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MODELLING THE DISTRIBUTION OF *SERIPHIUM PLUMOSUM* IN MSUKALIGWA LOCAL MUNICIPALITY, MPUMALANGA PROVINCE

By

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Dissertation Submitted in fulfillment of the requirements for the degree of Masters in Environmental Science in the Department of Geography and Geo-Information Sciences, School of Environmental Sciences, University of Venda

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April 2015

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Declaration

I, **Mutswari Humbelani Brenny,** declare that the thesis for the Masters degree at the University of Venda, hereby submitted by me, has not previously been submitted for a degree at this or any other university, and that it is my own work in design and execution, and that all reference material contained therein has been duly acknowledged

Signature..... Date...12/08/2015.....

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Abstract

The spread of *Seriphium Plumosum* is a critical ecological problem threatening grazing land in South Africa. *Seriphium Plumosum* is indigenous to South Africa and is spreading to other countries in Africa. Mapping the spatial distribution of *Seriphium Plumosum* is vital towards the management of its population and it will assist researchers, farmers and government to understand the environmental conditions favoured by the species. The main aim of the study is to examine and predict the spatial distribution of *Plumosum* using some abiotic factors. Remote sensing, Geographic Information System (GIS) modelling and ground truthing were combined, in order to achieve this goal. Unsupervised classification method was employed to classify the land cover and to guide the field work. Global Positioning System (GPS) coordinates were collected in the field to assist in manually digitizing the encroachment of *Seriphium Plumosum* from the satellite images and also to produce the locality map of *Seriphium Plumosum*. Digitized polygons were used to create training samples and to create the spectral signature of *Seriphium Plumosum*. Spectral signature and some abiotic factors were added into the Maximum likelihood classifier and classification results were seriphium Plumosum favourable conditions. The classification output indicates that *Seriphium Plumosum* prefers deep to very deep soil with loam clay, loams and sandy loams. It also indicates that *Seriphium Plumosum* prefers flat areas with rainfall between 651 to 750mm. The weight of each condition was ranked and incorporated into the model. The model output is in the form of a map which indicates the possible areas that can be invaded by *Seriphium Plumosum*. Ground verification was conducted to assess the accuracy of the model.

Key Words: *Abiotic factors, Classification, Digitizing, Distribution, Modelling, Geographic Information System, Encroachment, Global Positioning System, Remote sensing, Seriphium Plumosum.*

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CHATER 1

INTRODUCTION

1.1 Background to the research problem

A bush is defined as a woody perennial plant, smaller than a tree, with several major branches arising from near the base of the main stem (Okafor, 2013). It is also defined as a shrub or clump of shrubs with stems of moderate length. In South African literature, bush trees and shrubs grouped together are referred to as woody species (Hudak & Wessman, 2001). When these woody plants increase in abundance and density or cover one or more native species of woody plants through time they form an encroachment (Van Auken, 2000; Roques *et al.*, 2001). Encroachment of woody plants is defined by Moleele (1998) as a process that occurs when woody plants invade open grasslands. Encroachment of woody species endangers grassland biodiversity and threatens the sustainability of pastoral subsistence and commercial livestock grazing (Kgosikoma *et al.*, 2013).

Bush encroachment has caused a decline in the grazing capacity of vast areas in the South African Savanna and this was reported by Donaldson (1980) and Gammon (1984). Smith (2003a) estimates that 20 million hectares of South African grassland alone have been affected by bush encroachment. In South Africa, there are quite a number of encroaching species. However, most of these species include genera Acacia *(acatlensis),* Aestarace (*Seriphium Plumosum*) and Hakea *(corymbosa)*, Khaki Weed (*Tagetes minuta*), Lantana (*Lantana camara*) and Triffid Weed (*Chromolaena odorata*).

The phenomena of bush encroachment has not only pervaded South Africa's grasslands, but it has also done so in many other countries (Archer, 1995). It is also recorded that more than 10 million hectares (12%) of Namibia's land is encroached (Woiters, 1994). Zimmermann and Joubert (2002) estimated that about 26 million hectares of land in Namibia is affected by bush encroachment. The Directorate of Environmental Affairs (2003) and De Klerk (2004) indicate that species such as Silver Terminalia (*Terminalia sericea*), Purple pod Terminalia (*Terminalia prunioides*), Blue thorn (*Acacia Erubescens*), False umbrella thorn (*Acacia reficiens*), Black thorn (*Acacia mellifera*), Sickle bush (*Dichrostachys cineria*), and Mopane (*Colophospermum Mopane*) are the main cause of bush encroachment.

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In Botswana, most of the encroacher species comprise thorny and broad-leaved bush such as Silver Terminalia and have increased in density over the past years (Moleele, 2002). Mesquite (*Prosopis glandulosa*) and Creosote bush (*Larrea tridentata*) have been found in Western United States, and these have converted extensive areas of grassland into dense shrub-lands (Buffington & Herbel 1965). Pacala *et al.* (2001) indicate that the United states grassland is undergoing bush encroachment and is estimated to cover 330 million hectares. This is occurring in semi-arid western states.

In Australia, extensive areas of semi-arid woodland are now occupied by native shrubs at higher densities than thought to exist prior to European settlement (Noble, 1997). Numerous studies, all over the world, have shown significant increases in bush encroachment over approximately the last 50 years. Increases in woody plant cover have been documented for KwaZulu-Natal's grasslands (O'Connor, 2003), Eastern Cape savanna and grassland (O'Connor & Crow, 1999), open savanna (Dougill & Trodd, 1999), semi-arid savanna (Hudak & Wessman, 2001; Moleele *et al.,* 2002) and mesic savanna (Hoffman & O'Connor, 1999). In Mpumalanga, a significant increase in bush encroachment has been recorded in numerous studies over approximately the last decade (Lesoli *et al.*, 2013).

1.1. Statement of the research problem

Bush encroachment is a process by which encroaching woody species, often unpalatable to domestic livestock because of their chemical and/or physical defenses, suppresses palatable grasses and herbs (Ward *et al.,* 2005). According to Richter and Meyer (2001), bush encroachment in excess of 2500 tree equivalent, depending on the species and the affected area, can suppress grass production by as much as 82% in years of average rainfall. Consequently, bush encroachment reduces carrying capacity for grazing animals (Jeltsch *et al.*, 1997).

Seriphium Plumosum (Bankrupt bush) was viewed as an aggressive encroacher species in large parts of the grassland biome of South Africa (Mucina & Rutherford, 2006; Snyman & Le Roux, 2009). The species was listed as a proclaimed encroacher plant in CARA Legislation Regulation 16 of the Conservation of Agriculture Resources Act 43 (Jordaan & Jordaan, 2007). A study conducted in the 1970s (Roberts 1966) indicates that *Seriphium Plumosum* is an endemic species that was found earlier in high mountains of Thaba Nchu and later spread to the foot of the mountain (Snyman, 2009b).

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Seriphium Plumosum converted extensive areas of grassland into less productive shrubland–grassland. It has the capacity to proliferate in abundance in the disturbed or overgrazed areas and to significantly alter and diversify the distribution of native species (USCOP, 2004). The key to its successful expansion is that *Seriphium Plumosum* is unpalatable to livestock. As a results, it out-competes palatable grasses and produces thousands of seeds in one plant which are dispersed by wind to large areas, thus, invading areas which were previously free from invasion (Snyman, 2009b). *Seriphium Plumosum* encroachment appears to result from a number of distinct factors such as overgrazing and recovery from anthropogenic disturbance, and due to the distribution of the light seed by wind (Koekemoer, 2001).

Over the past four decades, its distribution down the slopes and valleys increased significantly, spreading to other African countries (Snyman, 2009a). Abundant arable land usually forms part of the first areas of encroachment (Snyman, 2009b). The plant prefers slightly sandier soils with low pH (Snyman & Le Roux, 2009), although soils with a clay content of up to 24% could still be encroached on if the drainage is sufficient and favours the establishment of this woody species (Wepener, 2007). The plant is abundant on rocky hill slopes which have higher fertility (Snyman and Le Roux, 2009).

1.2. Research aim and specific objectives

1.2.1. Research aim

The main aim of this study is to use GIS and remote sensing to map, examine, and predict the spatial distribution of *Seriphium Plumosum* using some of the abiotic factors.

1.2.2. Specific objectives

- To distinguish *Seriphium Plumosum* from other features using remote sensing techniques;
- To map the locality of *Seriphium Plumosum* using GIS;
- To examine some of the abiotic factors associated with the distribution of *Seriphuim Plumosum;*
- To predict areas at risk of being invaded by *Seriphuim Plumosum* in Msukaligwa Local Municipality; and

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- To verify the existence of *Seriphuim plumosum* in the predicted area.

1.3. Research questions

The study seeks to engage with and provide answers to the following questions:

- To what extent can we map and accurately distinguish *Seriphium Plumosum* species from other plant species?
- What are some of abiotic factors that are associated with distribution *of Seriphium Plumosum*?
- How best can we predict the habitat preference characteristics of *Seriphium Plumosum* using the abiotic factors?

1.4. Description of the study area

1.4.1. Location

The study was conducted in Msukaligwa Local Municipality which is located in Gert Sibande District in the Mpumalanga Province of South Africa (SA) (Figure 1.1). Msukaligwa Local Municipality is located between longitudes 29° 25' 00" and 30° 50' 00" and between latitudes 26° 10' 00" and 26° 55' 00". The total size of the Msukaligwa Local Municipality calculated using ESRI® ArcGIS™ software on an Africa Albers Equal Area Conic projection is approximately 6015 km^2. Msukaligwa Local Municipality is predominately rural in nature, with numerous formal settlements making up the urban areas such as Ermelo, Warburton, Chrissiesmeer, Breyten, Lothair, Davel and Sheepmoor (Msukaligwa Local Municipality, 2007). According to the results of the latest 2011 census, the population of the Msukaligwa Local Municipality is estimated at 149,377 (Statistics South Africa, 2012). The main economic activities comprise coal mining, timber industries and agriculture. The main drainage systems in the study area include the Vaal, Usutu and Umpuluzi Rivers. The study area was chosen because Msukaligwa Local Municipality is one of the municipalities in the country dominated by agricultural activities which is heavily encroached by *Seriphium Plumosum*.

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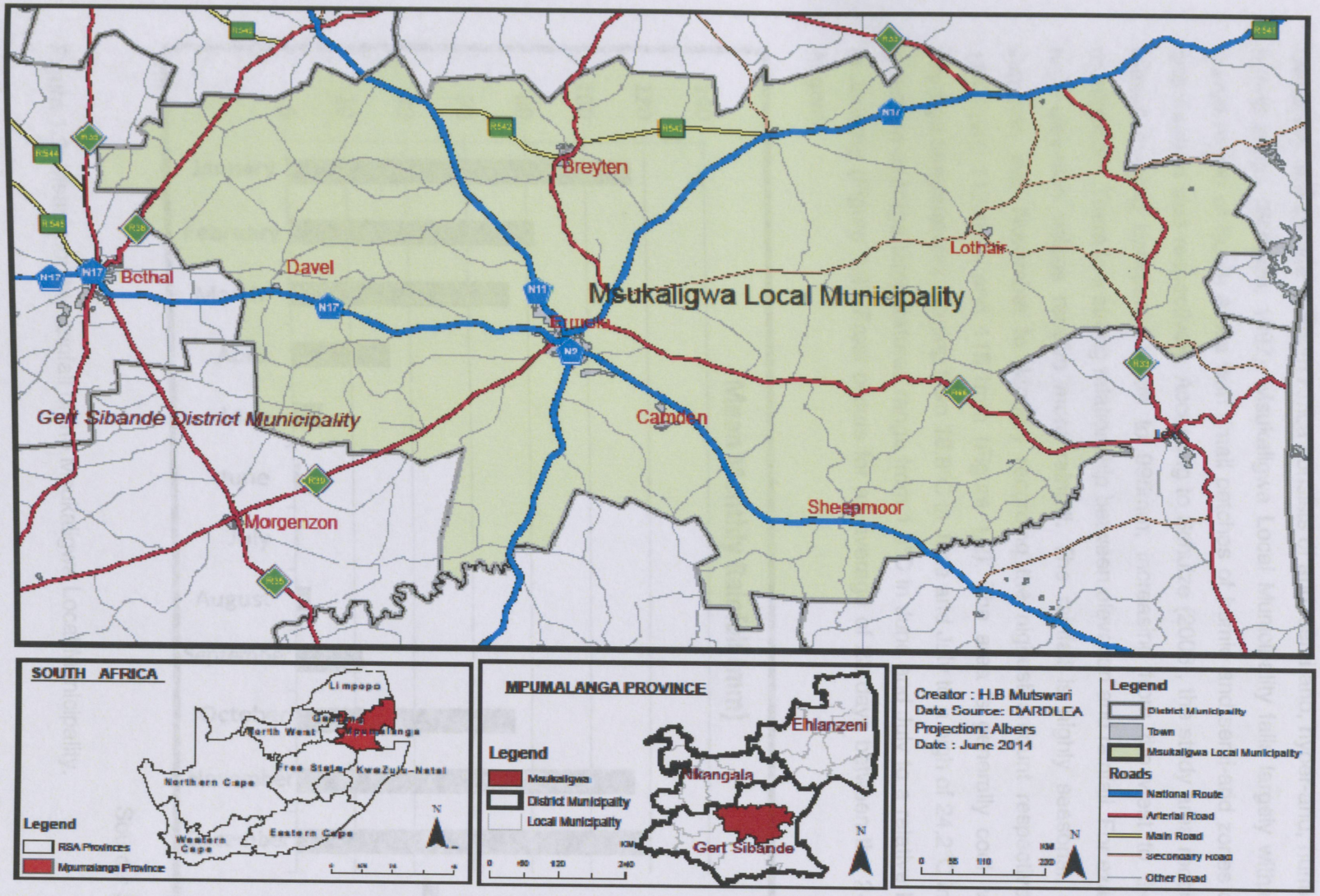
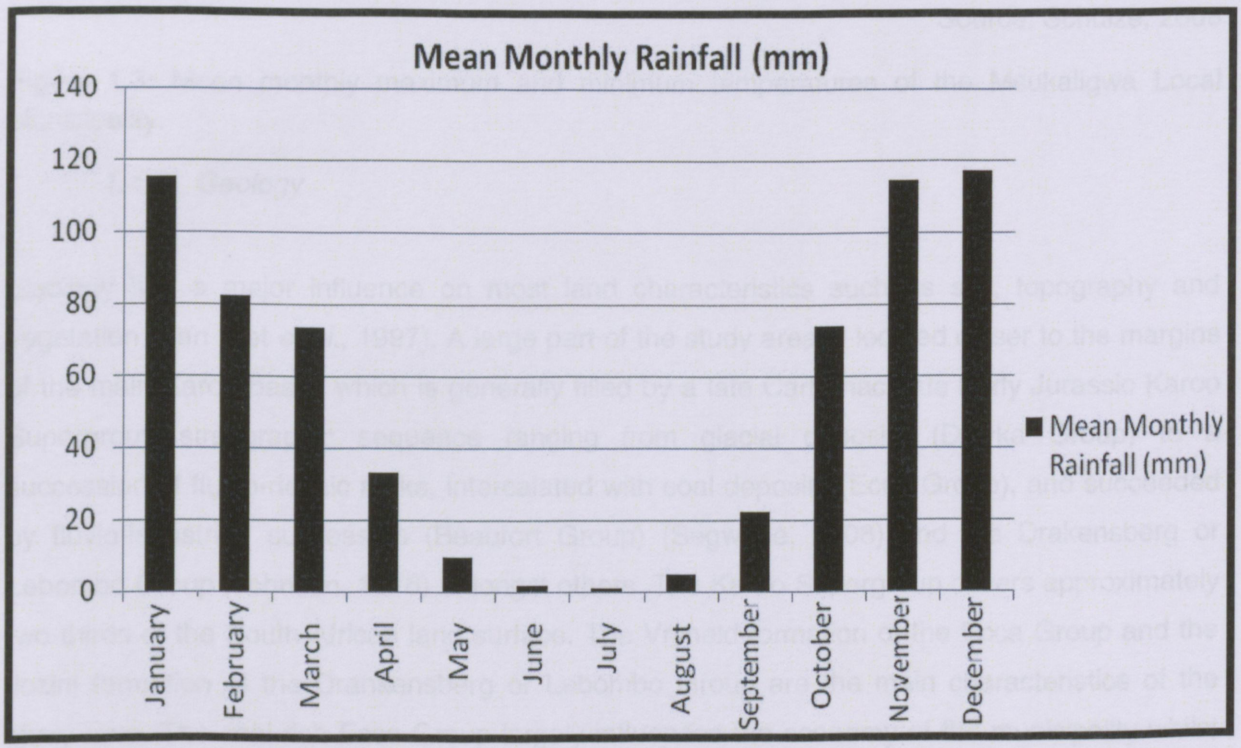


Figure 1.1: Locality map of the study area

1.4.2. Climate

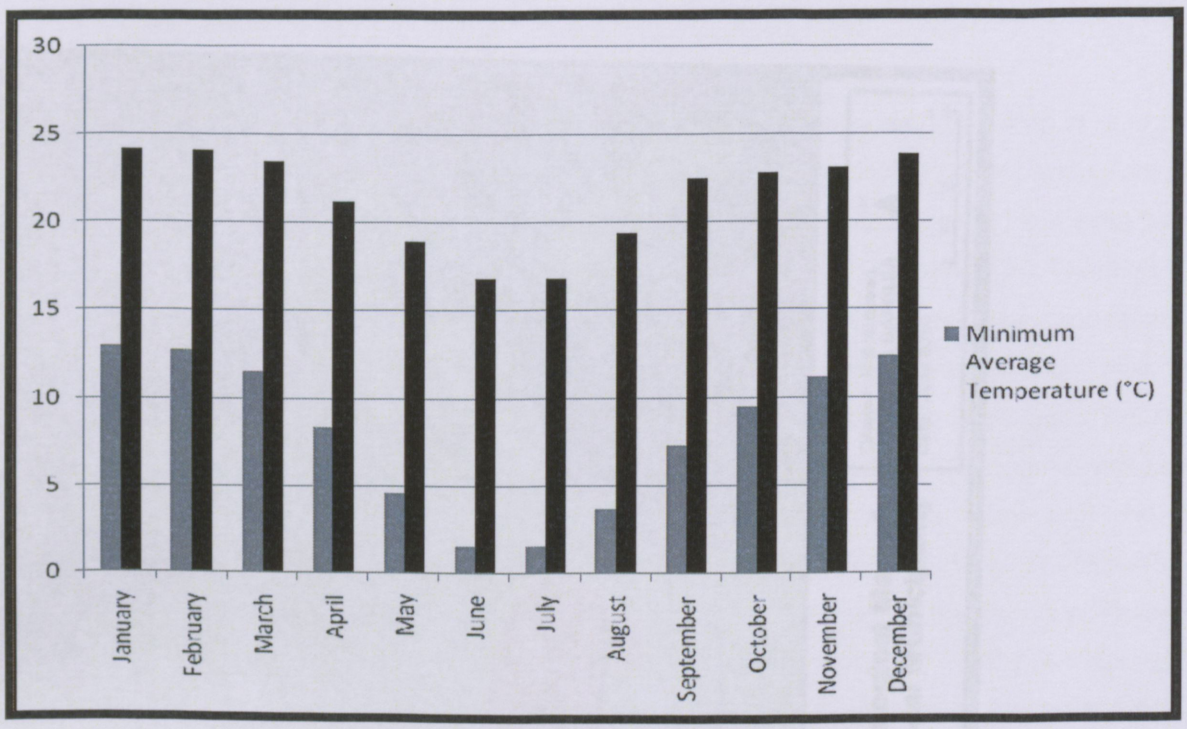
Generally, the climate in South Africa consists of arid, semi-arid, hyper-arid, humid and dry sub-humid zones (Schulze, 1997). Msukaligwa Local Municipality falls largely within the dry sub-humid region of South Africa with small patches of humid and semi-arid zones on the eastern and western side respectively. According to Schulze (2006), the study area receives an annual rainfall ranging between 542mm to 995mm, increasing from the west to the east of the municipality. There is a strong relationship between elevation and rainfall. For example, areas of high elevation values receive more rainfall. The rainfall is highly seasonal, and peaks in summer, with November to January recording the highest amount respectively as follows: 114.2mm, 117.1mm and 115.1mm (Figure 1.2). The area is generally cool, with maximum average temperatures ranging from 16.8°C in June and July to a high of 24.2°C in January. The minimum average temperatures range from 1.6°C in June and July to a relative high of 13.0°C in January (Figure 1.3). Frost occurs for an average of 23 days between the 24 May and 18 August.



Source: Schulze, 2006

Figure 1.2: Mean monthly rainfall of the Msukaligwa Local Municipality.

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Source: Schulze, 2006

Figure 1.3: Mean monthly maximum and minimum temperatures of the Msukaligwa Local Municipality.

1.4.3. Geology

Geology has a major influence on most land characteristics such as soil, topography and vegetation (Van Riet *et al.*, 1997). A large part of the study area is located closer to the margins of the main Karoo basin, which is generally filled by a late Carbonaceous Early Jurassic Karoo Supergroup stratigraphic sequence ranging from glacial deposits (Dwyka Group) to a succession of fluvio-deltaic rocks, intercalated with coal deposits (Ecca Group), and succeeded by fluvio-lacustrine succession (Beaufort Group) (Segwabe, 2008) and the Drakensberg or Lebombo Group (Johnson, 1976) amongst others. The Karoo Supergroup covers approximately two thirds of the South African land surface. The Vryheid formation of the Ecca Group and the Jozini formation of the Drankensberg or Lebombo Group are the main characteristics of the study area. The coal rich Ecca Group largely influences the economy of the municipality whilst the Drakensberg Group occurs in patches. In addition, the granites, tonalite and granitoids rocks of the Archean granitic crust (Meinhardskraal), the Transvaal Supergroup of the ancient crustal block volcanic Kaapvaal Craton, and the Witwatersrand super-group occurs in small patches (see Figure 1.4).

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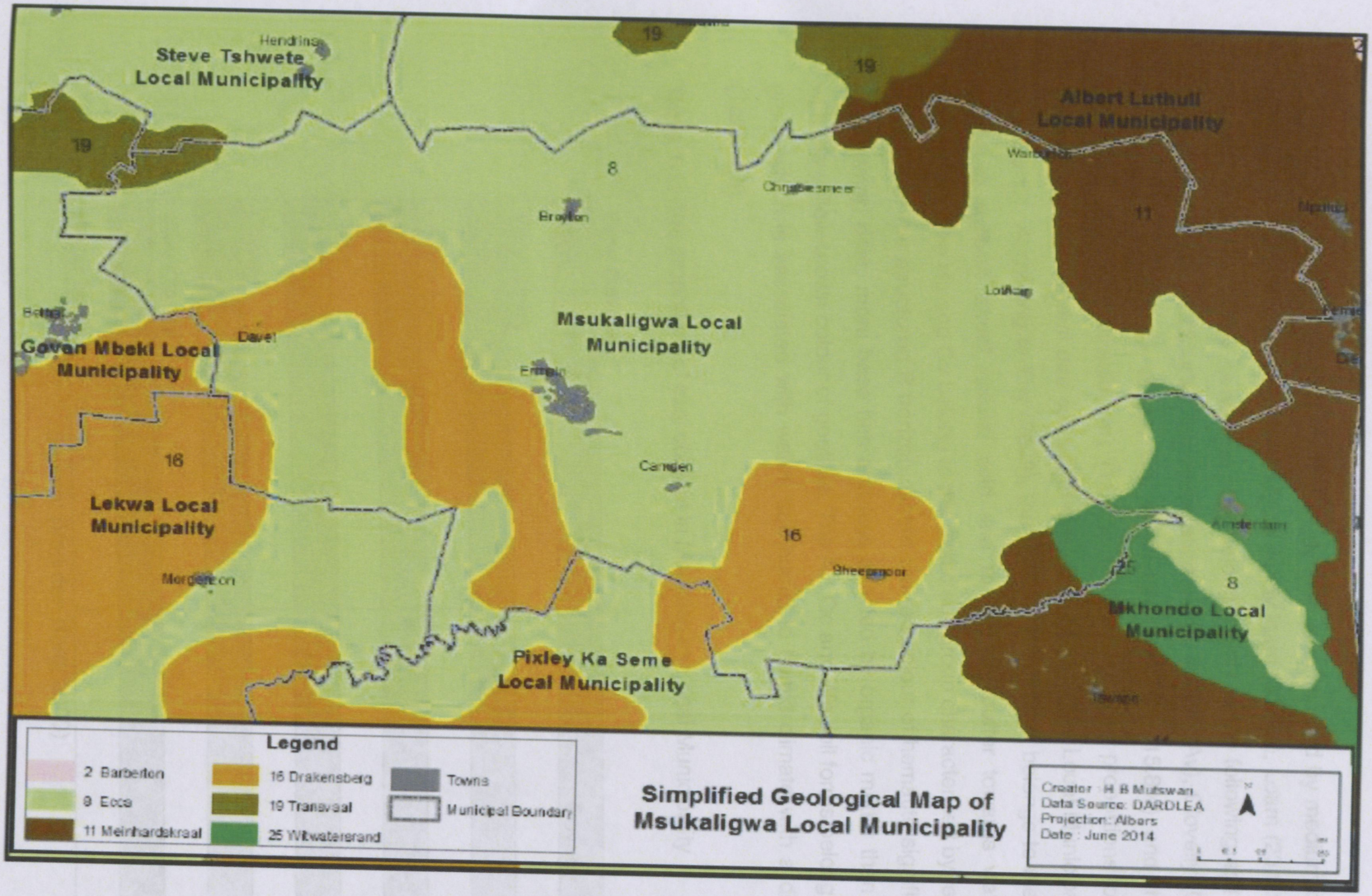


Figure 1.4: A simplified geological map of Msukaligwa Local Municipality

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1.4.4. Soils

According to Van den Berg (2000), the study area is dominated by medium deep to very deep high agricultural potential soils classified as sandy loam (35.5%), Loam (23.9%) and Loam Clay (22.9%) (Table 1.1). The mentioned soils belong mainly to the following soil form association: Hutton (Hu) dominant (23.4%), the association of Hu, Avalon (Av), Clovelly (Cv), Glencoe (Gc) (33.2%), the association of Av, Gc, Westleigh (We), Cv (15.8%) and the association of Rensburg (Rg) and Arcadia (Ar) (11.8%) (Table 1.2). The proportions of other soil form association, clay content and soil depth classes in Msukaligwa Local Municipality are illustrated in Table 1.1. According to Fey (2009), the Rg and Ar soil form belongs to the vertic soil group, known to support sweet natural veld and to strongly buffer towards water and chemical substances. The Hu and Cv belong to the oxidic soil group characterised by red or yellow-brown apedal B or red structured B horizon, where the red colour of hematite signifies conditions that are warmer, drier, more base rich and less affected by organic matter than those associated with the yellow-brown colour of goethite. The Av, Gc and We soil forms belong to the plinthic soil group which is associated with warm, sub-humid to humid climate with a distinct dry season (Table 1.3).

Table 1.1: The proportion of clay content in Msukaligwa Local Municipality

Clay Content

Class	Coverage in %
Very Sandy	0.3
Sandy	0.6
Loamy Sand	0.4
Sandy Loam	35.5
Loam	23.9
Loam Clay	22.9
Clayey	7.8
Clay	3.8
Very Clayey	2.8
Non-perennial Pans	0.1
Water bodies	1.9

Source: (Van den Berg, 2000)

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Table 1.2: The proportion of soil depth in Msukaligwa Local Municipality

Soil Depth

Class	Coverage in %
Very Deep	32.7
Deep	20.8
Medium Deep	26.9
Medium Shallow	0.4
Shallow	6.6
Very Shallow	8.7
Very Steep Slopes	0
Steep Slopes	1.9
Non-perennial pans	0.1
Water bodies	1.9

Source: (Van den Berg, 2000)

Table 1.3: The proportion of soil form association in Msukaligwa Local Municipality

Soil Formation

Class	Coverage in %	Class	Coverage in %
Hu-dominant	23.4	Hu, Sd, Sw, Gs	0.3
Hu, Av, Cv, Gc	33.2	Hu (30%), Sd (30%)	1.1
Av, Gc, We, Cv	15.8	Sd, Bo, My, Ar, Hu	0
Lithosols, Hu, Cv, Gc	0.3	Ar, My, Va	3.5
Lithosols, Cv, Gc, Hu	3.3	Ar-dominant	5
Lithosols, Hu, Cv, Sd, Sw	0	Rg, Ar	11.8
Lithosols, Cv, Va	0.3	Non-perennial pans	0.1
Gs, Cf, Es	0	Water bodies	1.9
Es, Gs, Cf	0		

Source: (Fey, 2009),)

1.5.5 Topography

The study area is located at the margins of the interior plateau towards the great escarpment of Southern Africa, which is characterised by high lying areas with an elevation ranging from 1 242 to 1 820 meters above sea level (Van den Berg, 2000). In fact, the elevation peaks at the centre and drops towards the interior plateau, as well as towards the narrow strip of the low lying land between the ocean in Mozambique and the great escarpment as shown in Figure 1.5. It is

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worthy mentioning that the boundary of the great escarpment in the study area is indistinct, but more pronounced towards the north around Lydenburg area and towards the south in KwaZulu Natal Drakensberg region. Apart from relatively high elevation values, the study area is characterised by gently undulating highland topography typical of the central Mpumalanga Province, with fairly broad to narrowly incised valleys of headwater drainages.

1.5.6 Vegetation

The study area is located in the Highveld region of the Mpumalanga Province. The high elevation values, as already discussed, are typical of the Highveld region compared to the relatively lower elevation values in the Lowveld area. The Acocks survey (1988) shows that the area is dominated by North-eastern Sandy Highveld and Themeda veld or Turf Highveld, which occupies 65.3% and 14.3% of the study area respectively. The Themeda veld is well-known for its palatability to grazing animals. Other vegetation types include Bankenveld (8.2%), Bankenveld to Sour Sandveld Transition (7.7%), Piet Retief Sourveld (4.4%) and the Turf Highveld to Highland Sourveld Transition (0.1%) as shown in Figure 1.6. The Mucina and Rutherford vegetation survey (2006) shows the dominance of the Eastern Highveld Grassland (*Gm 12*) (62.5%), Soweto Highveld Grassland((*Gm 8*) (13.8%), and KaNgwane Montane Grassland(*Gm 16*) (10.3%). The rest of the area is occupied by Amersfoort Highveld Clay Grassland (*Gm 13*) (8.3%), Wakkerstroom Montane Grassland (*Gm 14*) (4.2%) and Eastern Temperate Freshwater Wetlands (*AZF 3*) (1.0%) as shown in Figure 1.7. The presence of the commercial plantations of the *Eucalyptus* and Pine trees has transformed the natural vegetation in some parts and deserves to be mentioned.

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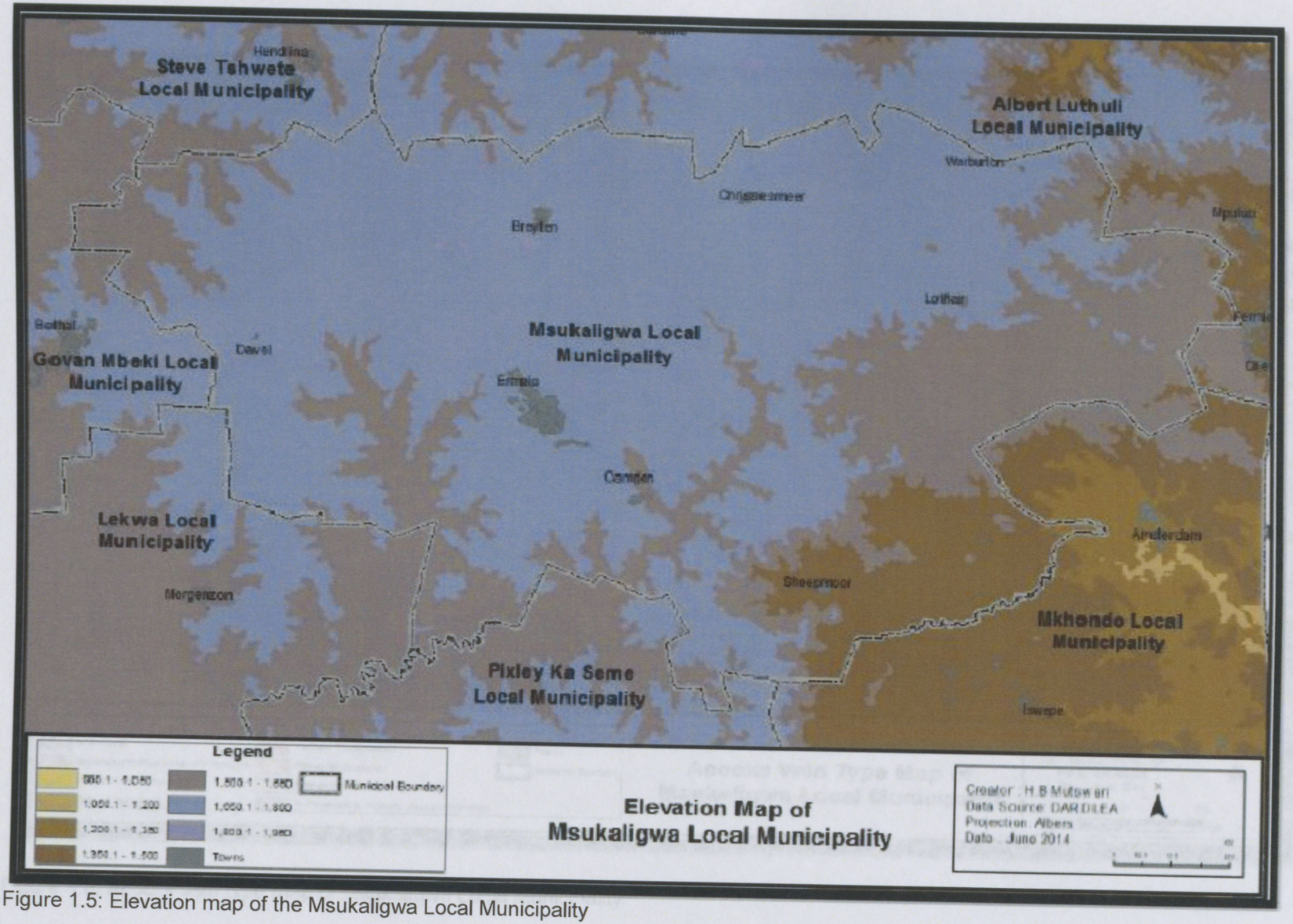


Figure 1.5: Elevation map of the Msukaligwa Local Municipality

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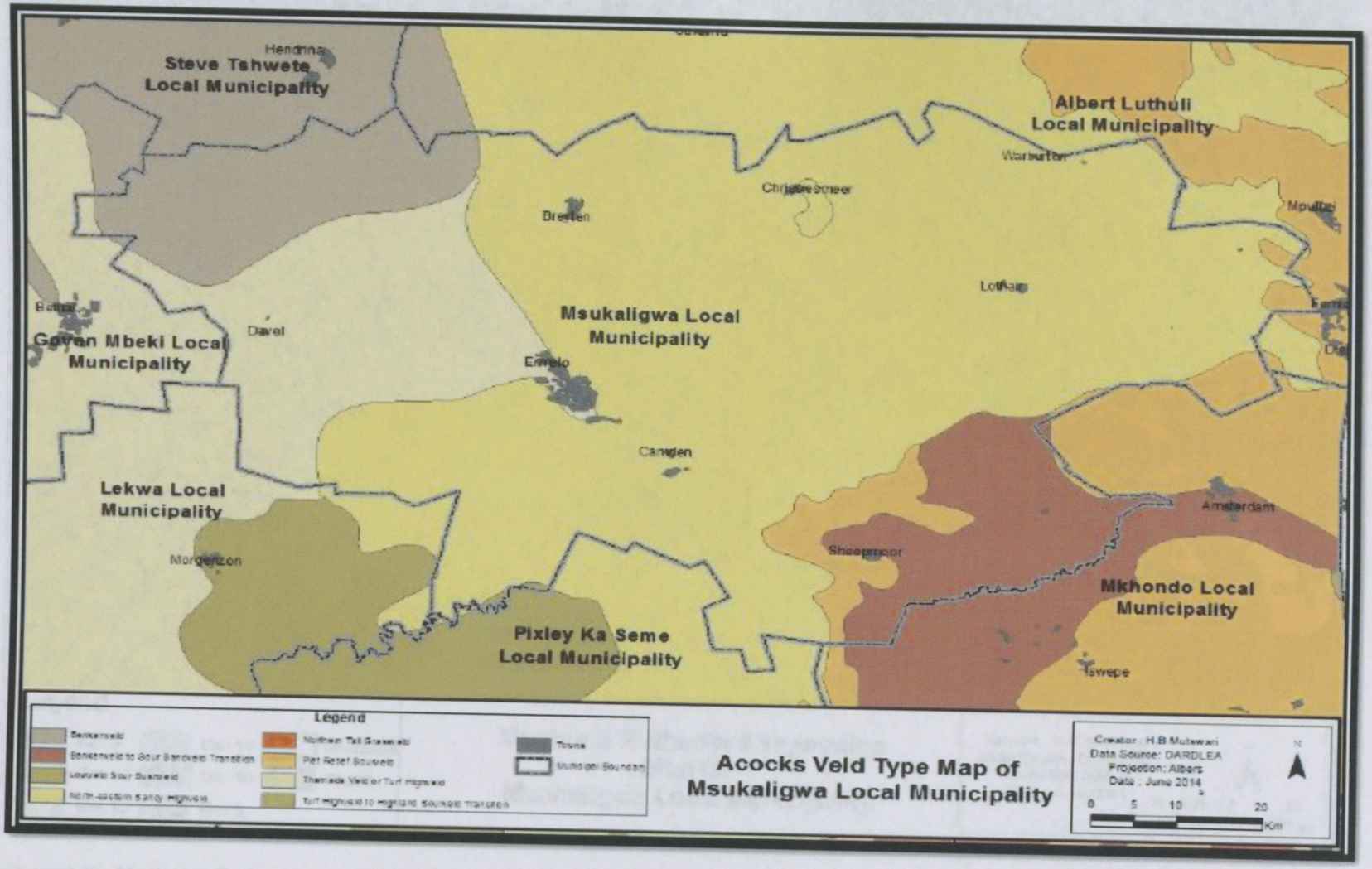


Figure 1.6: Acocks veld type map of Msukaligwa Local Municipality

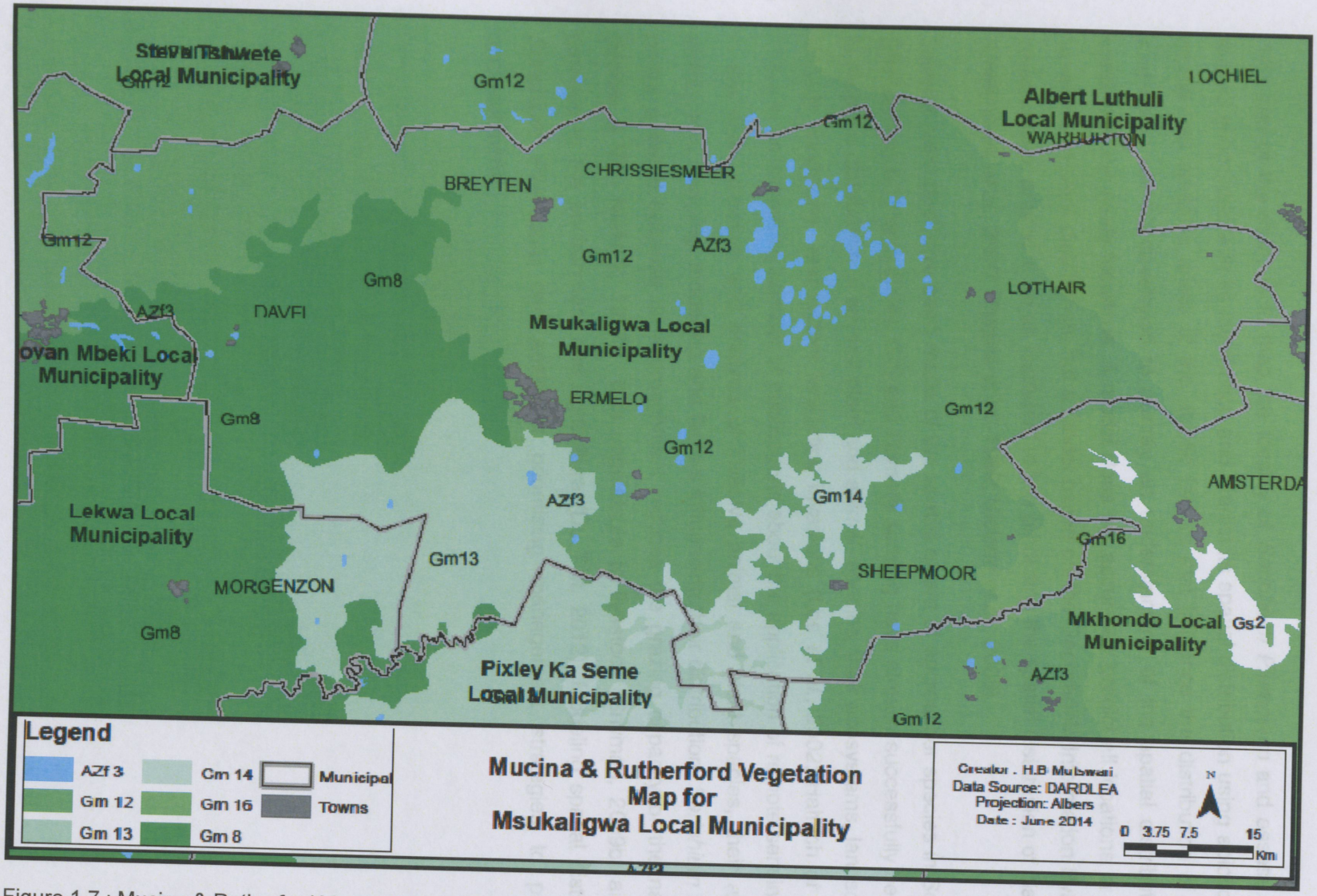


Figure 1.7 : Mucina & Rutherford Vegetation map of Msukaligwa Local Municipality

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1.6 The significance and justification of the study

The aim of the study is to map the locality of *Seriphium Plumosum* and assess the abiotic factors associated with its distribution and predict its spatial distribution using abiotic factors. A model that contains some of the abiotic factors that influence the distribution of *Seriphium Plumosum* will be developed to portray an understanding of the spatial distribution of the species in the study locations. A model does not accurately predict all locations or explain all variations in plant distribution, but a model based on the Geographic Information System (GIS) variable layer proved to be an important tool in predicting the spatial distribution of plant species (Collignham *et al.*, 2000; Higgins *et al.*, 1999; Nielsen *et al.*, 2008).

Several estimates have been made of the spatial extent of encroacher species in South Africa (Richardson & Wilgen 2004). GIS and Remote sensing have already successfully been applied to map the distribution of several plant and animal species, their ecosystems, landscapes, bio-climatic conditions and factors facilitating invasions (Los *et al.,* 2002; Haltuch *et al.,* 2000). There is an increasing number of publications about the application of remote sensing and GIS in the data collection and analysis of invasive animal and plant species, their abundance, distribution, mapping, modelling and factors influencing their distribution. *Seriphium Plumosum* poses a threat because its encroachment reduces the grazing capacity of the natural veld (Moore & Van Niekerk, 1987). It is unpalatable to livestock (Snyman, 2009b) and causes damage to the environment and agriculture (Du Toit, 2012). Modeling spatial distribution of *Seriphium Plumosum* can assist in prioritising management strategies to prevent its encroachment.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is a systematic process of identifying the existing work carried out by other researchers (Kothari, 2008). In this study, the review of literature is done to describe, subscribe and evaluate the reports and research publications related to the modelling of the spatial distribution of *Seriphium Plumosum*. The purpose of the review of existing literature is also to understand the concept of bush encroachment and factors that influence bush encroachment. In addition, the legislation regulating the conservation of agricultural resource is also studied. Furthermore, it explores the origin and spatial distribution of *Seriphium Plumosum*, its germination and habitat reference. The chapter also covers the effect of *Seriphium Plumosum* as an encroacher species, as well as the use of Remote Sensing and GIS techniques in vegetation mapping.

2.2 The concept of bush encroachment

Grassland degradation has been defined as the loss of utility or change of features of the rangeland ecosystem which cannot be replaced (Chrisholm & Dumsday, 1987; Desalew, 2008). Encroachment of shrub species is a type of grassland degradation whose excessive and undesirable increase in woody plant abundance results in the suppression of palatable grasses and herbs by encroaching woody species often unpalatable to domestic livestock (Ward, 2005; Zeleke, 2009). It is the main indicator of the state of land degradation (Saco *et al.*, 2006).

In South Africa, the encroachment by unpalatable trees and shrub species at the expense of palatable grasses is referred to as bush encroachment (Hudak, 1999). Bush encroachment is a form of land degradation that is common in subtropical and semi-arid systems (Golubiewski & Hall-Beyer, 2010). It is defined as the invasion and/or thickening of aggressive undesired woody species, resulting in an imbalance of the grass/bush ratio, a decrease in biodiversity, and a decrease in the carrying capacity (De Klerk, 2004). It manifests itself through an increase in density, cover, extent, biomass and species of woody plants (Archer & Stokes 2000; Van Auken

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2009) on land previously occupied by other vegetation or abundant agricultural lands. Bush encroachment is discernible by progressive growth of shrub cover, which is a common cause of herbaceous vegetation loss in dry savanna, and is responsible for a decline in range conditions (Oba, 2000). Shrub cover becomes a problem when it exceeds 30%, intensifies a decline in range condition, and is indicative of rangelands where the production systems are under environmental stress (Muriuki *et al.*, 2003).

Bush encroachment is considered to be particularly severe in arid and semi-arid grasslands (Kraaij & Ward, 2006). Trends towards increased bush encroachment in savannas have been documented in North America (Archer, 1995; Asner *et al.*, 2003), South America (Adamoli *et al.*, 1990; Zambrano & Farinas, 2001), Australia (Burrows *et al.*, 1990; Fensham & Fairfax, 2003; Fairfax & Archer, 2005) and India (Singh & Joshi, 1979). In southern Africa, numerous studies, over approximately the last 50 years, have shown significant increases in bush encroachment (Wigley *et al.*, 2009). Bush encroachment has led to changes in the composition and structure of semi-arid and arid grasslands of South Africa (Wepener, 2007).

The encroachment of shrub was first recorded in the 1920s and 1930s in the savanna areas of the Northern Province and KwaZulu Natal and in the 1940s in the arid savanna of the Kalahari (Wepener, 2007). The extent of bush encroachment on a 38 million hectares area of grassland in South Africa was evaluated in 1980, and it was found that 1.5 million hectares was heavily encroached and more than 9 million hectares was lightly to moderately encroached (Hoffman & Ashwell, 2001). In 1987, it was reported that 8 million hectares was encroached with woody species and the carrying capacity of the affected areas was reduced by up to 80% (Moore & Van Niekerk, 1987). In Mpumalanga, distribution of the encroachment of woody shrub species such as *Seriphium Plumosum,* onto abandoned cultivated lands and rangelands, was recorded (Snymam, 2009). *Seriphium Plumosum* is a declared indicator of bush encroachment in the Free State and the North West Province, and poses a serious threat to the management of sustainable utilisation in grasslands (Hatting, 1953; Krupko & Davidson, 1961).

The challenge of bush encroachment is a global concern; South Africa is not alone in its experience of the economic and environmental challenges posed by these plants. Despite a lack of statistical information, it is commonly believed that, approximately 10 million (m) hectares (ha), or 8.28%, of the surface area of the country is severely encroached (Henderson, *et al.*, 2006). This study will review some abiotic factors that influence the distribution of plants.

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2.3 Factors that influence bush encroachment

Factors that drive the process of bush encroachment have been widely studied because of the widespread nature and often negative implications of woody plant encroachment. Woiters (1994) indicate that the processes and events that influence bush encroachment are numerous and inter-linked. Bush encroachment drivers include incorrect grazing practices, lack or misuse of fire, absence of browsing animals, lack of mechanical damage by large wild animals such as elephants, and elevated concentration of CO_2 levels in the atmosphere, seed dispersal by livestock and rodents, soil erosion, decreased infiltration of water to the topsoil, and climatic change, changes in rainfall patterns and temperatures, above average rainfall; all these can facilitate the growth and subsequent spread of shrubs and other woody vegetation (Buffington & Herbel 1965; Archer 1995; Van Auken 2000; Fensham *et al,.* 2005). However, humans appear to be a major catalyst to the problem. These factors result in resource competition between grasses and woody plants. In particular, conditions that favour the growth of woody plants, or hinder the growth of grasses, will facilitate the process of woody plant encroachment. Karuaera (2011) indicates that invasive species have the ability to out-compete indigenous species and grass in the area, resulting in habitats being dominated by encroaching species.

2.3.1 Climatic factors

The climate is a major determinant of the geographical distribution of species and vegetation types. It determines the amount of water available for weathering minerals, transporting the minerals and releasing elements. Climate, through its influence on soil temperature, determines the rate of chemical weathering. Warm, moist climates encourage rapid plant growth and, thus, high organic matter production. The opposite is true for cold, dry climates. Organic matter decomposition is also accelerated in warm, moist climates. Under the control of climate freezing, thawing, wetting, and drying break parent material apart.

Rainfall causes leaching. Rain dissolves some minerals, such as carbonates, and transports them deeper into the soil. It is greatly influenced by local topography, and conditions of temperature, light, and moisture vary greatly, and these factors play an important role in the production, distribution and survival of plants (Tainton & Hardy, 1999).

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➢ *Temperatures*

The climate manages the spatial distribution and seasonal behaviour of plants. For instance, some plants in temperate regions first require exposure to chilling temperatures. The temperature is one of the major factors that control plant activity, phenologically (Tooke & Battey, 2010). Photosynthesis starts at a low temperature, reaches an optimum and decreases at higher temperatures due to the impaired carbon metabolism and substance transportation (Schulze, 2005; Larcher, 2003). From the ontogenetic point of view, temperature can affect plant mechanisms and physiology such as respiration, photosynthesis, and transpiration before initiating their growing season. Plant photosynthesis can reach standstill at extreme temperatures, and this was found by Xu and Baldocchi (2003) in a study to quantify the photosynthesis capacity under prolonged summer drought and high temperatures. It was found that photosynthesis processes of trees are prohibited when experiencing air temperatures exceeding 40°C. Larcher (2003) indicates that temperature influences the plant respiration rate. Plant respiration increases exponentially over a wider range of temperatures and is only inhibited at very high temperatures (Schulze, 2005). At extremely high temperatures, the heat damage to enzymes and membrane structures causes respiration activity to stop (Larcher, 2003).

Furthermore, flowering time is extremely important for the survival of a plant and flowering phenology is affected by temperature and photoperiod (Elzinga *et al.,* 2007). Wepener (2007), when he was controlling the *Seriphium Plumosum* encroachment in the Hartbeesfontein area of the North West Province, indicated that temperature does not only affect time-related plant growth, but it also exerts its effects spatially. Long term average temperature is considered a determinant factor of vegetation distribution, and is widely used in a lot of global vegetative models (Schulze *et al.,* 2005). The advancement or delay of plants due to the increase or decrease of temperature varies spatially. Therefore, the temperature change can also change the distribution pattern of plants species (Schwartz, 2003; Kai *et al.,* 1993).

➢ *Light*

Plants species could be influenced in their ecological and physiological responses by the surrounding vegetation and habitat environment, such as light (Henmann & Hugh 2010; Wright 2005). Plants species adapt differently to different light intensities. With regard to stress, understanding light requirement is important to plant physiology. Light plays an important role in the development of a plant. Processes such as photosynthesis and phototropism depend on the

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availability of light sources for plants (Long, 2011). Plants seek out light sources for energy and survival. Plant performance is enhanced through morphological and physiological acclimation to light environment (Kozlowski & Pallardy, 1996).

Light intensity contributes greatly to plant physiological processes since plant growth relies on a series of interactions that involve the presence of light. For example, photosynthesis enables plant metabolism processes to take place and provides the energy that fuels these processes. Light intensity levels can have a significant effect on photosynthesis rates, which are directly related to a plant's ability to grow. According to Jeanty (2008), light intensity has something to do with the amount of light energy made available to a plant. This can vary according to colour and the actual strength of the light. In addition, plants are typically most responsive to light that falls within the blue and red light ranges. In effect, higher light intensities make more energy available for plant photosynthesis processes to take place.

- *Precipitation*

Precipitation is the most important climatic factor that influences the pattern and productivity of woody plants in sub-Saharan Africa, since rainfall replenishes soil water used by plants (Molua & Lambi, 2006). The variability of the seasonal rainfall total and climate change increases the exposure of woody plants. In arid and semi-arid environments, the woody cover and density tend to increase with increasing mean annual precipitation (Sankaran *et al.*, 2005). Precipitation can also be crucial for plant phenology. The size of precipitation events has a strong impact on available soil moisture and related processes such as growth, mortality or establishment. Precipitation provides deep infiltration and thus fewer losses through evaporation but intense rainfall can lead to high water losses through runoff, if the soil texture, structure and roughness do not allow for fast infiltration (Fensham, Fairfax & Archer, 2005; Tietjen, Zehe & Jeltsch, 2009; Tietjen *et al.,* 2010). Variations on the inter-annual scale increase the frequency of multi-year droughts and can, therefore, cause severe diebacks of grasses. Juvenile shrubs and seedlings, especially those with low competitive strength, benefit from such situations (Buitenwerf, Swemmer & Peel, 2011; Ward & Esler, 2011). In addition, inter-annual variation causes consecutive years with above average precipitation which enable episodic mass recruitment of woody species (Joubert *et al.,* 2008; Kraaij & Ward, 2006).

High rainfall promotes an increase in woody vegetation cover; encroacher plants like *Acacia mellifera* require at least three years of successive good rainfall to recruit successfully (Joubert *et al.,* 2008) *Seriphium Plumosum* requires a summer rainfall of approximately 620 to 750 mm (Snyman, 2009a). Increased soil moisture availability, particularly when there is limited

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competition from grasses, allows woody plant seedlings to survive and grow into bush thickets. By contrast, drought, through restricted plant growth, seed germination and increased competition for limited water at high shrub densities, leads to the death of some plants (Roques *et al.*, 2001) and, thus, reduces bush encroachment. As a result, bush encroachment is a cyclic natural phenomenon influenced by recruitment and the death of encroacher plants in response to rainfall patterns (Wiegand *et al.,* 2006).

2.3.2 Soil Factors

Plants require soil to obtain water and nutrients for growth, and for anchorage and stability. Seeds will germinate; seedlings emerge and grow to produce under a great variety of conditions. Therefore, it is important to understand the soil environment in which plants grow, in order to recognise the limitations of that environment. Soil is one of the most important natural resources for plant growth. It is estimated that the rate of soil formation is about 2.5 cm every 150 years (Friend, 1992); That is, soil is non-renewable within the human-life-span. Soil, as the most important natural resource, is the key to the success and environmental harmony of any human use of land (Brady & Ray, 2002). It is crucial in life on earth; its quality determines the nature of plant ecosystems and the capacity of land to support animal life and society. Soil consists of mainly clay, silt, sand and gravel sized particles, which are products of weathering, organic materials arising from the growth of flora and fauna in and on the soil, and the soil atmosphere and soil water, which fill the voids between the solid particles. Usually, many plants require suitable soil that has sufficient and balanced quantities of plant nutrients and chemical properties, effective depth, favourable morphological properties, good internal drainage, and an optimal moisture regime (Du Plessis, 2003).

Soils vary widely in texture, structure, profile and depth. This reflects the interaction of geology, geomorphology and climate on one scale, and the influence of topography, relic features of past landforms, the kind and extent of vegetation cover, and animal activity on another scale (Frost *et al.,* 1986). Physical characteristics and the underlying geologic formation determine both nutrient content and the water nutrient retention capacity of a soil. Soil factors which influence plant distribution include:

- *Soil Texture*

Soil texture is a term which describes the mixture of different sizes of mineral particles. The mineral particles, originally from solid rock, assumed their present form because of physical and chemical processes called weathering (Fitzpatrick, 1986). At some stage, in the weathering

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process, mineral particles became a favourable medium for plant growth, that is, they were able to provide storage of water, air, and mineral nutrients, as well as space in which roots could grow (Thompson & Fredrick, 1993). Organic matter then accumulated near the soil surface due to the decomposition of plant residues (Fitzpatrick, 1986). Generally, organic matter further improved the properties of the soil as an environment for plant growth. The percentage of organic matter in soils is quite variable. Soil texture relates primarily to particles smaller than two millimeters (0.2cm) in diameter (sand, silt, and clay) since these are the particles most active in soil processes, which support plant growth. Coarser particles, such as gravel and stones, are either inert or detrimental to plant cultivation (Vimmerstat *et al.,* 1982).

Sandy soils usually have rapid water infiltration and good aeration, but low water holding and nutrient storage capacity. Silt, the intermediate size, feels smooth when dry, and slippery, but not sticky when moist. Because the smaller particle size promotes smaller pore spaces between particles, silty soils have a slower water intake rate but a higher water holding capacity than sandy soils (Hudson, 2001). Silt is an essential component of the medium textured, versatile soil called loam.

Clay exhibits some unusual properties, unexpected if it were merely composed of smaller particles or the same minerals that make up sand and silt (Passioura, 1991). Clay is largely composed of a different set of minerals called secondary minerals. These are weathering products of the primary minerals, namely quartz, feldspar, and mica of which sand and silt are largely composed (Fitzpatrick, 1986). One unusual property of clay is its attraction (called adsorption) for positive ions, such as calcium, magnesium, potassium, ammonium, and others. However, negative plant nutrient ions such as nitrate, phosphate, and sulphate are repelled by clay particles, and can only be stored for plant use to the extent that they occur dissolved in the water held in soil pores (Thompson & Fredrick, 1993).

Clay has a very high affinity for water, partly because of its small particle size and also because aforementioned positive ions associated with clay also attract water. Clay soil swells and they are known to have great strength and sticky nature. Amount of clay in a soil improves its capacity to hold water and plant nutrient ions (either in solution or by adsorption). The swelling and shrinking of clay also helps to form a favourable structure in medium textured soils (Tisdall, 1994). Coarse textured soils have low structural stability, low moisture holding capacity and low organic matter which limit plant development. Soil texture substantially influences the available soil moisture. The adhesive properties of water, in combination with the large surface area of clay-sized particles, allow clay to hold more water than sand. Silt loam contains the greatest

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quantities of plant available moisture because of the favourable distribution of macro and micro pore spaces (Barnes *et al.,* 1998).

- Soil Depth

The depth of a soil is considerably important both for agricultural and nonagricultural uses. A shallow-rooted crop may produce equally well on either a deep or shallow soil. However, deeply rooted plants such as trees or alfalfa require deep soils for the best growth. During drought periods, crops on shallow soils usually are the first to show damage because of the lack of moisture. This is a result of soil volume that cannot hold adequate water. Shallow soils restrict plant growth by impeding root growth and they provide only limited water and nutrient re-serves. The processes of soil formation may have been such that only a thin veneer of soil has formed over a very hard or resistant parent material. Erosion may have reduced the thickness of a once-deep soil. Coarse gravel and sand layers can also impede root penetration as well as sustain high water tables. In addition, root-restricting horizons or pans may have been formed during soil formation.

A soil that has a thickness greater than 1.5m is very deep. Any soil possessing a root-restricting horizon at a depth of less than 0.5 m is considered shallow. Moderately deep soils are those between these two extremes. In summary, the categories of soil depth are:

- Very deep - greater than 1.5m
- Deep - 1 to 1.5m
- Moderately deep - 0.5 to 1m
- Shallow - 0.25 to 0.5m
- Very shallow - less than 0.25m

Soil depth significantly affects soil moisture, runoff generation, and subsurface and groundwater flow (Seyfried *et al.,* 2009). Soil depth also provides an indication of the available water capacity, and exerts a major control on biological productivity (Gessler *et al.,* 1995,), which, in turn, affects evapotranspiration. Soil depth determines the total capacity of the soil for storing available water for plant growth. Deep-rooted plants on deep soils usually show smaller responses to surface water (irrigation) than shallower rooted crops on the same soil. Philip *et al.* (1970) in his study to determine some effects of soil depth on native vegetation produced each year found that soil depth has an effect on vegetation growth. Hulett *et al.* (1969) found that

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forage production increased as soil depth increased. Mason *et al.* (1967) also indicates that the deeper soil produced plants than the shallow soil.

- Soil Fertility

Soil fertility is inversely related to rainfall. In high rainfall areas, nutrients are lost through leaching. This negative correlation between rainfall and soil nutrient-availability is the basis for the distinction between moist-dystrophic savannas and arid-eutrophic savannas (Huntley, 1982). The availability of nutrients is influenced by parent geology, rate of weathering and transport of materials into and out of an area by water (Bell, 1982). Soil fertility is a key determinant of plant structure and functioning (Menaut *et al.,* 1995; Skarpe, 1992). It is the ability of the soil to supply essential plant nutrients and soil water in adequate amounts and proportions for plant growth and reproduction in the absence of toxic substances which may inhibit plant growth. It sets a limit on maximum plant productivity and a constraint on types of plants that can survive alternating periods of drought and favourable water relations. Total productivity is also constrained by availability of nutrients and is dependent on precipitation and past vegetation history and other factors such as parent material (Gambiza, 2001).

2.3.2 Topography

Landscape position causes localised changes in moisture and temperature. When rain falls on a landscape, water begins to move downward by the force of gravity, either through the soil or across the surface to a lower elevation. Even though the landscape has the same soil-forming factors of climate, organisms, parent material and time, drier soils at higher elevations may be quite different from the wetter soils where water accumulates. Wetter areas may have reducing conditions that will inhibit proper root growth for plants that require a balance of soil oxygen, water, and nutrients. Steepness, shape, and length of slope are important because they influence the rate at which water flows into or off the soil. If unprotected, soils on slopes may erode leaving a thinner surface layer. Eroded soils tend to be less fertile and have less available water than uneroded soils of the same series. Topographical aspect affects soil temperature. Generally, for most of the continental United States, soils on north-facing slopes tend to be cooler and wetter than soils on south-facing slopes. Soils on north-facing slopes tend to have thicker A and B horizons and tend to be less droughty. Slope, generally, is expressed as a percentage. Slope classes are used for interpretive purposes. The classes are nearly level, gently sloping, strongly sloping, moderately steep, steep and very steep.

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Topography also plays an important role in the distribution of plants. Southern hill-slope aspects (south-facing slopes= SFS) differ from northern ones (north-facing slopes= NFS) mainly as a result of the differences in radiation intensity. Radiation at 30°N latitude is more intense in southern aspects. This affects temperature, soil moisture, and soil aggregation processes, which, in tum, affect vegetation and fauna characteristics (Kirkby *et al.*, 1990). Variations in slope, aspect, curvature, upslope contribution area and relative elevation all affect the distribution of plants. The slopes facing south and west tend to be drier than the slopes facing north and east due to the relatively high radiation exposure of the sun. The steepness of a slope affects plant growth through differential incidence of solar radiation, wind velocity and soil type. A steep slope is susceptible to rapid surface runoff and soil erosion, which cause soil degradation. A slope can act as a barrier of seed dispersal depending on the plant species and their modes of dispersal, habitat fragmentation and their separation (American Journal of Botany, 2011). *Seriphium Plumosum* is abundant on rocky hill slopes where it first establishes itself on the southern slopes before spreading to valleys, and it seldom occurs in the wet (vlei) areas (Snyman, 2009a).

2.3.3 Anthropogenic factors associated with plant distribution

- Fire regime

Vegetation responds differently to fire depending on the degree to which above-ground plant parts such as stems and buds, and below-ground plant parts such as roots, rhizomes, and buried seeds are damaged or destroyed. Plant regeneration begins almost immediately following a fire. At any given location, vegetation develops over time in orderly stages called succession. Each successive stage is determined by climate, soil conditions, available of sunlight, and natural disturbances. In sour grassland areas of southern Africa, fire occurs naturally due to high incidence of lightning storms, which result in a 'fire climate', in both wet and dry periods (Everson, 1999). Fire provides conditions conducive to seedling growth. Shrubs, grass clumps, litter and sometimes canopy cover are removed, allowing increased light penetration to ground level and reducing competition for water and nutrients (Tierney, 2009).The changes in fire regime characteristics, such as frequency, intensity, extent, type and seasonality of fire, promote the dominance of the invaders (Brooks *et al.*, 2004). Frequently, burning using autumn burns to stimulate out of season growth, seriously retard grass development and provide the woody plant species with a competitive advantage over the grasses (Barac, 2003). Heat promotes germination in many legumes (Dixon; Flematti *et al.,* 2005). Fire increases shrub

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encroachment because of the drastic increase in seed germination, and shrub densities could occur after burning shrubs such as *Seriphium Plumosum* (Wepener, 2007).

- Land cover disturbances

Disturbances can vary greatly over temporal and spatial scales and have traditionally been viewed as uncommon, irregular events that cause abrupt structural changes in natural communities, thus moving them away from static, near-equilibrium conditions (Sousa, 1984). Disturbances is any relatively discrete event in time that disrupts ecosystem, community, or population structure, and that changes resources, availability of substratum, or the physical environment. Disturbances include the impact of anthropogenic influences and environmental causes, for example, grazing, herbivore, fire, drought, flood, spatial heterogeneities in water and nutrients and seed production. Seed dispersal of woody plant species deposited in disturbed environment such as abandoned fields and shifting cultivation leads to an increase in woody species and a decrease in grass cover (Vincent, 1999). Disturbances incorporate not only their introductions, but sometimes elimination of native species. Lykke (1998) indicates that disturbance in savanna environments frequently leads to vegetation changes that take place faster than natural vegetation transformations and often occurs in the form of continuous and widespread stress.

Poor grazing management practices have been blamed for the introduction and spread of invasive plants by the degradation and reduced competitive ability of the native plant communities (Frost *et al.*, 2003). Decades of overgrazing during the open range era paved the way for opportunistic winter annual grasses, such as cheat grass and medusa head. These grasses are fierce competitors that have high seedling vigor and are able to germinate, establish and complete their life cycle before the summer dry period (Frost *et al.,* 2003). The exploitation of resources by the annual grasses when combined with the overgrazing resulted in a decline in perennial grass populations. A shift in grazing management to better utilise the annual grasses then left the community open to the next wave of invaders such as *Seriphium Plumosum.* Livestock can disperse seeds by serving as transportation vectors for seeds that adhere to their coats (fur, wool, or hair). Livestock can also spread seeds by consuming and passing viable seeds through their digestive tract. While the total number of viable seeds that survive the digestive tract is greatly reduced, those seeds that do survive are deposited in a protective pile of concentrated nutrients that can increase the chance of germination (Frost *et al.,* 2003).

Though livestock grazing can increase the rate of weed invasion, the absence of grazing does not protect land from weeds. Ward (2005) indicates that bush encroachment is not only just

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caused by overgrazing. Moleele (2005) stresses that, the increase in density and cover of woody plant species coincided with the introduction of cattle in southern Africa. The empirical result of a study undertaken by Moleele (2005) confirms that cattle density is responsible for bush encroachment. Also Drewa *et* al. (2002) support the idea that cattle have been directly responsible for increased abundance and expanded distribution of invaders through consumption and dissemination of seed. According to Low and Rebelo (1996), the shrub-tree element comes to dominate the vegetation in areas, which are being overgrazed. According to Ward (2005), factors causing bush encroaching are poorly understood.

2.4 The Impact of bush encroachment on native plants

Bush encroachment is the suppression of palatable grasses and herbs by encroaching woody species often unpalatable to domestic livestock (Zeleke, 2009). Therefore, bush encroachment reduces the carrying capacity for livestock (Ward, 2005). The reduction in carrying capacity is of great significance because savannas in southern and central Africa contain a large and rapidly growing proportion of the world's human population, including many pastoralists whose livelihood is threatened by this process (Ward 2005). It leads to pseudo-droughts as a result of plant competition (Richter *et al.,* 2001). The effects of high-density trees on drought are the result of their high water use as influenced by their deep root system and evaporation level (Mathews & Brand, 2004). The effect of bush encroachment on soil water is also endorsed by a study by Smit and Rethman (1999) which indicates that there is a low soil water status at high tree densities. The impact of this low soil water status is reflected by the absence of herbaceous plants (Smit & Rethman, 1999).

The effects of encroacher species are particularly dramatic when they alter disturbance regimes beyond the range of variation to which native species are adapted, resulting in community changes and ecosystem level transformation (Brooks *et al.,* 2004). According to Ehrhorn (1996), the diversity of plant communities decline rapidly with increasing aridity.

- They compete with indigenous plants for nutrients such as phosphorus;
- They pose a threat to water security, that is, they consume too much water;
- They disturb ecological functioning of the natural system;
- Species such as the *Seriphium Plumosum* degrade the productive potential of the land; and

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- They intensify the intensity and spread of veld fires and also increase the intensity of desertification as they absorb too much water (Le Maitre *et al.,* 1995).

2.5 Legislature regulating the conservation of agricultural resources

Bush encroachment is defined as a stands of plants where individual plants are closer to each other than three times the mean crown diameter. Plants in this group are not alien plants, but indigenous plants that tend to become abnormally abundant when the area is degraded by, for example, overgrazing or injudicious fires. A list of indigenous plants that might indicate bush encroachment in specified areas of South Africa appears in Regulation 16 of the Conservation of Agricultural Resources Act 1983 (CARA), Act 43 of South Africa. The plants themselves are not the problem, but they can be regarded as a symptom of poor land management practices. Therefore CARA does not outlaw these plants, but instead prescribes management practices aimed at preventing bush encroachment, and combating it where it already occurs. If communities of plants from the list of indicators occur in the natural vegetation of an area, the land users have to take the necessary precautions to prevent the deterioration of their land to such an extent that bush encroachment takes place. In cases where bush encroachment has already taken place, the land users have to remove the cause of deterioration and combat the encroachment of indicator species

Table 2.1 : CARA listed species as declared indicators of bush encroachment

Botanical name	Common name	Application area
Acacia tortilis	Lopholaena	Gauteng, Mpumalanga, Limpopo , North-West
Maytenus polyacantha	Kraaldoring	Limpopo
Maytenus senegalensis	Red spike-thorn	KwaZulu-Natal
Rhigozum trichotomum	Three – thorn rhigozum	Northern Cape
Seriphium Plumosum	Bankrotbossie, Slangbos / Bankrupt bush	North West, Free State
Strychnos madagascariensis	Black monkey orange	KwaZulu-Natal Mpumalanga, Limpopo, North-West
Tarchonanthus camphoratus	Vaalbos / Camphor bush, Sagewood	Northern Cape, North West
Terminalia sericea	Silver cluster leaf	Gauteng, KwaZulu-Natal, Mpumalanga, Northern Cape, North-West, Limpopo
Asparagus	Wild asparagus	North West, Free State
Colophospermum mopane	Mopanie / Mopane	Limpopo

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Commiphora pyracanthoides	Cork tree, Common corkwood	Northern Cape
Acacia ataxacantha	Vlamdoring / Flame thorn	Gauteng, KwaZulu - KwaZulu - Natal, Mpumalanga, Eastern Cape, Limpopo
Acacia gerrardii	Red thorn	KwaZulu - Natal, Mpumalanga, Limpopo

Source: (National Department of Agriculture, 2012)

2.6 Origin and distribution of Seriphium Plumosum

Seriphium Plumosum is part of the aster or daisy family (*Asteraceae*) which is a taxon of dicotyledonous flowering plants (Robert *et al.,* 2001). They are mainly herbaceous plants distributed over most of the world (Robert *et al.,* 2001). The *Seriphium* genus is endemic in South Africa and is distributed to Namibia, Angola in Lubango, Zimbabwe and Mozambique (Koekemoer, 2001). *Seriphium Plumosum* commonly known as *Artemisia vermiculata*, *Elytropappus ruschianus*, *Stoebe cinerea* , *Stoebe burchellii*, *Stoebe cinerea*, *Stoebe vulgaris*, *Artemisia ambigua*, *Stoebe plumosa* (Koekemoer, 2001) is, in South Africa, also known as Slangbos, Bankrupt bush, Vaalbos, Khoi–kooigoed (Jordan, 2009). Diversity for the *Seriphium Plumosum* in South Africa was identified in Namaqua, Hantam, Fynbos, Eastern Cape, Drankesberg, and Belfast (Snyman 2009a). The highest distribution of *Seriphium Plumosum* is in Mexico and the second highest in South Africa (Koekemoer, 2001). It is mainly found in the mountainous and coastal regions of the Western Cape, with a few species spreading into Eastern and Northern Cape.

2.6.1 Description and germination of Seriphium Plumosum

Seriphium Plumosum is an annual herbaceous member of the Asteraceae, made up of 36 species, of which two are in Madagascar and 34 in South Africa (Jordan, 2009). The species evolved from Stoebe cinerea by mutations and this changed its character and enabled it to invade the grassland (Roux, 1969). It is a small multi-stemmed woody shrub that grows to an average height of 60 cm and a width of 60 cm (Schmidt *et al.*, 2002). *Seriphium Plumosum* appears to be a sprawling, much-branched, grey shrub. Looking closer, one notices that the slender, wiry branches are soft woody and at right angles to the stem. The short shoots are covered with whitish, woolly, clustered leaves, which are minute, tufted and pressed to the stem, giving the plant a granular appearance. The plants show aromatic characteristics by yielding volatile oil, which acts as a successful protective measure against animal grazing by making it

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unpalatable (Snyman, 2009b). *Seriphium Plumosum* is supported by its root system which may vary from 1m around the plant and can be 1.8m deep (Jordaan, 2009). It is a woody plant with branches at the base, and does not have a well-defined main trunk (Jordaan, 2009). It grows to a height of approximately 0.6 m (Snyman, 2011). *Seriphium Plumosum* has small flowers, but these are usually grouped together in an inflorescence that is called a head, which gives the appearance of being a single flower. This led to the family's earlier name of Compositae. The flower heads of a *Seriphium Plumosum* shrub are grouped in small clusters towards the end of the main shoots, forming a spike-life inflorescence. Pale brown bracts surround the purple disc florets and give the spikes a golden appearance (Badenhorst, 2009). Under normal climatic conditions, flowering takes place during March to May and, to a lesser extent, in September (Snyman, 2009b).

2.6.2 Seriphium Plumosum Seed Dispersal

The spread of seeds plus their ability to remain viable in the soil for many years poses one of the most complex problems for control (Ayele, 2007). This fact makes eradication difficult for many seed producing weeds (Monaco *et al.,* 2001). Shrub seeds are dispersed by wind, water, animals, as well as humans and machinery. *Seriphium Plumosum* is dependent on wind pollination and this causes the trend of forming dense stands in time, as clearly observed in the veld (Van Wyk, 2004). Ripened seed can cling to the shrubs for as long as 5-6 months, before falling down (Snyman, 2010a). This trend lengthens the distribution period of the seed. Every shrub produces thousands of seeds, sometimes forming a yellow carpet under the bushes, awaiting favourable climatic conditions for germination or distribution. Usually, a seedling forms seed in the same year of its germination (Snyman, 2009a). Animals, including humans, are responsible for scattering *Seriphium Plumosum*. They may carry the seeds on their feet or the seed might cling to their fur or clothes. In most cases, the long distance dispersal of seed occurs when they are transported on motor vehicles or machinery (Gupta & Sharma, 1977). For example, *Seriphium Plumosum* has occurred on higher mountains and, over years, has spread down the mountains to lower-lying areas where it is found today (Snyman, 2009b). Due to wind, the seeds were distributed to low land areas from mountainous area. Over the past four decades, its distribution down the slopes and valleys drastically increased (Snyman, 2009b). The seeds were possibly spread by wind, animals, water and human beings over long distances. It first established themselves on the southern cooler/moister slopes and later spread to the valley with sandy/acidic soil and areas of high rainfall. *Seriphium Plumosum* spread to

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ridges, and the plains. It is seldom found in the wet areas where the clay content and potential of the soil may be too high (Snyman & Le Roux, 2009).

2.6.3 Habitat of Seriphium Plumosum

Seriphium Plumosum requires a summer rainfall of approximately 620–750 mm, which is usually required for the optimal growth of bankrupt bush (Hatting, 1953; Snyman, 2009a). This reflects the precipitation boundary between mesic and semiarid grassland. *Seriphium Plumosum* prefers moist valleys where the areas are mostly dry, rocky, sandy slopes and flats (Koekemoer, 2001). The plant prefers slightly sandier soils with a low pH (Krupko & Davison, 1961; Roberts, 1966; Smit, 1955; Snyman & Le Roux, 2009; Walker & Noy-Meir, 1982), although soils with a clay content of up to 24% could still be encroached on if the drainage is sufficient and favours the establishment of this woody species (Wepener, 2007). It is abundant on rocky hill slopes where it first establishes itself on the southern slopes before spreading to valleys, but it seldom occurs in wet (vlei) areas (Roberts, 1966; Snyman, 2009a) which have higher fertility, clay and Na content in the soil (Snyman & Le Roux, 2009). The species avoid high water soil conditions, shallower clay soils, high soil fertility (organic matter) and saline/sodic soil (Snyman, 2012).

Seriphium Plumosum grows to its optimum in sandier soils and, according to previous research; it does not grow well in heavy clay soils (Smit, 1955; Krupko & Davidson, 1961; Walker & Noy-Meir, 1982). Sandier soils leach water and nutrients faster, thus favouring trees and shrubs with deeper root systems (Walker & Noy-Meir, 1982; Rango *et al.,* 2005). Fields withdrawn from cash-crop cultivation, degraded and overgrazed areas are favourable habitats for *Seriphium Plumosum* encroachment due to the low soil fertility (organic matter) (Snyman, 2009a). *Seriphium Plumosum* mainly found in the Bankenveld (Veld Type 61b) and the sandy *Cymbopogon-Themeda* veld (Veld Type A50) as classified by Acocks (Hatting, 1953; Low and Rebelo, 1996).

2.6.4 Effect of Seriphium Plumosum as a proclaimed encroacher plant

Seriphium Plumosum encroachment reduces the grazing capacity of the natural veld (Moore & Van Niekerk, 1987), but increases transpiration (thus lowering the soil moisture available for grass growth) (Donaldson, 1980). In 1987, the total area encroached by *Seriphium Plumosum* in the grassland of the Free State was estimated at 30 000 hectares. When dense strands of *Seriphium Plumosum* occur, the grass production can be suppressed by up to 75% (Richter, 1988). *Seriphium Plumosum* currently is viewed as an aggressive encroacher species in large

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parts of the Grassland Biome of South Africa (Mucina & Rutherford, 2006; Snyman & Le Roux, 2009), specifically the Cymbopogon-Themeda Veld (Acocks, 1988). Parts of the Eastern Cape, Free State, Mpumalanga, North West and Gauteng Provinces are mostly affected (Krupko & Davison, 1961; Snyman, 2009a).

The spread of *Seriphium Plumosum* from mountainous to inland areas threatens agricultural activities and depreciates the value of land. It is difficult to underestimate the problem because farmers depend on land to produce, but the encroachment of *Seriphium Plumosum* prevents farmers from achieving their objectives. The species rigorously decreases the agricultural production (Snyman, 2009b). *Seriphium Plumosum* also impacts adversely on biodiversity, water-use efficiency and underground water tables, thereby contributing to the process of desertification. Surveys done in bush-affected areas show that there is a highly significant negative correlation between the increasing problem of bush densities and the occurrence of a perennial and total grass diversity and cover (Gemedo, 2004). The key to its successful expansion is that *Seriphium Plumosum* is unpalatable to livestock. Therefore it out-competes palatable grasses and produces thousands of seeds in one plant, which are dispersed by wind to far away places, thus invading areas which were previously free from invasion (Snyman, 2009b). Farmers spend thousands of rands yearly in eradicating the *Seriphium Plumosum*. However, its spatial distribution is unknown.

2.7 Species Distribution Modelling

To predict species potential distribution, a range of models have been developed. While major differences exist regarding the statistical algorithms used and their species occurrence data type requirements, all models generate predictions in multidimensional ecological space. According to the ecological niche theory Hutchinson (1957), each species depends on the existence of a specific set of environmental conditions for its long-term survival. This concept refers not only to the abiotic environment but also to biotic factors of the respective ecosystem determining the abundance of resources, as well as trophic chain interactions. As a consequence of such biotic interactions (competition, predation), but also of geographic barriers to dispersal and colonization, as well as anthropogenic pressures, species in reality never fully occupy their fundamental niche, that is the ecological-geographic space which meets their requirements (Anderson *et al.*, 2003).

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2.8 Remote Sensing and GIS techniques in mapping vegetation

Remote sensing and Geographical Information Systems (GIS) provide a vast amount of information about the land and improve the understanding of the earth systems (Chuvieco & Huete, 2010). Remote sensing and GIS is widely applied in collecting and processing data and in studying complex geographic terrain types and diverse inaccessible ecosystems. GIS and remote sensing activities encompass a multitude of activities; include the operation of satellite systems, image data acquisition and storage, the subsequent data processing, interpretation, dissemination of the proceeded data and image products (Chuvieco & Huete, 2010). The techniques have the unique ability to capture a spatial and temporal snapshot of an ecosystem that can feasibly be used to establish geographic context and perform spatial interrogation of ecological health and inventory (Patil & Myerst, 1999).

Remotely sensed and GIS data have the potential to provide large-scale information on vegetation in semi-arid and arid rangelands (Tueller, 1987). They provide an opportunity to monitor and understand spatial patterns of vegetation and to inform the understanding of biotic and abiotic processes related to those patterns (McGlynn, 2006). The technique, being objective, cost efficient, regularly repeatable, and able to rapidly map large areas, has potential as an alternative means of weed mapping, (McGowan *et al.,* 2001). The utility of remote sensing and GIS in the assessment of bush encroachment has been demonstrated by a number of authors. A variety of images have been utilised in the process, and these range from aerial photographs (e.g. Hudak & Wessman 1998; O'Connor & Crow 1999), satellite imagery (e.g. Hudak & Wessman 2001), combinations of aerial photographs and satellite images (e.g. Hudak & Wessman 2001; Laliberte *et al.* 2004). Munyaradzi (2012) used remote sensing to investigate spatial and temporal patterns of soil erosion and encroachment by a woody shrub species, *Pteronia incana*, in a catchment in Ngqushwa District, Eastern Cape Province, South Africa between 1998 and 2008. Such analysis is extremely useful in monitoring vegetation and change over time, particularly the effectiveness of control strategies. GIS is considered to be the nerve centre that handles geographic information because it can integrate all sources of spatial data (Remote Sensing, cartography, census data, global positioning system,. among others) (Chuvieco and Huete, 2010). Remote sensing and GIS also creates some problems mainly related to data availability and hardware costs, but a trend towards the convergence of both technologies is evident. Integration of remote sensing data and GIS is facilitated by a number of developments (Congalton, 1988).

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2.9 Image Classification

Image classification refers to the extraction of differentiated classes or themes, usually land-cover and land-use categories, from raw remotely sensed digital satellite data (Meyer, 2008). Contained information in remote sensed images includes spectral pattern, spatial pattern and temporal pattern which can be used to conduct image classification (Meyer, 2008). Spectral pattern refers to the family of classification procedures that utilise this pixel-by-pixel spectral information as the basis for automated land cover classification. It involves the categorisation of image pixels on the basis of their spatial relationship with pixels surrounding them. Spatial classifiers might consider such aspects as image texture, pixel proximity, feature size, shape, directionality, repetition and context. These types of classifiers attempt to replicate the kind of spatial synthesis done by the human analyst during the visual interpretation process.

A wide range of classification methods has been developed to derive land cover information from remotely sensed images. Since remotely sensed images consist of rows and columns of pixels, per-pixel approach, either supervised or un-supervised, has been the conventional method for weed mapping (Dean & Smith, 2003).

- *Supervised Classification*

The image analyst "supervises" the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of the various land cover types present in a scene (Kumar, 2013). To do this, representative sample sites of known cover type, called training areas, are used to a compile a numerical "interpretation key" that describes the spectral attributes for each feature type of interest (Kumar, 2013). Each pixel in the data set is then compared numerically to each category in the interpretation key and labeled with the name of the category it "looks most like" (Kumar, 2013).

- *Unsupervised Classification*

This procedure is applied in two separate steps. The fundamental difference between these techniques is that supervised classification involves training steps followed by a classification step. In the unsupervised approach, the image data are first classified by aggregating them into the natural spectral groupings, or clusters present in the scene. Then the image analyst determines the land cover identity of these spectral groups by comparing the classified image data to ground reference data. Pixel-based classification methods, by using multi-spectral classification techniques, fundamentally assign a pixel to a class according to the spectral

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similarities (Jensen, 1986; Gong *et al.*, 1992; Casals-Carrasco *et al.*, 2000). Although the techniques are well developed and many successful applications have been reported, it suffers from ignoring the spatial pattern in classification. The Maximum Likelihood Classification (MLC), which is the most widely used per-pixel method, is said to be limited by utilising only spectral information without considering texture and contextual information (Zhou & Robson, 2001; Dean & Smith, 2003) Maximum Likelihood Classification is a classical classifier and the most common technique presented in the literature (Benedictsson *et al.*, 1990; Foody *et al.*, 1992; Paola, 1994). The maximum likelihood decision rule is based on the probability that a pixel belongs to a particular class. The basic equation assumes that these probabilities are equal for all classes, and that the input bands have normal distributions.

2.10 Elements of aerial photo interpretation

Eight fundamental parameters are used in the interpretation of remote sensing images, namely size, shape, tone, texture, site, association, shadow, and pattern (Kumar, 2013). In some cases, a single element alone is sufficient for successful identification. In others, the use of several different elements will be required. Tone refers to the relative brightness or colour of objects in an image (Kumar, 2013). Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone allow the elements of shape, texture, and pattern of objects to be distinguished (Kumar, 2013).

Shape refers to the general form, structure, or outline of individual objects. Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape, except where man has created a road or clear cuts. Pattern refers to the spatial arrangement of visibly discernible objects (Kumar, 2013). Typically, an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees and urban streets with regularly spaced houses are good examples of pattern (Kumar, 2013). Texture refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation. Smooth textures are very often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance (Kumar, 2013).

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Shadow is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier (Sabnins, 1987). However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings. Shadow is also useful for enhancing or identifying topography and landforms, particularly in radar imagery (Sabnins, 1987). Association takes into account the relationship between other recognisable objects or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification.

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CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter reveals and describes the logic behind the research methods and techniques used in the study. The research adopted the methodological flow where design data collection and analysis are integrated for the development of the model. This is a quasi-experimental design which includes a desktop study, reconnaissance survey, classification and modelling. This chapter explains the process of manual digitizing, use of land cover map, satellite images, GPS coordinates and abiotic factors, in order to predict the probable areas that can be invaded by *Seriphium Plumosum*. Abiotic variables classification procedure and weigh and class ranking is also explained. Figure 3.1 shows the main workflow of the methodology. Furthermore, this chapter also explains the accuracy assessment conducted in this study

3.2 Research Design

This is Quasi Experimental design which includes desktop study, reconnaissance survey, classification and modelling. Transect map was created in order to access affected areas by seriphium Plumosum. Desktop study was conducted to mask out and validate the satellite image. Classification was also conducted to understand the abiotic factors associated with seriphium Plumosum. Modelling was applied in order to incorporate the abiotic factors and delineated seriphium plumosum in order to predict the spatial distribution of Seriphium Plumosum.

3.2.1. *Overall research Methodology*

The study adopted the methodological flow were design data collection and analysis are integrated together for the development of the model. Methodological Flow is presented in Figure 3.1

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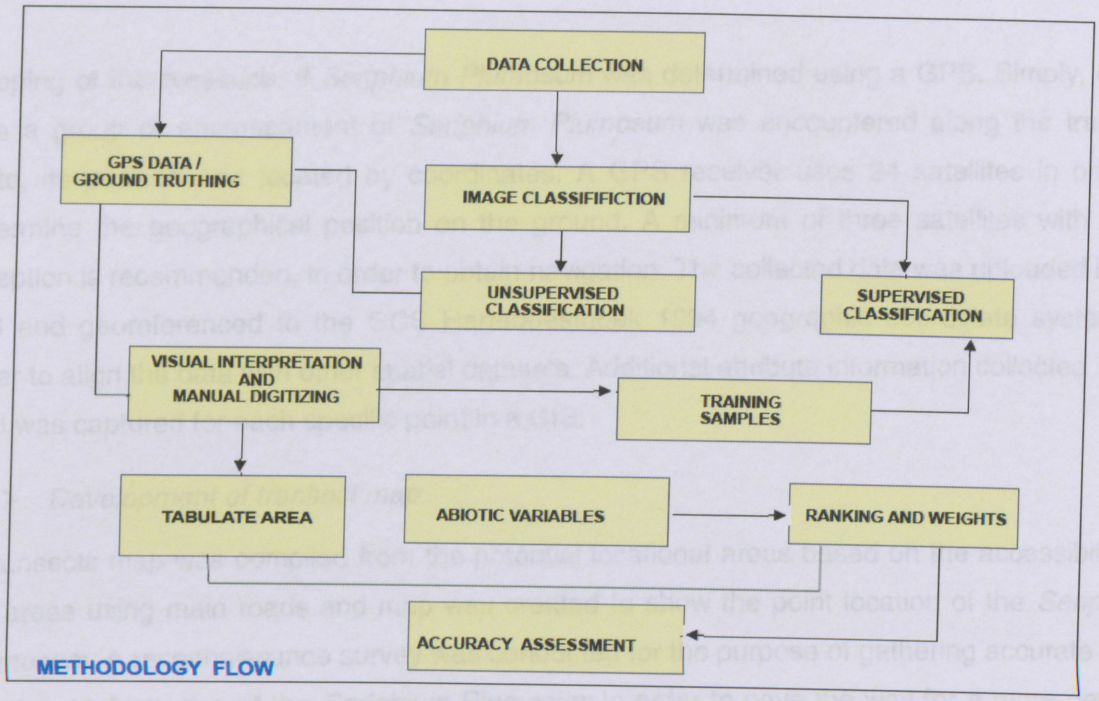


Figure 3. 1: Methodology Flow chart

3.2.1. *Ethical consideration*

Permission to undertake the study was requested from the Department of Agriculture in Mpumalanga Province and other relevant institutions. GIS Data Disclaimer was signed with the Mpumalanga department of agriculture indicating that "whilst all possible care and attention has been taken in the production of this map and/or report, the Department of Agriculture, Rural Development and Land Environment Affairs (DARDLEA), or any of their representatives, do not accept responsibility for any loss or damage occasioned by use of information presented within the digital data or accompanying report. Any boundaries, areas and/or sizes (hectares) either implied or inferred within the report do not have any legal status what-so-ever. While DARDLEA will make every effort to ensure the availability and integrity of its GIS resources, it cannot guarantee that this will always be available, and/or free from any effects.

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3.3 Field Data collection

Mapping of the presence of *Seriphium Plumosum* was determined using a GPS. Simply, every time a group or encroachment of *Seriphium Plumosum* was encountered along the transect route, its position was located by coordinates. A GPS receiver uses 24 satellites in orbit to determine the geographical position on the ground. A minimum of three satellites with good reception is recommended, in order to obtain navigation. The collected data was uploaded into a GIS and georeferenced to the GCS Hartebeesthoek 1994 geographic coordinate system, in order to align the data with other spatial datasets. Additional attribute information collected in the field was captured for each specific point in a GIS.

- *Development of transect map*

A transects map was compiled from the potential locational areas based on the accessibility of the areas using main roads and map was created to show the point location of the *Seriphium Plumosum.* A reconnaissance survey was conducted for the purpose of gathering accurate point locational information of the *Seriphium Plumosum* in order to pave the way for a more detailed identification of the affected areas. Reconnaissance survey was used in this study because it allows the researcher to target certain areas that warrant further investigation. Potential survey areas was selected by masking out the land cover from a Land Cover 2000 database such as plantation, towns, mines and cultivated land that are less likely to be affected by *Seriphium Plumosum*. The collected geographical coordinates were indicating the dominancy of *Seriphium Plumosum.*

- Reconnaissance Survey

A reconnaissance survey was conducted for the purpose of gathering accurate point locational information of the *Seriphium Plumosum,* in order to pave the way for a more detailed identification of the affected areas. In this study, a reconnaissance survey was useful in allowing the researcher to target certain areas that warrant further investigation. Potential survey areas were selected from a Land Cover 2000 database by masking out the land cover such as plantations, towns, mines and cultivated land that are less likely to be affected by *Seriphium Plumosum*. A transects map was compiled from the potential locational areas based on the accessibility of the areas using main roads, and a map was created to show the point location of the *Seriphium Plumosum.* The collected geographical coordinates indicated the dominancy of *Seriphium Plumosum* in Msukaligwa Local Municipality and 78 points are indicated in Figure 3.2

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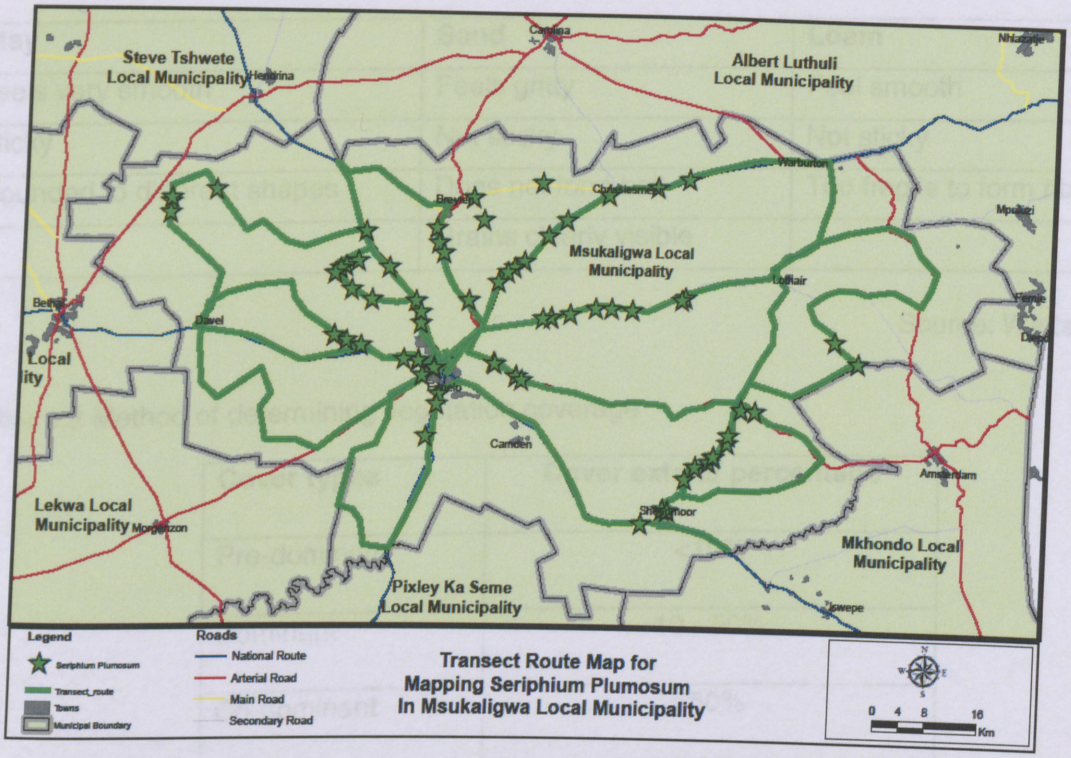


Figure 3. 2: Transect route map

Soil, vegetation and topographic characteristics around *Seriphium Plumosum* locational points were determined through visual observation as additional information useful for comparison with the existing spatial datasets. The soil was described according to a Munsell soil colour chart (Munsell Soil Colour Charts, 2000). The main soil characteristics collected included the soil colour, and texture.

The method that was used to determine the soil texture was the feel method. Soil sample was moistened, then rubbed between hands until it was uniformly moist and squeezed out between the thumb and forefinger to try and form a ribbon. Soil texture was determined using information in Table 3.1. The vegetation cover percentage and cover type was then determined using information in Table 3.2. Other topographic variables collected include slope percentage, elevation (determined using a GPS) and slope position (see Appendix A).

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Table 3.1 Method of determining texture by feel

Clay	Sand	Loam
Feels very smooth	Feels gritty	Feel smooth
Sticky	Not sticky	Not sticky
Mounded to different shapes	Does not form ball	Too fragile to form ribbon
	Grains clearly visible	

Source: Watts (1996)

Table 3.2 Method of determining vegetation coverage

Cover types	Cover extent/ percentage
Pre-dominant	<10%
Dominant	10 - 50%
Co-dominant	>50%
Suppressed	

Source: FAO (2006)

3.4 Source of data and necessity

The LANDSAT 7 Thematic Mapper (ETM+) imagery for this study was provided by the Global Land Cover Facility (GLCF). The image was acquired on 1 June 2005 at 12:00:00 AM (Figure 3.3). The image was selected based on the low percentage of cloud cover and the limited budget for the project. The spatial resolution of the LANDSAT 7 ETM+ imagery is 30m x 30m on the ground. The ETM+ bands used in the study are shown in Table 3.3. *Seriphium Plumosum* mapping, in this study, was based on visual interpretation and vectorization of SPOT 5 imagery (panchromatic sharpened images at 2.5 m resolution and multispectral bands merged with panchromatic bands resulting in 5m resolution) from various acquisition dates from 2009 to 2012 for the entire country. A SPOT 5 satellite image was utilised because it had already been acquired by governmental agencies and provided high resolution air photo-like quality for vegetation mapping (Le Roux *et al.*, 2008a; Taruvinga, 2008). Furthermore, compression of imagery (that is, to enhanced compressed wavelets) made it possible to rapidly and

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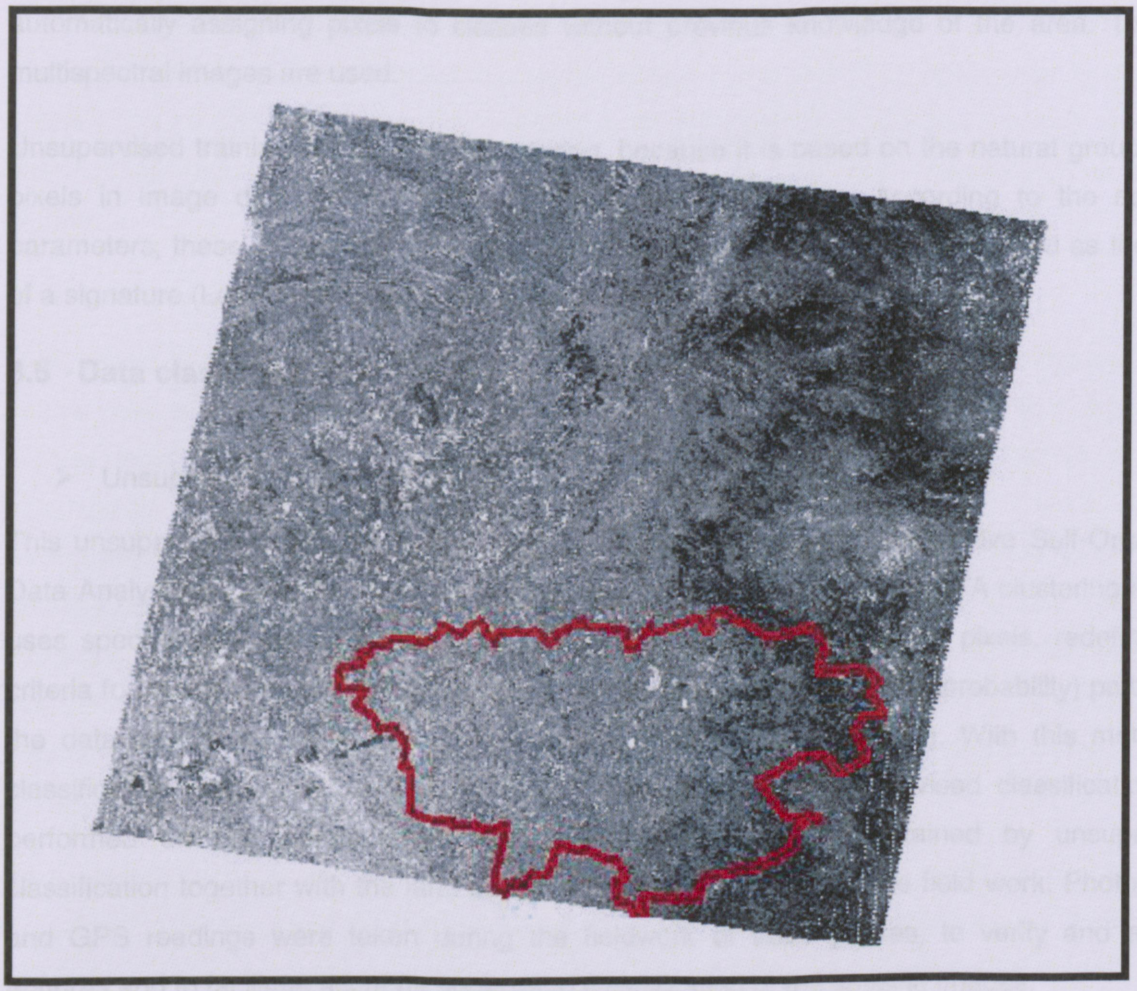
simultaneously view several images as one layer in a seamless coverage (that is, using Image Catalogue developed as an extension in Esri® ArcMap software). *Seriphium Plumosum* was mapped by delineating the outer boundary of encroachment from SPOT 5 satellite images in ArcMap and it was identified by their tone, and association.

Table 3.3 Landsat ETM+ sensor bands used in the study

Band	Color	Spectral Range(microns)
Band 1	Blue	0.45 to 0.515
Band 2	Green	0.525 to 0.605
Band 3	Red	0.63 to 0.690
Band 4	Near-IR	0.75 to 0.90
Band 5	Mid-IR	1.55 to 1.75
Band 6	Far-IR	10.40 to 12.5
Band 7	Pan-sharpened Thermal/panchromatic	2.09 to 2.35

Source: http://www.landsat.co.za/

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Source : Source: http://www.landsat.co.za acquired 1 June 2005

Figure 3.3: LANDSAT 7 ETM+ satellite image downloaded 2005 in Classification of the Satellite Images

All bands were selected, in order to create the spectral signature of the *Seriphium Plumosum*. The satellite image was georeferenced and projected. Land cover classes were used to produce thematic land use cover maps. The process of land use classification is not in itself a task of great difficulty; it only requires considerable knowledge and care to prepare a satisfactory land classification scheme (Campbell, 2002). It is, however, an important stage in image analysis. Lilles and Keifer (1994) stated that the overall objective of an image classification procedure is to automatically categorise all pixels in an image into land cover themes. Before the fieldwork, the satellite remote sensing image from 2005 was interpreted visually and unsupervised classification was then carried out, in order to test the distinctness of classes. It is the process of

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automatically assigning pixels to classes without previous knowledge of the area. Typically, multispectral images are used.

Unsupervised training is also called clustering, because it is based on the natural groupings of pixels in image data when they are plotted in feature space. According to the specified parameters, these groups can later be merged, disregarded, manipulated or used as the basis of a signature (Leica Geosystems GIS & Mapping, 2003).

3.5 Data classification methods

- Unsupervised classification

This unsupervised classification was performed using the ISODATA (Iterative Self-Organizing Data Analysis Technique algorithm) (Tou & Gonzalez, 1974). The ISODATA clustering method uses spectral distance or probability measures, iteratively classifies the pixels, redefines the criteria for each class, and classifies again, so that the spectral distance (probability) patterns in the data gradually emerge (Leica Geosystems GIS & Mapping 2003). With this method of classification, the original images produce natural classes. Unsupervised classification was performed on the image, using 10 classes. These images obtained by unsupervised classification together with the land cover map were used to guide the field work. Photographs and GPS readings were taken during the fieldwork of training sites, to verify and analyse features and to facilitate accurate supervised classification of the satellite images.

- *Supervised Classification*

McCoy (2005) stated, in a supervised classification approach to mapping, that one of the primary steps involves visiting field sites for the purpose of establishing training sites from which training data are derived. In the case of identifying features, patterns and land use classes in the 2005 LANDSAT TM image, individuals (both local and officials) were interviewed to assist in the identification process. Spot images and aerial photographs were of great help. During the field work, ground control points were obtained, and these were used to georectify the images.

Subsequently, after the field work to obtain ground truth data, supervised classification was performed on LANDSAT ETM+ image. This process uses training areas/fields defined by the user to create 10 classes. It serves as a guide and a 'true' representation of the study area as observed or obtained during the course of the field work. For each of the classes, 25 training sample areas, on average, were selected to ensure that there was enough information to

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generate effectual land use/land cover classes. Scholz *et al.* (cited in Campbell, 2002) concluded that the most important aspect of training areas is that all land cover types in the scene must be adequately represented by a sufficient number of samples in each class. The training samples were generated using spatial analyst tools and this created a spectral signature.

- *Generation of Spectral signature*

A signature is a range of brightness values of pixels for each band of digital images. These values have statistical meaning (mean, standard deviation etc.) so that each pixel is assigned to a class based on how well it matched with this signature. Collections of signatures were done by selecting training pixel samples that were representative of a particular class. Training samples for the study area were collected using the Arcgis 10.1 spatial analyst tool. Training sites were determined using visual inspection and by overlying the locations of GPS data onto image. The training site for 10 land use and cover types was created based on the in-situ assessment of the site carried out during the fieldwork and ground truthing exercise. With the help of aerial photos and field work investigation, knowledge of the data and of the classes desired was acquired before classification.

The representative land use and cover types in the image, which included (1) *Seriphium Plumosum*. (2) Grassland (3) Plantations (4) Water bodies (5) Forest (6) Wetland (7) Bare rock (8) Cultivated land (9) Urban and (10) Mines were assigned unit class number 1 to 10 and digitized logically to form the training site. The signature files which contain the statistical information about the reflectance values of the pixels within the training site for each of the ten landuse and landover types or classes was developed. Spectral signature files of *Seriphium Plumosum* were created using all seven satellite bands from landsat image using a model builder and create signature tool in Arcgis. Having created the signature file, each pixel in the study area now had a land use and land cover value in each of the seven bands of the Landsat-7 ETM+ Imagery, thus ensuring that data were ready for supervised classification

In this study, the Maximum Likelihood Classifier (MLC) decision rule was employed. The MLC is based on the probability that a pixel belongs to a particular class. MLC uses basic equation to assume that these probabilities are equal for all classes, and that the input bands have normal distributions (ERDAS, 2003). In other words, it is based on the probability that a pixel belongs to a particular class (ibid, 2003). The Maximum classifier was used in this research, since higher accuracies were achieved than those realized using any other classifiers. In addition, this classifier is to provide the highest classification accuracies. The Maximum Likelihood Classifier

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forms a power classification as it is implemented quantitatively, in order to consider several classes and several spectral channels simultaneously (Campbell, 1996).

3.6 Delineating the locality of *Seriphium Plumosum*

Although the viewing procedure was quite simple, *Seriphium Plumosum* interpretation or detection often required verification in the field and high-level scrutiny. For example, as indicated in Le Roux *et al.* (2008), it was sometimes difficult to distinguish between *Seriphium Plumosum* and other Shrubs. Not all *Seriphium Plumosum* was difficult to interpret and map; as illustrated above, encroachment *Seriphium Plumosum* has a unique and a noticeable colour as (see Figure 3.4)



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Figure 3. 4 : *Seriphium Plumosum* in the field

3.7 Determining abiotic variables associated with distribution of *seriphium Plumosum*

If the distribution of a species is to be predicted accurately, it is important to understand the factors which affect the types and numbers of individuals within a community. The first step, therefore, was to try and determine the factors affecting the distribution of *Seriphium Plumosum* from literature and from field observations. The knowledge from literature and field observations assisted me to do species modelling. Abiotic variables were modelled and distributed over the study area using the ArcGIS model builder program to produce different data layer maps. Clay content, soil depth, mean annual rainfall, land cover, and slope and aspect raster data were used in this study. All these data sets were uploaded into Arcgis 10.2 together with the delineated *Seriphium Plumosum* shapefiles. Data were clipped using raster dataset clip and the Msukaligwa vector polygon was used as an output feature. Africa Albers equal area conic projection was used to project the data. Spatial analyst tool was used to reclassify all the raster data sets. Data were classified as follows:

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- *Slope*

The FAO (2006) classification class was used to classify the slope gradient. It was classified into nine classes as follows:

Table 3.4: Slope classification class

Slope Class	Slope %
Flat to nearly level	0 - 1 %
Very gently sloping	1 - 2 %
Gently sloping	2 - 5 %
Sloping	5 - 10 %
Strongly sloping	10 - 15 %
Moderately steep	15 - 30 %
Steep	30 - 60 %
Very steep	60 - 100 %
Extremely steep	>100 %

Source: FAO (2006)

- *Aspect*

Aspect was classified using a 360° compass and the FAO (2006) classification classes as follows:

Table: 3.5: Aspect classification class

Abbreviation	Direction	Aspect Degree
N	North	338-23°
NE	North East	23-68°
E	East	68-113°
SE	South East	113-158°
S	South	158-203°
SW	South West	203-248°
W	West	248-293°
NW	North West	293-338°
ND	Not known	

Source: FAO (2006)

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- *Clay Content*

Clay content was divided into eleven classes, namely very sandy, sandy, sandy loam, loam, loam sand, loam clay, clayey, clay, very clayey and proximity to water bodies.

- *Soil depth*

It was divided into nine classes as follows: Very deep, deep, medium deep, shallow, medium shallow, very shallow, steep slopes and proximity to water bodies. The tabulate area tool was used to calculate the percentage of dominancy of *Seriphium Plumosum* in the delineated area.

- *Rainfall*

Annual rainfall in a raster format was used together with delineated *Seriphium Plumosum* to calculate the dominancy of *Seriphium Plumosum* in the area. It was grouped into five classes.

- *Land cover*

Land cover data were classified into Cultivated land, Grassland, forest plantation, Dams/Lakes, Degraded erosion, mines, Thicket and Bushland. The spatial analyst tool was used to calculate dominancy of *Seriphium Plumosum* in all classes.

3.8 Predict the probable areas that can be invaded by Seriphium Plumosum

Individual abiotic variables considered in the previous section - Clay content, Soil depth, Rainfall, Slope, Aspect, Land cover - each comprise a separate layer in the GIS analysis. Numeric ratings (weights) assigned to each layer were determined by means of both literature and k-th percentile. k-th percentile value of each variable was calculated. Percentile function was used to establish a threshold of acceptance for each class. In order to determine the weight of each variable class, zonal statistics in spatial analyst tool and Percentile function from Microsoft excel were used. Percentile values were used to weigh the effect each layer has during model calculation. At this point in the procedure, each layer received a weight ranging from 1 to 5 points. Taken together, the points assigned to the six layers added up to a total of 30 points and each layer were dived by 30. The output results were the percentage of influence each input layer has on the *Seriphium Plumosum* distribution. Tabulate area and percentile results were calculated per class and 1 to 5 classes were classified as follows:

1 - Very low

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2- Low

3- Moderate

4- High

5- Very High

3.8.1 Combination of abiotic variables using the model

Finally, after all the weights for each class within each layer had been determined, all layers were introduced into the model (Figure 3.5) created using Model Builder in ArcGIS.

The model tool was designed to produce a final composite image which numerically ranks each 30-meter site (pixel in the array) based on the combined attributes of the individual variables. This was accomplished by each cell in the grid having a unique location attribute. Thus, cells with the same 'location' on different layers are associated with each other across layers, and can be overlaid together to produce a final composite image of *Seriphium Plumosum* distribution. Data manipulations and map creation were conducted using ArcGIS (Environmental Systems Research Institute, Inc.)

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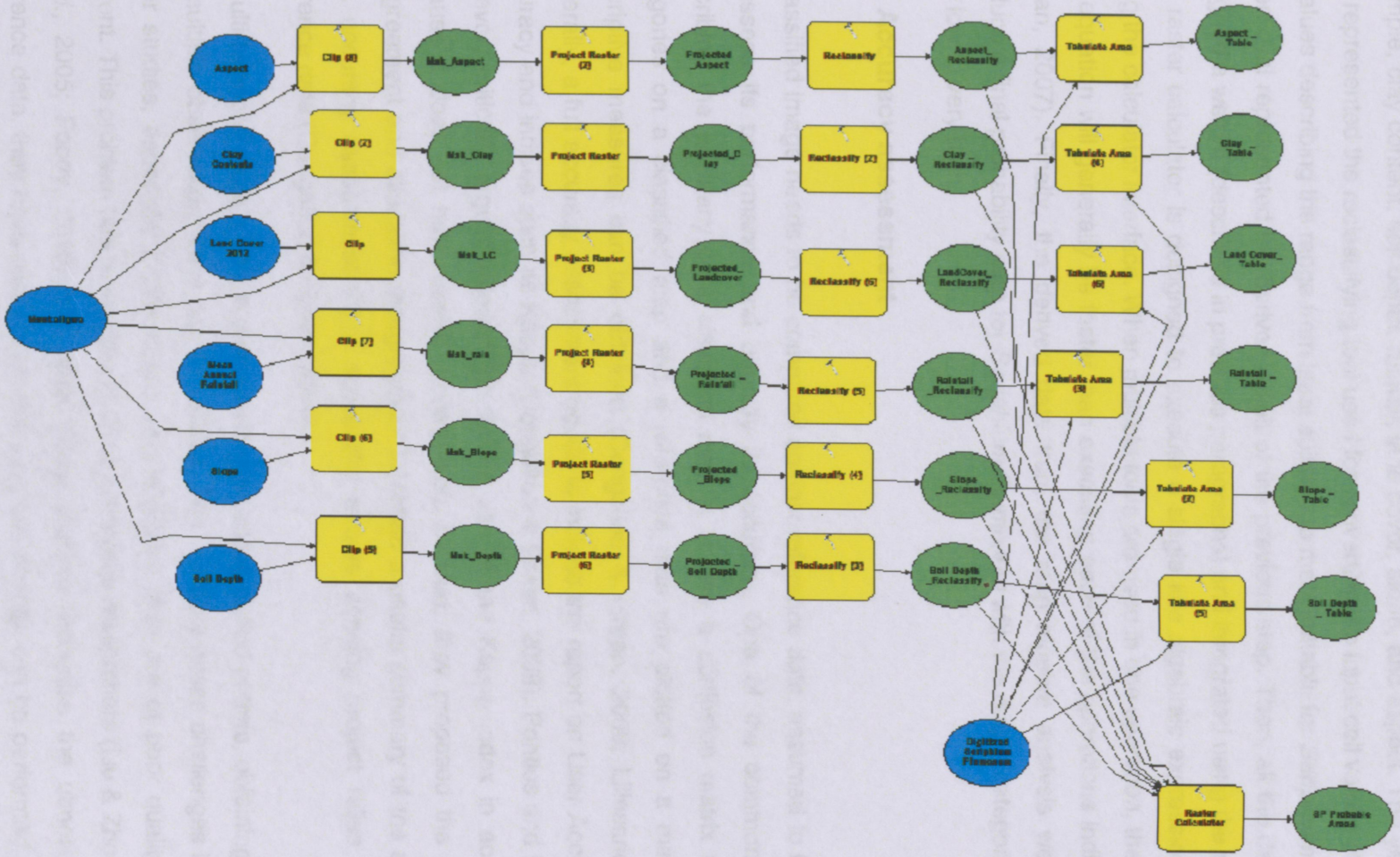


Figure 3.5: Model indicating procedures followed when modelling the distribution of *Seriphium Plumosum*.

In Figure 3.5, the blue oval represents the data that one submits to the model for processing, for example, clay content, soil depth, rainfall, land cover, slope, and aspect. The yellow rectangular box represented the reclassifying tool used for converting the input cell values of the input layers to values describing the range from least suitable to most suitable for *Seriphium Plumosum*. The green oval represented the derived result of the previous step. Then, all the derived data were assigned a weight (described in previous paragraphs) and integrated using the raster calculator. The raster calculator is designed to execute a single line algebraic expression using multiple using the calculator interface. When multiple tools are used in one operation, the performance of this equation will generally be faster than executing each of the operations individually (Gorr & Kurlan, 2007). Finally, the derived data from the map algebra analysis were classified to produce a final probability map for *Seriphium Plumosum* with the output categories ranging from very low to very high.

3.9 Accuracy assessment

A classified image needs to be compared against reference data, assumed to be true, in order to assess its performance and quantify its accuracy. One of the common procedures in describing the accuracy of a classified map is to use a confusion matrix where a set of categories on a classified map and a reference map are plotted on a matrix from which descriptive measures can be obtained (Congalton & Green, 2008; Lillesand *et al.,* 2004). Generally, a full accuracy assessment needs to include the report on User Accuracy, Producer Accuracy and indices such as Kappa (Congalton & Green, 2008). Pontius and Millones (2011), however, critically argued against the further use of the Kappa index in accuracy analysis because it does not have useful interpretation. Instead, they proposed the use of quantity disagreement and allocation disagreement to obtain a useful summary of the accuracy. Either way, accuracy assessment for a successful remote sensing project relies heavily on the reference data (Congalton & Green, 2008).

In multi-temporal studies where data spans over a long period of time, obtaining reference data for multiple observation dates can be difficult. This certainly poses challenges in land use/land cover studies, especially if information and reference data are of poor quality or even non-existent. This problem has been discussed by numerous researchers (Liu & Zhou, 2004; Baraldi *et al.,* 2005; Foody, 2010) and, while these authors recognise the utmost importance of reference data, they have also shown that land use change can be performed when reference data are limited. Foody (2010) even concluded that it is possible to estimate the accuracy of change detection without ground data. Since there are no published *Seriphium Plumosum* maps

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available for Mpumalanga, verification was based on field observations and discussion with other experts. The main purpose of verification, in this study, was to verify the presence of *Seriphium Plumosum* in the field. Field verification was conducted in July 2013 . This date was selected because is dry season and Seriphium Plumosum was visible. It is noteworthy that field observations were aimed at areas that were difficult to map, for example areas with emerging or scattered *Seriphium Plumosum* .

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CHAPTER 4

DATA PRESENTATION AND INTERPRETATION

4.1. Introduction

This chapter, focuses on presenting the results. The results cover the aspect of identification of *Seriphium Plumosum* in the SPOT image, image classification using Landsat 7, and distribution of *Seriphium Plumosum* in relation to abiotic factors. Probable areas that have the potential risk of *Seriphium Plumosum* invasion will be covered in this chapter.

4.2. Identification of *Seriphium Plumosum* from other features

- *Desktop Study*

Geographical coordinates were used as locality reference for *Seriphium Plumosum.* Geographical coordinates were displayed on the desktop together with the satellite images. Remote sensing techniques such as colour, tone, association, and literature review information were used to visually identify the locality of *Seriphium Plumosum. Visually, Seriphium Plumosum* in SPOT image appears brownish in colour, taller than the native species. During the survey it was notices that *Seriphium Plumosum* prefers areas with grasses, abounded agricultural lands, areas with area flat to steep gentle sloping, and along the river banks were the animals graze. All these knowledge was used to delineate the locality of *seriphium plumosum (*Figure 4.1 and 4.2*)*. The extent of 1552 ha were delineated as a base map or areas affected by *seriphium plumosum*. The Delineated polygons were used to create training site and generation of spectral signatures.

- *Land use features and coverage in percentage*

Satellite image were obtained for the period 2005 and supervised classification was conducted. Landsat images were classified for the entire Msukaligwa local municipality. Nine classes were classified using supervised classification derived. Classification results (Figure 4.3) on the map reveal that grassland is dominated in the entire parts of the municipality at 46.85%. The image also explains that plantation is more dominated in the eastern part of the image, whereas forest is seen dominated in the south east of the municipality at 3.4%. *Seriphium Plumosum* is seen to be scattered all over the municipality at 7.1 %. Patches of cultivated land is also more visible from the centre stretching to the west part of the municipality at 20.26 %. Water bodies were

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also classified and appear grey in the image at 3.41%. The image also displays the distribution of mines at 7.3%. Delineated *Seriphium Plumosum* polygons were overlayed on top of image to view the correspondence. The red circled areas (Polygons) indicate area where there was *Seriphium Plumosum* (Figure 4.4). The results indicated that polygons were displayed in the areas that were classified as *Seriphium Plumosum* in the supervised classification.

During field verification, GPS coordinates of areas affected by *Seriphium Plumosum* were collected and uploaded in ArcGIS together with aerial photograph and SPOT image, in order to assist in the process of manual digitizing. Areas affected by *Seriphium Plumosum* were visually interpreted and manually digitized. In most areas, *Seriphium Plumosum* appears taller than other native species in the SPOT Image. *Seriphium Plumosum* appear dark brownish in the satellite image. During ground truthing, *Seriphium Plumosum* was found to be more dominant in flat to gentle sloping; some were found in disturbed areas such as mines and abandoned agriculture lands. It was also dominant in the steep degraded areas along river banks. Colour and association were used to identify *Seriphium Plumosum* in the satellite image.

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Figure 4.1: Delineated the locality of in SPOT 5 Image *seriphium plumosum.*

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Figure 4.2: Delineated the locality of *seriphium plumosum* in Msukaligwa Local Municipality.

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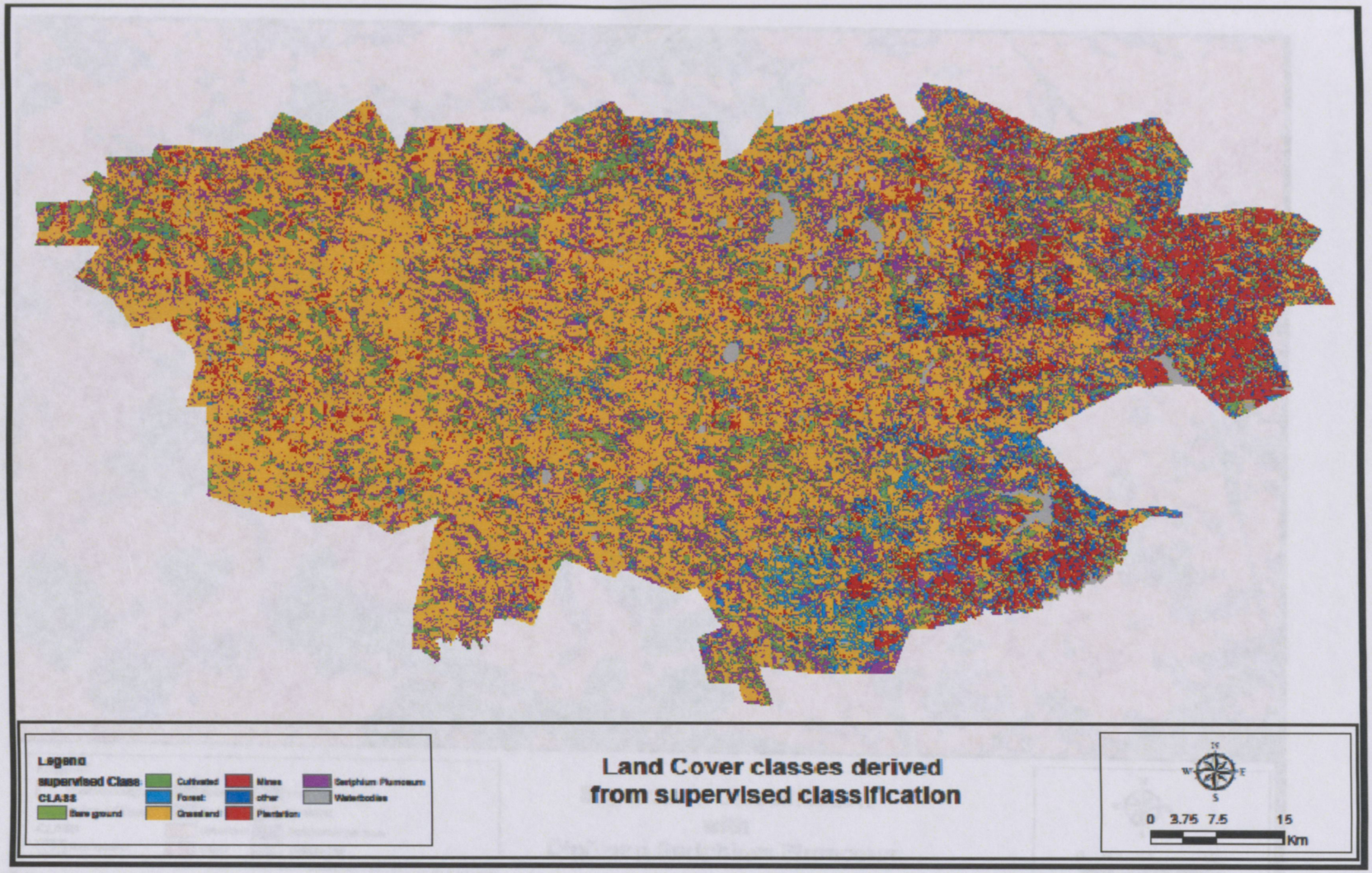


Figure 4.3: Land cover classification map

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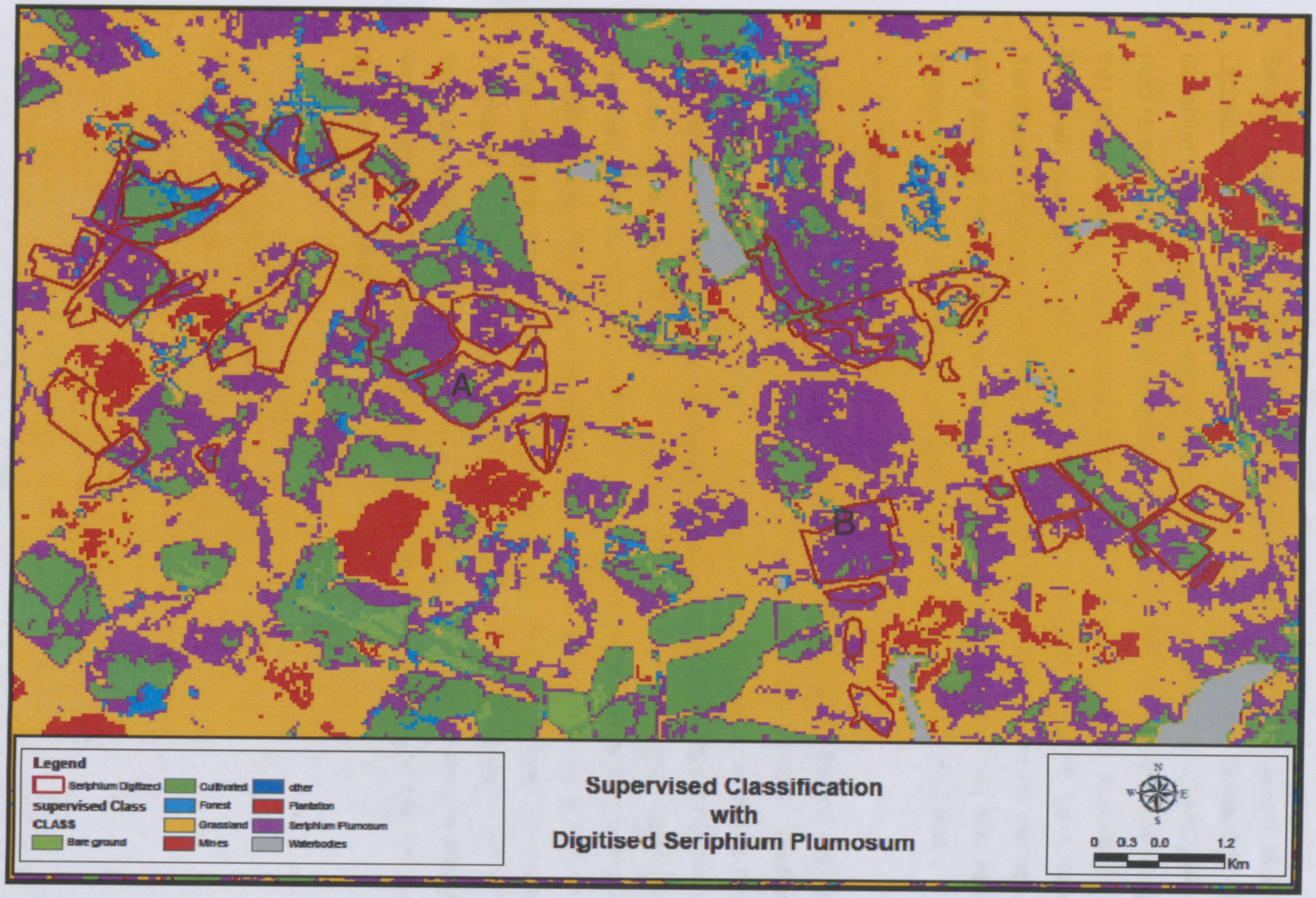


Figure 4.4: Supervised classification indication the distribution of *Seriphium Plumosum*

4.3 Classification results and delineated polygons

Satellite images were obtained for the period 2005 and supervised classification was conducted. Landsat images were classified for the entire Msukaligwa Local Municipality. Ten groups were classified using supervised classification derived map (Figure 4.3). Classification results on the map reveal that grassland is dominant in all parts of the municipality. The image also explains that plantations are more dominant in the eastern part of the image, whereas forests are seen in the south east of the municipality. *Seriphium Plumosum* is seen to be scattered all over the municipality. Patches of cultivated land are also more visible from the centre stretching to the west part of the municipality. Water bodies were also classified and they appear grey in the image. The image also displays the distribution of mines and cultivated land.

- *Issue of Detectability*

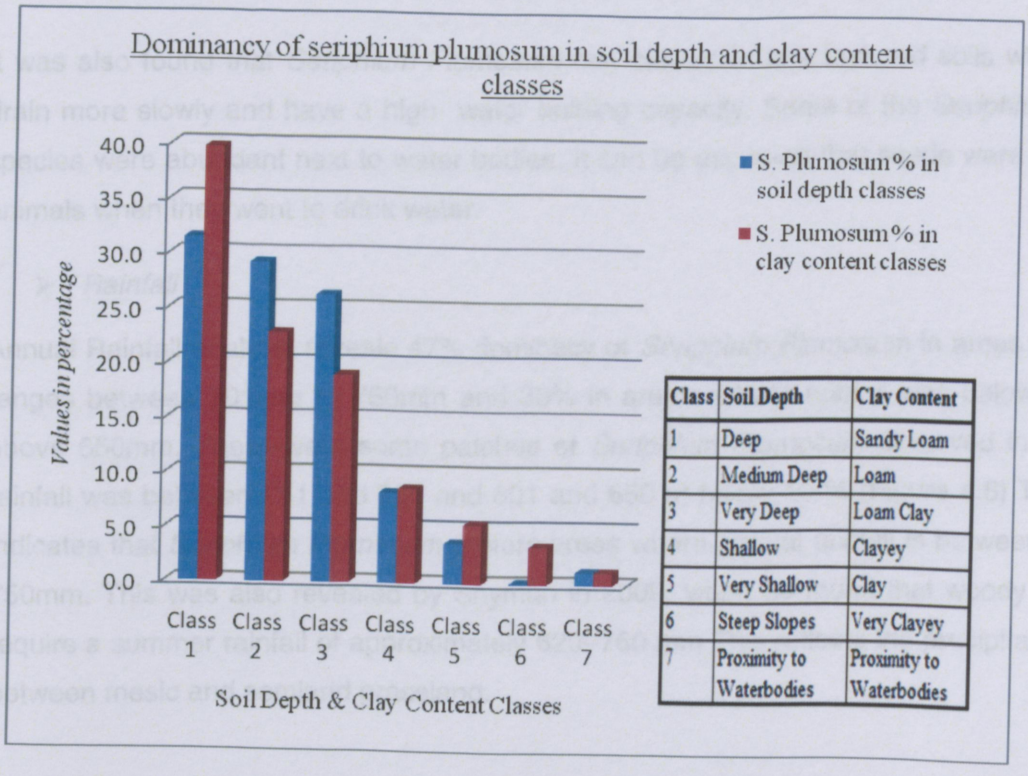
Some of the low accuracy results achieved in identifying *Seriphium Plumosum* using the manually digitizing techniques compared to supervised classification method. This can be explained in terms of Detectability. Detectability can be described as the degree of ease or difficulty that is encountered in extracting *Seriphium Plumosum* from other features. Figure .4.4 indicate the digitized polygon of *Seriphium Plumosum* in red colour. Supervised classification map was used as the background to view the relationship between digitized polygon and the classified map. The results show that some of the area delineated polygons also overlap to other Landover classes, whereas the classified map detect specifically the areas with *Seriphium Plumosum* In point of interest A, *Seriphium Plumosum* was delineated but inside the polygon there are some other classes. In point of interest B, only grassland and *Seriphium Plumosum* were delineated. The results also reveal that species or other Landover such as bare ground, grasses can be classified.

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4.4 Distribution of Seriphium Plumosum in relation to abiotic variables

➢ *Soil Depth*

The results of soil analysis reveal a 32.4% dominancy of *Seriphium Plumosum* on deep soil, and 29.2% in deeper soil, as well as 26.3 % in very deep soils. *Seriphium Plumosum* was more dominant in deep to very deep soil compared to shallow and steep slopes (Figure 4.5). The results also reveal that 8.2 % of seriphium plumosum preferred shallow soil and 3.7% very shallow soil. *Seriphium Plumosum* was also found in steep slopes at 0.1 % dominancy and in areas which were in close proximity to water bodies at 1.1%. *Seriphium Plumosum* was more abundant in deeper soil than in shallow soil. Deeper soil is an environment which is favourable to grasses, creeping species and shrubs. However, during the visual survey, *Seriphium Plumosum* was more dominant than other species. Therefore, *Seriphium Plumosum* outperforms other species and is more dominant. There was a decrease of *Seriphium Plumosum* in steep slopes; only a few patches of *Seriphium Plumosum* were identified. In terms of growth, the percentage cover of *Seriphium Plumosum* increased as depth increased and decreased as depth increased. Deep soils support the development of *Seriphium Plumosum*.



Class	Soil Depth	Clay Content
1	Deep	Sandy Loam
2	Medium Deep	Loam
3	Very Deep	Loam Clay
4	Shallow	Clayey
5	Very Shallow	Clay
6	Steep Slopes	Very Clayey
7	Proximity to Waterbodies	Proximity to Waterbodies

Figure 4.5: Soil depth and Clay content results in relation to *Seriphium Plumosum* distribution

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- *Soil Texture*

Soil texture means the relative proportion of the various size groups of individual soil particles. Texture provides important information regarding water holding capacity, permeability and erodibility. Growth and development of the plant is primarily based on the soil texture. Root penetration, nutrition absorption through soil particles, water holding capacity, water infiltration and percolation are affected by texture type. Soil analysis results reveal that *Seriphium Plumosum* was dominant in sandy loam soil at 40% and in loam soil, 23%. Loam clay soil was also found to be a habitat preferred by *Seriphium Plumosum* at 19 %. The analysis also reveals the distribution of *Seriphium Plumosum* in clayey soil with 9 % extent and 5 % in clay soil (Figure 4.5). Patches of *Seriphium Plumosum* plant in very clay soil made up 3%, while those next to water bodies made up 1%. Sandy loams are coarse textured soils characterised by low water holding capacity. It drains quickly and is low in nutrients. The findings of this study which show that *Seriphium Plumosum* prefers coarse textured soils are similar to those of Snyman's (2012) observation. *Seriphium Plumosum* was also found in loam soils but the extent was less compared to species in sandy loam. Loam soil has the greatest available water holding capacity. It has both large pores for infiltration and drainage, and medium-sized pores to store water. Water stored in this textural class of soils can be extracted by plants.

It was also found that *Seriphium Plumosum* can survive in fine textured soils where the soils drain more slowly and have a high water holding capacity. Some of the *Seriphium Plumosum* species were abundant next to water bodies. It can be assumed that seeds were distributed by animals when they went to drink water.

- *Rainfall*

Annual Rainfall analysis reveals 47% dominacy of *Seriphium Plumosum* in areas where rainfall ranges between 701mm to 750mm and 30% in arears where rainfall was below 700mm and above 650mm. There were some patches of *Seriphium Plumosum* observed in areas where rainfall was between 751 and 850 and 601 and 650 at below 10 % (Figure 4.6) Therefore, this indicates that *Seriphium Plumosum* prefers areas where annual rainfall is between 650mm and 750mm. This was also revealed by Snyman in 2009, when he found that woody dwarf shrubs require a summer rainfall of approximately 620–750 mm This reflects the precipitation boundary between mesic and semiarid grassland.

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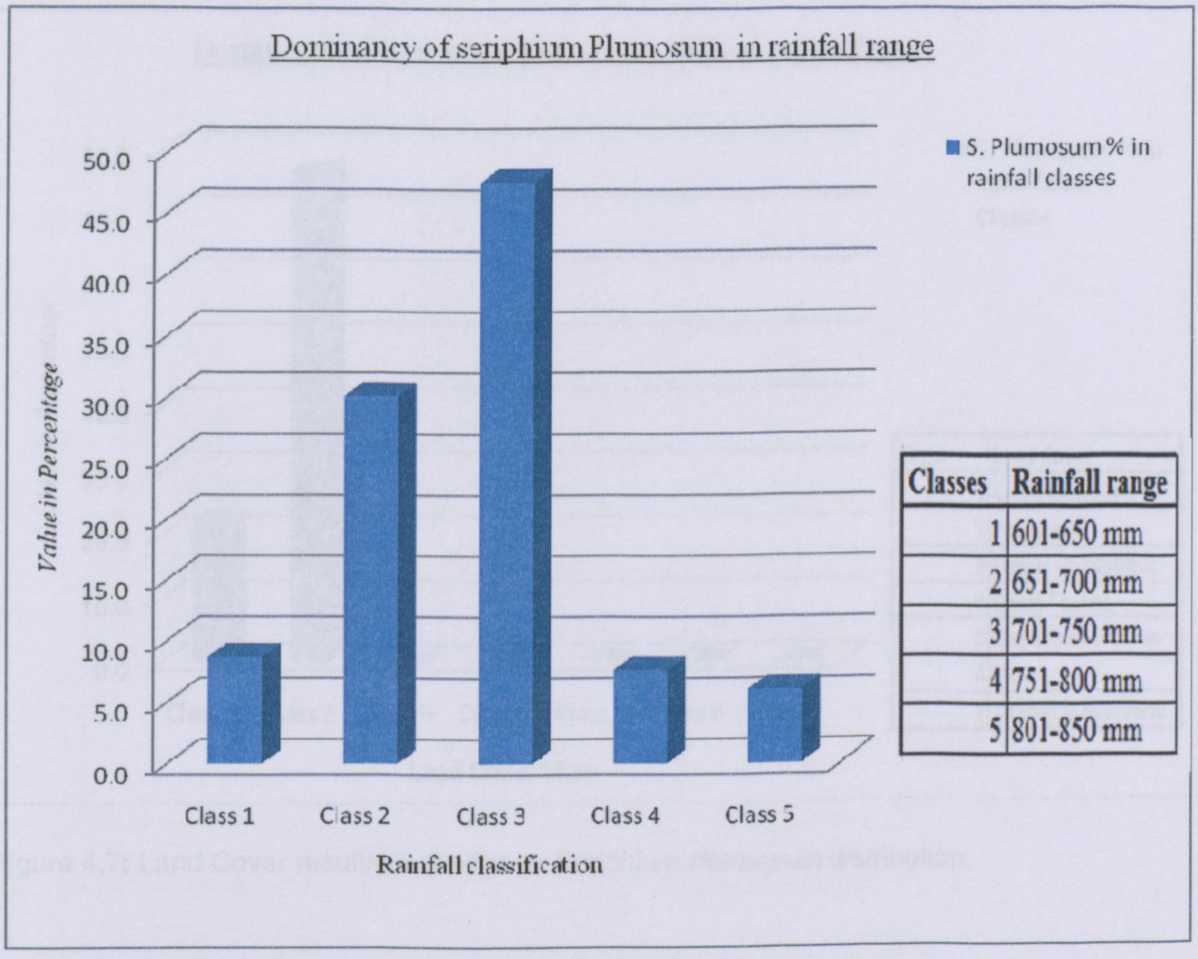


Figure 4.6: Rainfall results in relation to *Seriphium Plumosum* distribution

- *Land cover*

Land cover analysis reveals that *Seriphium Plumosum* was dominant in grasslands which are categorised as class 2. It was recorded that more than 70 % dominacy of *Seriphium Plumosum* was in grassland areas and 20 % in cultivated land (Figure 4.7). Cultivated land refers to areas that were previously cultivated and later abanded. These areas are classified as cultivated areas. The results also reveal that a near absence of *Seriphium Plumosum* in other classes such as forests, plantations, dams, degraded erosion, mines and thicket bushland.

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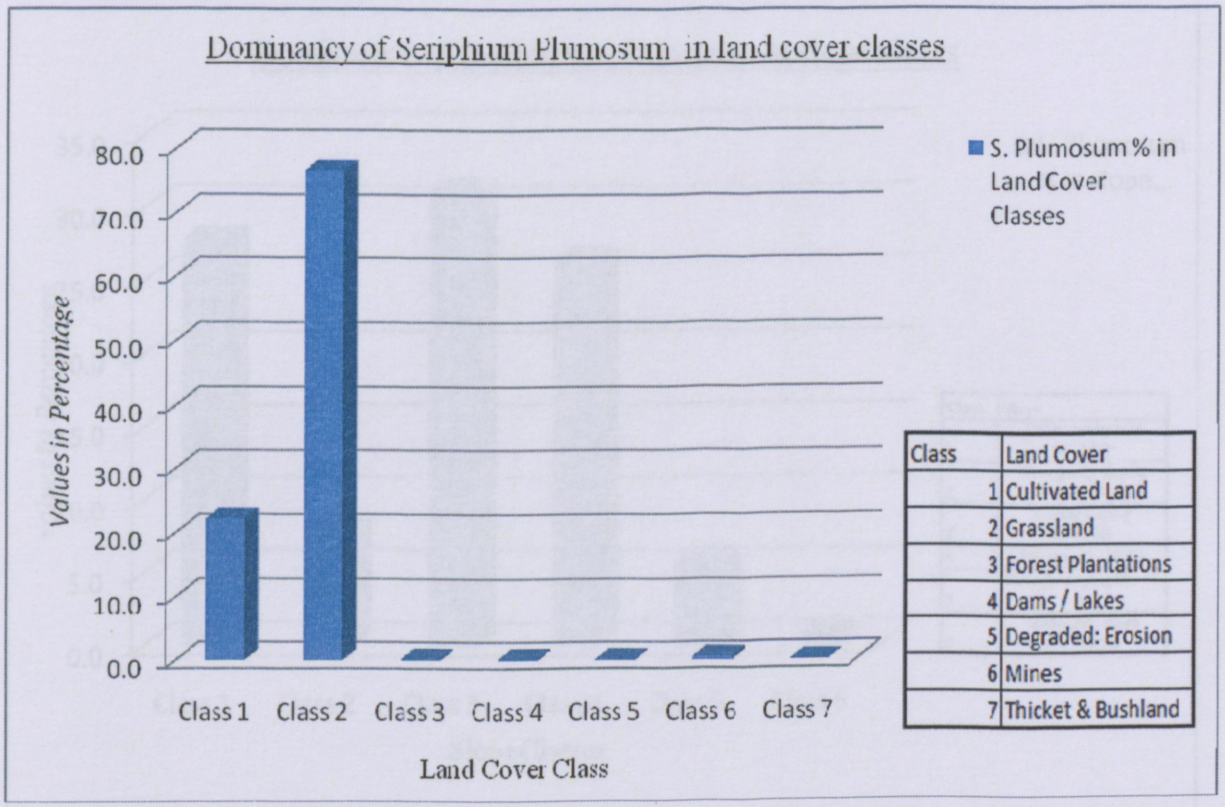


Figure 4.7: Land Cover results in relation to *Seriphium Plumosum* distribution

- *Slope*

A slope is the incline or gradient of a surface and is commonly expressed as a percent. Slope analysis reveals that 31.2% of *Seriphium Plumosum* is found in gently sloping land, 27% is found in flat to nearly level areas with a 0 to 1 % slope gradient (Figure 4.8). Patches of *Seriphium Plumosum* were recorded in very gently sloping and strongly sloping classes. The results also reveal that 0.6% of *Seriphium Plumosum* was found in steep slopes. These results correlate with the results found by Jordan (2009). He indicated that *Seriphium Plumosum* is a low fertility plant that prefers lighter soils and occurs mostly on foot slopes and mid slope terrains. Slope is known to reduce the infiltration efficiency of precipitation beause the steeper the slope, the greater the run-off. It modifies the intensity of isolation, temperature and moisture of the surface soil. A slope also affects erosion and depth of soil as the greater the slope, the greater the erosion. The depth of soil in the hills varies with the increase of the slope. Thus, a slope affects vegetation of the site through its effect on the run-off, insolation, temperature, moisture and depth of soil.

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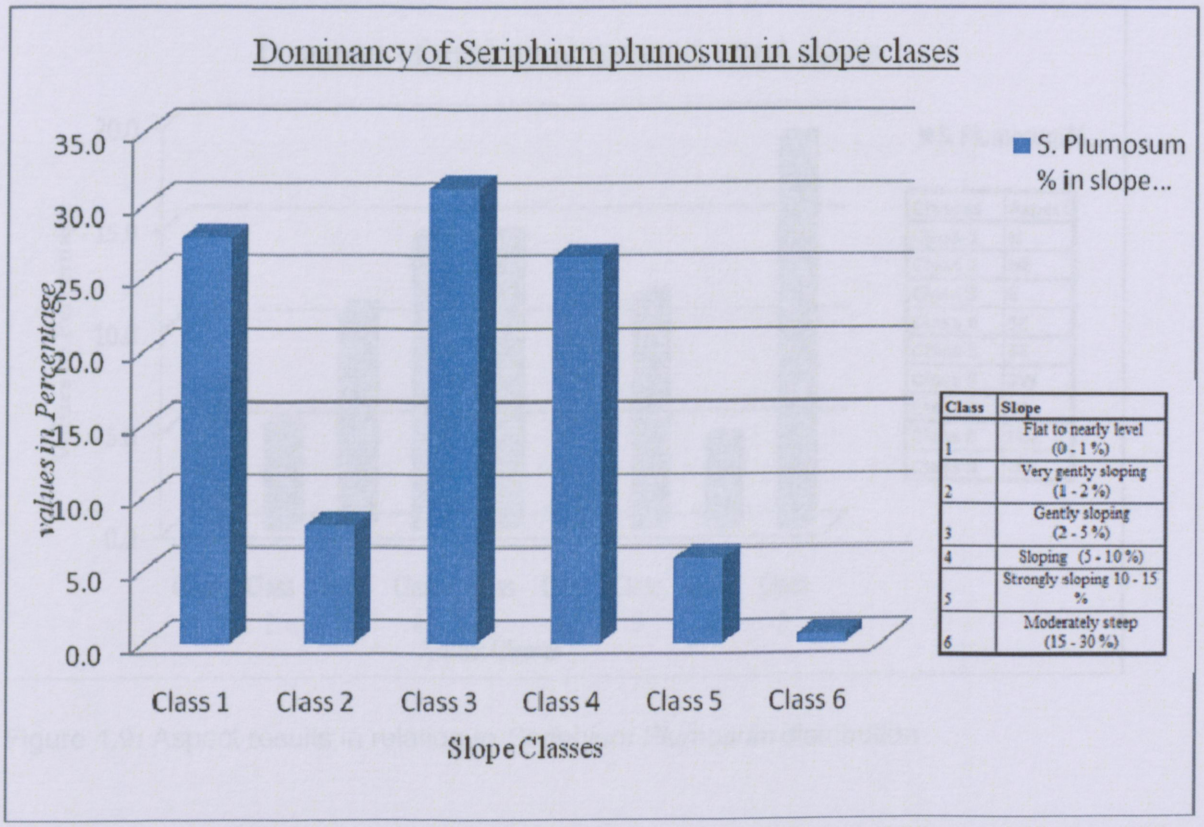


Figure 4.8: Slope results in relation to *Seriphium Plumosum* distribution

- *Aspect*

Aspect is the direction towards which a slope faces and it determines the amount of insolation received by a slope. It is known that southern slopes are warmer than northern slopes and, consequently, temperatures differ. Foremost, the results reveal that 19.2 % of the species found were unknown. The results also reveal that *Seriphium Plumosum* was abundant in all slope aspects (Figure 4.9). Aspect influences different species at different aspect of a slope or area. Similarly, different aspects receive insolation differently. The eastern slope is exposed to the sun in the earlier part of the day and so dew is seen. In the morning, soil moisture has not melted, resulting in seedlings being killed. However, the western aspect has a desiccating effect due to the noon day's sun. *Seriphium Plumosum* was dominant in all slope aspects.

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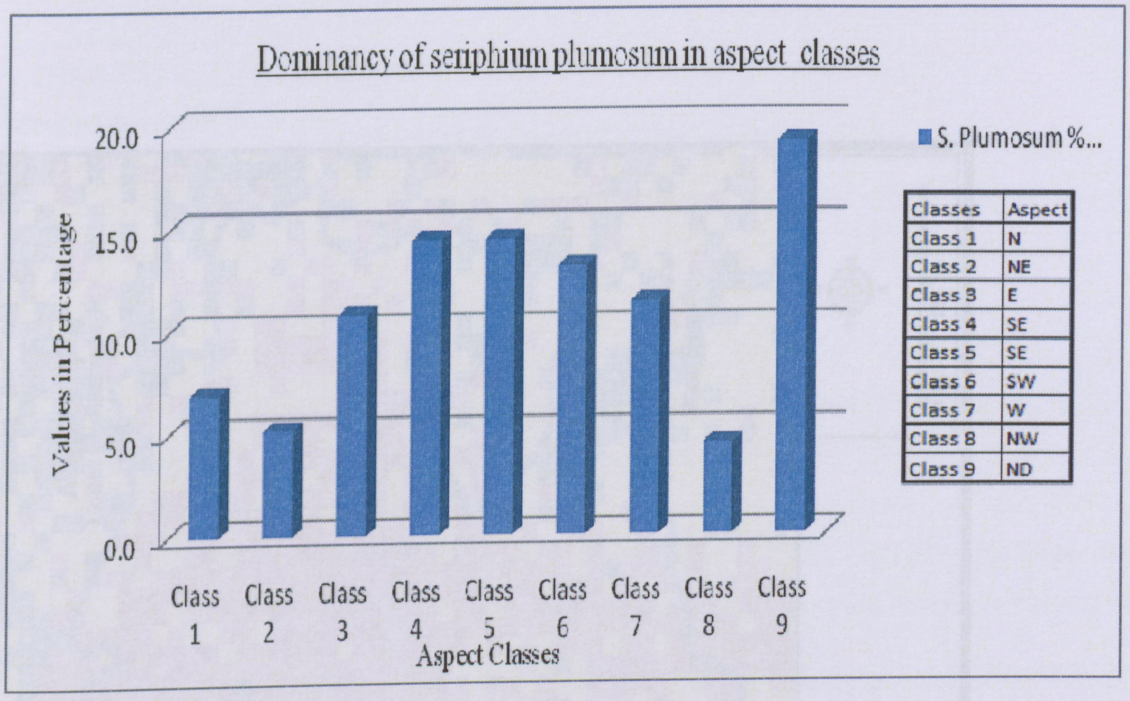


Figure 4.9: Aspect results in relation to *Seriphium Plumosum* distribution

4.5 Probable areas to be invaded by Seriphium *Plumosum*

The *Seriphium Plumosum* distribution probability map in Msukaligwa Local Municipality analyzed using the map algebra tool reveals that there are very few patches in the eastern part of the municipality (Figure 4.10). The very low number of patches is indicated in dark green. Few patches were found in the south west of the study area, however, *Seriphium Plumosum* was dominant in the eastern part of the area. Furthermore, there were some patches in the central part of the study area. A high to very high number of patches were more visible in the central and western parts of the study area. Using visual interpretation, it can be argued that *Seriphium Plumosum* distribution occurs in the entire municipality at different rates. The central and western part of the study area is prone to high distribution levels than the eastern part of the study area.

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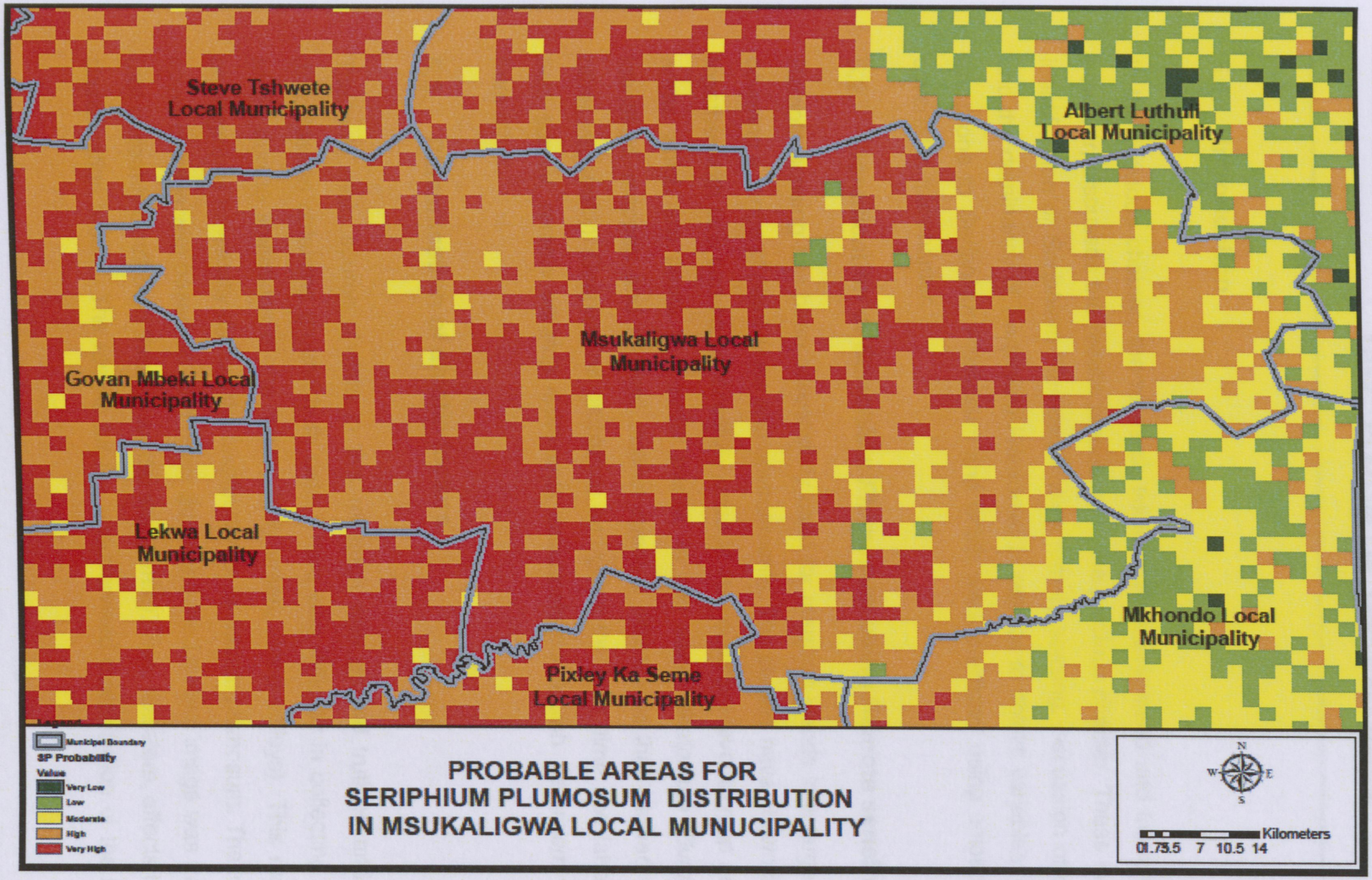


Figure 4.10: Probable areas for *Seriphium Plumosum* distribution

CHAPTER 5

DISCUSSION OF THE FINDINGS

5.1. Introduction

In the previous chapter, the research findings were presented and interpreted. This chapter, however, discusses the results presented in the previous chapter. These include the aspect of identification of *Seriphium Plumosum* using remote sensing, discussion of classification output and the dominancy of *Seriphium Plumosum* in relation to abiotic variables. Possible areas that are prone to *Seriphium Plumosum* and which were predicted using abiotic variables are also covered in this chapter.

5.2. Identification of *Seriphium Plumosum* using Remote sensing techniques

Remote sensing has been successfully used for mapping weeds in a large number of studies covering a range of plant types and environments. The studies have shown that remote sensing together with GIS can be successfully used at the municipal level to map and predict probable areas which are prone to invader plants. In this study, *Seriphium Plumosum* was visually identified, mapped and showed distinct spectral differences that allowed differentiation from other vegetation. Despite the problems, and given the cost, time and labour requirements of field survey, remote sensing represents accurately distinguish *Seriphium Plumosum* species from other.

5.3. Classification of abiotic factors

The only main source of data in this research was ground truthing and there were some difficulties in obtaining ground truth data. There was difficulty in collecting GPS data in other areas due to limitations of the terrain (hilly areas, steep valleys). This research used aerial photographs to visually digitize the distribution of seriphium plumosum. The identification of land cover classes was based on land cover 2000 and the Landsat image was from 2005 GPS data (not uniformly distributed throughout the study area). This, therefore, affects the validation of the classification results. The results for the unsupervised classification of the Landsat data were

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identified as they could be seen on SPOT images and aerial photographs. It was also possible to identify the classes using a land cover map and satellite images.

Supervised classification presents the results for the Maximum Likelihood Classifier (MLC). MLC using training sets from the same image provides an excellent method for mapping vegetation classes, once training sets have been selected and all possible sources of confusion included as training sets. The MLC is an algorithm that quantitatively classifies pixels by evaluating both the variance and covariance of the categorical spectral response pattern (Lillesand *et al.,* 2004). This is based on the assumption that similar features with a similar spectral signature have a normal distribution and that their statistical probability can be computed. It is a technique of supervised classification that the analyst defines training areas to train the algorithm, which then classify pixels based on their likelihood to belong to the defined class. Land cover classes were classified and identified. The supervised classification results, using MLC, showed masked areas classified as *Seriphium Plumosum.*

A combination of all Landsat bands was used to extract the spectral signature of *Seriphium Plumosum* and classify *Seriphium Plumosum*. Field verification data was used to assess the accuracy. *Seriphium Plumosum* was different from most other land covers, but in some areas, its reflectance was similar to that of many native pasture species. There was a difficulty in classifying the cultivated land, which are cultivated land which is planted and the one which is not planted.

MLC also classifies the disturbed areas (open ground patches in the grassland as *Seriphium Plumosum.*). Mines and urban areas sometimes had a similar reflectance. Field data were used to carry out a supervised classification of the imagery. In such a classification, the user locates known areas of various land cover types on the imagery, and uses these to 'train' the classifier to map the land cover on the rest of the imagery. *Seriphium Plumosum* from the supervised classification map was visually compared with the land cover 2000 map. It was also concluded that *Seriphium Plumosum* is more dominant in grassland and disturbed areas. Disturbances can be in the form of abandoned cultivated land, mines, degraded and bare rock.

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5.4. Abiotic Variables used to predict the Seriphium Plumosum Prone areas

- *Soil Depth*

Based on the results from this study, soil depth in the study area varies from deep, medium deep, very deep, shallow, very shallow, steep slope to areas close to water bodies. Results reveal that *Seriphium Plumosum* appears to be dominant in areas where soil depth ranges between deep to very deep. These findings are in agreement with a study conducted by Jordan (2007) who indicated that *Seriphium Plumosum* is a multi-stemmed woody shrub that grows to an average height of 60cm, a width of 60cm and is supported by its root system which may vary from 1m around the plant and 1.8m deep. Deep to very deep soil is an environment favoured by grasses, creeping species and shrubs. However, during the visual survey, *Seriphium Plumosum* was found to be more dominant than other species. *Seriphium Plumosum* outperforms other species encroaching the area. Seriphium plumosum decreased in steep slopes as only a few patches of *Seriphium Plumosum* were identified.

In terms of growth, the percent cover of *Seriphium Plumosum* increased as depth increased and decreased as depth increased. Deep soils support the development of *Seriphium Plumosum*. A study by Schenk and Jackson (2002) which focused on rooting depth clearly showed that woody plants are, on average, more deeply rooted than herbaceous ones. Deep soils have the ability to facilitate downward water infiltration and to retain little moisture near the soil surface; this benefits shrub species having extensive, coarse root systems (Holechek *et al.,* 2001). Deeper soil favours the root penetration of plants and shallow soil limits the amount of water and nutrients supplied to plants. However, this can be the reason why *Seriphium Plumosum* prefers deep to very deep soils. Soil depth data were extracted from Mpumalanga soil depth data and the class distribution was based on 3675 sampling site. The steep and very steep slopes were not adequately sampled by the soil sample database. It should, therefore, be borne in mind that data are skewed and biased towards the less steep areas.

- *Soil texture*

Soil texture refers to the degree of fineness or coarseness created by the close packing of variously sized particles together in a soil (Osman, 2013). Soil texture depends on the relative amount of sand, silt, and clay. According to Ramade (1981), soil texture governs most of the properties of the soil, its permeability, its capacity to retain water, its degree of aeration, and its ability to support a permanent plant cover. In each texture class, there is a specific amount of sand, silt, and clay that each class contains. Soil texture is one of the vital factors of soil that

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affects its fertility and productivity. Soil texture has the ability to make the nutrients stored in the clay–humus complex available to plants, its ability to withstand mechanical working of the top soil, and, finally, its ability to support a permanent plant cover

A tree species may occur on a variety of soil textures in their natural habitat, but their best growth occurs in the most suitable sites. This study reveals that *Seriphium Plumosum* prefers soil sandy loam soil and loam soils, but it can also be found in clay soils but at a lesser extent compared to sandy loam soil. Although *Seriphium Plumosum* was found to grow on a wide variety of soils throughout its range in Msukwaligwa Local Municipality, various studies found that it prefers sandy soil. These results are similar to those of Krupko and Davison (1961), Roberts (1966), Smit (1955), Snyman and Le Roux (2009); Walker and Noy-Meir (1982) who reveal that *Seriphium Plumosum* prefers sandy soil.

The Floristic Baseline Survey that was conducted in Tweefontein farm, Ogies in Mpumalanga, reveals that *Seriphium Plumosum* was the most common species that covers farm and sand soil found to occupy the majority of Tweefontein (De Castro, 2010). The results from this study also correspond with the plant ecological study conducted in Rietvallei nature reserve in Gauteng Province in 2004. It can be concluded that *Seriphium Plumosum* prefers sandy soil because it is loose and friable; It absorbs water rapidly and drains quickly. Sandy soil is usually poor in fertility and suffers from water scarcity. Loam soils are medium textured soils having generally more nutrients and humus than sandy soils, and they have better infiltration and drainage than clay soils. Loams are desirably porous and retain sufficient water, nutrients and air. *Seriphium Plumosum* species do well in sandy loam to loam soils because of adequate water, air, and nutrients. Clay soils have the ability to retain large amounts of water but drain very slowly. They are often waterlogged. They are fertile but plants usually suffer from oxygen stress in clay soils. This is the reason why *Seriphium Plumosum* does not prefer clay soil.

- *Rainfall*

Rainfall is the primary source of water for both plants and animals. Three main characteristics of rainfall are its amount, frequency and intensity, and these vary from place to place, day to day, month to month and also year to year. Information of the amount, intensity and distribution of monthly or annual rainfall is useful for species distribution. The availability of water in the soil affects plant growth, especially the capability to absorb nutrients needed for plant growth and development. Rainfall can regulate plant competition through water availability and nutrients. It can also influence the distribution of plant species.

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Rainfall is among the most important drivers of the spatial distribution of flora. Spatial distribution of plants is often limited due to variation in rainfall. Rainfall is the key factor influencing the structure and function of the semi-arid ecosystem (Knapp & smith, 2001; Austin *et al.,* 2004). Mean annual rainfall for Msukwaligwa Local Municipality ranges from 542 to 995 mm, increasing from west to east. This study reveals that *Seriphium Plumosum* was abundant in areas where rainfall ranged from 651 to 750 mm. These results are similar to those of a study conducted for conservation value of the Egoli granite grassland and the endemic grassland in South Africa (Bredenkamp et al., 2006). It was found that *Seriphium Plumosum* was dominant in the degraded grassland conditions where mean annual rainfall was 670 mm. Bredenkamp *et al., (*2006) also indicated that *Seriphium Plumosum* is also found in typically overgrazed and disturbed grassland with other grasses such as Eragrostis Curvula and Aristida species).

- *Land Cover*

Land cover results reveal that *Seriphium Plumosum* was dominant in grassland and cultivated areas. It was found that *Seriphium Plumosum* was dominant in grassland areas by 75%. Grasslands are natural ecological communities dominated by grasses with less than 10% natural tree or shrub cover. They contain many grass species and an even greater diversity of other herbs. Grasslands are among the most rich plant species communities. Twenty percent of *Seriphium Plumosum* was found in areas used for cultivation. It was also found that *Seriphium Plumosum* does not prefer forest plantations, water bodies and other classes. The encroachment of *Seriphium Plumosum* in grassland modifies the composition, spatial distribution, and productivity of grassland.

Replacement of short-rooted grasslands or crops, which tend to use water seasonally, or with deeper rooted forests that tend to use water all year, has dramatic impacts on catchment water yield (the amount of water lost from a catchment as groundwater recharge and lateral flow to rivers). Generally, woody thickening leads to deeper rooting depth and larger root biomass, allowing plants to access a larger volume of soil water for longer periods. Woody vegetation often uses deep soil water whereas grasses have much shallower roots and are more reliant on rainwater inputs to the upper soil. Use of deep soil water has been shown to increase with the amount of woody plant cover and the proportional use of deep water stores increases during dry periods when rainwater input is minimal. Access to larger water stores may allow increased canopy conductance (the ease with which water can move out of the canopy into the atmosphere) in woody vegetation, particularly when combined with larger leaf areas. These results in elevated transpiration compared to that of grasslands.

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- *Slope and aspect*

Slope analysis results reveal that *Seriphium Plumosum* were dominated in gentle slopes, flat to nearly level, and sloping which is gently sloping . The results also reveal that very gentle slopes, strongly sloping and moderate slopes less are domiant. A gently sloping which is 2- 5 % was highly preferred by *Seriphium Plumosum* and class 6; the moderate steep was the least preferred. The minority of *Seriphium Plumosum* was recorded on very gentle slopes at 7 % at the slope range. A slope is one of the most important factors of universal soil loss such as slope angle, length and curvature influence runoff, drainage, and soil erosion (Aandahl, 1948). It causes a significant difference in soil physico-chemical properties (Brubaker *et al.*, 1993). Erosion increase is associated with increase in slope length and slope steepness. Slopes influence the soil plant productivity and distribution, for example, soil clay content differs with slope positions. The maximum soil clay content is normally found in bottom slopes rather than higher and medium slopes. In the latter, plants which do not prefer steep slopes will not produce well.

5.5. Areas prone to *Seriphium Plumosum* distribution

Based on the modelling results, the output of the model clearly elaborates that there is high probability of *Seriphium Plumosum* distribution in Msukwaligwa Local Municipality. This means that abiotic factors in the study area can favour the distribution of *Seriphium Plumosum*. During the field survey, *Seriphium Plumosum* was found to encroach the central part of the municipality more (this is the area where many coordinates were collected). The encroachment was also seen during the visual digitizing. Most of the predicted areas in the study area are already encroached by *Seriphium Plumosum* and the chances of it spreading are high.

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CHAPTER 6

CONCLUSION

6.1. Introduction

In the previous chapter, the research findings were discussed. The primary focus of this chapter is to relate these findings with the objectives of the study. The conclusion and recommendations are made based on the results. The first section presents the conclusion of the research while the second section presents the research limitations and suggests areas for further research study.

6.2. Conclusion

The main objective of this section is to draw conclusions based on the research findings. The main aim of this study was to use GIS and remote sensing to map, examine, and predict the spatial distribution of *Seriphium Plumosum* using some of the abiotic factors. Remote sensing has been successfully used to distinguish *Seriphium Plumosum* from other features using visual interpretation, colour and association. The species appear dark brown and taller compared to other native species. GPS coordinates which were collected successfully worked as the georeference of areas affected by *Seriphium Plumosum.* The collected GPS was also useful during the process of manual digitizing which led to the development of *Seriphium Plumosum* shapefiles. The created shapefiles were used to create the spectral signature.

Examining some of the abiotic factors associated with the distribution of *Seriphuim Plumosum* was useful to enable one to understand the habitat preference of *Seriphium Plumosum.* This study revealed that *Seriphium Plumosum* prefers deep to very deep soils with Loam clay texture, loams and sandy loams. The slope should range between flat to sloping area which is 5 to 10%, Rainfall ranging 651 to 750. However, although *Seriphium Plumosum* prefers these conditions, it does not mean that it cannot be distributed to the other habitats because it was also found in other habitats at a lower rate.

The study also indicates that *Seriphium Plumosum* prefers cultivated land. The visual interpretation in the field showed that there was no visible *Seriphium Plumosum* in the cultivated land. It can, however, be assumed that this is the land that was previously cultivated or it is already classified as cultivated land. It is documented that *Seriphium Plumosum* prefers

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disturbed areas or abundant land. Therefore, it can be concluded that the area was cultivated when the land use cover image taken and is abandoned during the study. All the variables were combined and used to predict the locality of *Seriphium Plumosum*. The results were classified into four categories. Very high probability areas- these are areas which are highly likely to be invaded by seriphium plumosum. This category is more dominant in the central part of the municipality. It can also be assumed that it is because of the abundance of land, and the large stretches of land used for grazing. Very high Probability areas are also due to deep soils in the area. Verification was conducted to check if the species is located in areas that are likely to be encroached.

6.3. Research Limitations

This was an experimental project from which many lessons were learnt. The ability to obtain ground truth data was the largest limiting factor in this research. Since obtaining ground truth data was not possible for this research, using higher resolution imagery was the best alternative method. Unfortunately, the amount of no-cost and/or low-cost high resolution imagery was limited, and this resulted in dissertation using the Landsat ETM+ image acquired in 2005.

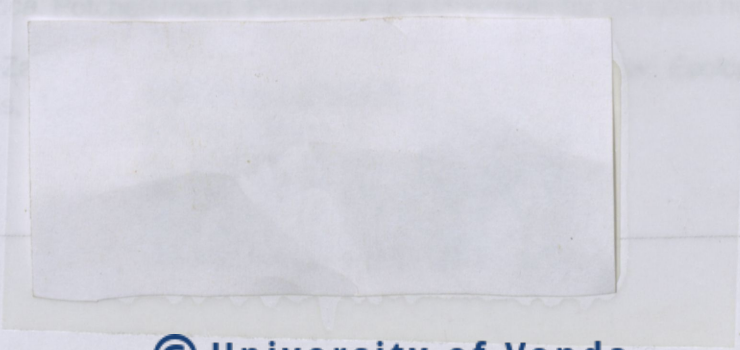
Another limitation in this research was the researcher's inexperience in conducting real-world land cover classification and deriving ground truth from remotely sensed imagery. If individuals with greater remote sensing experience and proficiency were to conduct similar studies, they would most likely achieve more accurate results in a shorter period of time. These limitations, however, did not have any significant impact the researcher achieving the objectives of this research.

6.4. Suggested areas for further research study

There are many possible areas for further research based on the findings and results of this study. One possible avenue of expanding on this research would be to use a larger number of study areas with a wider variety of biotic and abiotic factors. In addition to image classification methods and the classification scheme, ground truth data is another avenue for future research. This study used ETM+ imagery with acquisition in 2005. Using a wider variety of imagery with a closer date of acquisition could possibly lead to a more objective evaluation of the classification accuracy. Acquiring more recent imagery for analysis could also result in a more accurate prediction of species distribution. The future of high accuracy seriphium plumosum mapping relies on the use of hyperspectral imagery. Hyperspectral sensors capture data over a very

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large number of extremely narrow spectral bands. These sensors have limited availability at present, but offer the best potential for mapping weeds, and distinguishing those with subtle reflectance differences from other vegetation.



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Appendices

1. APPENDIX 1

APPENDIX A: Field Data collection Form

Range	Texture	Cover Type	Extent
1	Sandy	Pre-dominant	<10%
2	Loam	Dominant	10 - 50%
3	Clay	Co-dominant	50 - 90 %
4		Suppressed	>90 %

NO	Latitude	Longitude	Height	SP Coverage	Sp extent in Percentage	Texture by Feel method
1	-26.5235	29.97537	1716 m	2	2	1
2	-26.5235	29.97538	1717 m	2	2	1
3	-26.5235	29.97538	1720 m	2	2	1
4	-26.5235	29.97538	1720 m	2	2	1
5	-26.514	30.05574	1762 m	1	1	1
6	-26.5155	30.05789	1753 m	1	1	1
7	-26.5331	30.08729	1742 m	1	1	2
8	-26.5332	30.08729	1739 m	1	1	2
9	-26.5387	30.09515	1743 m	2	2	2
10	-26.7311	30.26511	1465 m	1	1	1
11	-26.7097	30.29406	1447 m	3	3	1
12	-26.7097	30.29407	1450 m	3	3	1
13	-26.7112	30.3014	1440 m	1	2	1
14	-26.7112	30.3014	1440 m	1	1	1
15	-26.6688	30.323	1525 m	1	1	1
16	-26.6509	30.33726	1543 m	1	1	1
17	-26.6509	30.33731	1541 m	1	2	1
18	-26.6444	30.3557	1519 m	3	3	1
19	-26.638	30.36087	1506 m	3	3	1
20	-26.6368	30.36203	1500 m	3	3	1
21	-26.6186	30.37994	1494 m	4	4	2
22	-26.6086	30.38136	1486 m	3	3	1
23	-26.5727	30.3975	1565 m	1	1	1
24	-26.5749	30.41616	1544 m	2	2	3
25	-26.5058	30.55494	1556 m	1	1	3
26	-26.4779	30.52145	1603 m	1	1	1
27	-26.4217	30.3154	1700 m	4	4	1
28	-26.4251	30.31101	1709 m	3	4	1
29	-26.44	30.24317	1708 m	3	3	1

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30	-26.439	30.21501	1702 m	3	3	1
31	-26.439	30.19351	1653 m	3	3	1
32	-26.4466	30.15834	1736 m	2	2	1
33	-26.4519	30.13313	1683 m	2	2	1
34	-26.4521	30.1325	1691 m	1	1	1
35	-26.4545	30.12141	1725 m	3	3	1
36	-26.5122	29.95304	1745 m	1	4	2
37	-26.5122	29.95304	1745 m	1	4	2
38	-26.5122	29.95304	1746 m	1	4	2
39	-26.5122	29.95304	1746 m	1	4	2
40	-26.5122	29.95304	1746 m	1	1	2
41	-26.4869	29.85418	1679 m	3	3	3
42	-26.4792	29.83703	1668 m	3	3	3
43	-26.4792	29.83704	1662 m	3	3	1
44	-26.3006	29.60935	1676 m	1	1	2
45	-26.2947	29.61033	1679 m	1	3	2
46	-26.2828	29.67039	1687 m	3	2	2
47	-26.3793	29.86686	1762 m	3	3	2
48	-26.3858	29.8503	1731 m	1	1	1
49	-26.3886	29.84284	1720 m	4	2	1
50	-26.3948	29.8354	1697 m	3	2	1
51	-26.4168	29.85892	1769 m	2	1	1
52	-26.4312	29.88668	1726 m	4	4	1
53	-26.558	29.985639	1752 m	1	1	2
54	-26.5203	29.968021	1754 m	2	1	1
55	-26.539	29.965537	1754 m	4	4	1
56	-26.5728	29.979367	1754 m	1	1	1
57	-26.5824	29.977234	1754 m	1	1	3
58	-26.5923	29.969763	1755 m	1	1	3
59	-26.6358	29.975834	1756 m	1	1	3
60	-26.5732	30.064612	1756 m	1	1	2
61	-26.5664	30.054014	1757 m	1	1	1
62	-26.4291	30.05493	1757 m	2	2	1
63	-26.4112	30.060641	1758 m	1	1	1
64	-26.3935	30.070437	1758 m	3	1	1
65	-26.3607	30.064651	1759 m	4	1	0
66	-26.3357	30.043195	1759 m	1	1	1
67	-26.3291	30.037718	1759 m	2	2	1
68	-26.3157	30.030969	1759 m	2	2	1
69	-26.3088	30.018195	1759 m	2	2	1
70	-26.3024	29.998782	1759 m	2	2	2
71	-26.3052	29.959133	1761 m	4	4	3

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72	-26.2922	29.935364	1761 m	3	3	3
73	-26.2867	29.929851	1762 m	3	3	1
74	-26.2573	29.881223	1763 m	3	3	1
75	-26.3506	29.87685	1763 m	4	4	3
76	-26.3834	29.906561	1764 m	3	2	2
77	-26.3929	29.914789	1766 m	4	4	2
78	-26.4082	29.927939	1766 m	4	4	2
79	-26.4487	29.949242	1766 m	4	4	2
80	-26.5471	29.9507	1767 m	3	2	2
81	-26.5167	29.9154	1767 m	3	3	3
82	-26.5024	29.8907	1769 m	3	3	2
83	-26.4377	29.9354	1769 m	4	4	1
84	-26.4367	29.925	1770 m	4	4	1
85	-26.4339	29.9126	1770 m	3	4	3
86	-26.432	29.8793	1770 m	4	4	3
87	-26.4262	29.8698	1770 m	4	4	2
88	-26.4053	29.9231	1770 m	4	4	1
89	-26.3615	29.8821	1770 m	4	4	1
90	-26.3511	29.8793	1770 m	4	3	3
91	-26.3631	29.7913	1771 m	3	3	1
92	-26.3244	29.9754	1771 m	4	4	1
93	-26.313	29.9963	1771 m	4	4	1
94	-26.2721	30.1248	1771 m	3	3	1
95	-26.3866	30.1279	1771 m	3	3	1
96	-26.4014	30.1503	1771 m	2	1	1
97	-26.4095	30.165	1772 m	3	2	1
98	-26.4209	30.175	1772 m	2	3	1
99	-26.3086	30.1717	1772 m	3	3	1
100	-26.3153	30.1584	1773 m	2	2	1

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GERT SIBANDE DISTRICT OFFICE

Litiko Letekulima, kutfutfukiswa Kwetindzawo Tasemakhaya Netekuphatfwa Kwemhlaba | *Departement van Landbou, Landelike Ontwikkeling en Grondadministrasie* | *umNyango wezokulima nokuTjala, zokuThuthukiswa kweeNdawo zemaKhaya nokuPhathwa koMhlaba*

Enquiry : F.A Koegelenberg
Tel : 0178115811

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

The purpose of this letter is to inform you that I give Ms H.B Mutswari permission to conduct the research titled **Modelling the distribution of *Seriphium Plumosum* in Msukaligwa Local Municipality, Mpumalanga province**. This also serves as assurance that the department complies with requirements of the Promotion of Access to Information Act ("PAIA"), No 2 of 2000 which gives effect to the constitutional right of access to any information held by the State and any information that is held by another person and that is required for the exercise or protection of any rights. And bearing in mind the Protection of Personal Information Act, No 4 of 2013 that promotes the protection of personal information by public and private bodies.

Her research will require her conduct field works in the farms and collect spatial data in the field, source data from various institutions. We believe that this type of work has direct benefit to all local community. To this end, it will be highly appreciated if you could give her the necessary authorization to conduct her research. Thank you in advance for your cooperation

Yours Sincerely

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Mr. F.A Koegelenberg

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