A total amount of R114 355.00 was approved for operations for the flowering period 2013-2014. The amount accounts for 84% of the total costs of pompom weed management in the Free State (Table 4.5). The remaining 16% is for costs traditionally hidden in the overhead account. Table 4.5 below shows the final cost breakdown per activity.

In the reporting period 2013-2014, Activity for land rehabilitation amounted to 81% of the total costs incurred, followed by Site visits and action-plan formulation at 6% (Table 4.5). Activity for implementation and maintenance of an environmental management system then followed at 4%, and then Medical examinations and Activity for environmental training of employees/ Field workers followed each at 3%. Herbicides costs were least at 1% of the total costs for the flowering period (Table 4.6).

Table 4.5: Cost per activity centre for the flowering period 2013- 2014

Activity Centre	Activity	Cost per activity	Cost per activity centre	Percentage cost per activity
Invasion detection	General Surveys	0	0	0
Environmental remediation	Activity for land rehabilitation	R107 630.00	R113 350.00	81%
	Activity to purchase herbicides	R1 320.00		1%
	Activity for medical examinations	R4 400.00		3%
Monitoring and evaluation	Site visits and action plan formulation	R7 466.00	R7 466.00	6%
Research and development	Activity to train and develop future conservationists and ecosystem scientists	0	R3 781.00	0
	Activity for environmental training of employees/ field workers	R3 781.00		3%
Social activities	Activity to activate the public about pompom weed	R2 245.00	R2 245.00	2%
Administrative activities	Activity for environmental improvement activities	0	R5 480.00	4%
	Activity for implementation and maintenance of an environmental management system	R5 480.00		
Total cost accounted for			R132 322.00	100%
Approved Plan of Operations costs			R114 355.00	86%
Pompom weed costs hidden in the overhead account			R17 767.00	14%

4.2.3.1 Monetary Environmental Accounting: Trend analysis

Figure 4.10 below shows an increase in the cost of managing pompom weed for the flowering period 2011-2012 and again for 2012-2013. About 3% of resources spent in 2009-2010, were for General surveys in the activity centre Invasion detection (Figure 4.11, Table 4.1). In the subsequent years, this activity was absorbed in the activity centre Environmental remediation, where general surveys were conducted by contractors as part of Activity for land rehabilitation. On average, a 344% increase in pompom weed management expenditure from 2010-2011 to 2011-2012 was reported, whereas a 35% decrease in costs was reported between 2012-2013 and 2013-2014. Through the years, a significantly higher percentage of resources were spent on Environmental remediation, Activity for land rehabilitation (Fig 4.11). For training employees and field workers or contractors, a higher percentage was spent in the period 2010-2011. With the exception of 2010-2011, Site visits and action plan formulation is consistently the second high spender, followed by Activity to implement and manage an EMA system for the periods 2009-2010, 2010-2011 and 2013-2014 (Fig 4.11).

Figure 4.10: Pompom weed management cost trend analysis from 2009 to 2014

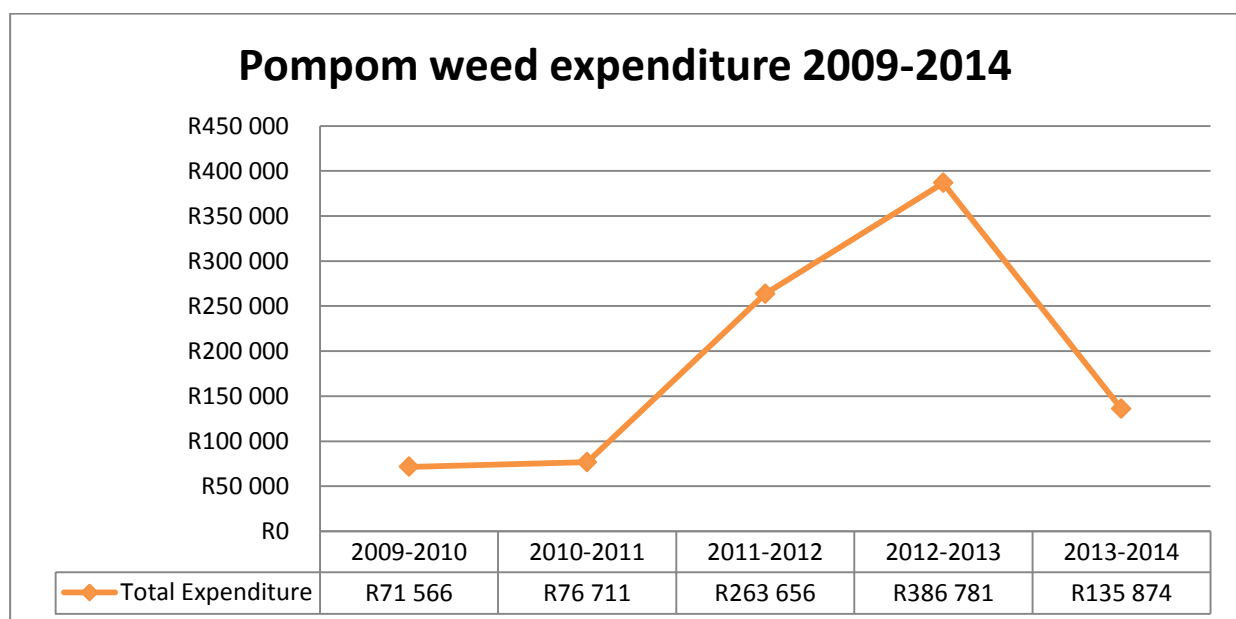
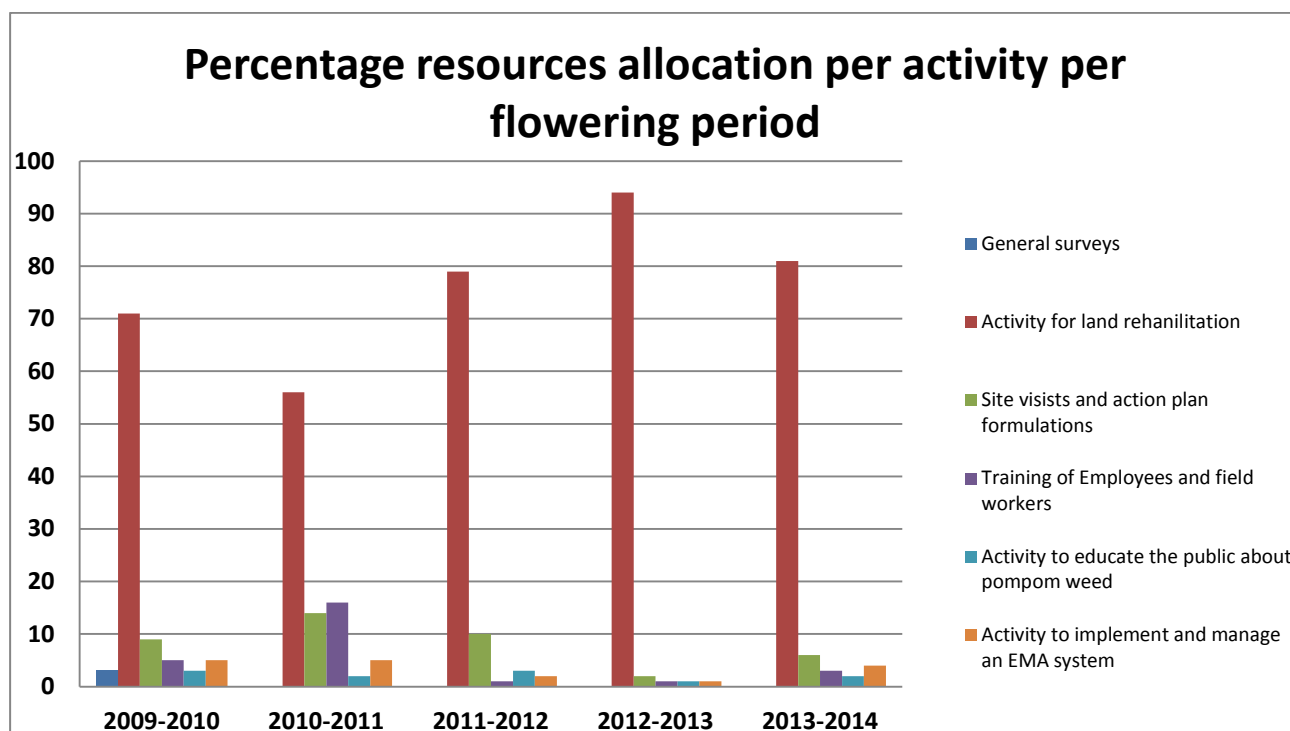


Figure 4.11: Resources allocation per activity trend analysis from 2009 to 2014



To evaluate the efficiency of ISP interventions in managing pompom weed in the Free State, and justify the expenditure reported above, Efficiency ratios were calculated for the different flowering periods using the formula; $\text{Efficiency ratio} = \frac{\text{Total costs for the flowering period}}{\text{number of plants reported}}$. The number of plants was not reported for 2009- 2010, hence the efficiency ratio could not be calculated for the period. From 2010-2011 onwards however, an increase in efficiency, as informed by the efficiency ratios, is reported (Table 4.6). The results suggest that management approaches applied were successful.

Table 4.6 Efficiency ratios for the different flowering periods as well as for the entire reporting period (2009- 2014)

Flowering Period	Total costs accounted for	Total number of plants	Efficiency ratio
2009-2010	R71 566.00	Not reported	n/a
2010-2011	R76 711.00	45667	1.68
2011-2012	R263 656.00	12071	21.82
2012-2013	R386 781.00	796	485.91
2013-2014	R135 874.00	250	543.5

Despite the positive results stated above, an important observation to note is that a vacuum left after clearing pompom weed, is being taken over by other invasive species such as *Verbena bonariensis*, *Asparagus larycinus*, *Verbena brasiliensis* and *Opuntia stricta* (Fig 4.12). *A. larycinus*, although not exotic, has invasive properties in the Free State. The species invades the grasslands and cannot be used as a substitute because it is not palatable for life stock (Mothogoane, Personal Communication, October 2, 2015). This therefore creates a problem for farmers in the province.

Of the three alien species recorded in the area, *V. bonariensis* is most abundant. Similar to pompom weed, *V. bonariensis* is a National Environmental Management: Biodiversity Act 10 of 2004 (NEMBA) category 1b species. NEMBA category 1b species are invasive species that may not be owned, imported into South Africa, grown, moved, sold, given as a gift or dumped in water. Category 1b species are major invaders that must be contained and assistance from the government is needed when the species is being removed. The species therefore carries as much treat to natives in the area as pompom weed and has potential to require as much effort and resources in managing, containing and controlling.

Figure 4.12: Other invasive species posing a risk of replacing pompom weed in Free State. Image (a) = *Verbena bonariensis*, (b) = *Asparagus larycinus*, (c) = *Verbena brasiliensis* and (d) = *Opuntia stricta* ()



Images: M. T. Sethusa; Plant species identified: SANBI, Biosystematics (M. Mothogoane, T. Nkonki and T. Jaca)

4.3 Summary

Results obtained from this study show a steady increase in the number of pompom weed localities from 2009-2010 until 2012-2013, following which a steep decline was reported. The highest species abundance however, was recorded for the 2010- 2011 flowering season followed by an increasing decline for the subsequent reporting periods (Fig 4.4). The reported increase in species abundance in 2010-2011, was followed by an increase in monetary expenditure indicative of increased effort for 2011-2012 and again for 2012-2013 (Fig 4.10). A positive outcome of this response is indicated by pompom weed being reduced to its lowest detectability level in 2013-2014 (Fig 4.9). The

results confirmed that ISP strategies for pompom weed management were successful in the Free State province.

These results are tabled and critically analysed in the next chapter.

CHAPTER 5

DISCUSSION

5.1 Introduction

Results reported in chapter 4 are tabled and discussed in this chapter, following which recommendations and a conclusion will be delivered.

5.2 Discussion

From 2009 to 2014, a total amount of R 934 588.00 was spent on pompom weed management in the Free State alone. About 13% of the total costs was traditionally hidden in overhead accounts, and was therefore never reported on prior to this study. The total reported amount R 934 588.00 was spent in five activity centres, namely, Invasion detection, Environmental remediation, Monitoring and evaluation, Research and Development, Social activities and Administrative activities. The Activity for land rehabilitation in Environmental remediation accounts for a total of R 771826.00, which is about 83% of the total costs incurred. Monitoring and evaluation as well as Activity for implementation and maintenance of an environmental management System, which are as important as the field work in ensuring a successful programme rollout, accounts for 6.2% and 2.5% of costs respectively.

Due to the importance of monitoring and evaluation as well as the implementation and management of the environmental management system, the reported effort and investment is far less than that the required value for efficient management. The above stated statement is qualified by the number of record errors encountered, as well as the time spent in cleaning data for the current study. Failure to clean and manage data

usually results in less accurate reporting and as such negatively affects planning for future interventions. Furthermore, inadequate monitoring and evaluation fails to inform intervention modification, therefore hampering maximum return in interventions.

Despite the above discussed challenges, pompom weed management was successful in the Free State. This is indicated by a decline in collection localities as well as species abundance as reported in chapter 4. The result is confirmed by the change in reflectance analysis reported, which also indicated the lowest level of invasion for 2013-2014, since the inception of ISP in 2009. For the rest of the country however, pompom weed management is still a major problem and is becoming financially unbearable for ISP (Manyama, Personal Communication, March 3, 2015). Severe fragmentation and the localised nature of invasion made successful management of the species possible in the Free State province. These invasion properties are however not common for the rest of the country. As a result, pompom weed seems to be expanding its range countywide and remains an important threat to native species. For this reason, plans are on the way to have management of the species handed over to DEA.

Contrary to species specific strategies employed by ISP, DEA employs areas-based approaches wherein a specific area is treated at a given time, without considering the biology of invasive species represented (Manyama, Personal Communication, March 3, 2015). Although this approach deals with the issue of invasive species replacing one another, it however poses a threat of fuelling pompom weed spread. Recommendation 3 below, together the other listed recommendations, is therefore key to successful pompom weed management going forward.

5.3 Recommendations and conclusion

1. From 2010 to date, the function of Activity for land rehabilitation was carried out by different contractors appointed through a tendering process for each flowering

period. There was therefore no expertise build up from year to year in terms of species identification and data collection, hence the need for data cleaning for the current study. It is therefore recommended that, if contractors are to be employed for pompom weed field work, three year contracts be entered into between the relevant government entity and these contractors. This will ensure increased competency and will also provide credible experience for field workers, thus making them marketable. The reported 3% of the total cost spent in field workers training from 2009 to 2014 will also be reduced drastically. A need for close monitoring to minimise irregularities was also identified in this regard.

2. In the duration of this study, a gap in managing an EMA system was observed. This was evident in the different formats of the achieved occurrence localities, as well as a lack of a fortified linkage between field expenditure and field work performed. Without an efficient EMA system, the good work performed by ISP, where pompom weed is reduced to non-detectable levels using remote sensing in Free State, would be clouded by irregularities in administrative functions. It is therefore recommended that a management team comprising of an administrative manager as well as a data manager be created to support current structures in ensuring smooth EMA execution.
3. Both species-specific and area-based strategies are not without fault. It is therefore recommended that an area-based approach, which also takes into account the biology of invasives invading a particular area, be employed in treatments. This will ensure that new invaders do not take over from where pompom weed was cleared, and handling does not facilitate spread or fuel vigorous invasions in the next flowering period.
4. For financial reporting, it is recommended that ABC, which is used to accurately report on costs incurred be used. As indicated in this study and many more studies before the current, traditional methods leaves some costs hidden in overhead account and are therefore not accurate.

In Conclusion, pompom weed management initiatives implemented in the Free State province were found to be efficient. It is however difficult to report on biodiversity and ecosystem services loss, as unexpected problems such as new invaders replacing pompom weed were encountered. A more inclusive study, which takes into account other threats, should be conducted to attend to this question. A negative (a pristine area) and a positive control (a heavily invaded area) should also be included in the study to avoid misinterpretations.

5.4 Summary

Results obtained in this study show pompom weed management approaches employed by ISP to be successful in the Free State. This success is attributed to the nature of invasion in the province. ISP's increasing efficiency in the Free State however (Table 4.6), creates a platform upon which good management strategies may be based. These strategies will need to be adjusted per invasion pattern and per given area. Successful management is however feasible if an efficiently run EMA system is in place, accompanied by close monitoring and timely responses. The accuracy of monetary reporting could be improved by employing ABC, which will ensure that accurate efficiency assessments and expenditure justification are performed.

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APPENDICES

Appendix 1: Results presented as a poster at the Symposium of Contemporary Conservation Practice 2015 (SCCP2015).



Accounting for Biodiversity and Ecosystem services loss in response to invasions by Alien and Invasive Species: A pompom weed case study

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Introduction

Invasion by Alien and Invasive Species (AIS) is the second most important threat, after infrastructure development, to native biodiversity and sustained delivery of ecosystem services. For this reason, the Department of Environmental Affairs through SANBI's Invasive Species Programme (ISP), rolled out a nation wide initiative to detect, control, contain and/ or eradicate alien and invasive species. ISP applies species-specific strategies to carry out the mandate, at the cost of an estimated R6.5 million annually. Traditionally, some environmental expenditure is often hidden in overheads accounts, resulting in un-comprehensive expenditure reporting. By employing Activity Based Costing (ABC) however, through which overhead costs are accumulated per activity and assigned to a service causing the activity, distortions inherent in traditional cost accounting systems are remedied. Using Pompom weed as an indicator species, expenditure trends (collated using ABC) are investigated and compared with invasion shifts as well as trends in invasion abundance.

Materials and methods

Study Area

- ❖ The study was conducted in the Free State province of South Africa
- ❖ Kroonstad, the first locality from which pompom weed was reported in the Free State, was used as a starting point

Data Collection

- ❖ Monetary and conditional data was collated for the flowering periods 2009-2010, 2010-2011, 2011-2012, 2012-2013 and 2013-2014

Data Analysis

- ❖ Monetary data
 - Monetary data was collated using ABC principles
 - Expenditure trends were then investigated
- ❖ Conditional data
 - Landsat 7 remote sensing images were extracted, reflectance congruency with pompom weed flowering period was established.
 - Finally pompom weed abundance trends in response to ISP initiatives employed were investigated

Results

Results are reported in three sections Monetary, Collections and detectability.

Monetary reporting

- ❖ An increase in pompom weed expenditure was reported for 2011-2012 and again for 2012-2013. Pompom weed expenditure declined for the flowering period 2013-2014.

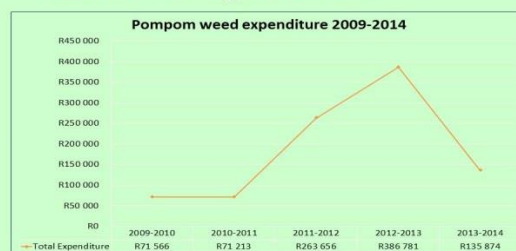


Figure 1: Pompom weed management cost trend analysis from 2009 to 2014

Pompom weed collections

- ❖ The number of localities from which pompom weed was recorded increases steadily until 2012-2013, with a steep decline reported between 2012-2013 and 2013-2014.
- ❖ Species abundance however, was at its peak in 2010-2011, with a constant decline reported in the subsequent years.

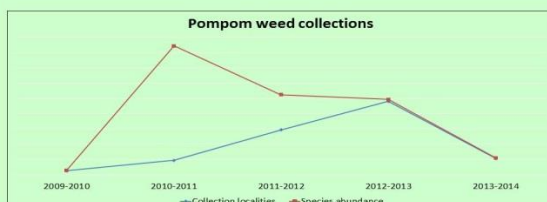


Figure 4.4: Trend analysis of Pompom weed collections from 2009 to 2014

Pompom weed detectability post ISP interventions

- ❖ An increase in change reflectance is indicated from 2011-2012 to 2012-2013, while the lowest ever reported reflectance was for flowering period 2013-2014. This suggests that pompom weed management initiatives were successful in this locality.

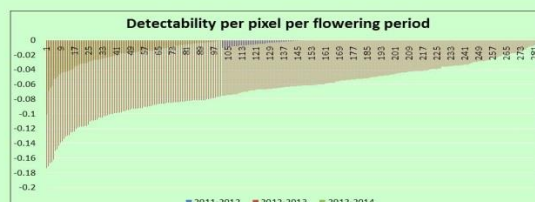


Figure 2: Trend analysis of pompom weed detectability in Kroonstad, Locality 1

Conclusion and Recommendations

An increase in species abundance for the year 2010-2011 (Figure 2) was followed by an increase in monetary expenditure in 2011-2012 and 2012-2013 (Figure 1). A positive result of this response is indicated by pompom weed being reduced to its lowest detectability level to date in 2013-2014 (Figure 3). The results confirmed that ISP strategies for pompom weed management are successful in the Free State

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