Optimising vegetation assessments to facilitate wildlife management

by

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Declaration

I, Michael William Zingel declare that the thesis, which I hereby submit for the degree Magister Scientiae (Wildlife Management) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature: ____________________

Date: _11 September 2015____

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SUMMARY

Vegetation assessment is a requirement for the identification and understanding of components of complex ecosystems that characterise wildlife areas. It is important that assessment methods are reliable yet practical for use in wildlife management.

There are many assessment methods in use. This study sets out to compare two methods that fulfil these requirements and to examine synergy to optimise assessment.

The study area is Evelyn Game Ranch situated on the farms Kranenberg 162 MS and Evelyn 159 MS in the Messina magisterial district, Limpopo province, South Africa. It covers 1 293 ha. The owner of Evelyn Game Ranch suggests that overgrazing by livestock in years gone by caused degradation of the veld. The intention is to remedy degradation of the different vegetation communities that comprise the veld.

Difficulty exists in delineating the different vegetation communities into manageable entities and relating those with shared floristic attributes to one another. The aim of this study is to show that a map derived from digital Google Earth imagery and classification described by PHYTOSET procedures is less complicated, more objective and less time consuming to develop than the widely used method of physiognomic mapping and vegetation analysis using Braun-Blanquet procedures.

Both approaches yielded outcomes usable for modelling for ranch management. However neither was sufficiently superior to allow disregard for the other. I suggest that synergy of the two approaches is a solution, with complementary elements of each applied to a project.

Better options are likely to emerge and may develop in a way that would obviate the need for synergies and would suffice on their own. Two methods are suggested. As is the case with PHYTOSET procedures, iterative data and objective classifications characterise these approaches.

ACKNOWLEDGEMENTS

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

In South Africa the area devoted to wildlife ranching and private wildlife reserves has grown significantly since 1990 to 20.5 million ha in 2006 (National Agricultural Marketing Council NAMC 2006). There are many reasons for the growth of this land use. An expectation is created among owners and managers of wildlife savanna areas that land degradation associated with previous kinds of land use would disappear and that wildlife land use would be self-sustaining (NAMC 2006). This generally has proved to be a misconception, as savanna does not necessarily revert to its original state after a damaging factor has been removed (Van Rooyen 2002).

Land degradation and consequent low returns on land under wildlife continue. Popularly held views on solutions to the problem often detract from holism to commitment to rehabilitation of degraded land and do not offer a sustainable alternative to unsustainable land use in the past (NAMA 2006).

One widely applied approach is to reduce numbers of ungulates to relieve pressure on vegetation; but to increase the market value of the wildlife component to compensate for this deficit in potential revenue (Fourie 2011). Reducing common species or genotypes and particularly replacing them with higher value wildlife is a popular way of achieving this objective (Kriek 2011).

Savanna vegetation within the confines of fenced units is less well understood than fauna and with regard to the latter most knowledge relates to large mammals (Mc Naughton & Georgiadis 1986). Therefore, management systems need to have a means of defining vegetation at any particular time and rating the effect of management decisions on the vegetation by means that are within the ken of management. However, it must be recognised that the nature of vegetation is merely diagnostic of the condition of an environmental entity of far greater complexity (Westfall 1992).

Degradation of natural vegetation in the north of the Limpopo province is evident (Aliber, Maluleke, Manenzhe, Paradza & Cousins 2013). Neighbouring farms often show clear differences that may be attributed to differences in management strategy and the impact of livestock or game over time. Evelyn Game Ranch is in this area. It was a cattle ranch and was converted to wildlife in 1989. The owner is disturbed by the lack of recovery from the effect of overstocking with cattle in the past. His situation is typical of that of many wildlife ranchers in the area.

The need to use and consume natural resources sustainably is widely appreciated. However, this is often not being put into practice due to lack of understanding of the relevant technology and aversion to the cost of the means of implementation of management systems and their monitoring. There appears to be a need for a rapid, low cost means of vegetation assessment of species abundance and cover per plant community; delineation of such community boundaries and knowledge of their size. Following on from that is the need for a means to monitor the effect of management applied to an area, with due consideration of the land use option applied.

The study suggests a simple and cost effective method of vegetation mapping supported by floristic data. Geographical information system (GIS) data have been used for generating environmental metadata subject to botanical decision support systems (Orland, Budthimedhee & Uusitalo 2001) and subject to a code of ethical conduct (Wayne 2005). The question is whether a Google Earth image supported by floristic data can be used as one such tool to meet these needs. In addition it is suggested that the maps and floristic data be used to facilitate adaptive resource management.

The mapping method and complementary floristic data assessment technique are compared with a widely applied method of physiognomic-physiographic stratification of the study area using Braun-Blanquet procedures. Stratification of a study area with the aid of any clear aerial image is done in order to select suitable vegetation sampling sites. In this study stereo photographs were used. Braun-Blanquet procedures were followed to classify the vegetation into a hierarchical system in which associations between species are identified to suggest communities and subcommunities.

BECVOL surveys although not part of the Braun-Blanquet classification procedures provide more pertinent information on the different communities that are identified with Braun-Blanquet despite the fact that they were devised to be specifically relevant to wildlife ranching (Smit 1996).

The motivation for this study was to produce an affordable and easily accessible base on which rigorous adaptive resource management (White 2001) can be practiced in the study area, and which may also be applied more widely.

Adaptive resource management depends on the use of models such as the substitution tables in Van Rooyen (2002), relating carrying capacity and accessible browse to species of ungulates and numbers thereof. However, the data fed into models has to be scientifically reliable. The study addresses this need regarding plant communities on a wildlife enterprise.

Wildlife management requires more than knowledge of the biological dimensions of the resource being managed. White (2001) illustrates recognition of the reality that the human dimension is a vital aspect by reference to the critical differences that exist between wildlife departments and biology departments at universities. The requirements for wide adoption of a base for rigorous wildlife management are that it be cost effective (White 2001) and easily understood by management.

1.2 STATEMENT OF THE PROBLEM

Difficulty exists in delineating the different vegetation communities into manageable entities and relating those with shared floristic attributes to one another.

1.3 AIM

The aim is to show that a map with spatial features derived from digital Google Earth imagery and descriptive elements derived from vegetation classification described by PHYTOSET procedures is less complicated, more objective and less time consuming to develop than a physiognomic map derived from stereo-photography and supported by vegetation analysis using Braun-Blanquet procedures as currently used.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

It is essential that the potential and limitations of a wildlife area be understood. Also reliable yet practical data needs to be collected and delimitation be done to facilitate management. Wildlife management depends on mapping of the delimitation (Bothma 2002). Therefore floristic assessment and mapping of a wildlife area must be done before extensive developments are undertaken. Floristic assessment in itself is important for identification and interpretation of complex ecosystems in wildlife areas. Assessment of vegetation's potential for provision of food and cover is the basis for making informed decisions on conservation and wildlife management. Analysis of field data assists in the identification of sensitive areas, highlights biodiversity issues and provides framework for understanding ecosystems (Chytry, Schaminée & Schwabe 2011).

It is advantageous to assess the vegetation thoroughly to support initial mapping decisions that are made in anticipation of their indicating plant communities. Management of each plant community individually may be impractical, as they may be in small units and widely distributed (Visser 2005). However regularly recurring occurances of groups and associations may be mapped as mosaics (Braun-Blanquet 1932).

The Braun-Blanquet or Zürich-Montpellier approach is widely used for floristic assessment (Bothma, van Rooyen & van Rooyen 2004). One of the main benefits of this approach is that the vegetation across the globe has been and currently still is, surveyed and classified, using this fairly uniform protocol (Chytry et al. 2011). The first phase is termed analytical, the analysis of the sample sites and the second phase is termed synthetic, arising from comparison of the analyses of the sample sites. In the synthetic phase the ties by which species are bound are revealed. These bonds describe certain communities (Braun-Blanquet 1932). In conjunction with stereo aerial photography physiographic-physiognomic maps can be constructed. The approach is used as the basis for phytosociological mapping. The construction of such a phytosociological map is demonstrated in the study.

Stereo aerial photographs were traditionally used as basis for physiographic-physiognomic vegetation mapping from which potential sample sites for floristic data may be selected (Bothma et al. 2004). The method provides a three-dimensional representation of surface features, that facilitates mapping. Problems encountered with this method include radial distortions, altitude-related scale differences, and often inconvenient scales, which hinder precise vegetation mapping (Malan & Westfall 1987). Excessive detail present in aerial photographs can be confusing and time consuming to the novice in stratification procedures.

The study also investigates alternative vegetation stratification, included in the PHYTOSET procedures (Westfall 2008) using maps derived from satellite imagery, to overcome these problems. The PHYOSET procedures include an independent programmatic floristic classification and calculation of correspondence of the communities with maps derived from satellite imagery. In addition to showing correspondence, the data collected provide a qualitative and quantitative description to the stratified mapped units, which in turn could be used to justify management decisions (Orland et al. 2001).

2.2 VEGETATION PHYTOSOCIOLOGICAL ANALYSIS USING BRAUN-BLANQUET PROCEDURES

2.2.1 Analytical phase

In the analytical phase factors that influence plants are recorded at each site. Precision in observation of habitat in the analytical phase is reflected in the subsequent synthetic phase when there is clarity of ecological characterisation of such sites demonstrated by associations of species derived from analysis of cover-abundance data (Werger 1974).

2.2.2 Environmental parameters

Abiotic environmental parameters, such as altitude, aspect, slope, geology, land type, soil depth, soil colour, soil texture, and surface rock cover should also be recorded at the sampling site. Biotic environmental factors such as presence of trampling, fire or bush encroachment should also be noted as they may assist in explaining differences between field data findings and consequent classification output.

Abiotic environmental parameters

Altitude, rock cover (percentage), erosion, soil depth and soil texture could contribute to explanation of synthetic characteristics of plant communities as grouped from analysis of species related data. Observations of these features are therefore valuable. Wherever there are drainage peculiarities at a site they are to be recorded. Indicator grass species are to be expected in poorly drained soils (Scott 1955).

The nature of the topography at each site gives rise to external forces that influence plant communities as distinct from the influence of interspecific competition. Such forces can have a profound effect. Their influence is seen in repeated responses of plants, giving rise to both mosaics and distinct belts of vegetation type (Braun-Blanquet 1932, Visser 1995). Therefore, relating sites to the catena is helpful in understanding the repetition of topographical influence (Scholes 2005 pers. com.)[1] Furthermore, plant communities exhibit differing responses to exposure to solar radiation and moisture conditions that depend on slope and aspect (Braun-Blanquet 1932, Barbour, Burk & Pitts 1980). Soil moisture is influenced by slope as it affects run-off and retention at various points down a slope and exposure to solar radiation (Braun- Blanquet 1932, Barbour et al. 1980).

Soil colour usually varies with water content and is thus an indicator of subsurface drainage (Soil Classification group 1991). This in turn will influence the presence of plant species.

Biotic environmental parameters

Trampling has both positive and negative aspects on veld quality (Tainton 1981, Dugmore 2010). In the context of this study the intention was to record trampling conditions that would likely have negative effects. Overgrazing in arid areas is a contributor to desertification (Braun-Blanquet 1932, Esler, Milton & Dean 2006). Indications of overgrazing would be pointers to understanding differences between sites.

Post fire environments favour plants with high light and high nutrient requirements (Bond 1996). Tillering of perennial grasses benefits from the exposure to light after burning (Tainton 1981). The response of trees and shrubs to fire varies considerably and is reflected in the density of individuals, and the cover that they contribute (Jordaan 1999). Signs of recent fire are therefore relevant to site recordings.

Both bush encroachment and the density of woody plants affect the composition of the veld in savanna vegetation, though number of plants per ha has a greater impact than canopy spread cover (Peel 1989). Hence the need to observe these features at each site.

2.2.3 Synthetic phase

Determination of the synthetic characteristics of plant communities is an essential principle of Braun-Blanquet plant sociology (Braun-Blanquet 1932). Field data has to be processed so that it will be compatible with spreadsheet programs while retaining descriptive and location records of each sample site or relevé.

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[1] SCHOLES, M. 2005. Personal communication. School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Private Bag X3, Wits, 2050, Johannesburg, South Africa

TURBOVEG is a data base management system that can process vegetation data to produce a matrix with species values in rows and relives in columns and is referred to as a raw table. The TURBOVEG package has been extended to a version for all Microsoft® Windows® platforms (Hennekens & Schaminée 2001) to the benefit of a wide range of potential users of the technology.

MEGATAB version 4 is a spreadsheet program to handle vegetation tables prepared by TURBOVEG. A TWINSPAN program is built into MEGATAB by means of which the relevés are dichotomously classified relative to cover-abundance values of the species in each. This is the vital first step in arranging species and relevés to identify plant communities.

The approach is prejudiced by field data collection that is not fully iterative (van der Maarel 2007; Tichý, Chytrý. Hájek, Talbot & Botta-Dukát 2010). Hierarchical approaches have been improved by using iterative field data (Chytrý et al. 2011).

Manual rearrangement of species is generally needed after TWINSPAN clusters have been produced to identify diagnostic, constant and dominant species. Fidelity measures should be calculated to determine the fidelity of each species to a plant community (Chytrý et al. 2011).

Plant community data are complex and ecologists often use ordination techniques to represent samples (relevés) and species as faithfully as possible in a low-dimensional space. Furthermore, ordination facilitates representation of important and interpretable gradients and avoids the interpretation of noise (Podani 2001).

Relevés differ from each other with regard to the species present and the abundance of those species. A degree of similarity/dissimilarity can therefore be calculated between all relevés. The purpose of the ordination is to find what groupings of relevés there are and how these groupings correspond with groupings in the final phytosociological table. The analysis sequencing and grouping may also support findings other than floristic observations that have ecological relevance recorded in field data.

Classified data as produced by means of MEGATAB may be exported with relevé identification. In the export process it is possible to modify the cover-abundance values to derivatives that may be more useful in further processing and to add information (Van Der Maarel 2007; Hennekens 2012,). Such is the case with ordination, where transformed cover-abundance data from the MEGATAB table may be processed.

It is possible to ordinate relevés in the matrix along various axes. A single axis would produce a sequence of relevés in a straight line. Two axes yield a two-dimensional representation and three axes would produce a three-dimensional representation. There are a number of axes from which to choose. A scree plot shows the fraction of the total variance in the data that is explained by each axis (Podani 2001). The two axes with the highest percentages are generally chosen as they will produce the greatest spread on a two-dimensional plane.

However, various combinations are often tried to investigate different environmental variables. This can be helpful in explaining why the classification turned out in a particular way, with relevés grouped as they are. It can be that a certain axis, while not being one of the top differentiating axes, can yield sequencing helpful in suggesting an explanation that recorded underlying factors brought about. This may therefore help to explain differences between plant communities in a way helpful to management. Usually there are so many contributing factors that the two axes most strongly demonstrating differentiation are plotted against each other for the purpose of revealing communities.

OptimClass (Tichý et al. 2010) is a new method that was developed to abandon classification of sample sites and associations of subjectively identified frequently occurring species as focal points. OptimClassing is based on objectively determined faithful species associations. Species are indicated as faithful by means of Fisher's exact test indicating sufficient presence at various levels (Tichý et al. 2010). Faithful species are clustered by the OptimClass method where they indicate mapping areas. In national and regional vegetation surveys huge numbers of sampling sites are needed to adequately represent a mapping unit. TURBOVEG or JUICE software can process and cluster the volumes of data that have to be related to each other in the classification process (Tichý 2002).

In JUICE the processing starts with identification of a group of relevés in which the majority of species present are of a predefined group. The fidelity of all species to the identified group of releves is calculated. These species are then ranked in order of the fidelity that has been determined. The species that have the highest fidelity in the resulting ranking are then grouped and the process repeated. Repetitions continue to optimise the detection of co-occurrences as substantiated statistically (Tichý 2002).

The JUICE programme is versatile in that it is also suited to small phytosociological data sets. The JUICE programme is designed to accept input data in several forms including species check list and header data in plain text. Furthermore it has a number of useful export options to facilitate practical use of classification in text, spreadsheet programmes, statistical programmes and maps (Tichý 2002).

2.2.4 Additional surveys to characterise plant communities

Once the plant communities have been established, additional surveys can be done to describe the structure of the vegetation. Measuring the structure of the vegetation is of particular importance on a wildlife ranch.

Biomass Estimates from Canopy Volume (BECVOL) model

In order to add to the description of plant communities the Biomass Estimates from Canopy Volume (BECVOL) model version 2 (Smit 1996) may be applied to several selected representative sample plots of each community as identified by the Braun-Blanquet procedures.

The description adds to the findings regarding woody species present, their contribution to cover and structure of plant communities. In Smit (1996) it is stated that the principal implications of trees in savannas are firstly their competition with the herbaceous layer for resources, secondly the browse component and thirdly their contribution to sub habitats which favour certain desirable grass species. Regarding competition for resources, in Van Rooyen (2002) between 700 and 1,000 trees is considered the maximum for arid savanna.

The model has been computerised with the use of dBASE IV programming language. The model’s primary calculations determine the canopy volume from data collected in the field. An estimate of leaf volume and leaf mass per individual woody specimen is derived from the canopy volume by applying regressions of canopy volume to leaf volume and leaf mass. From these calculations Evapo-transpiration Tree Equivalents (ETTE) and Browse Tree Equivalents (BTE) are derived. Secondary calculations present these derivations per ha for each species and for the woody species as a whole. The calculations are further stratified to indicate leaf mass and BTE for browse below 1.5 m, below 2.0 m and below 5 m to facilitate estimation of browse available to various species of herbivore differing with regard to their maximum browsing height (Smit 1996).

Regardless of the shape of a tree, recording the following measurements will allow the program to calculate its estimated spatial canopy volume:

a. Tree height (in m),
b. Height of maximum canopy diameter (in m),
c. Height of first leaves (in m),
d. Height of first potential leaf bearing branches (in m),
e. Maximum canopy diameter (in m), and
f. Base diameter of the canopy at the height of first leaves or leaf bearing branches.

2.3 PHYTOSET PROCEDURES

2.3.1 Satellite imagery

Changes in contemporary environmental planning represent a continuing displacement of reductionist explanatory approaches, such as Braun-Blanquet procedures, by holistic and exploratory means to achieve planning solutions. This calls for changes in the kind of tools that the planner uses. Such planning solutions must include qualitative and quantitative decision aids (Orland et al. 2001).

Virtual Globe software systems are ways to visualise and share environmental data (Sheppard & Cizek 2009). The virtual globe type of visualisation, of which mapping derived from satellite imagery is one, and metadata derived from it are used for communicating scientific and environmental information.

Google Earth employs differing scales for maps that include a particular location. As increase in detail is desired, so the type of map changes and scales of succeeding maps increase. Maps at each scale have their particular characteristics. Google Earth mapping at the scale helpful as an alternative to stereoscopic generation of physiographic maps is at 15 m x 15 m pixel size (TerraMetrics & Google Earth 2012a).

Global coverage at 15 m resolution is available, and is regularly updated by Google Earth in association with TerraMetrics from uncompressed Landsat 7 source data provided to TerraMetrics by the United States of America, National Aeronautics and Space Administration NASA. Google Earth maps at 15 m resolution are identified by the appearance of TerraMetrics at the foot of any view at this level (TerraMetrics & Google Earth 2012b) the date of capture of the view is also indicated. Landsat 7 imagery is recognised as a suitable source of data for plant community mapping (Xie, Sha &Yu 2008).

Mapping derived from satellite imagery goes beyond the realm of conventional spatial data and geographic information science, engaging more complex dimensions of human perception. Consequently there are risks and benefits, which need to be balanced (Sheppard & Cizek 2009). On the question of validity, including correctness and appropriateness of the information, visualisation research is necessary. Regarding reliability, it must be possible to achieve consistency in repeated applications.

Orland et al. (2001) consider that the use of virtual imagery in landscape research must be justified by objective data from researchers who are well acquainted with the subject matter, clear description of method and stated levels of efficacy.

To address questions of different kinds, data may be processed with tools such as models according to hierarchical references to capture the basic characteristics of the data source. Digital imagery analysis tools such as the classifier of Google Earth images (Westfall 2008) used in this study are such presentation media. It is important that metadata are generated and accessible in a way that is relevant and consistent and that method, including processing description, is recorded (Wayne 2005).

The resultant metadata require scrutiny in a detached evaluation setting (Orland et al. 2001). It is incumbent on the professional concerned to be knowledgeable about the aspect of the environment being investigated and to be able to present an objective outcome.

Another approach that has similar advantages of availability and cost is Iso-clustering. Iso is an abbreviation for the iterative self-organising method of clustering. In this way of clustering, during each iteration, all pixels are assigned to existing cluster centres and new means are recalculated for every class (Xie et al. 2008). The algorithm separates all pixels into distinct unimodal groups in the multidimensional space of a multiband raster. The number of groups is specified by the operator. The function is usually used for unsupervised classification.

The optimal number of classes to specify is generally unknown. Therefore it is prudent to enter a conservatively high number, analyse the resulting clusters and re-run the function with ever decreasing numbers until a meaningful result is generated.

The Iso-cluster algorithm is an iterative process for computing the minimum Euclidian distance when assigning each candidate pixel to a cluster. The process begins with arbitrary means being assigned by the programme, one for each cluster as selected. Every pixel is assigned to the closest of these means, all of which are in multidimensional space.

New means are recalculated for each cluster based on the attribute distances of the pixels that belong to the cluster after the first iteration. The process is continually repeated, each pixel being assigned to the closest mean in the multidimensional space and new means are calculated for each cluster based on the membership of pixels from each successive iteration. The number of iterations of the process may be specified. The number should be sufficiently large to ensure that after running through the specified number, the migration of pixels from one cluster to another is minimal. In this way all the clusters achieve stability. If the specified number of clusters is increased, the number of iterations should also be increased. The specified number of clusters is the maximum number of resultant clusters that can emerge from the clustering process. However, the number may be reduced. The following circumstances will bring about reduction.

The frequency of occurrence of value data proximate to the initial arbitrary cluster means may be so low that the means may not have the opportunity to absorb enough pixels. Clusters consisting of fewer pixels than specified in minimum size class will be eliminated at the end of the iterations. Neighbouring clusters merge when the statistical values are similar on reaching stability. Keeping clusters that are so close to each other having minimal statistical difference would be an unnecessary division of data.

2.3.2 Floristic correspondence

Scale-related vegetation sampling is a method used to sample and floristically analyse vegetation. This sampling technique is an essential element of the PHYTOSET suite of programs. Westfall, van Staden, Panagos, Breytenbach & Greeff (1996) provide a detailed step-by-step description of the scale-related sampling and analysis method. Scale-related sampling assumes that plant communities are distinct in the context of the scale. For farm purposes a scale of 1:12 000 is recommended and sampling related to that scale provides suitable results for management (Westfall et al. 1996). This can be compared with the scale of 1:1,500,000 used by Acocks (1953) for the mapping of South Africa's vegetation types.

In the PHYTOSET program package the sequence of sample sites is determined by constructing a matrix with species recorded in the sample sites by plant number in the matrix as rows and sample sites as columns. For the purpose of sequencing sample sites plant number is used merely to signify occurrence. The extent of cover is not a consideration in this instance.

The initial sequence of sample sites is by number of species that are recorded in each site (Westfall 1992). A method of achieving this is to count the occurrences in the matrix, of all the species in each sample site. The sample sites can then be sequenced, either ascending or descending, according to the totals for each sample site. This sequence is called the occurrence sequence because the one extreme of the sequence represents the sample site that has the most species and the other extreme the sample site that has the least species.

Similarity sequencing is then sought by minimising the non-occurrences or those gaps, termed separation units, in the species rows between the first and last occurrence of a species across sample site columns in the entire matrix. This is done by computing the total number of separation units, moving the first column successively across the matrix and selecting the position for the sample site so moved, where the total number of separation units in the matrix is least. The new sequence is then treated in the same way, moving the new first column across the matrix and determining the next sequence with the least number of separation units. This process continues until the optimum result is reached and no further reduction is achieved.

Then the order of sample sites is reversed so that the last column becomes first and the process is continued until a new minimum number of separation units is reached. This is then reversed and the process of reversing is repeated until no further reduction is achieved by reversal. A state of minimum entropy will then have been achieved. This is the final sequence of sample sites, yielding a pattern on which community identification depends, reached by an entirely objective process (Westfall 1992).

A measure of verification of the sample site sequencing aspect of the classification process is expressed as classification efficiency. Classification efficiency is based on the relationship between total separation units and the total of all gaps in the matrix. It is calculated as follows:

$$E\% = 100 - \frac{(TSU \times 100)}{AG}$$

Where E = classification efficiency,

TSU = total separation units and

AG= all gaps in the matrix.

A 100 % classification efficiency would be where there are no separation units and all gaps are outside of pattern. A classification efficiency of 62% and higher would indicate robust efficiency in terms of the method itself (Westfall et al. 1996). Values markedly lower would indicate shortcomings in the classification process or data.

Sample sites in their eventual sequence are programmatically grouped based on the degree of species difference allowed between sample sites. Therefore, species that occur in all sample sites and species that occur in one sample site only are excluded. The degree of difference may be selected and tested programmatically.

Species sequencing depends on similarity in distributions according to sample site groups or combinations of sample site groups. Species in such sequence are then placed in species groups in descending order of occurrence in the diagnostic portion of the matrix. Balance is necessary between outliers and species that contribute to pattern. Single occurrence of a species in the matrix, in a combination of sample site groups or in a single sample site group is not relevant to species grouping as there is no contribution to pattern. Species rows in the matrix are rearranged accordingly. Species sequencing has no effect on the number of separation units in the matrix as the sample site sequence is not changed. The position of sample sites in these groups are compared with their positions in the areas of maps generated from satellite image stratification in correlation tables.

Crown cover refers to the projected (on the ground) crown of an individual plant. Canopy cover refers to the combined projected crown cover of a number of plants. The percentage canopy cover per growth form in each community is also generated by PHYTOSET. The input data are the frequency and mean crown diameter of each species within each growth form, which were recorded in the sample sites comprising the community.

The PHYTOSET program also calculates the ‘strong’ and ‘weak’ competitors based on the assumption that there is a linear relationship between frequency and cover within a growth form class, provided that cover is adequately determined (Westfall 1992). Regressions are used to infer which species were ‘strong competitors’ and which were ‘weak competitors’ (Westfall 1992). A ‘strong competitor’ was regarded as a species whose mean crown cover was greater than that expected from the regression for the frequency concerned, whereas a ‘weak competitor’ was regarded as a species whose mean crown cover was less than that expected from the regression for the frequency concerned. A regression as illustrated in Figure 2.1 may be generated from the mean crown cover of the species and their respective frequency that occur within a growth form class of a plant community.

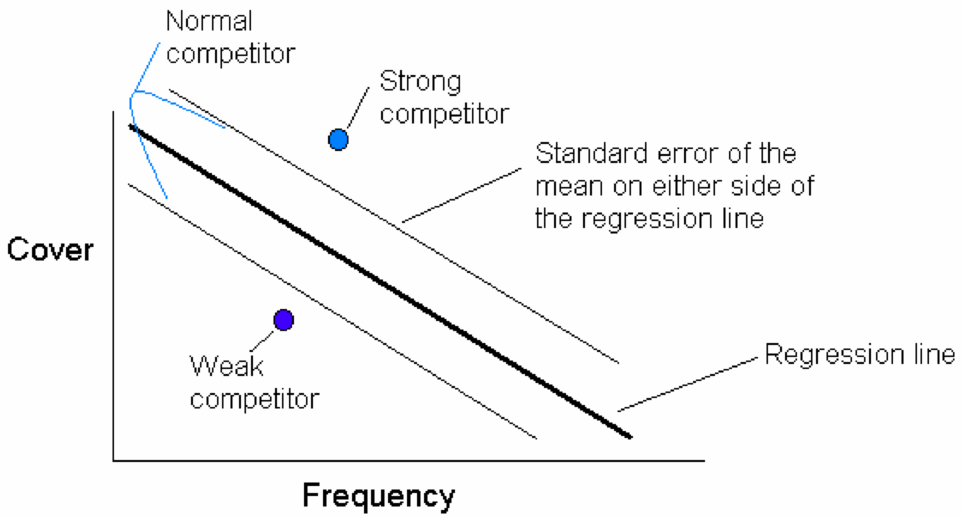

Figure 2.1: A linear relationship between cover and frequency ratios within a growth form class provided that cover is adequately determined after Westfall (1992).

The PHYTOSET program calculates the above ground standing biomass of graminoids. from cover and frequency values (Westfall 1992).

2.4 MODELING AS A TOOL IN WILDLIFE MANAGEMENT

The principle of adaptive resource management is appropriate to decision making regarding wildlife (Starfield & Bleloch 1991). However, successful adaptive resource management depends on rigour in its application (White 2001) and the necessary elements are:

- Definition of objectives for management,
- Development of models for management strategies; at least contemplative, but typically mathematical,
- Implementation of management options and,
- Evaluation of the impact of management implemented.

Modelling in engineering and physical sciences is a routine procedure and performed with confidence. Confidence in these sciences is based on good data and a good understanding of the field in which the modelling is done (Starfield & Bleloch 1991). In nonphysical sciences, such as wildlife management, data are seldom complete nor is the understanding of the structure of the problems being addressed good.

Models in the nonphysical sciences are somewhat speculative (Starfield & Bleloch 1991) and should therefore be used with due consideration of these shortcomings. The models should be designed acknowledging the relative paucity of data and understanding so as to explore consequences of what is believed to be true. However, it is important that data that is used is valid to the extent that output is sought (Starfied, Smith & Bleloch 1994).

In this way living with the available data forces re-evaluation of data and whatever beliefs were held, thereby improving the understanding of the structure in which modelling is seeking solutions to problems. A consequence of this is collection of data that in turn leads to better models (Starfield & Bleloch 1991).

White (2001) considers it the duty of researchers to provide reliable knowledge to wildlife managers in a way, such as modelling, that will give them options for their decision making. To achieve this, researchers need to be innovative and flexible in their modelling, but disciplined about the knowledge for which they are responsible.

Starfield & Bleloch (1991) consider it preferable for ecologists to use a few simple parallel models that can be interpreted in combination rather than to attempt to build more complex single models.

CHAPTER 3: THE STUDY AREA

3.1 INTRODUCTION

The property Evelyn Game Ranch (see below) was formerly used for cattle ranching, but during the 1990s it was gradually converted into a wildlife ranch for tourism including, but not limited to, hunting. The owner suggests that stock farming resulted in overgrazing and is concerned by the lack of recovery.

3.2 LOCATION

The study area is situated on the farms Kranenberg 162 MS and Evelyn 159 MS in the Messina magisterial district, Limpopo province, South Africa, between latitudes 22° 17' 19" S and 22° 19' 38" S and longitudes 29° 48' 51" E and 29° 51' 52" E (Figures 3.1, 3.2 & 3.3). It covers 1 293 ha.

3.3 TERRAIN, FORM, DRAINAGE, LAND TYPE, GEOLOGY AND SOILS

The altitude on the farm ranges from 560 m to 601 m above mean sea level (Chief Directorate of Surveys and Mapping 1996, Figure 3.3). The study area is situated in the Ae 266c and Fb 143d land types (Land Type Survey Staff 2003a, Figure 3.4) in the tertiary drainage area A71 and therefore in the A primary drainage area of South Africa which feeds the Limpopo River (Directorate of Hydrology 1999).

The North-western section of the study area belongs to Land Type Ae 266c (Figure 3.4), which consists of undulating to rolling footslopes and valley bottoms, punctuated by rocky crests (Land Type Survey Staff 2003b). The geology of the underlying rock strata in the area is Bulai gneiss and metaquartzite, gneiss and amphibolite of the Beit Bridge Complex (Land Type Survey Staff 2003b). Ninety per cent of the terrain has slopes from 2 – 10%. The greatest part of the land type is footslopes where the dominant soil form is Hutton and comprises 60% of the area. The remainder of the footslopes is predominantly deep yellow soils of the Clovelly soil form. Red to yellow apedal, freely drained soils with a high base status are the dominant soils in the area. Seventy per cent of the crests are rock and the remainder is soils of the Mispah form. Valley bottoms are predominantly soils of the Oakleaf soil form with streambeds and Hutton soil forms also occurring.

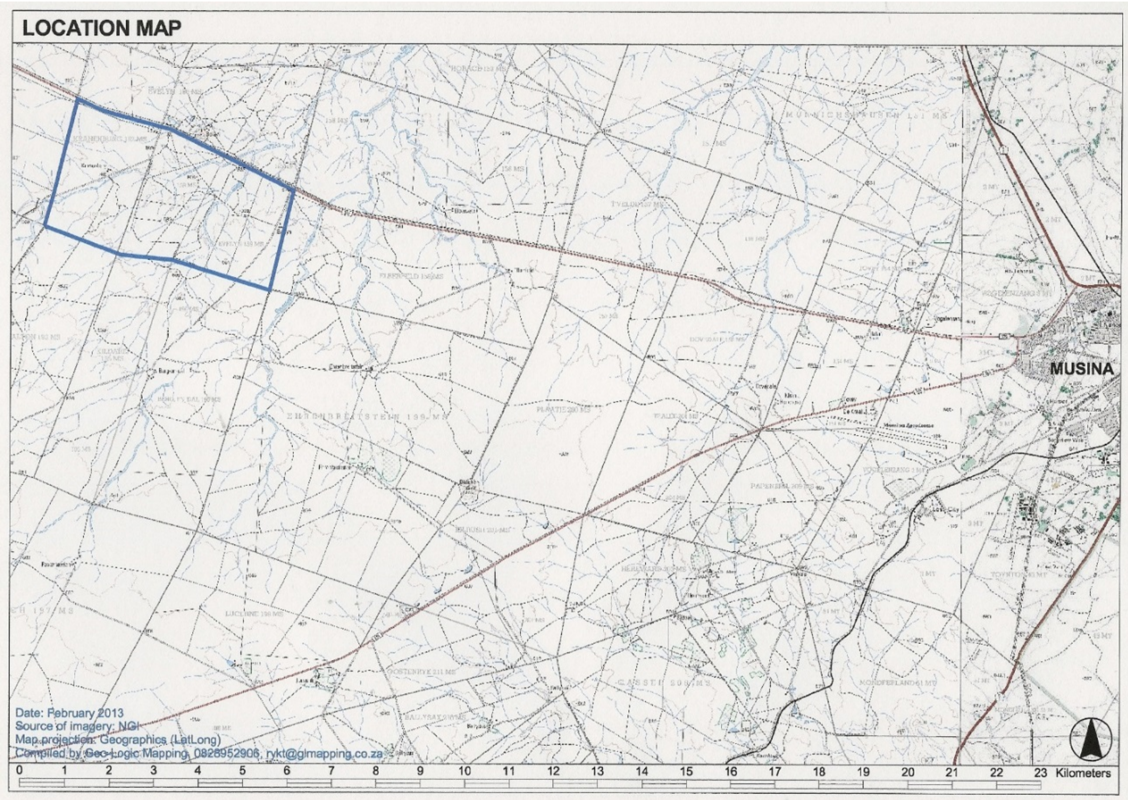

Figure 3.1: Location of the study area in relationship to the town of Musina (Geo-Logic Mapping 2013).

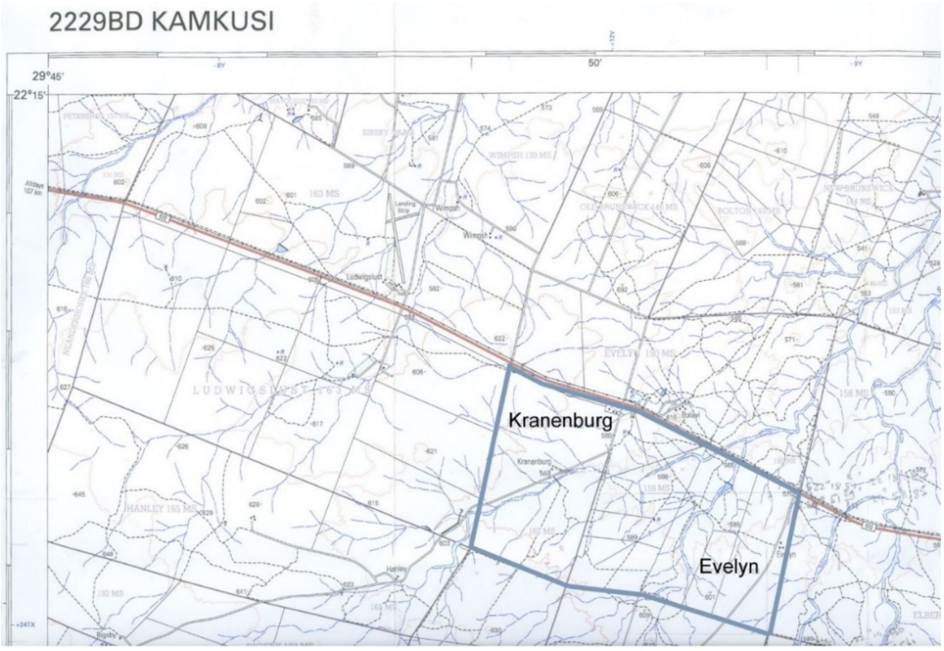

Figure 3.2: North-western corner of Topocadastral Map 2229 BD Kamkusi in which Kranenberg 162 MS and Evelyn 159 MS are located showing the co-ordinates (Chief Directorate of Surveys and Mapping 1996).

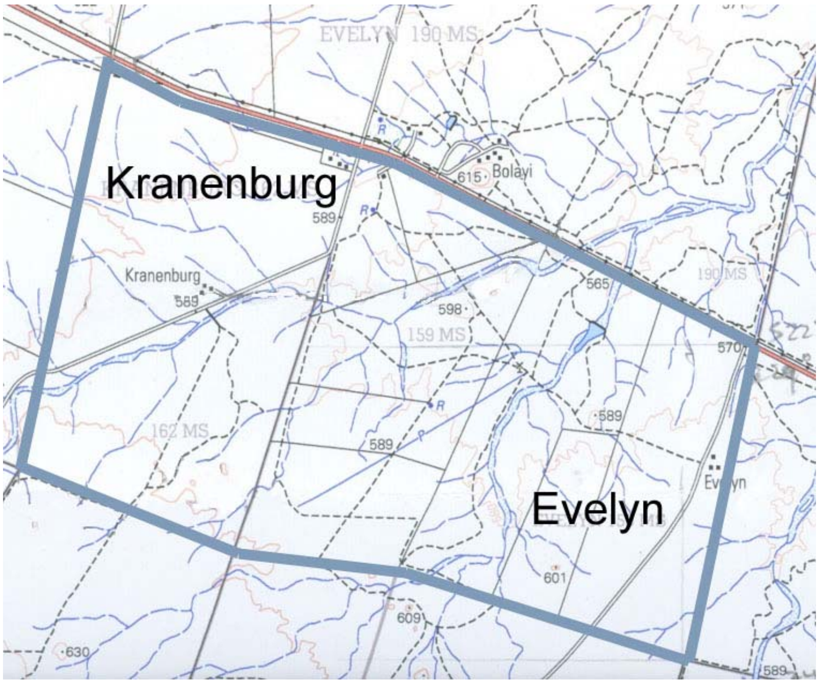

Figure 3.3: Kranenberg 162 MS and Evelyn 159 MS showing the 580 m and 600 m contours and the elevation of peaks in the rock crests (Chief Directorate of Surveys and Mapping 1996).

Most of the study area is situated in Land Type Fb 143d (Figure 3.4). The land type has 80% undulating to rolling midslopes, footslopes and valley bottoms and has 20% crests. The soils are of various origins but primarily from weathered parent material. The underlying rock formations are metaquartzite and gneisses of the Mount Dowe Group, leucogneiss, amphibolite and metapelite of the Malala Drift Group and porphyroblastic biotite gneiss of the Bulai Gneiss Formation, Dominion Group. All three groups are of the Beit Bridge Complex. Soils become progressively deeper from crests through midslopes and footslopes to valley bottoms. The soil forms become more varied down the terrain from Glenrosa and shallow Hutton forms on crests to Hutton, Glenrosa, Oakleaf and Clovelly forms on valley bottoms. Lime is often visible especially in the valley bottom soils. Only 30% of crests are rock, compared with 70% on the neighbouring Ae266c land type. The crests do not disturb the undulating to rolling terrain. The slopes vary from 1 to 8% throughout the terrain (Land Type Survey Staff 2003b).

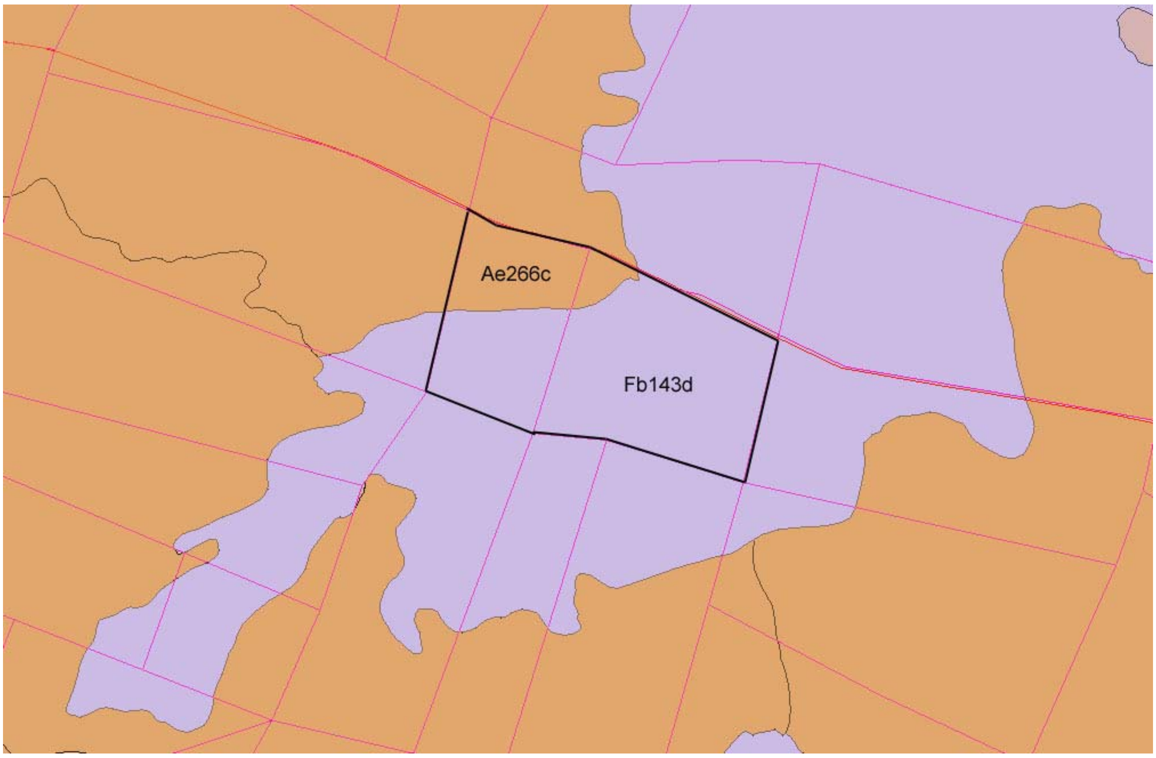

Figure 3.4: Land type map with the study area outlined in black (Land Type Survey Staff 2003a).

3.4 CLIMATE

Land types Ae266 and Fb143 are in Climatic zone 1041 that has low and variable rainfall, is hot and is almost frost free (Land Type Survey Staff 2003b). Mean annual rainfall for all weather stations in the zone is 316 mm. The mean annual rainfall from 1966 to 2008 of the two stations closest to the study area, Messina Police Station and Messina Macuville, was 323.7 mm and 358.7 mm respectively (South African Weather Service 2009). In 60% of the recorded years, monthly rainfall in the zone was equal to or greater than 18 mm over a six-month period from October to March. In 80% of the recorded years this level of rainfall was recorded in only 3 months, November to January (Land Type Survey Staff 2003b). Consequently one could expect 40% of the seasons to be drought seasons as far as grazing is concerned and half of these could be serious drought periods.

The hottest month in Climatic zone 1041 is January with a mean daily maximum temperature of 33.5ºC and mean daily minimum temperature of 21.0ºC (Land Type Survey Staff 2003b). The comparative temperatures for the local Messina Macuville weather station for January are slightly lower with a mean daily maximum of 31.5˚C and a mean daily minimum of 20.5˚C (South African Weather Service 2009). July is the coldest month in Climatic zone 1041 with mean daily maximum and mean daily minimum temperatures of 24.9ºC and 5.7ºC respectively (Land Type Survey Staff 2003b). A mean daily maximum of 23.3˚C and mean daily minimum of 6.8˚C are the comparative July temperatures for Messina Macuville weather station (South African Weather Service 2009). The mean duration of the frost period in the zone is 22 days, in late June and early July, with the mean number of actual frost days at four. The mean heat units above 10ºC in the zone are 2 905 degree days from October to March and 1 564 degree days from April to September (Land Type Survey Staff 2003b). These values are among the highest for South Africa.

3.5 VEGETATION

The study area is in the dry subdivision of the Savanna Biome (Westfall & Van Staden 1996). It falls within the Mopani Veld, Veld Type 15 of Acocks (1953, 1975) and Mopane Bushveld of Low & Rebelo (1998). Most of Evelyn Game Ranch falls within the Limpopo Ridge Bushveld with the Musina Mopane Bushveld covering the western part of the ranch (Mucina, Rutherford & Powrie 2005; Mucina & Rutherford 2006). The Ae Land Type typically supports Musina Mopane Bushveld, while the Fb Land Type typically supports Limpopo Ridge Bushveld (Mucina & Rutherford 2006).

Certain tall trees of the two vegetation units are conspicuous features. *Colophospermum mopane* is diagnostic of both vegetation units. *Combretum apiculatum* is diagnostic of the Musina Mopane Bushveld unit while *Adansonia digitata, Commiphora glandulosa* and *Terminalia prunioides* are diagnostic of Limpopo Ridge Bushveld (Mucina & Rutherford 2006). The Limpopo Ridge Bushveld vegetation unit is often fragmented and interspersed within the Musina Mopane Bushveld (Mucina & Rutherford 2006).

CHAPTER 4: MATERIAL AND METHODS

4.1 INTRODUCTION

Physiographic-physiognomic mapping of vegetation units is standard practice in initial stratification of African savannas (Bothma et al. 2004). It is used for the selection of field sample sites for the data included in the Braun-Blanquet suite of procedures. Vegetation stratification, using a map derived from satellite imagery and co-ordination of the outcome with an independent programmatic floristic classification, is an alternative method demonstrated in the study.

The survey for the Braun-Blanquet method was that of the Zurich-Montpellier School of Phytosociology (Braun-Blanquet 1932).

For the alternative method a completely different survey was conducted, using scale-related vegetation sampling included in the PHYTOSET suite of procedures. Auckamp cited in Westfall et al. (1996) states that the results from this method indicate a vast improvement on previous methodology yet remain within the flexible approach of Braun-Blanquet techniques.

4.2 BRAUN-BLANQUET PROCEDURES

Mapping

Physiographic-physiognomic vegetation mapping was done by using a stereo pair of 1:50 000 aerial photographs Numbers 545 and 546 that include the study area in series 908 dated 25/6/87.

Features suggesting homogeneous areas of vegetation and their boundaries were discerned by viewing the stereo pair of aerial photographs through a stereoscope and drawing these on to an enlarged aerial photograph. The enlargement was the study area portion of one of the pair of 1:50 000 aerial photographs. It was enlarged to A1 size resulting in a scale of 1: 7 850 that was convenient for fieldwork.

The Braun-Blanquet approach was used for floristic assessment. The first phase was analytical of every sample site, where details are recorded that describe the sites. The second phase is the synthetic phase arising from comparison of the analyses of the sample sites to determine species associations. These associations indicate the sites' representation of different communities (Braun-Blanquet 1932).

Analytical phase

The analytical phase commenced after the drawing of physiographic-physiognomic boundaries on the enlarged aerial photograph. The resulting physiographic-physiognomic map was used to select potential sites for collecting floristic data. After consideration of the features of this map it was considered necessary to select 35 sites, each well within the drafted boundaries to provide sufficient field data.

Floristic data were collected from 14th of March to 8th of April 2009. After ground-truthing of the apparent representativeness of each potential site within its physiographic-physiognomically mapped area, the site was either confirmed or a more representative position nearby was selected. Data sheets were used to record the locality, the date, and location of each site by GPS using a Garmin nüvi 205 instrument and a broad description by way of dominant plants. The following habitat evaluation criteria were recorded at each site.

Coordinates:	Coordinates were obtained from the Garmin nüvi 205
Altitude:	Altitude (in m) was obtained from the Garmin nüvi 205
Vegetation type:	The vegetation type according to Mucina & Rutherford (2006) was noted.
Vegetation description:	A broad description of the vegetation type that was observed at each site was given with due regard to the indication suggested by the physiographic-physiognomic map. Matching of vegetation type recorded at each site was helpful in ground truthing the physiographic map.
Topography:	The topography at each site was described.
Aspect:	Aspect was recorded either North, Northeast, East, Southeast, South, Southwest, West , Northwest or flat for each site.
Slope:	Slope was estimated at each site and recorded in degrees.
Soil colour:	Surface soil colour was described at each site.

Drainage:	Wherever there were apparent drainage peculiarities of a site they were recorded.
Erosion:	Type and extent of erosion was noted wherever it was observed.
Rock cover:	Percentage of the area of each site covered by rock was estimated and recorded.
Soil depth & soil texture:	Revelation of soil depth by disturbances within and in the proximity of each site was noted. Soil texture was estimated by a field method as described in Smith (2006).
Trampling / overgrazing:	Evidence of these two factors was sought at each site and findings recorded.
Fire:	Signs of recent fire were sought and presence or absence was recorded for each site.
Bush encroachment:	For each site at which bush encroachment occurred the number of woody plants per ha was estimated and the relevant species noted.
Cover by growth form:	Total cover of trees > 6 m, trees >2 – 6 m, shrubs, grasses and forbs was recorded.

Trees, shrubs, grasses and forbs were recorded by species and accorded cover-abundance values using the following Braun-Blanquet scale (Werger 1974).

r A single individual with minimal cover;
\+ Present but not abundant with canopy cover less than 1% of the site area;
1 Abundant or if not then of sufficient canopy size to provide an aggregate of 1% to 5% canopy cover of the site;
2a Any number of individual specimens with canopy cover >5% up to 12% of the site area;
2b Any number of individual specimens with canopy cover >12% up to 25% of the site area;
3 Any number of individual specimens with canopy cover >25% up to 50% of the site area;
4 Any number of individual specimens with canopy cover >50% up to 75% of the site area;

5 Any number of individual specimens with canopy cover >75% up to 100% of the site area.

Representative plant specimens were collected for verification of identity in the HGWJ Schweickerdt Herbarium of the University of Pretoria.

Synthetic phase

The second phase of the Braun-Blanquet procedure commenced with the TURBOVEG programme that simultaneously installed MEGATAB with a built-in TWINSPAN programme. Field data of species and site identification were captured using TURBOVEG. Importing the TURBOVEG data into MEGATAB yielded a raw data table consisting of a matrix of relevés in columns and species in rows. After running the TWINSPAN programme on the raw data table a first approximation of the final classification was obtained. This TWINSPAN classified table was then exported to a Microsoft Windows Excel file for further refinement.

The initial structure of plant communities that was derived from the data analysis was developed further by moving species rows and relevé columns. The best groupings were related to the physiographic-physiognomic vegetation map for apparent correspondence. Where adjustment appeared logical, movements of relevé columns were tested for their impact on the apparent plant communities. Where moves were justified by improved correspondence they were retained.

Ordination was then applied to visualize the relationships between the relevés. The floristic data were ordinated using Principle Co-ordinates Analysis (PCoA) in the SYN-TAX 2000 computer program (Podani 2001).

The data captured in the matrix for analysis were derived from the Excel spreadsheet. The cover-abundance values were converted to percentages using the midpoint of the cover-abundance class (Werger 1974; Van Der Maarel 2007). These percentages were then standardized using a natural logarithmic ($\log_e$) standardisation. The Bray-Curtis distance measure was applied for the PCoA. Groupings of relevés in the ordination were compared with groupings of relevés in the classification. Eventual outliers were considered for inclusion in other groups, with due regard to the physiographic-physiognomic vegetation map and changes made where appropriate.

Biomass Estimates from Canopy Volume (BECVOL) model

In order to describe the structure of plant communities the Biomass Estimates from Canopy Volume (BECVOL) model version 2 (Smit 1996) was applied to a sample in each community as identified by the Braun-Blanquet procedures.

Regardless of the shape of a tree, recording the following measurements will allow the programme to calculate its estimated spatial canopy volume:

Tree height (m),
Height of maximum canopy diameter (m),
Height of first leaves or potential leaf-bearing branches (m),
Maximum canopy diameter (m), and
Base diameter of the canopy at the height of first leaves or leaf-bearing branches (m).

Transects were selected at sites representative of the plant communities concerned. Transects were all 100 m long running in a north-south direction. A rope with 20 sections, marked off with coloured adhesive tape at 5 m intervals was used to demarcate the transect. Transects were 2 m wide. The measurements of the required dimensions were made with the aid of an expandable range rod calibrated in 0.5 m sections with coloured tape.

The model's primary calculations estimate leaf volume and leaf mass per individual woody specimen, that was rooted within or growing over a transect, from data collected in the field. From these calculations Evapotranspiration Tree Equivalents (ETTE), Browse Tree Equivalents (BTE) and Canopy Sub habitat Index (CSI) were derived.

The definitions in Smit (1996) of these derived values are:

ETTE - leaf volume equivalent of a 1.5 m single stemmed tree.

BTE - leaf mass equivalent of a 1.5 m single stemmed tree.

CSI - canopy spread area of those trees in a transect under which grasses associated with shade conditions are most likely to occur, expressed as a percentage of the total transect area.

Secondary calculations present these derivations per ha for each species and for the woody species as a whole. The calculations are further stratified to indicate leaf mass for browse up to 1.5 m, up to 2.0 m and up to 5 m to facilitate estimation of browse available to various species differing with regard to their maximum browsing height.

The dry leaf mass is calculated from the spatial canopy volume of a plant. In setting up the model selected species were analysed by destructive harvesting. Regressions in the models relate to such species. Therefore, when capturing data, species have to be selected from the programme's list. The model caters for exceptions with two general sets of regressions, one for microphyllous and another for broad-leaved species, should a particular species not occur on the model's species list (Smit 1996). A user may also use a similar species that is included in the species list, provided that the substitution is indicated.

Primary and secondary calculations were done using the BECVOL software. These data were saved in Excel. Both quantitative and qualitative results are useful in describing plant communities indicated by the synthetic phase of Braun-Blanquet floristic assessment. The data also has value for modelling as advocated by Starfield and Bleloch (1991).

4.3 PHYTOSET PROCEDURES

Mapping

Satellite imagery was tested for its relevance to plant community demarcation at farm scale 1:12,000. Whilst much satellite imagery is useable for the purpose, Google imagery was tested because of its general availability and cost considerations. The Google TerraMetrics 15 m resolution imagery used in the PHYTOSET procedures was obtained free of charge.

A simple classifier, which is contained in the PHYTOSET programme package (Westfall 2008), was constructed in which vegetation units were dichotomously arranged in sequence according to a pixel frequency histogram.

The pixels in the Google TerraMetrics 2007 mid-resolution image (TerraMetrics & Google Earth 2012a) in Figure 4.1 represent areas of 15 m x 15 m. A histogram was constructed including all pixels' mean reflectance values. The histogram generally follows a normal distribution where the extremes represent non-vegetation reflectance such as buildings and roads. These extremes of about 15% of the pixel mean reflectance values were allocated a single colour. The remaining 85% were then dichotomously sequenced and demarcated by the classifier to represent vegetation units. False colour was accorded to each unit to distinguish them from each other (Figure 4.2). This is a simplified form of the processes used in Westfall & Malan (1986) and Malan & Westfall (1987). As the number of demarcated units increased the mean standard deviation for all the units decreased and then increased. The lowest mean standard deviation for all the units is the point at which the largest, most homogeneous plant communities were expected to occur. Homogeneity in this sense is where the mean standard deviation is least.

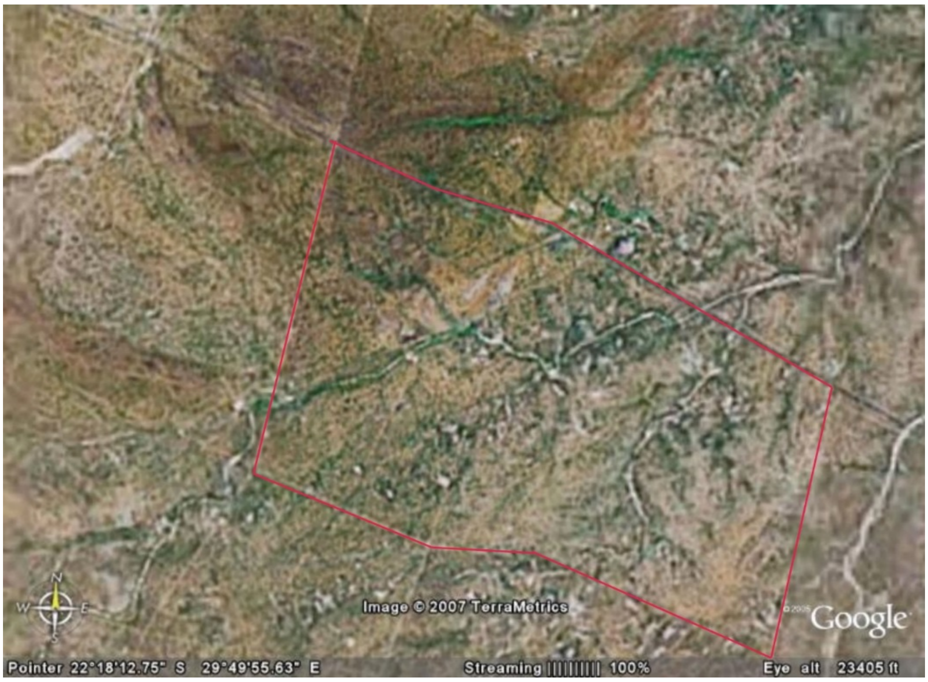

Figure 4.1: Google Earth TerraMetrics satellite imagery with study area outlined in red (Google Earth 2013).

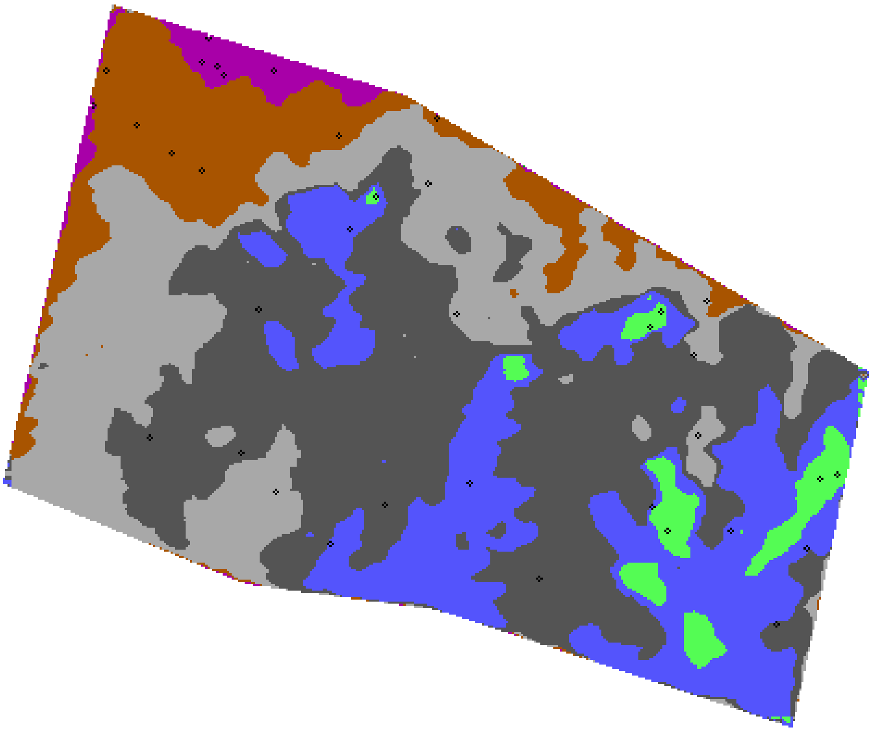

Figure 4.2: Random sample sites represented by dots generated for the study area showing six potential sites per initially stratified unit.

The resultant output was then filtered for scale using median filters. Median filters of 7 X 7 and 9 X 9 pixels were used which is commensurate with ground scales of 1:9 000 and 1:12 000 respectively. These procedures have been included in the PHYTOSET program package (Westfall 2008[2]). The program also calculated the areas of each potential vegetation unit.

Random sampling sites were generated for each of the units, which are shown in Figure 4.2 using the PHYTOSET program package. Ideally four or more sites were to have been sampled in each potential vegetation unit (Westfall et al. 1996). Six sites per unit were generated in case any of the sites on the ground could not be sampled.

Floristic classification

Scale-related vegetation sampling was used to sample and floristically analyse the vegetation according to the method provided in Westfall et al. (1996). For farm purposes a

[2] Dr R.H. Westfall may be consulted regarding the classification of images supported by Satellite Imagery, Satellite Imagery and the PHYTOSET computer package.

scale of 1:12 000 is recommended and sampling related to that scale is considered in Westfall et al. (1996) to provide results relevant for management.

The first aspect of sampling was to determine species presence. The quadrat size of 10 m x 20 m was used which relates to a scale of 1:12 000 (Westfall et al. 1996). Each species found in a particular quadrant and identifiable at the time of sampling was recorded and a growth form and cover value assigned to it. The definitions used for the growth forms were as follows:

- Tree: A single-stemmed woody plant ≥ 2 m tall, or if multi-stemmed then ≥ 5 m tall;
- Shrub: A single-stemmed woody plant 1 - < 2 m tall, or if multi-stemmed then 1 - < 5 m tall;
- Dwarf shrub: A woody plant < 1 m tall;
- Graminoid: Plants belonging to the families Poaceae, Cyperaceae and Restionaceae;
- Forbs: Non-graminoid herbaceous plants, mainly annuals and geophytes

The growth form most prevalent in the study area for each species was selected as representative. In situations where the tree form and shrub form appear to need separate analysis, a distinguishing description was added at species level.

The second aspect of sampling was to estimate cover of the species recorded in the quadrat by plant number scale, using variable-sized belt transects (Westfall & Panagos 1988). Transect width for each species was a function, 4/5ths, of the mean centre-to-centre distance between specimens of that species recorded at the sample site. Transect length was determined by the mean crown diameter. Mean crown diameter was related to a PHYTOSET table in which transect length is taken from 15 specified diameter cover classes, ranging from 0.001 – 0.01 m to 6.101 – 9.87 m (Table 4.1). Some transects were extended well beyond the confines of the sample site quadrat. If transect width exceeds transect length, no count is taken and merely presence was recorded

The number of individuals per species per transect at each sample site was indicated by code numbers and alphabetic symbols. A “+” indicates presence only after which the value ascends in numerical order to the value 9 and thereafter from A to W, with W representing a count >31 specimens in a transect (Table 4.2).

Observations including mean crown diameter code were entered into a field data sheet for each relevé (Figure 4.3).

Table 4.1: Cover sampling transect lengths determined from mean crown diameter classes

Crown diameter (m)	Crown code	Transect length (m)
0.001 – 0.010	A	0.15
0.011 – 0.020	B	0.45
0.021 – 0.030	C	0.75
0.031 – 0.050	D	1.20
0.051 – 0.080	E	1.95
0.081 – 0.130	F	3.15
0.131 – 0.210	G	5.10
0.211 – 0.340	H	8.25
0.341 – 0.550	I	13.35
0.551 – 0.890	J	21.60
0.891 – 1.440	K	34.95
1.441 – 2.330	L	56.55
2.331 – 3.770	M	91.50
3.771 – 6.100	N	148.05
6.101 – 9.870	O	239.55

Table 4.2: The plant number scale showing plant count, cover codes and percentage cover

Count	Code	% cover
0	+	0.01
1	1	0.10
2	2	0.40
3	3	0.91
4	4	1.61
5	5	2.52
6	6	3.63
7	7	4.94
8	8	6.45
9	9	8.18
10	A	10.08
11	B	12.20
12	C	14.51
13	D	17.03
14	E	19.75
15	F	22.68
16	G	25.80
17	H	29.12
18	I	32.65
19	J	36.38
20	K	40.31
21	L	44.44
22	M	48.78

23	N	53.31
24	O	58.05
25	P	62.99
26	Q	68.13
27	R	73.47
28	S	79.10
29	T	84.76
30	U	90.70
31	V	96.85
>31	W	100.00

Cover analysis

The data were processed using the PHYTOSET program to compute mean canopy cover for each species, in each sample site. As the plant number increases from 1 relating to 0.1% canopy cover, canopy cover increases in accordance with the law of diminishing marginal return to >31, code W relating to 100% canopy cover. Therefore numbers throughout the matrix in the PHYTOSET phytosociological table relate to canopy cover and are comparable even though the transect lengths may have differed from species to species and site to site.

FIELD DATA SHEET

Observer:________________________ Sample/Relevé number:________________

Study:____

Latitude (DD MM SS):______________ Longitude (DD MM SS):______________

Date: ___________________________ Scale:________________________________

Habitat description:____

Growth form code	Species name, nickname or number	Mean crown diameter	Plant count	Cover	Growth form code	Species name, nickname or number	Mean crown diameter	Plant count	Cover

Figure 4.3: Field data sheet.

The surveys were conducted from 1st March to 19th March 2008.

The specimens were then assessed relating them to herbarium accessions. The data were then analysed using the PHYTOSET program package (Westfall 2008).

Standing biomass of graminoids

The computer package also calculated the aboveground standing biomass of grasses and sedges in each community. These calculations are based on canopy cover and space between competing graminoid plants (Panagos 1999)

CHAPTER 5: RESULTS

5.1 INTRODUCTION

Plant community identification was achieved by traditional Braun-Blanquet procedures and by the modified PHYTOSET procedures adhering to the principles on which each set of procedures are based. Each set of procedures was accompanied by a map indicating the delineation of plant communities.

5.2 TRADITIONAL BRAUN-BLANQUET PROCEDURES

5.2.1 Physiographic mapping

The physiographic map is shown in Figure 5.1

5.2.2 Classification by Braun-Blanquet procedures

Output from MEGATAB and further refinement according to Braun-Blanquet procedures produced the differential table shown in Table 5.1.

The differential table indicated five communities, one of which was subdivided into two sub-communities, and thirteen species groups. The next step was to relate the groups to the locations of the relevés on the physiographic map of Evelyn Game Ranch. Where relevé groups were contiguous and the individual relevés occurred in what was apparently the same unit of the physiographic map and this apparent similarity could be validated by reference to field data, the dividing line was removed. The process was continued until the number of kinds of area on the physiographic map that were sampled and of the relevé groups in the matrix corresponded. The physiographic map then corresponded with the relevé groups in the matrix.

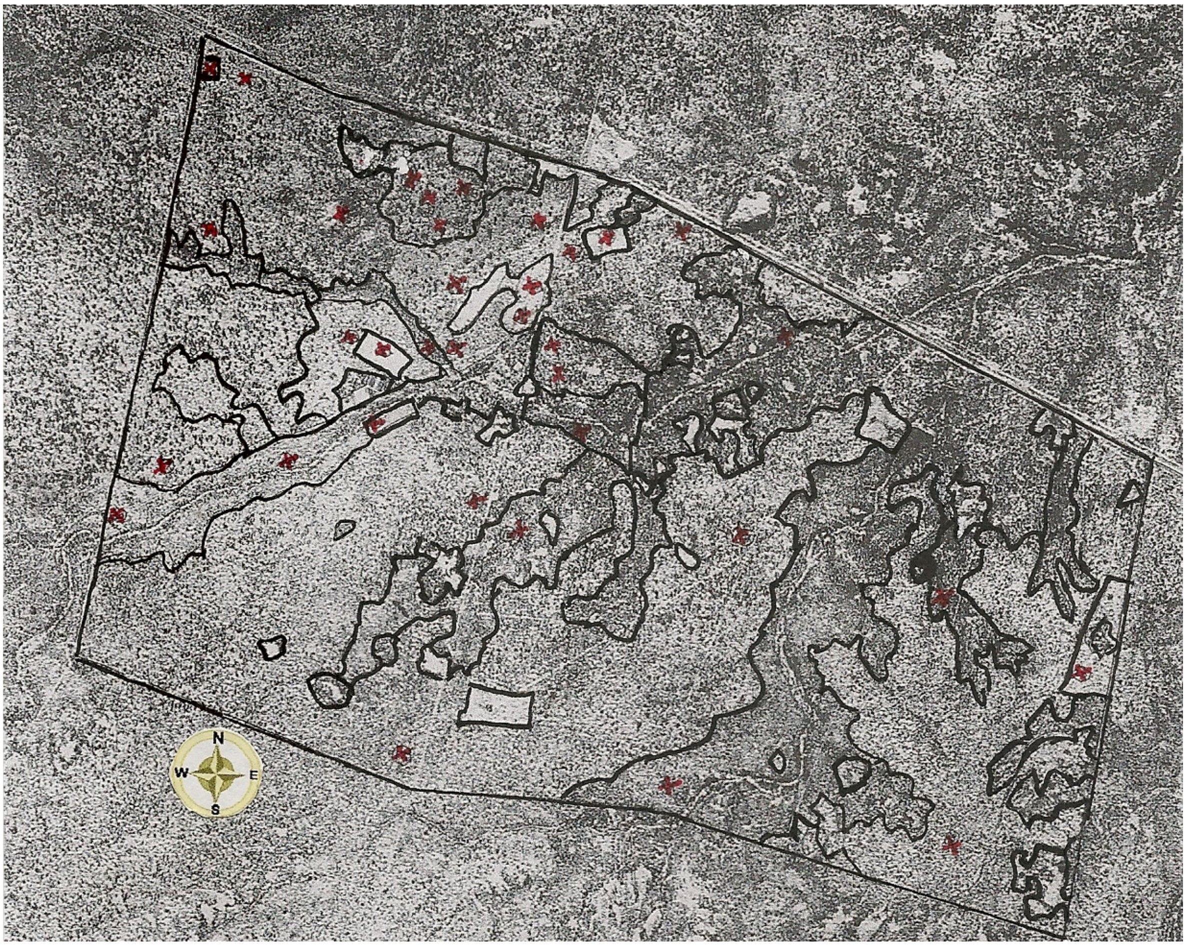

Figure 5.1: Physiographic map on an aerial photograph with boundaries of features observed by stereoscopy drawn by hand with 35 sample sites indicated.

Table 5.1 Differential table of Evelyn Game Ranch generated by MEGATAB, modified after PCoA ordination and correspondence with the physiographic map

Community number	1				2								3											4								5			
Sub community													3.1				3.2																		
Relevé number	21	33	35	10	5	4	13	27	29	6	7	3	34	32	1	2	17	25	19	22	12	9	15	23	20	31	8	24	11	26	28	16	18	14	30
SPECIES GROUP 1																																			
Pupalia lappacea	2	2	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	2	.	.	.
Setaria sagittifolia	2	3	2	.	.	.	.	.	.	.	.	.	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eleusine coracana	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhynchosia minima	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Digitaria eriantha	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lonchocarpus capassa	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SPECIES GROUP 2																																			
Kirkia acuminata	.	5	.	.	3	3	5	5	6	6	6	5	.	3	3	2	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.
Chamaesyce neopolycnemoides	2	.	.	.	2	.	2	.	2	2	.	.	2	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Rhigozum zambesiacum	.	.	.	.	2	.	.	.	.	.	.	2	.	.	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
Zornia capensis	.	.	.	.	.	2	2	.	.	.	.	2	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Enteropogon macrostachyus	.	.	.	.	.	.	.	.	.	.	.	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Monsonia angustifolia	.	.	.	.	.	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SPECIES GROUP 3																																			
Combretum apiculatum	3	.	3	2	6	1	2	3	3	2	.	2	.	.	.	2	.	.	.	3	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.
Barleria lancifolia	2	.	2	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Barleria crossandriformis	.	2	2	2	.	.	.	.	.	2	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sterculia rogersii	.	.	.	2	.	.	.	.	.	2	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Panicum deustum	2	.	2	.	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Abutilon angulatum	.	2	2	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SPECIES GROUP 4																																			
Boscia albitrunca	3	.	.	.	.	.	.	.	.	.	.	.	.	3	2	3	2	3	3	3	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.
Commiphora mollis	5	.	.	.	.	.	.	.	.	.	.	.	.	.	2	5	3	.	2	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euphorbia ingens	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Grewia monticola	.	.	.	.	.	.	.	.	.	.	.	3	.	.	2	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chamaecrista absus	.	2	.	.	.	.	.	.	.	.	.	2	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gisekia africana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
Kyllinga alba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Amaranthus thunbergii	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SPECIES GROUP 5																																			
Commiphora glandulosa	.	.	.	.	.	5	.	.	.	.	3	.	5	3	5	5	3	2	3	3	.	3	.	.	3	.	.	.	.	.	.	.	.	.	.
Commiphora edulis	.	3	.	.	2	.	.	.	3	.	3	.	3	.	2	2	3	5	.	.	.	5	2	.	.	.	.	.	.	.	.	.	.	.	.
Sclerocarya birrea	3	3	.	.	5	.	.	.	.	.	.	2	5	.	3	2	2	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Maerua parvifolia	.	.	.	.	.	2	.	.	3	3	.	2	2	.	.	.	.	.	.	2	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.
SPECIES GROUP 6																																			
Hermbstaedtia odorata	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	2	.	2	.	.	.	.	.
Boerhavia coccinea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	2	.	.	3	2	.	.	.	.	.	.
Pechuel-loeschia leubnitziae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	3	.	.	.	.	.
SPECIES GROUP 7																																			
Euphorbia inaequilatera	.	.	.	.	.	.	2	.	.	.	.	2	.	.	2	.	3	.	2	.	2	2	2	.	.	.	.	.	.	2	2	.	.	.	.
Ceratotheca triloba	.	.	.	.	.	2	2	.	.	.	.	2	.	2	.	.	.	.	.	.	.	.	.	.	2	2	.	.	2	3	2	.	.	.	.
Eragrostis lehmanniana	.	.	.	.	.	2	.	.	.	.	2	.	.	.	.	2	.	.	.	.	2	2	.	2	.	.	2	.	3	.	.	.	.	.	.
Adansonia digitata	.	.	.	.	.	.	3	.	.	.	.	3	.	.	2	.	.	.	.	.	3	.	.	5	.	.	.	.	3	.	.	.	.	.	.
Acacia senegal	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.	.	.	.	2	.	3	.	.	.	.
Sida alba	.	.	.	.	.	.	2	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
Commiphora schimperi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.	.	3	.	.	.	.	.	.	.	.
Hermannia glanduligera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.	.	.
Aristida diffusa	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.
SPECIES GROUP 8																																			
Grewia flavescens	3	2	2	.	2	3	5	2	5	.	2	2	2	2	.	.	2	2	.	.	2	.	.	2	.	.	.	2	.	.	.	.	.	.	.
Eragrostis biflora	.	3	2	.	2	2	.	2	2	2	5	.	2	2	.	.	.	2	.	.	.	.	2	2	.	.	5	.	.	.	.	.	.	.	.
Leucas glabrata	.	2	2	2	.	2	.	2	2	.	.	.	.	2	2	2	.	2	.	.	2	2	.	.	2	2	2	.	.	.	.	.	.	.	.
Panicum maximum	2	.	2	2	2	.	2	.	.	2	3	2	.	.	2	2	.	.	.	.	3	.	.	3	.	3	.	.	2	.	.	.	.	.	.
Corchorus asplenifolius	2	2	.	2	.	2	2	.	.	2	.	2	2	.	.	2	2	.	.	.	.	.	.	2	.	2	.	.	.	2	2	.	.	.	.

Jatropha spicata	. . . 2	2 . . . . . 2 .	. . . .	. . . . . 3 2	. . . 2	. . . .
Cyperus species	. . . 2	. . . .	. . . 2	. . . . . 2 .	. . . 2	. . . .
SPECIES GROUP 9						
Vernonia cinerascens	. . . .	. . . .	. . . .	. . . .	2 . . . . . 2 .	. 2 . .
Hibiscus calyphyllus	. . .	. . . .	. . . .	. . . .	2 2	. . 2 .
Becium angustifolium	. . . .	. . . .	. . . .	. . . .	. . . . . 2 . .	2 . 3 .
Kleinia species	. . . .	. . . .	. . . .	2	. . . . . . 2 2	. . . 2
SPECIES GROUP 10						
Acacia tortilis	. . . .	. . . .	2 . 2 .	. . . . 2 . 2	5 5 6 5 5 5 5 3	. . 5 5
Indigofera bainesii	. 2 . 2	. . . .	. 2 . 2	2 . . 3 . . 3	. . . 3 . 6 . .	. . 2 .
Indigofera species	. . . .	2	. . . 2	2 . . . 2 . .	. . . .	2 2 2 2
Eragrostis aspera	. . . .	. . . .	. . 2 .	. . . .	2 2	2 . . .
SPECIES GROUP 11						
Eragrostis trichophora	. . . 3	3 3 5 5 3 . 2 5	2 3 6 6	5 5 3 2 6 5 5	3 5 2 2 5 3 . 2	2 2 2 3
Aristida congesta subsp. *barbicollis*	. . . .	2 . 2 . 2 3 3 5	3 2 . 2	2 . . 2 . 3 2	3 2 . 5 2 2 3 3	. 2 . .
Indigastrum species	. 2 . .	2 . 2 . . . 2 .	2 2 2 .	2 . 2 2 2 . 2	2 2 3 3 2 5 2 2	2 . . .
Bulbostylis hispidula	. . . .	. 2 . 2 . . . 2	2 2 2 2	2 . 2 2 . 2 .	. . . 2 2 . . 3	. 2 2 .
Solanum kwebense	. . . .	. 2 2 . 2 . 2 .	2 2 2 2	. . . . 2 . 2	2 . . 2 . . 2 2	. . . 2
Waltheria indica	. . . .	. 2 . 2	. . 2 2	2 . . 2 2 . .	2 . 2 2 2 . 2 2	. 2 . .
Stipagrostis uniplumis	. . . .	2 2 3 3 2 . . 2	. . . .	. . . . 3 3 2	. . . 2 . 2 2 2	. 2 . .
Phyllanthus parvulus	. . . .	. . . 2 . . . 2	2 . . .	. . . .	 2	. . 2 .
Hermannia modesta	. . . .	. . 2 . 2 . . .	. . . .	. . 2 . . . 2	. . . .	. 2 . .
Acacia erubescens	. . . .	2	. . 2 .	. . . .	. . . .	. . 3 .
Geigeria burkei	. . . .	. 2 2	. . . .	. 2 . . 2 . .	. . . . . . 2 .	. . . 3
Seddera capensis	. . . .	2	2 . . .	. . . .	. . . 2	2 . 2 2
SPECIES GROUP 12						
Terminalia prunioides	2 3 5 6	2 6 6 5 5 5 5 5	5 2 3 .	6 . 3 5 5 3 6	3 . . 2 . 2 2 2	6 3 6 3
Colophospermum mopane	5 . 6 6	3 5 5 5 5 5 . 3	2 5 2 2	3 3 6 3 5 3 3	2 2 3 2 3 . . 3	6 6 6 6
Grewia villosa	. 3 3 2	2 3 . 2 . . 5 .	5 3 3 3	3 2 . 2 3 . 3	2 2 . 2 2 . 2 .	3 3 3 2
Achyranthes aspera	2 2 2 3	2 2 2 2 . 2 2 2	2 2 5 2	. 2 2 2 2 2 2	2 . 2 . . 3 2 .	2 2 3 5
Aristida adscensionis	2 3 2 3	5 3 5 3 6 3 3 5	2 3 5 6	5 2 5 3 2 2 5	3 3 3 . 3 3 3 2	3 3 2 2
Enneapogon cenchroides	2 2 2 2	2 2 3 2 . 2 2 2	3 3 2 2	2 2 2 . 2 2 2	3 2 3 2 2 5 6 3	3 2 3 2
Dichrostachys cinerea	2 . 2 .	. . 3 2 2 2 2 2	2 2 2 2	. 2 3 2 3 2 .	3 5 3 5 5 3 3 .	2 2 3 2
Melinis repens	2 2 . 2	5 3 2 3 2 5 3 5	2 2 2 5	3 2 . . 2 3 2	2 2 2	3 . 2 .
Grewia bicolor	3 6 3 3	5 3 5 3 3 3 5 3	5 3 5 5	3 5 . 2 5 3 3	5 2 . . . 2 2 .	. 3 3 3
Digitaria velutina	3 2 . 2	3 3 2 2 2 3 2 2	2 . 3 2	2 2 2 2 3 2 2	3 . 2 3 2 2 2 .	. . 2 2
Tragus berteronianus	. 2 . 2	2 2 2 2 2 2 2 2	2 3 2 2	3 . 3 3 2 2 2	2 . . . 2 . . 2	3 3 2 2
Dicoma tomentosa	2 2 . 2	2 2 2 2 2 2 2 2	2 2 2 3	3 . 2 2 2 2 2	2 2 2 . 2 2 2 2	2 2 2 .
Megalochlamys revoluta	2 3 2 .	2 2 . 2 . 2 2 .	2 2 3 2	2 2 2 2 2 2 2	. 2 2 . 2 2 . .	2 2 . .
Sida dregei	2 2 2 2	2 2 2 2 2 3 2 2	2 2 . 2	. 2 . 2 3 3 2	. 2 2 . 2 2 2 2	2 2 . 2
Ocimum americanum	. 2 2 2	2 2 2 2 2 2 . 3	2 2 2 2	2 . 2 2 2 2 2	. 2 2 2 3 . . 3	. 2 . .
Cenchrus ciliaris	2 . 2 .	. . . . 3 3 . .	. . . .	. . . . 3 . 2	. . 2 . . . 2 2	. . 2 .
Geigeria acaulis	. 2 . 2	2 2 2	2 . 2 2	2 . 2 2 2 2 3	. 2 . 3 . . 2 2	. 2 . .
Ptycholobium contortum	2 2 2 .	. 2 2 2 2 2 2 2	. 2 3 2	2 . 2 2 2 2 .	2 . 2 2 2 2 . .	2 2 2 2
Calostephane divaricata	2 2 . 2	3 3 2 2 2 2 . 2	2 2 2 2	2 2 2 2 2 2 2	2 2 . 2	2 2 . 2
Kyphocarpa angustifolia	2 . 2 2	2 2 2 2 2 . 2 .	. 2 2 2	. 2 . 2 . 2 3	2 2 . 2 2 . . 2	2 2 2 2
Schmidtia pappophoroides	. 2 . 2	. 2 2 2 . . . 2	. . . .	. . . .	. 2 . 3 . . 2 2	. 2 . .
Commicarpus pilosus	2 2 2 .	. . . .	2 2 2 .	. . . . . 2 2	. . 2 3	2 . 2 .
Acacia nigrescens	3 3 6 5	. . . .	. . 2 .	. . . 2 . 2 .	. . . 2 . 3 . .	3 2 . .
Acalypha indica	2 2 2 2	2 2 . 2	2 2 2 .	2 2 2 . . 2 2	2 2 2 . . . 2 .	. . 3 2
Aptosimum lineare	2 2 . 2	. 2 . 2 . 2 2 2	2 . 2 .	2 . 2 2 2 . 2	. 2 2 . . 2 2 .	. 2 3 2
Melhania rehmannii	2 2 2 2	2 2 2 2 2 . 2 .	2 2 2 2	2 . . 2 . . 2	2 2 . 2 2 2 2 2	. 2 2 2
Brachiaria deflexa	2 . 2 2	2 2 2 . 2 2 . 2	2 2 2 .	2 . 2 2 2 2 .	2 2 . 2 . 2 2 .	2 2 2 2
Commelina benghalensis	2 2 2 .	2 2 . . . 2 2 2	2 2 2 2	2 2 . 2 2 2 2	. . 2 2 2 2 . .	. . 2 2
Tephrosia purpurea	2 . . 2	2 2 2 2 2 2 . 2	. 2 2 2	2 2 . 2 2 . .	. . . 2 2 . 2 2	. . . 2
Bidens bipinnata	2 2 2 2	2 . . . . 2 . 2	2 2 . .	. . . .	2 . 2	2 . . .
Evolvulus alsinoides	. . . 2	. 2 2 2 2 . . 2	2 2 2 2	2 . 2 2 2 2 2	. 2 . 2 . . 2 2	. . 2 .
Asparagus species	. 2 2 .	2 . 2 2 2 2 . 2	2 . . .	. 2 . . 2 2 2	2	2 2 . .
Leucas sexdentata	2 . . .	. 2 . 2	. . 2 .	. 2 2 . 2 . .	2 2	2 . . 2
Acrachne racemosa	2 2 . 2	. . . .	. . 2 2	. 2	2 . 2	. . 2 .
Chloris virgata	. . . 2	. . . . . 2 . 2	2 . . .	. . . .	2	. . . 2
Barleria lugardii	. 2 . .	2	. . . .	. . . .	. . . .	. . . 2
Urochloa mosambicensis	2 . . .	 2	. . . .	. . 2	2 2	. . . .
Pergularia species	2 . . 2	. . . .	. . . .	. . . .	. . . .	. . 2 .
Cucumis species	2 . . .	. . . .	. . . .	. . . .	. . 2	. . 2 .

Barleria holubii	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2	.	.
Ledebouria species	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis bicolor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.
Boscia foetida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2	.
Setaria verticillata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
Datura species	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coccinia rehmannii	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lotononis species	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tephrosia species	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Barleria affinis	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Secamone species	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sutera species	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crotalaria sphaerocarpa	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Monechma divaricatum	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euphorbia species	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Abutilon austro-africanum	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pavonia species	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhynchosia totta	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cucumis zeyheri	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyphostemma cirrhosum	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Grewia flava	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hibiscus micranthus	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Holubia saccata	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ledebouria marginata	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Limeum fenestratum	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhynchosia species	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gardenia resiniflua	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Vigna oblongifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
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Phyllanthus maderaspatensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.
Monsonia species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.
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Commicarpus pentandrus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Barleria species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Monechma species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2

The scree plot output from the PCoA on the floristic data showed that the first two axes explained most variation, being 15% and 12% for the first and second axis respectively (Figure 5.2).

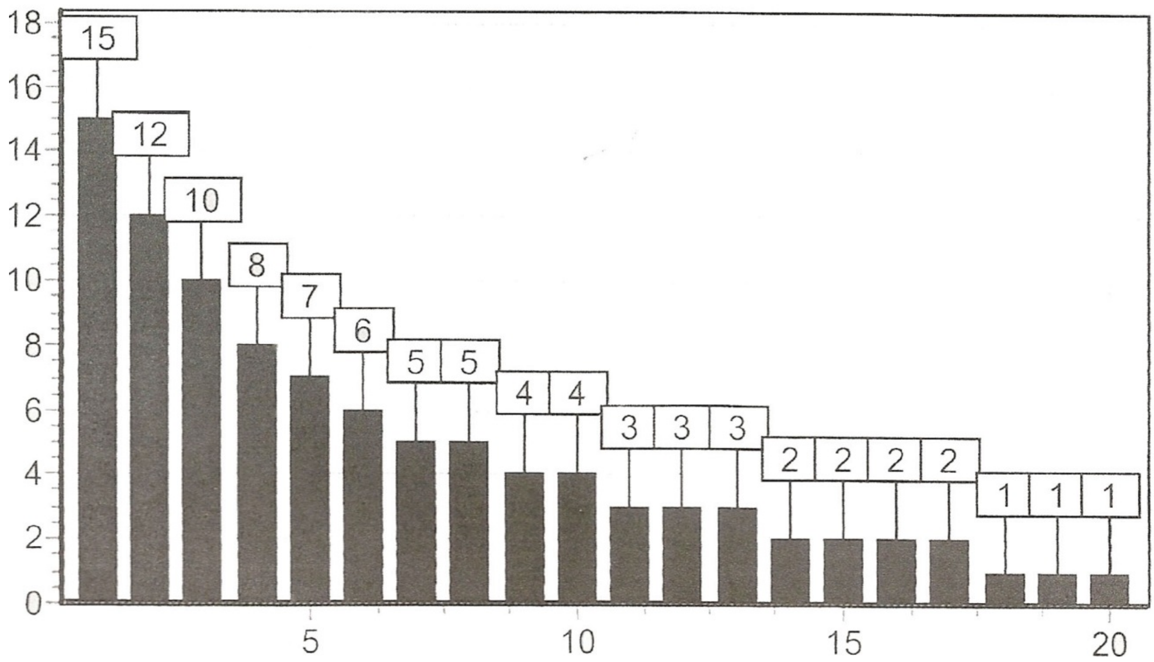


Figure 5.2: Scree plot of various differentiation axes generated by PCoA from floristic data.

These two axes were consequently taken to produce a scatter diagram of the relevés in two dimensional space (Figure 5.3). Thereafter the relevés were colour indexed to indicate the relationship of the clusters to classified communities (Figure 5.4). The ordination supported the classification with a fairly good separation between the clusters. Relevé 25 was classified as part of the *Boscia albitrunca* – *Commiphora edulis* Short Closed Woodland (Table 5.1), whereas the ordination showed closer linkages with the *Pupalia lappacea* – *Acacia nigrescens* Riparian Thicket or *Kirkia acuminata* – *Melinis repens* Tall Closed Woodland (Figure 5.4). The groupings of relevés on the spreadsheet having corresponded with the ordination analysis, the phytosociological table was accepted (Table 5.1 & 5.2).

Naming of the communities by structural group and formation class was done according to Edwards (1983).

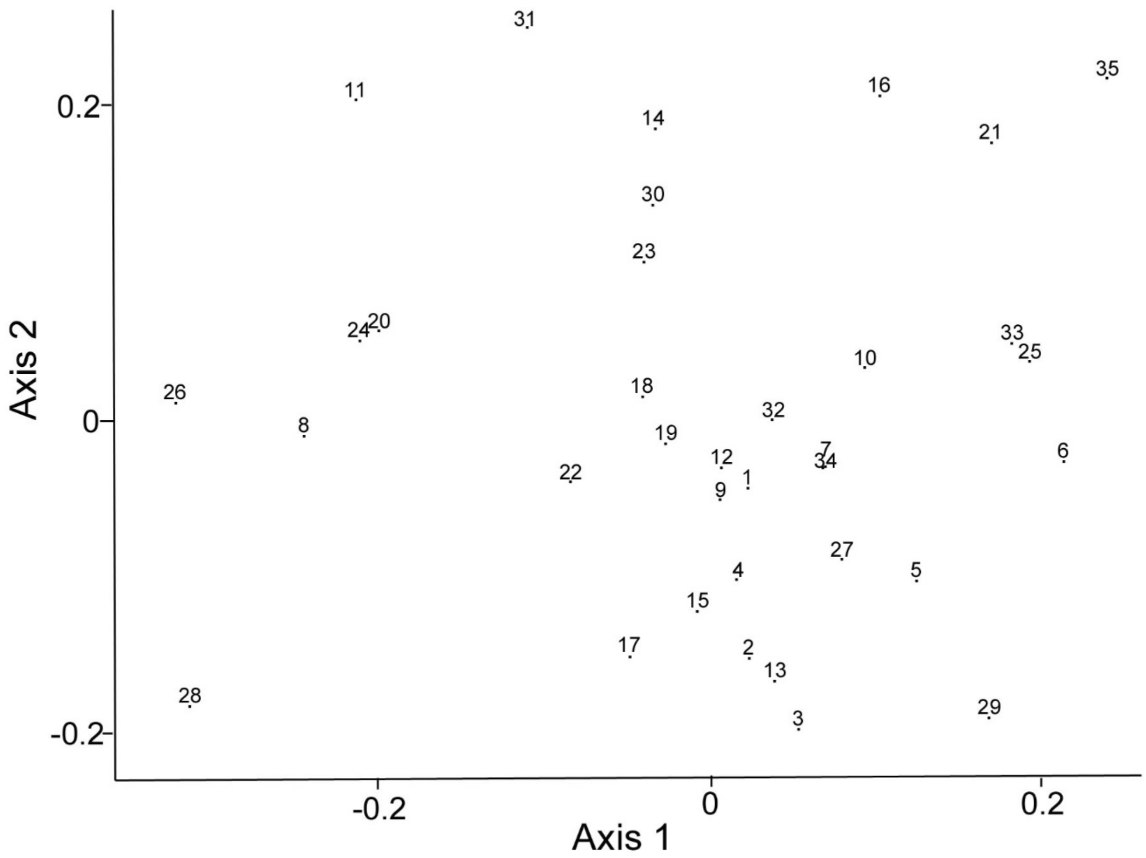
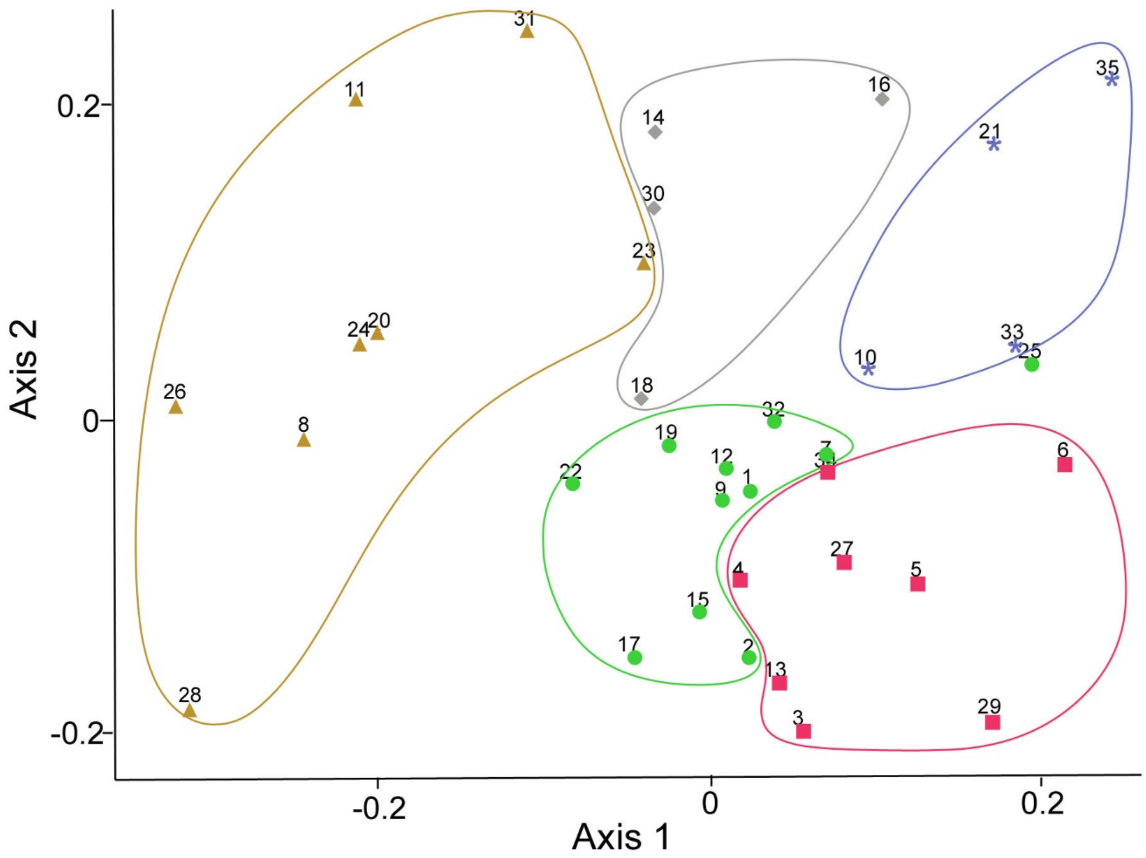


Figure 5.3: Two dimensional ordination achieved by plotting the two linear axes from PCoA that showed the greatest differentiation.



Colour key	Plant communities
Blue	*Pupalia lappacea – Acacia nigrescens* Riparian Thicket
Red	*Kirkia acuminata – Melinis repens* Tall Closed Woodland on flat rocky outcrops
Green	*Boscia albitrunca – Commiphora edulis* Short Closed Woodland on sandy soils
Brown	*Acacia tortilis – Enneapogon cenchroides* Short Open Woodland on old fields and borrow pits
Grey	*Terminalia prunioides – Colophospermum mopane* Tall Closed Shrubland of dry water courses

Figure 5.4: Two dimensional ordination related to the phytosociological table, with relevé symbols coloured to indicate the plant communities that they represent.

Table 5.2: Relevé co-ordinates, corresponding ordination cluster and phytosociological affinity.

Evelyn Game Ranch: Co-ordinates of Braun Blanquet releves			**Ordination cluster group / phytosociological map area**				
Relevé Number	Co-ordinates South	Co-ordinates East	*Pupalia lappacea – Acacia nigrescens* Riparian Thicket	*Kirkia acuminata – Melinis repens* Tall Closed Woodland	*Boscia albitrunca – Commiphora edulis* Closed Woodland	*Terminalia prunoides – Colophospermum mopane* Tall closed Shrubland	*Acacia tortilis – Enneapogon cenchroides* Open Woodland
1	22°18.142	29°50.262			Yes		
2	22°17.985	29°50.208			Yes		
3	22°17.765	29°49.983		Yes			
4	22°17.715	29°49.892		Yes			
5	22°17.737	29°49.660		Yes			
6	22°17.740	29°49.252		Yes			
7	22°18.353	29°49.100		Yes			
8	22°18.074	29°49.721					Yes
9	22°18.017	29°49.567			Yes		
10	22°18.018	29°49.816	Yes				
11	22°17.975	29°50.095					Yes
12	22°17.805	29°50.162			Yes		
13	22°17.649	29°50.001		Yes			
14	22°18.332	29°49.493				Yes	
15	22°18.063	29°49.875			Yes		
16	22°18.550	29°50.051				Yes	
17	22°19.070	29°49.748			Yes		
18	22°19.237	29°50.526				Yes	
19	22°19.248	29°51.365			Yes		
20	22°18.920	29°51.650					Yes
21	22°18.672	29°51.250	Yes				
22	22°18.454	29°50.262			Yes		
23	22°17.876	29°49.999					Yes
24	22°17.796	29°50.382					Yes
25	22°17.856	29°50.266		Yes			
26	22°17.924	29°50.128					Yes
27	22°17.652	29°49.770		Yes			
28	22°17.322	29°49.245					Yes
29	22°17.454	29°49.462		Yes			
30	22°18.493	29°49.021				Yes	
31	22°18.264	29°49.734					Yes
32	22°17.777	29°50.525			Yes		
33	22°18.007	29°50.777	Yes				
34	22°18.539142	29°49.926			Yes		
35	22°18.280	29°50.280	Yes				

5.2.3 BECVOL results

In order to add to the description of plant communities the Biomass Estimates from Canopy Volume (BECVOL) model was applied to a survey plot representative of each community as identified by the Braun-Blanquet procedures. The results obtained with the BECVOL method are shown in Table 5.3.

In community 2, the *Kirkia acuminata – Melinis repens* Tall Closed Woodland, the transects did not include the tall species *Adansonia digitata* and *Kirkia acuminata*. These species were omitted as the method requires calculations from of the measurements of each individual specimen encountered in a transect. That would have distorted the outcome of analysis as these species reach sizes far in excess of the other woody species. Total leaf mass for this community was consequently probably underestimated. Nevertheless, it was observed that lower growing woody species contributed 1276 kg of dry leaf mass per ha. Community 2 as will be seen in table 5 ranked third out of five. Evapotranspiration tree equivalents ETTE at 5 710 are consequently understated by excluding these large trees. Browse determination in browse tree equivalents BTE at less than 5 m is realistic. This community had the highest density of woody plants, 2 250 individuals per ha and the species with the highest density was *Colophospermum mopane.*

Table 5.3 indicates the status of encroachment by woody species for each community. Total BTE in all communities exceeds 1200. Canopied sub habitat index (CSI) is well in excess of 40% in community 3 *Boscia albitrunca – Commiphora edulis* Short Closed Woodland, and community 1 *Pupalia lappacea – Acacia nigrescens* Riparian Thicket. However, canopied sub habitat index is understated by the avoidance of the two tall growing species *Adansonia digitata* and *Kirkia acuminata* in community 2. Therefore, in three of the communities canopied sub habitat was high.

Biomass estimates of the *Pupalia lappacea – Acacia nigrescens* Riparian Thicket reflect an abundance of foliage, with large and small trees interspersed. However, accessible browse was low, the lowest at >1.5 m and second lowest at >2.0 m. The high canopied sub habitat index suggested that high quality grass would augment herbage in this community.

TABLE 5.3: BECVOL generated report on trees and shrubs

SPECIES	Plant numbers	Leaf volume	Total ETTE	Leaf DM kg	Leaf DM< 1.5m kg	Leaf DM< 2m kg	Leaf DM< 5m kg	Total BTE	BTE< 1.5m	BTE< 2m	BTE< 5m	CSI:Trees > 2m tall	CSI:Trees > 4 m tall
Pupalia lappacea – Acacia nigrescens riparian Thicket Bushland represented by survey plot 5													
Acacia nigrescens (normal)	100	1437	2875	684	44	68	386	2737	176	274	1545	12.6	12.6
Colophospermum mopane (normal)	600	1648	3295	847	34	77	724	3387	136	309	2896	33.3	33.3
Combretum erythrophyllum (normal)	50	41	83	19	5	12	19	74	21	50	74	0.9	0.0
Commiphora pyracanthoides (normal)	50	215	431	96	0	0	96	384	0	0	384	3.5	3.5
Grewia bicolor (normal)	150	276	553	123	70	115	123	494	279	460	494	7.0	0.0
Grewia flavescens (normal)	50	283	566	121	34	55	121	485	136	220	485	5.1	5.1
Grewia villosa (normal)	150	81	163	28	27	28	28	110	107	110	110	0.0	0.0
Terminalia prunioides (normal)	200	1032	2065	459	29	74	459	1835	114	294	1835	20.1	20.1
Totals	1350	5015	10030	2377	242	429	1956	9506	969	1716	7822	82.4	74.6
Kirkia acuminata – Melinis repens Tall Closed Woodland on flat rocky outcrops represented by survey plot 2													
Colophospermum mopane (normal)	900	601	1203	310	142	209	310	1239	568	835	1239	9.7	1.3
Dichrostachys cinerea (normal)	200	238	475	99	34	57	99	397	135	227	396	2.8	0.0
Grewia bicolor (normal)	300	721	1442	322	145	231	322	1286	578	925	1287	13.5	0.0
Grewia flavescens (normal)	200	383	767	150	75	112	150	598	300	448	598	6.2	1.3
Grewia villosa (normal)	200	104	207	36	36	36	36	144	144	144	144	0.0	0.0
Totals	2250	2855	5710	1276	535	806	1276	5104	2139	3224	5104	42.2	8.5
Boscia albitrunca – Commiphora edulis Short Closed Woodland on sandy soil represented by survey plot 1													
Acacia tortilis (normal)	50	75	149	34	29	34	34	137	116	137	137	0.0	0.0
Colophospermum mopane (normal)	100	551	1102	283	3	8	154	1133	14	34	617	11.1	11.1
Commiphora pyracanthoides (normal)	100	2723	5445	1205	121	221	878	4818	482	885	3511	37.9	35.5
Dichrostachys cinerea (normal)	100	123	247	51	23	41	51	205	91	163	205	2.0	0.0
Dichrostachys cinerea (coppice)	50	1	3	1	1	1	1	2	2	2	2	0.0	0.0
Grewia bicolor (normal)	200	317	634	142	86	116	142	567	345	462	567	4.0	0.0
Grewia flavescens (normal)	200	525	1050	209	171	209	209	837	683	835	837	7.4	0.0
Grewia villosa (normal)	350	500	1001	195	192	195	195	782	770	782	782	0.0	0.0
Sclerocarya birrea (normal)	50	2657	5313	1175	0	0	425	4699	0	0	1700	35.5	35.5
Totals	1200	7473	14944	3295	626	825	2089	13179	2503	3300	8357	97.9	82.0
Terminalia prunoides – Colophospermum mopane Tall Closed Shrubland of dry water courses represented by survey plot 4													

Acacia tortilis (normal)	150	166	331	76	70	76	76	303	282	303	303	0.0	0.0
Colophospermum mopane (normal)	350	590	1180	304	43	73	304	1215	170	290	1215	11.2	8.0
Combretum apiculatum (normal)	50	126	251	55	4	8	55	221	15	31	221	2.5	2.5
Dichrostachys cinerea (normal)	550	90	179	35	35	35	35	142	142	142	142	0.0	0.0
Grewia bicolor (normal)	100	51	103	23	13	18	23	92	51	70	92	0.2	0.0
Grewia flavescens (normal)	50	48	96	17	14	17	17	68	54	68	68	0.0	0.0
Terminalia prunioides (normal)	500	825	1650	368	103	171	368	1472	412	682	1472	16.4	8.3
Totals	1750	1896	3791	878	281	397	878	3513	1125	1586	3513	30.2	18.7
Acacia tortilis – Enneapogon cenchroides Short Open Woodland on old fields and borrow pits represented by survey plot 3													
Acacia nigrescens (normal)	50	86	172	39	24	37	39	158	98	149	158	1.1	0.0
Acacia tortilis (normal)	200	445	889	206	146	204	206	822	582	817	822	5.1	0.0
Colophospermum mopane (normal)	200	59	118	31	31	31	31	122	122	122	122	0.0	0.0
Dichrostachys cinerea (normal)	200	447	894	191	53	95	191	763	212	380	763	6.9	2.5
Grewia bicolor (normal)	100	97	194	44	28	36	44	174	110	144	174	0.9	0.0
Grewia villosa (normal)	50	81	161	30	30	30	30	121	121	121	121	0.0	0.0
Totals	800	1215	2429	540	311	433	540	2160	1245	1732	2160	14.1	2.5

Key to column headings

Plant numbers	=	Plants per ha
Leaf volume	=	Leaf volume cu m / ha
Total ETTE	=	Total Evapotranspiration Tree Equivalents
Leaf DM kg	=	Estimated Leaf Dry Mass kg
Leaf DM< 1.5m kg	=	Estimated Leaf Dry Mass under 1.5m kg
Leaf DM< 2m kg	=	Estimated Leaf Dry Mass under 2m kg
Leaf DM< 5m kg	=	Estimated Leaf Dry Mass under 5m kg
Total BTE	=	Total Browse Tree Equivalents (leaf dry mass g /250)
BTE< 1.5m	=	Browse Tree Equivalents under 1.5m
BTE< 2m	=	Browse Tree Equivalents under 2m
BTE< 5m	=	Browse Tree Equivalents under 5m
CSI:Trees > 2m tall	=	Canopied Sub habitat Index:Trees > 2m tall
CSI:Trees > 4 m tall	=	Canopied Sub habitat Index:Trees > 4 m tall

In the *Kirkia acuminata – Melinis repens,* Tall Closed Woodland on flat rocky outcrops community 2, a consequence of excluding tall species *Adansonia digitata* and *Kirkia acuminata* from sampling emphased the contribution of lower growing woody species. Nevertheless, these lower growing species contributed 1 276 kg of dry leaf mass per ha and this community was shown in Table 5.3 to rank third out of five. It is accessible browse expressed in browse tree equivalents BTE at less than 5 m that is important. In this study the comparison of methodology had to be relevant in wildlife management terms.

Canopied sub habitat index CSI was also understated by the avoidance of the two tall growing species. Therefore bearing in mind the exclusion of *Adansonia digitata* and *Kirkia acuminata* from analysis in community 2, this community and the *Boscia albitrunca – Commiphora edulis* Short Closed Woodland on sandy soils, community 3 and *Pupalia lappacea – Acacia nigrescens* Riparian Thicket, community 1, displayed very high sub canopied habitat characteristics. The consequence was that grass species diversity was reduced there.

Table 5.3 indicates the status of encroachment by woody species for each community. Total BTE in all communities exceeded 1200. In community 2 *Colophospermum mopane* at 900 individuals per ha is a threat. These were typically small spindly plants. This species and growth form are at dangerous levels of 600 per ha in community 1 *Pupalia lappacea –, Acacia nigrescens* Riparian Woodland.

Sub canopied habitat Index was well in excess of 40% in community 3 *Boscia albitrunca – Commiphora edulis,* Short Closed Woodland, and community 1 *Pupalia lappacea – Acacia nigrescens*, Riparian Thicket and understated in community 2.

Community 3 *Boscia albitrunca – Commiphora edulis*, short closed woodland, sandy soil group (Figure 5.5) contributed more accessible browse than do the other areas.

There was a high proportion of trees with foliage higher than 5 m from ground level as shown in Table 5.3. While foliage at such height did not contribute to browse it did increase the canopy thereby increasing the sub habitat for higher potential grass species (Smit 1996). However, no such difference in higher potential grasses was revealed.

The areas represented by *Kirkia acuminata – Melinis repens,* Tall Closed Woodland (Figure 5.6) had isolated large *Kirkia acuminata* and *Adansonia digitata* specimens. As these specimens did not contribute to accessible browse and in view of one such specimen's impact on the outcome of a 200 m^2 survey plot, the plot representing the group was selected so as to avoid such an inclusion. Therefore, while the available browse estimate is useful the canopied sub habitat index Canopied Sub-habitat Index was understated.

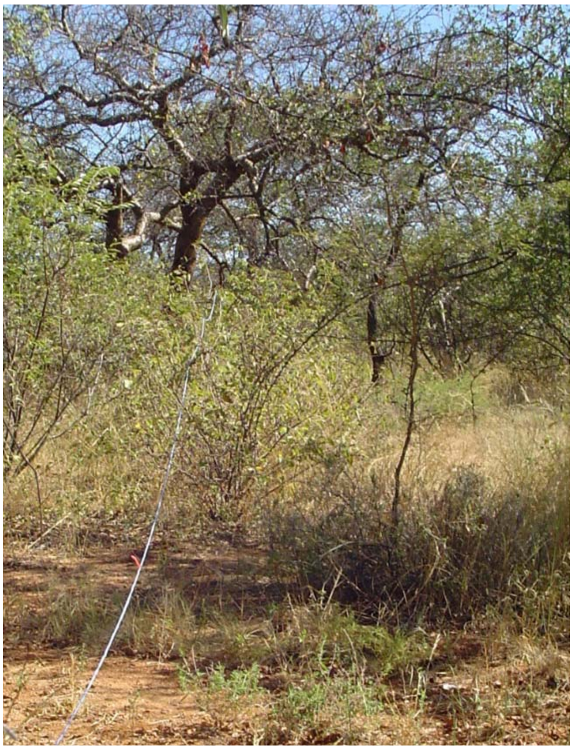


Figure 5.5: *Boscia albitrunca – Commiphora edulis* Short Closed Woodland on sandy soil.

Figure 5.6 *Kirkia acuminata – Melinis repens* Tall Closed Woodland on flat rock outcrop terrain group.

BECVOL estimates suggested that the woody species in the *Acacia tortilis* – *Enneapogon cenchroides* Short Open Woodland on old fields and borrow pits (Figure 5.7) contribute modestly to the browse on the property in that accessibility to smaller browsers was good. However, the total availability was low.

Figure 5.7. *Acacia tortilis* – *Enneapogon cenchroides* short open woodland on old fields and borrow pits.

Contrarily the area represented by the *Terminalia prunoides* – *Colophospermum mopane* Tall Closed Shrubland, of dry water courses (Figure 5.8) was a poor contributor of browse, not only due to paucity of foliage but due to tall plants with less accessible browse.

Figure 5.8. *Terminalia prunoides* – *Colophospermum mopane* Tall Closed Shrubland of dry water course.

Figure 5.9. *Pupalia lappacea – Acacia nigriscens* Riparian Thicket.

Estimates of community 1, the *Pupalia lappacea – Acacia nigriscens* Riparian Thicket (Figure 5.9), reflected an abundance of foliage, with large and small trees interspersed. Browse <5 m at 7 822 kg per ha was at a high level, comparable with *Boscia albitrunca – Commiphora edulis* Short Closed Woodland.

5.2.4 Phytosociological mapping

Analysis of field data indicated communities which closely matched the stereo-photograph based original physiographic-physiognomic map. An overlay coloured according to relevé groups is presented in Figure 5.10.

The final phytosociological table resulting from data analysis was used for completion of the physiographic map and for providing a key broadly describing the vegetation in the plant communities that the map areas represent and the total area of each plant community (Figure 5.11).

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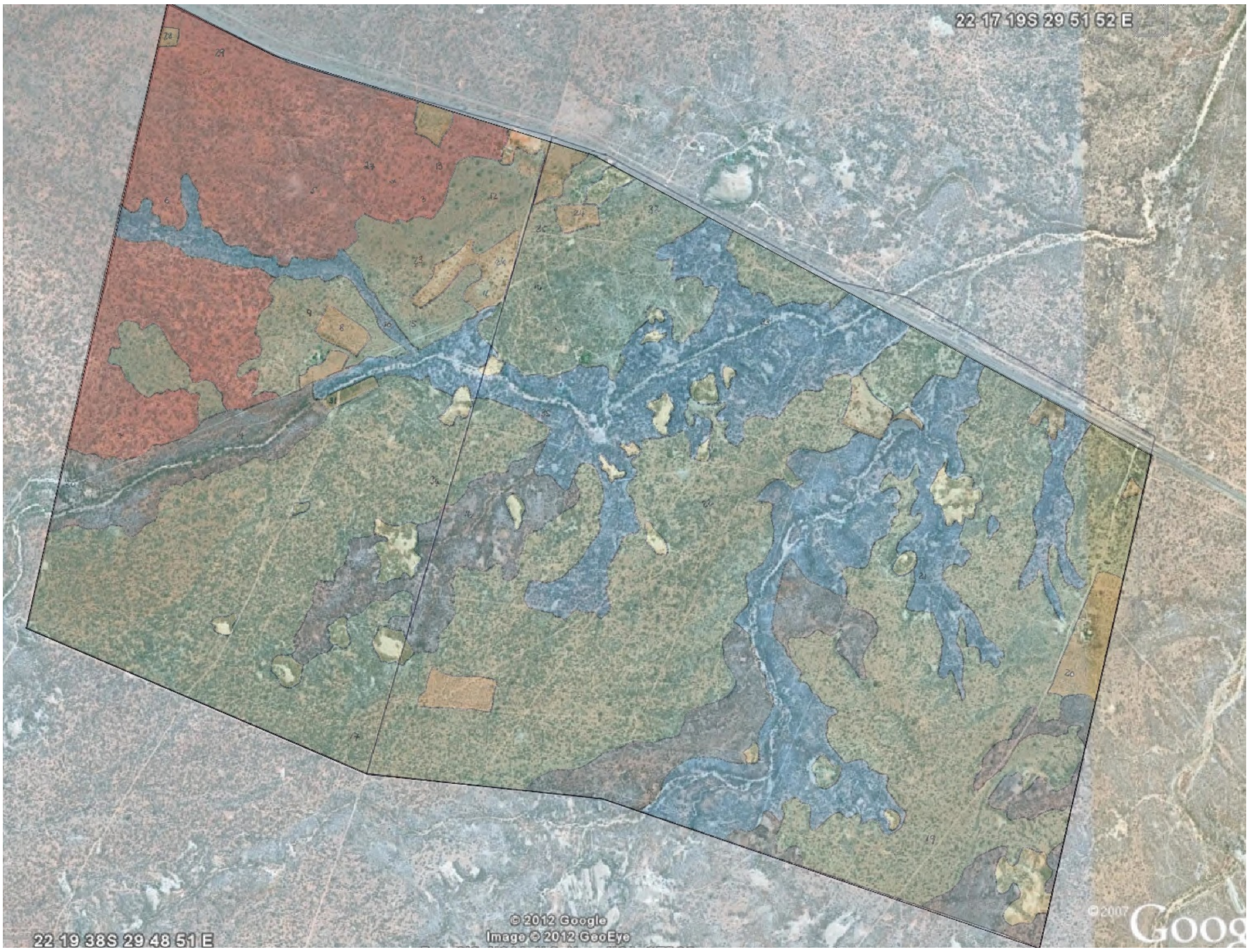
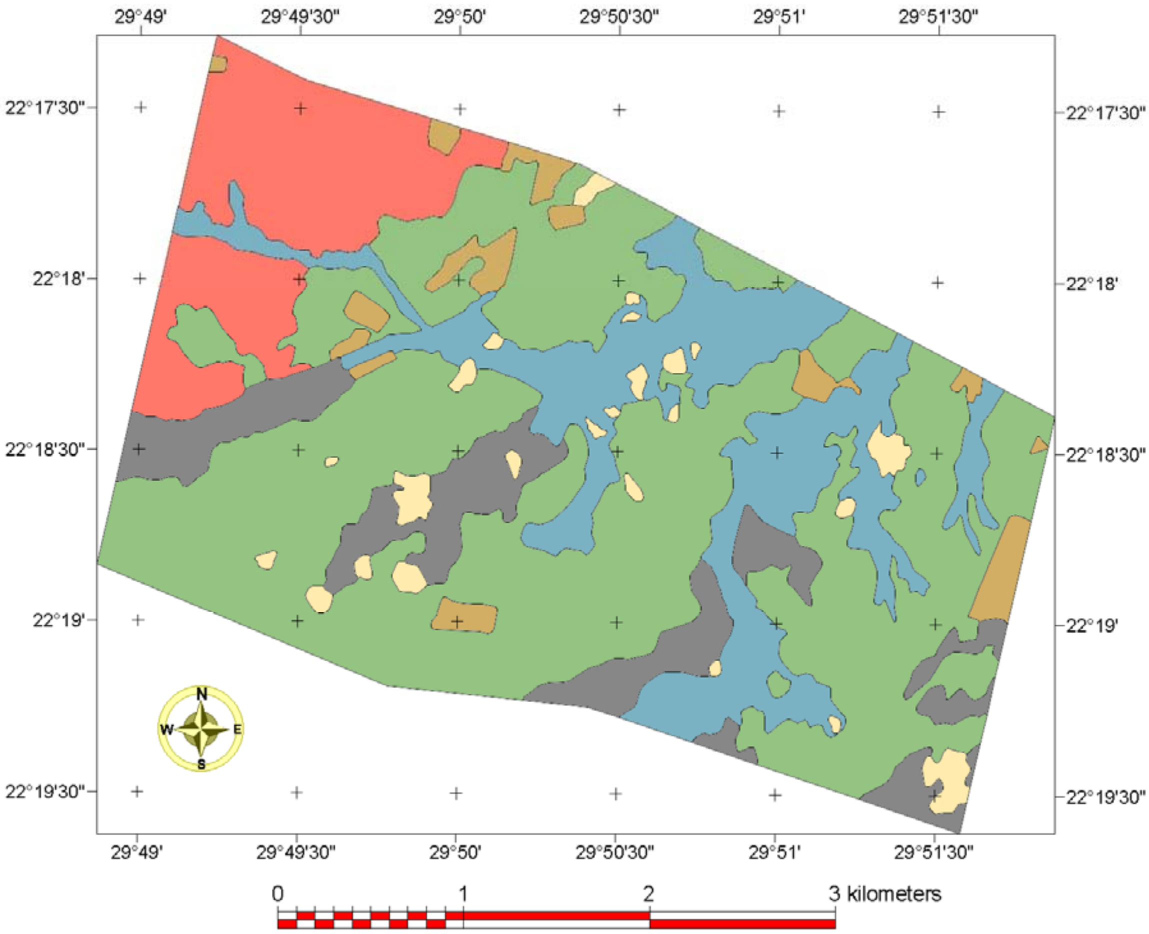


Figure 5.10: An overlay coloured in accordance with the floristic analysis of plant communities in preparation for a final vegetation map.



No	Colour key	Plant communities	Area (ha)	% of total area
1	*Blue*	*Pupalia lappacea* □ *Acacia nigrescens* Riparian Thicket	242.11	18.33
2	*Red*	*Kirkia acuminata* □ *Melinis repens* Tall Closed Woodland on flat rocky outcrops	169.10	12.80
3	*Green*	*Boscia albitrunca* □ *Commiphora edulis* Short Closed Woodland on sandy soils	689.67	52.21
4	*Brown*	*Acacia tortilis* □ *Enneapogon cenchroides* Short Open Woodland on old fields and borrow pits	46.83	3.55
5	*Grey*	*Terminalia prunoides* □ *Colophospermum mopane* Tall Closed Shrubland of dry water courses	139.37	10.55
6	*Cream*	*Colophospermum mopane* □ *Grewia bicolor* Tall Closed Woodland on granite outcrops	33.85	2.56
		Total	**1320.92**	**100.0**

Figure 5.11: Final map showing plant communities on Evelyn Game Ranch, based on the final phytosociological table and calculation of the areas of each community.

5.3 PHYTOSET PROCEDURES

5.3.1 Mapping

The pixels of the study area in the digital Google Earth image in Figure 4.1 were dichotomously defined in sequence according to a pixel frequency histogram. The classifier that is contained in the PHYTOSET program package (Westfall 2008) was used for this purpose.

The initial classification of the satellite image of the study area, with median filtering corresponding to 1:12 000 scale, indicated six homogeneous vegetation units. This corresponded with a visual reconnaissance of the study area. The six homogeneous units were used as the basis to select random sample sites or relevés (Figure 4.2).

5.3.2 Floristic classification by PHYTOSET procedures

Random sampling sites as shown in Figure 4.2 were used as the basis for selection of relevés. Eighteen sites were selected representative of the surrounding area in each situation.

The PHYTOSET program floristically analysed the field data and sequenced the sample sites to yield a matrix (Table 5.4). Species are on the y axis and their occurrence in the sample sites is indicated in the rows by plant number. Sample sites are on the x axis and species in each is indicted by corresponding plant number in the columns.

Table 5.4: PHYTOSET phytosociological table: classification of sample sites (x-axis) grouped into communities (stippled lines) with species (y-axis) grouped into distribution ranges. Plant Number Scale codes in the matrix are used only to indicate presence.

Community number				1					2						3					
Relevé numbers	16	14	15	17	13	7	3	1	5	18	2	4	10	8	6	11	12	9	Species	SU"s
Acacia tortilis subsp. *heteracantha*	7	D		+		3													4	2
Waltheria indica			2	+					1										3	4
Indigofera nebrowniana		4		7															2	1
Acacia nigrescens					+	1	B												3	0
Enneapogon cenchroides							+	1	3										3	0
Sclerocarya birrea								1		5									2	1
Adansonia digitata					1				3	+									3	3
Commiphora mollis							9	+											2	0
Terminalia prunioides											+	5	1	G		8		F	6	2
Aptosimum lineare				2								2		5	9	A	+	6	7	8
Commiphora merkeri													7	2	3		1		4	1
Asparagus suaveolens									+		1	+				+	+		5	4
Melhania rehmannii		3										+			+	3	+		5	11
Grewia occidentalis							+				+				+				3	6
Commiphora glandulosa															B			9	2	2
Commiphora edulis			5										E	7					3	9
Eragrostis sp.														2				2	2	3
Panicum maximum						4	9	7	1	8	4	3				+		1	9	4
Combretum apiculatum				9			E	3	3		4	9		4	1				8	4
Stipagrostis uniplumis	1						8			1	4	1				+	3		7	10
Kirkia acuminata							6	1	5	E	J		+						6	1
Melinis repens									1	4	+	2							4	0
Digitaria velutina	2	9	B	B	E	3	D	C	H	L	2	L	G	A	9	4	7	E	18	0
Aristida adscensionis	E	G	F	G	D		5	C	+	5	7	2	H	8	2	A	B	8	17	1
Grewia bicolor		1	5	2	A	5	4	B	5	B	4	9	G	F	B	5	9	G	17	0
Schmidtia pappophoroides	B	4	+		6	A	1	6	+	+	2	+		J	9	5	2	7	16	2
Terminalia prunioides shrub	1			4	9	B	5	B	3	9	4	6	+	+	9	2	8	4	16	2
Eragrostis trichophora	3		6	5	C		5	A	1	5		2	4	1	E	5	D	6	15	3
Kyphocarpa angustifolia			+	1	1	1	+	2	2	+	+	+	+	+	1	+	+		15	0
Colophospermum mopane shrub	+		2	5	9	A	B	4	1	5	+	3		J		B	A	3	15	3
Ptycholobium contortum		1		2	2	3			5	+		+	1	1	1	+	2		12	4
Megalochlamys revoluta		2	+	1			2	7		2	1		2	5		+			10	5
Dichrostachys cinerea	5	7	+	1		+	+	2		3						5	1		10	7
Eragrostis lehmanniana	+	+			3	5		2		+		3		1	+	1			10	6
Colophospermum mopane			2	5		5	6	B			7	3		J		F		3	10	6
Dicoma tomentosa		2	2	+	+				6	+	2	2	+						9	3
Ocimum americanum	5		2	+	2				1			1				+	+	4	9	9
Tephrosia purpurea		4		1	1			+	+	2	8	4		+					9	4
Grewia flavescens var. *flavescens*					3	7	3	+		8	1		4	B					8	2
Grewia villosa			+		+			+		4	+			3				3	7	9
Indigastrum parviflorum	F		G	C									5			+	6	8	7	11
Sida dregei					+	+			+	+	3					+			6	6
Achyranthes aspera		3	+							+	+				+				5	9
Gymnosporia buxifolia				1	+		+				1								4	4
Abutilon angulatum var. *angulatum*						1				+				2	+				4	6
Eragrostis superba								+											1	0
Setaria verticillata						9													1	0
Pechuel-loescha leubnitziae						2													1	0
Digitaria eriantha											2								1	0
Barleria crossandriformis														B					1	0
Grewia flava															7				1	0
Unidentified forb No. 1																	3		1	0
Unidentified forb No. 2			4																1	0
Kyllinga alba									+										1	0
Asparagus sp.									1										1	0
Boscia albitrunca													+						1	0
Cenchrus ciliaris								3											1	0
Acacia senegal								+											1	0
Indigofera sp																		2	1	0
Kirkia wilmsii															5				1	0
Heteropogon contortus											4								1	0
Ceratotheca triloba		2																	1	0
Maytenus heterophylla				1															1	0
																			360	178

SU column:
The number of non-occurrences or those of the gaps, termed separation units, in the species row concerned between the first and last occurrence of that species across sample sites from left to right in the matrix.

Species column:
The number of sample sites across the matrix in which the species concerned occurred.

The SU column shows the number of non-occurrences or those of the gaps, termed separation units, in the species row concerned between the first and last occurrence of that species across sample sites from left to right in the matrix (178). The species column shows the number of sample sites across the matrix in which the species concerned occurred.

The total number of cells in the matrix (1134) is the product of the number of sample sites (18) and species recorded (63). All gaps (774) are the difference between the total number of cells in the matrix (1134) and the total of species occurrences (360) and are therefore not just included gaps (Westfall 1992). Hence classification efficiency was obtained using the equation:

$$E\% = 100 - \frac{(178 \times 100)}{774}$$

$$= 77$$

The efficiency of the floristic classification (Table 5.4) at 77% is well above the 62% threshold of the method as set in Westfall et al*.* (1996).

5.3.3 Cover analysis

Within each community a regression of the mean crown cover of all the species for a growth form class against their respective number was generated. Deviations of individual species' crown cover to number from what was predicted were identified. Species that were inferred to be 'strong competitors' and those that were inferred to be 'weak competitors' are shown in Tables 5.5, 5.6 and 5.7.

For each species frequency (F) indicating the number of relevés in the community concerned, in which specimens of that species were identified, is listed together with an actual cover, predicted cover according to the regression and difference between actual and predicted cover. Positive differences above the standard error of the mean indicate 'strong competitors' and negative differences below the standard error of the mean indicate 'weak competitor' species for each regression.

Table 5.5: Analysis of the composition of community 1 per growth form, showing actual percentage cover, percentage cover predicted by PHYTOSET from the cover frequency relationship and the difference between the two and total cover per growth form.

Growth form	'Competition' range	Species	F	Actual cover (%)	Predicted cover (%)	Difference (%)	Total cover for growth form (%)
Trees							1.36
	Normal	*Commiphora edulis*	1	0.42	0.12	+0.30	
		Colophospermum mopane	3	0.91	0.71	+0.20	
		Adansonia digitata	1	0.02	0.12	-0.10	
	Weak	*Acacia nigrescens*	2	-.02	0.41	-0.40	
Shrubs							17.34
	Strong	*Acacia tortilis* subsp. heteracantha	4	3.82	2.33	+1.48	
		Terminalia prunioides shrub	4	3.6	2.33	+1.35	
		Combretum apiculatum	1	1.36	0.26	+1.11	
	Normal	*Colophospermum mopane* shrub	5	3.53	3.02	+0.51	
		Grewia flavescens var. *flavescens*	2	0.97	0.95	+0.03	
		Pechuel-loeschia leubnitziae	1	0.07	0.26	-0.19	
		Maytenus heterophylla	1	0.02	0.26	-0.24	
		Grewia bicolor	5	2.60	3.02	-0.42	
		Gymnosporia buxifolia	2	0.02	0.95	-0.93	
		Grewia villosa	2	0.00	0.5	-0.94	
	Weak	*Dichrostachys cinerea*	5	1.26	3.02	-1.76	
Dwarf shrubs							2.46
	Strong	*Indigofera nebrowniana*	2	1.09	0.30	+0.80	
	Normal	*Ocimum americanum*	4	0.56	0.47	+0.08	
		Unidentified species No.1	1	0.27	0.21	_0.06	
		Melhania rehmannii	1	0.15	0.21	-0.06	
		Ptycholobium contortum	4	0.30	0.47	-0.17	
		Abutilon angulatum var. *angulatum*	1	0.02	0.21	-0.19	
		Waltheria indica	2	0.07	0.30	-0.23	
		Sida dregei	2	0.00	0.30	-0.29	
Grasses							37.86
	Strong	*Aristida adscensionis*	5	18.51	7.98	+10.53	
	Normal	*Setaria verticillata*	1	1.36	-0.01	+1.38	
		Panicum maximum	1	0.27	-0.01	+0.28	
		Stipagrostis uniplumis	1	0.02	-0.01	+0.03	
		Digitaria velutina	6	8.94	9.98	-1.04	
		Eragrostis trichophora	4	3.60	5.98	-2.39	
		Schmidtia pappophoroides	5	4.59	7.98	-3.39	
	Weak	*Eragrostis lehmanniana*	4	0.57	5.98	-5.41	
Forbs							11.36
	Strong	*Indigastrum parviflorum*	3	10.50	1.57	+8.93	
	Normal	*Aptosimum lineare*	1	0.07	0.76	-0.69	
		Ceratotheca triloba	1	0.07	0.76	-0.69	
		Achyranthes aspera	2	0.15	1.17	-1.01	
		Tephrosia purpurea	3	0.30	1.57	-1.27	
		Megalochlamys revoluta	3	0.09	1.57	-1.49	
		Dicoma tomentosa	4	0.14	1.98	-1.84	
		Kyphocarpa angustifolia	4	0.05	1.98	-1.93	

Table 5.6: Analysis of the composition of community 2 per growth form, showing actual percentage cover, percentage cover predicted by PHYTOSET from the cover frequency relationship and the difference between the two and total cover per growth form.

Growth form	'Competition' range	Species	F	Actual cover (%)	Predicted cover (%)	Difference (%)	Total cover for growth form (%)
Trees							16.44
	Strong	*Acacia nigrescens*	1	3.05	1.00	+2.05	
	Normal	*Colophospermum mopane*	2	3.96	2.49	+1.47	
		Kirkia acuminata	4	6.50	5.47	+1.03	
		Commiphora mollis	2	2.05	2.49	-0.44	
		Sclerocarya birrea	2	0.65	2.49	-1.84	
	Weak	*Adansonia digitata*	2	0.23	2.49	-2.26	
Shrubs							25.17
	Strong	*Combretum apiculatum*	3	5.39	3.26	+2.13	
		Grewia bicolor	4	7.13	5.13	+2.01	
	Normal	*Terminalia prunioides* shrub	4	5.95	5.13	+0.83	
		Gymnosporia buxifolia	1	0.00	-0.47	+0.47	
		Acacia senegal	1	0.00	-0.47	+0.47	
		Grewia occidentalis	1	0.00	-0.47	+0.47	
		Grewia villosa	2	0.41	1.40	-0.99	
		Colophospermum mopane shrub	4	4.11	5.13	-1.02	
		Grewia flavescens var. *flavescens*	3	1.84	3.26	-1.42	
	Weak	*Dichrostachys cinerea*	3	0.33	3.26	-2.93	
Dwarf shrubs							0.72
	Strong	*Ptycholobium contortum*	2	0.63	0.32	+0.31	
	Normal	*Asparagus* sp.	1	0.03	0.02	+0.01	
		Ocimum americanum	1	0.03	0.02	+0.01	
		Waltheria indica	1	0.03	0.02	+0.01	
		Asparagus suaveolens	1	0.00	0.02	-0.01	
		Abutilon angulatum var. *angulatum*	1	0.00	0.02	-0.01	
	Weak	*Sida dregei*	2	0.00	0.32	-0.31	
Grasses							43.48
	Strong	*Digitaria velutina*	4	26.28	7.39	+18.89	
	Normal	*Cenchrus ciliaris*	1	0.23	-1.08	+1.31	
		Kyllinga alba	1	0.00	-1.08	+1.08	
		Eragrostis superba	1	0.00	-1.08	+1.08	
		Stipagrostis uniplumis	2	1.64	1.74	-0.1	
		Melinis repens	2	0.43	1.74	-1.31	
		Eragrostis lehmanniana	2	0.10	1.74	-1.64	
		Panicum maximum	4	4.92	7.39	-2.47	
		Aristida adscensionis	4	4.89	7.39	-2.50	
		Eragrostis trichophora	4	3.81	7.39	-3.58	
		Enneapogon cenchroides	3	0.25	4.56	-4.31	
		Schmidtia pappophoroides	4	0.94	7.39	-6.45	
Forbs							2.66
	Strong	*Megalochlamys revoluta*	3	1.44	0.56	+0.88	
	Normal	*Dicoma tomentosa*	2	0.91	0.49	+0.42	
		Achryranthes aspera	1	0.00	0.42	-0.42	
		Kyphocarpa angustifolia	4	0.20	0.63	-0.42	
		Tephrosia purpurea	3	0.11	0.56	-0.45	

Table 5.7: Analysis of the composition of community 3 per growth form, showing actual percentage cover, percentage cover predicted by PHYTOSET from the cover frequency relationship and the difference between the two and total cover per growth.

Growth form	Competition range	Species	F	Actual cover (%)	Predicted cover (%)	Difference (%)	Total cover for growth form (%)
Trees							26.72
	Strong	*Kirkia acuminata*	2	4.55	2.24	+2.31	
		Colophospermum mopane	5	8.23	6.02	+2.21	
	Normal	*Commiphora edulis*	2	3.09	2.24	+0.85	
		Commiphora glandulosa	2	2.55	2.24	+0.31	
		Terminalia prunioides	6	7.19	7.28	-0.08	
		Kirkia wilmsii	1	0.31	0.98	-0.66	
		Boscia albitrunca	1	0.00	0.98	-0.97	
	Weak	*Commiphora viminea*	4	0.79	4.76	-3.96	
Shrubs							28.15
	Strong	*Grewia bicolor*	8	13.37	8.07	+5.30	
	Normal	*Colophospermum mopane*	6	7.56	5.60	+1.97	
		Grewia flava	1	0.62	-0.59	+1.21	
		Unidentified forb No. 1	1	0.11	-0.59	+0.70	
		Gymnosporia buxifolia	1	0.01	-0.59	+0.60	
		Grewia flavescens var. *flavescens*	3	1.74	1.88	-0.15	
		Dichrostachys cinerea	2	0.33	0.65	-0.32	
		Grewia occidentalis	2	0.00	0.65	-0.64	
		Grewia villosa	3	0.23	1.88	-1.66	
		Combretum apiculatum	4	1.44	3.12	-1.68	
	Weak	*Terminalia prunioides*	8	2.74	8.07	-5.33	
Dwarf shrubs							2.18
	Strong	*Blepharis crossandriformis*	1	1.52	0.52	+1.01	
	Normal	*Ptycholobium contortum*	6	0.09	-0.10	+0.19	
		Ocimum americanum	4	0.22	0.15	+0.07	
		Melhania rehmannii	4	0.12	0.15	-0.03	
		Asparagus suaveolens	4	0.02	0.15	-0.13	
		Sida dregei	2	0.12	0.40	-0.28	
		Abutilon angulatum var. *angulatum*	2	0.05	0.40	-0.34	
		Indigofera sp.	1	0.05	0.52	-0.47	
Grasses							36.59
	Strong	*Digitaria velutina*	8	14.40	8.93	+5.47	
	Normal	*Heteropogon contortus*	1	0.20	-1.86	+2.06	
		Digitaria eriantha	1	0.05	-1.86	+1.91	
		Eragrostis sp.	2	0.10	-0.32	+0.42	
		Melinis repens	2	0.05	-0.32	+0.37	
		Aristida adscensionis	8	8.76	8.93	-0.18	
		Schmidtia pappophoroides	7	6.60	7.39	-0.79	
		Eragrostis trichophora	7	5.63	7.39	-1.76	
	Weak	*Stipagrostis uniplumis*	4	0.33	2.77	-2.44	
		Panicum maximum	4	0.33	2.77	-2.44	
		Eragrostis lehmanniana	4	0.14	2.77	-2.63	
Forbs							6.19
	Strong	*Aptosimum lineare*	6	3.10	1.30	+1.80	
	Normal	*Indigastrum parviflorum*	4	1.58	0.85	+0.72	
		Tephrosia purpurea	3	1.01	0.63	+0.38	
		Achryranthes aspera	2	0.00	0.40	-0.40	
		Megalochlamys revoluta	4	0.38	0.85	-0.47	
		Dicoma tomentosa	3	0.10	0.63	-0.52	
	Weak	*Kyphocarpa angustifolia*	7	0.02	1.53	-1.51	

Classification of the floristic data by PHYTOSET indicated only three plant communities that were sufficiently different to be considered coherent communities (Table 5.4). In view of this, the pattern of the satellite image, with some increase in mean standard deviation, was restratified, grouping together smaller units to yield a three unit vegetation map (Figure 5.12).

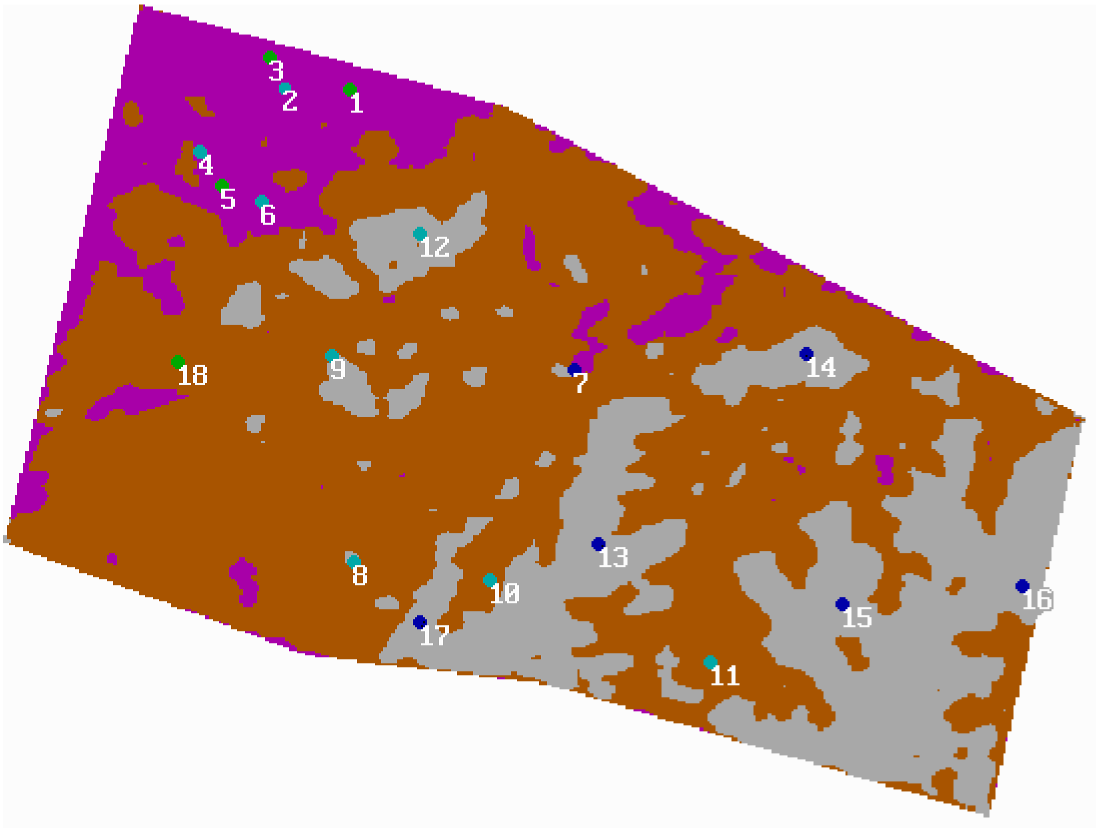


Figure 5.12: Google satellite image pattern refined after floristic classification suggesting plant communities; mapping unit 1 (grey) is 317 ha; mapping unit 2 (magenta) is 177 ha; mapping unit 3 (brown) is 799 ha. Numbered sample sites showing floristic grouping; community 1 (blue); community 2 (green); community 3 (turquoise).

Community delimitation is based on floristic classification. Sample sites in their eventual sequence were grouped based on the degree of species difference allowed between sample sites. The position of sample sites in these groups may be compared with their locations in the areas of maps generated from satellite image stratification in correspondence tables.

The floristic classification was compared to the satellite imagery with median filtering corresponding to 1:12 000 scale. The degree of correspondence between satellite image stratification and vegetation classification was determined. However, improved correspondence was obtained with satellite imagery filtered with a 7 x 7 pixel median filter corresponding to 1:9 000 scale (Table 5.8). Figure 5.12 is the three vegetation unit map generated with the median filter corresponding to 1:9 000 scale.

Table 5.8 is the correspondence table showing a similarity matrix for samples grouped according to the floristic classification (set A) and according to the satellite map filtered for 1:9 000 scale (set B). Overall, the correspondence between the two approaches was 76%. Relevés 2 (community 3, mapping unit 2); 6 (community 3, mapping unit 2); 12 (community 3, mapping unit 1); and 18 (community 2, mapping unit 3) were misplaced on the Google imagery, while 9 and 8 are also misplaced on the figure. Ground truthing suggested that the placement of these sample sites was as indicated in the floristic classification. Correspondence was closer when filtering with a 7 x 7 pixel median filter relating to 1:9 000 scale than when the 9 x 9 pixel median filter was used, which relates to scale 1:12 000.

Table 5.8: Matrix showing percentage correspondence between the floristic classification (Set A) and satellite image filtered for 1:9 000 scale for sample site placement (Set B).

		Set A			Correspondence
		1	2	3	
Set B	1	92	0	13	92
	2	0	66	30	66
	3	0	20	71	71
Mean correspondence					76%

5.3.4 Standing biomass of graminoids

Table 5.9 shows the analysis of the grass and sedge canopy cover and gives an estimation of their standing biomass at the time of sampling.

TABLE 5.9: Mean cover (%) and standing biomass (kg/ha) of grasses and sedges on Evelyn Game Ranch.

	Community 1		Community 2		Community 3	
	Mean cover (%)	Mean biomass (kg/ha)	Mean cover (%)	Mean biomass (kg/ha)	Mean cover (%)	Mean biomass (kg/ha)
Artistida adscensionis	18.5	468.6	4.9	287.3	8.8	393.7
Cenchrus ciliaris			0.2	48.3		
Digitaria eriantha					0.1	16.6
Digitaria velutina	8.9	392.6	26.3	680.0	14.4	479.9
Enneapogon cenchroides			0.3	71.0		
Eragrostis lehmanniana	0.6	89.5	0.1	38.7	0.1	44.1
Eragrostis sp.					0.1	33.2
Eragrostis superba			<0.1	5.5		
Eragrostis trichophora	3.6	227.8	3.8	288.2	5.6	273.9
Heteropogon contortus					0.2	31.0
Kyllinga alba			<0.1	5.5		
Melinis repens			0.4	79.2	0.1	19.4
Panicum maximum	0.3	41.4	4.9	334.5	0.3	66.6
Schmidtia pappophoroides	4.6	268.5	0.9	114.6	6.6	280.9
Setaria verticillata	1.4	76.3				
Stipagrostis uniplumis	0.0	11.4	1.6	123.3	0.3	66.6
Total	37.9	1576.1	43.5	2076.4	36.6	1705.7

5.3.5 Growth form analysis

The PHYTOSET program generated an analysis of the percentage that each growth form contributed to the total canopy cover in each community. The analysis was helpful in providing an overview of the state of dynamic interplay between woody and herbaceous species per community in the study area. Comparative percentages of growth forms are shown in Figure 5.13.

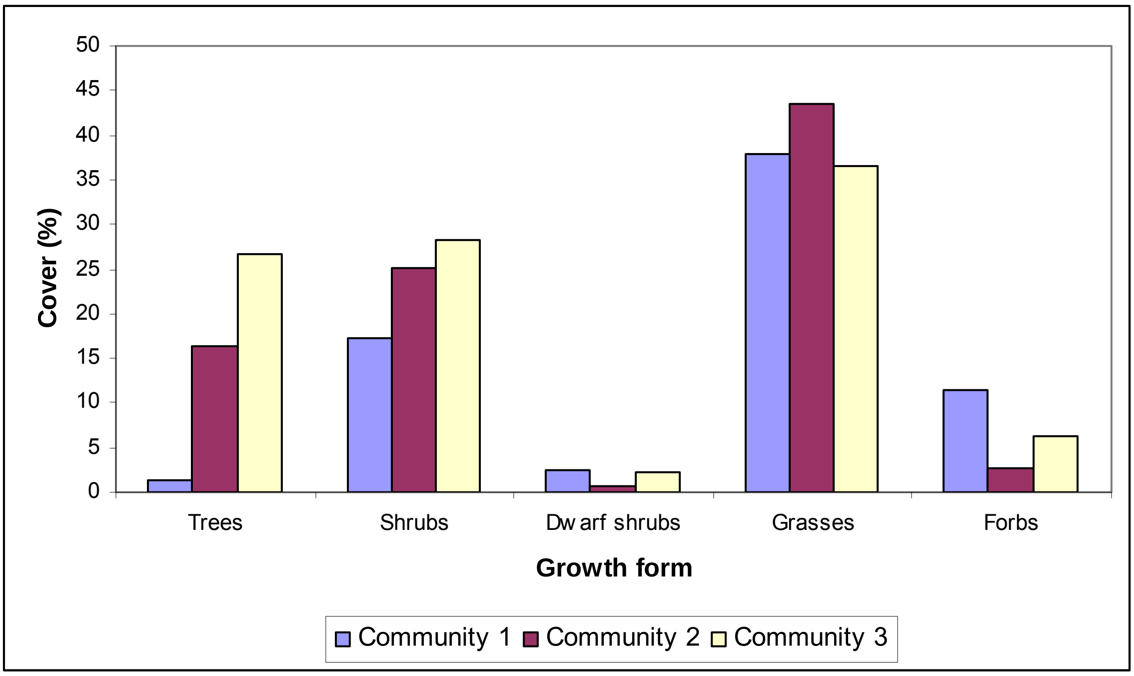


Figure 5.13: Percentage cover of five growth forms in three communities on Evelyn Game Ranch estimated by means of PHYTOSET from frequency and mean crown diameter of species comprising the five growth forms recorded in the sample sites representing the three communities.

5.3.6 Description of plant communities

Species have been arranged in Table 5.4 to indicate diagnostic ranges of species within each community and across communities. *Acaciella tortilis* subsp. *heteracantha* (former *Acacia tortilis* subsp. *Heteracantha)* and *Indigofera nebrowniana* are diagnostic for Community 1, *Commiphora mollis* and *Enneapogon cenchroides* characterise community 2 and *Terminalia prunioides* (tree growth form) and *Aptosimum lineare* characterise Community 3.

Community 1: *Acacia tortilis* subsp. *heteracantha – Indigofera nebrowniana* Woodland (Figure 5.9)

The mapping unit to which this community corresponded covered 317 ha (Figure 5.12). ‘Strong competitors’ among the shrubs were *Acaciella tortilis* subsp. *heteracantha* (former *Acacia tortilis* subsp. *heteracantha), Terminalia prunioides* and *Combretum apiculatum,* whereas *Acaciella nigrescens* (former *Acacia nigrescens)* was a ‘weak competitor’ (Table 5.5). Pioneer grasses dominated the open areas, while *Digitaria velutina* and *Panicum maximum* dominated the spaces under the trees and shrubs. The richness of grass species was poorest in this community with the standing biomass of the graminoid component estimated at 1 576 kg per ha (Table 5.9).

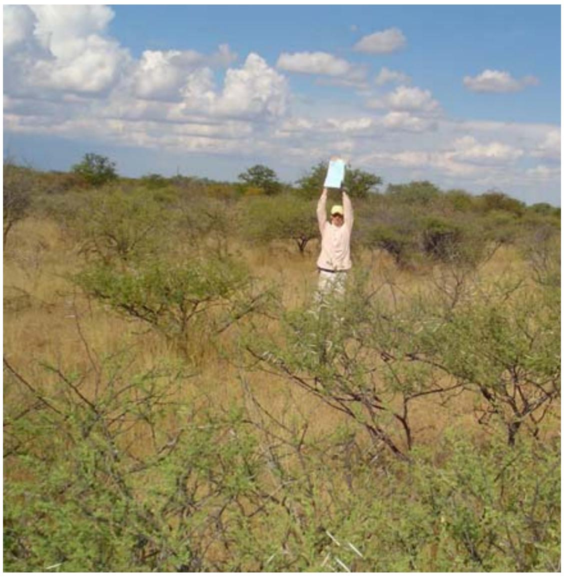


Figure 5.14 *Community 1: Acacia tortilis* subsp. *heteracantha* **–** *Indigofera nebrowniana* Woodland at sample site 16.

Community 2: *Commiphora mollis* – *Enneapogon cenchroides* Woodland (Figure 5.10)

Floristically this community was transitional between communities 1 and 3. The mapping unit to which it corresponded covered 177 ha (Figure 5.12). *Acaciella nigrescens* (former *Acacia nigrescens)* was a 'strong' tree competitor (Table 5.6). The 'strong' grass competitor, *Digitaria velutina,* dominated under trees and shrubs. The species richness of grasses was higher than in community 1 (Table 5.9). Community 2 is largely in the northwest of the study area. The vegetation there is classified by Mucina & Rutherford (2006) as Musina Mopane Bushveld, whereas the rest of the study area is largely Limpopo Ridge Bushveld. An important feature which sets Musina Mopane Bushveld apart from Limpopo Ridge Bushveld is denser grass cover especially where soils are deep (Mucina & Rutherford 2006). This is borne out in the study where standing biomass of grasses and sedges (Table 5.9) estimated at 2 076 kg per ha is the highest.

Community 3: *Terminalia prunioides – Aptosimum lineare* Woodland (Figure 5.11)

The mapping unit to which this community corresponded covered 799 ha (Figure 5.12). *Colophospermum mopane* was a 'strong' contributor in both tree and shrub growth forms (Table 5.7). There were parts of the study area where this species was so dominant. that other species appeared to have been forced out. However, *Grewia bicolor* cover exceeded that of all other species in this particular community. The species richness of

Figure 5.15: Community 2: *Commiphora mollis* – *Enneapogon cenchroides* Woodland, sample site 1.

grass was fair in comparison with that of the other two communities. *Digitaria velutina* was a 'strong' competitor. However, as the tree and shrub cover was so high in this community, 14.4% cover by *Digitaria velutina* was not surprising and this species contributed most to the estimated 1 706 kg per ha of standing biomass of graminoids (Table 5.9). Limpopo Ridge Bushveld is typically moderately open savanna with sparse grass, forb and dwarf shrub cover. This feature was evident in the study area.

Figure 5.16: Community 3 *Terminalia prunoides* – *Aptosimum lineare* Woodland at sample site 11.

CHAPTER 6: DISCUSSION

6.1 BRAUN-BLANQUET PROCEDURES

6.1.1 Physiographic-physiognomic mapping

Mapping the boundaries of features that would indicate the position of plant communities requires practical experience in interpretation of aerial photographs. It is important that the initial mapping is done thoroughly as potential sample sites for Braun-Blanquet relevés are selected from this map (Bothma et al. 2004). Relevance of vegetation stratification depends on sample sites being representative of the features that are mapped and after analysis placing mapping entities into groups that are phytosociologically distinct. The end result must be a vegetation map on which wildlife managers can rely for the positions and extent of defined vegetation types.

Advantages of drawing off a stereo pair of aerial photographs is that one can map areas with specific diagnostic features. It does not hinder isolation of areas for individual attention or removal from general stratification. It also allows investigation of mapping units that might be different floristically in the knowledge that they can be joined after the analytical and synthetic phases of investigation if not different.

The disadvantage of this approach is subjectivity on the part of the person drawing the initial map. In the case of non-georectified aerial photographs, radial distortions, altitude-related scale differences and often inconvenient scales, hinder precise vegetation mapping (Malan & Westfall 1987). The use of georectified aerial photographs will avoid these disadvantages.

6.1.2 Classification using Braun-Blanquet procedures

Table 5.1 shows the differential phytosociological table with 13 species groups and five communities. The patterns that were achieved serve as a useful tool by which to identify any part of the study area with one of five communities that were eventually identified. In this way subdivision of community 3 was corroborated by 3(a) having a closer relationship with community 2 than the other, 3(b).

Groupings are diagnostic of community commonality. The groupings have potential value to wildlife managers in identifying problems and anticipating the extent to which management will need to be applied throughout the property after their discovery in a particular location.

The five groups finally corresponded with the physiographic-physiognomic mapping. Relevés 25 and 23 were moved to the groups with which they appeared better associated with due regard for their positions on the physiographic-physiognomic map.

There is an element of subjectivity in the manipulation. There is also an inherent problem with classification of data that are not ordinal and therefore not suited to mathematical analysis, as is the case with Braun-Blanquet cover-abundance data (Van Der Maarel 2007). However, this was addressed by converting the cover-abundance values to the mid-points of the percentage cover classes. There is necessity for objective checking the outcome after spreadsheet manipulation with an ordination process from the raw data. Derivation of ordinal values from cover-abundance data as described was essential.

6.1.3 BECVOL and description of plant communities

Braun-Blanquet cover-abundance results were not sufficiently descriptive of the plant communities. Results of the BECVOL model were used to address this shortcoming. The quantitative aspects of BECVOL augment the non-iterative nature of values used in Braun-Blanquet cover-abundance classification.

BECVOL procedures did not require the same intensity of sampling as for cover-abundance data. Care was taken to select sites that were typical of each plant community. However the reduction in number of sample sites added to subjectivity of the Braun-Blanquet procedures.

6.1.4 Vegetation mapping

The affinities of the sample plots in the differential table (Table 5.1) were used to compare with the physiographic-physiognomic map and to produce a vegetation map. The floristic data were ordinated directly from the raw data matrix using PCoA in the SYN-TAX 2000 computer program (Podani 2001). The outcome corresponded well with the phytosociological table.

Further descriptions of the communities resulting from BECVOL analysis are presented in Table 5.3. Here the nomenclature of Edwards (1983) is used. In generating the vegetation map, the map areas were calculated and the total area of each kind of plant community is shown in the key.

The final vegetation map (Figure 5.11) is a valuable wildlife management tool.

6.2 PHYTOSET PROCEDURES

6.2.1 Protocols in the use of geospatial metadata

It is important that metadata are generated and accessible in a way that is relevant and consistent, and also that the detailed methods, are clearly recorded (Wayne 2005). This is the case with metadata generated by the Google image classifier in this study. The resultant metadata require scrutiny in a detached evaluation setting (Orland et al. 2001).

As it is incumbent on the professional concerned to be knowledgeable about the aspect of the environment being investigated, sample identities were verified by comparison with specimens at the HGWJ Schweikerdt Herbarium. An objective outcome has been achieved.

6.2.2 Mapping

Both satellite image stratification and PHYTOSET floristic classification were objective and consequently repeatable. However, the sampling scale of 1:12 000 meant that narrow vegetation units such as riparian vegetation were included in larger units. Furthermore the extremes of about 15% of the pixel mean reflectance values were effectively removed from the mapping process. In the process pixels probably representing some of the dense riparian vegetation in the study area were omitted from classification. This is a negative aspect of the PHYTOSET programme.

The resultant metadata were presented in the form of vegetation maps (Figures 4.2 and 5.12). This was a simplified form of the processes used in Westfall & Malan (1986) and Malan & Westfall (1987).

Filtering the resultant output for scale using median of 7 X 7 and 9 X 9 pixels, commensurate with ground scales of 1:9000 and 1:12000 respectively (Westfall 2008[3]) provided options for correlation of classifications of satellite imagery and floristic data .

Calculation by the pixel classifier of the areas for each suggested vegetation unit is essential for eventual use of assessments for management purposes.

[3] Dr R.H. Westfall may be consulted regarding the classification of images supported by satellite imagery, satellite imagery and the PHYTOSET computer package.

The initial classification of the satellite image of the study area, with median filtering corresponding to 1:12 000 scale, indicated six homogeneous suggested vegetation units. This corresponded with a visual reconnaissance of the study area. The six homogeneous units were used as basis to select random sample sites or relevés. The selected relevé sites are shown in Figure 5.13.

6.2.3 Classification by PHYTOSET procedures

Six sampling sites were programmatically generated for random placement in each of the six initially homogeneous units that are shown in Figure 4.2. Ideally four or more sites should be sampled in each potential vegetation unit (Westfall et al. 1996). This was important as many of these potential sample sites were unsuitable. Some were in ecotones, others in disturbed areas, and yet others did not appear to be representative of the surrounding vegetation.

Species

Most of Evelyn Game Ranch falls within the Limpopo Ridge Bushveld with the Musina Mopane Bushveld covering the North-western part of the ranch (Mucina et al. 2005, Mucina & Rutherford 2006). The Limpopo Ridge Bushveld vegetation unit is often fragmented and interspersed with Musina Mopane Bushveld (Mucina & Rutherford 2006). This fragmentation probably contributes to the reason for some of the potential sites differing from their surroundings.

On the other hand it is accepted by Braun-Blanquet (1932) that regularly recurring intermingling of groups and associations may be mapped as units. In such diverse areas it is considered necessary to assess the vegetation of regularly alternating groups and associations thoroughly to support mapping decisions (Braun-Blanquet 1932).

Therefore it may have been preferable to ignore fragmentation and sample sites regardless of their surroundings. In so doing it would have ensured that the optimal four sites per mapping area in the initial map (Figure 4.2) was achieved. Such an approach is what Orland et al. (2001) advocate in their contention that metadata derived from geospatial data require scrutiny in a detached evaluation setting. They also state that the aspect of the environment being investigated be thoroughly understood to enable presentation of an objective outcome.

The first aspect of scale-related vegetation sampling (Westfall 1996) was to determine species presence. In adherence to the protocols in Scale-related vegetation sampling, the growth form that was most prevalent in the study area for each species was the one that was used throughout. However, a distinguishing description was added at species level for *Colophospermum mopane* and *Terminalia prunoides.* Tree form and shrub form appeared to need separate analyses as the shrub growth forms of both these species were considered to be serious encroachers prior to commencement of the study. In the case of *Colophospermum mopane* at 900 individuals per ha in community 2 (Table 5.3) this species proved to be a threat.

The sequence of sample sites is determined by constructing the matrix with species recorded in the sample sites on the y-axis and sample sites on the x-axis. For the purpose of sequencing sample sites, plant number was used merely to signify occurrence (Table 5.2). Attributes other than mere presence were used for cover-frequency, growth form and standing biomass of graminoids analyses in the PHYTOSET program package.

Species sequencing in Table 5.4 depends on similarity in distributions according to sample site groups or combinations of sample site groups. Species rows (the y-axis), in the matrix are rearranged accordingly. Species sequencing had no effect on the number of separation units in the matrix as the sample site sequence (the x-axis) was not changed, which is vital to maintaining the principle of objectivity in PHYTOSET procedures.

Classification efficiency based on the relationship between total separation units and the total of all gaps in the matrix was a satisfactory 77%. A value as high as this indicates that if some of the species were omitted on a reclassification, the sample site sequence would not be affected (Westfall et al. 1996).

Communities

Community delimitation is based on species turnover over the sampled gradient. Sample sites in their eventual sequence are programmatically grouped based on the degree of species difference allowed between sample sites. Therefore species that occur in all sample sites and species that occur in one sample site only are excluded. The degree of difference was tested programmatically and the resultant three groups emerged over a wide range. This was indicative of a robust distinction between the three communities.

Cover

The second aspect of sampling was to gain data for computation of cover estimates of the species recorded in each quadrat by plant number scale. Variable-sized belt transects were used in order to deal adequately with the whole range of plant sizes that were found (Westfall & Panagos 1988).

Transect width for each species was 4/5ths of mean centre to centre distance between specimens of that species recorded at each sample site. Transect length was determined by mean crown diameter. This resulted in transects ranging from 0.15 m to 239.55 m (Table 4.1).

While records of species presence is dependent on occurrence in a sample site quadrat, the determination of number and cover extends beyond the confines of 20 m x 20 m in dealing with larger species present in that quadrat.

Tabulated count cover values (Table 4.2) are all derived on the basis of numerical and measured observations and are therefore appropriate for classification that relies on ordination of values. This is a significant advance on Braun-Blanquet cover-abundance values which are not ordinal and require derivatives for processing. The validity of such derivations is in doubt (Van Der Maarel 2007).

The count cover data were processed by the PHYTOSET program to compute mean canopy cover for each species that was recorded in each sample site quadrat.

Within each community represented by such sample site quadrats a regression was generated of the mean crown cover of the species for a growth form class against their frequency. These regressions infer which species were 'strong competitors' and which were 'weak competitors' by virtue of their departure from the percentage cover predicted by the PHYTOSET regression. The results are comprehensively shown in Tables 5.3, 5.4 and 5.5.

Should it be considered necessary to reduce an encroaching species, the positive differences would indicate by how much cover of the species concerned would have to be reduced to reach the regression line. However, differences may be entirely natural due to co-existence of strong competitors resulting from differing compensatory density regulation (Münkemüller, Bugmann & Johst 2009). Therefore caution should be applied in practice and monitoring would be advisable.

In community 1 in shrub growth form *Acaciella tortilis* subsp. heteracantha *(*former *Acacia tortilis* subsp. heteracantha), *Terminalia prunoides* and *Combretum apiculatum* were 'strong competitors'. These species are known as encroachers and need to be monitored both for their intrinsic value and for their value as indicator plant species for management purposes. *Acaciella nigrescens* (former *Acacia nigrescens)* is a preferred browse tree. Being a 'weak competitor' in community 1, it may be under pressure and should be monitored.

A species that is a 'weak competitor' in one community may be a 'strong competitor' in another. This is the case with *Acaciella nigrescens* (former *Acacia nigrescens)* that is a 'strong competitor' in community 2. This emphasises the importance of recognising plant communities and monitoring the effect of management in each. Community 2 is transitional between communities 1 and 3.

Analysis of composition and cover in Tables 5.5, 5.6 and 5.7 facilitates numerical treatment of the values to estimate canopy cover of each community by species and growth form by means of models (Starfield & Bleloch 1991) (Starfield et al. 1994). This would aid management in assessing opportunities and threats.

6.2.4 Encroachment

Encroachment by woody species is a problem in the study area. Should it be considered necessary to reduce an encroaching species, the positive differences from predicted cover would indicate by how much cover the species concerned would have to be reduced to reach the regression line.

Colophospermum mopane is a prominent contributor to tree and shrub growth forms in community 3. Figure 5.13 illustrates that woody growth forms contribute proportionately more cover in community 3 than they do in the other two communities. With focus on *Colophosperum mopane* and strong shrub competitor *Grewia bicolor*, priority may be given to reduction of woody growth forms in community 3.

6.2.5 Correspondence of geospatial metadata with floristic classification

Classification of the floristic data by PHYTOSET principles indicated only three plant communities that were sufficiently different to be considered coherent communities (Table 5.4). In view of this, the pattern of the satellite image, with some increase in mean standard deviation, was redefined programmatically, grouping together smaller units to yield a three vegetation unit map (Figure 5.13).

The positions of the sample sites were based on the map (Figure 4.2) that suggested six potential vegetation units with due regard for avoidance of ecotones. The positions of sites 4, 7, 8 and 9 in the map suggesting three vegetation units (Figure 5.13) are not ideal from an ecotone perspective, a negative consequence of the change to scale 1:9,000.

Correspondence at 76% was obtained with satellite imagery filtered with a 7 x 7 pixel median filter presenting finer definition and corresponding to 1:9 000 scale (Table 5.6). Figure 5.8 is the three vegetation unit map generated with the median filter corresponding to 1:9 000 scale. This is the map finally accepted for the study.

PHYTOSET accepts the outcome of duly described objective satellite image classification. Similarly it accepts the outcome of defined and similarly objective floristic classification. The PHYTOSET approach relates the outcomes of the two classifications with the highest degree of correspondence achieved within the parameters of the respective classifications. The degree of correspondence achieved in the study was 76%. When comparing this 76% correspondence with apparent total correspondence with Braun-Blanquet procedures the criticisms cited in Van Der Maarel (2007) should be born in mind including that of circular argumentation.

6.2.6 Standing biomass of graminoids

The computer package calculated the standing above ground biomass of grasses and sedges in each community (Table 5.7). These calculations are based on canopy cover and space between competing graminoid plants at the time of sampling (Panagos 1999). Apart from the value of the calculations of standing biomass and the contributions of the species concerned in each community, the data suggest a basis for veld condition scoring and carrying capacity modelling. However this potential should be approached with caution due to above average rainfall during the season leading up to the time of data collection.

The surveys were conducted from 1st March to 19th March 2008. The mean rainfall recorded at the two weather stations closest to the study area for the season until commencement of the study was 404.5 mm (South African Weather Service 2009), 60 mm higher than the mean average annual rainfall for these weather stations. Grass density increases rapidly with a rainfall increase in semi-arid regions (Stuart-Hill 1989). This was seen when comparing grass cover with that seen in previous years. Stuart-Hill (1989) points out that in such circumstances percentage species composition may be invalid for prediction of grazing capacity or run-off. However, it was possible to record data regarding grass species that in dry years would not have been possible.

The low, variable rainfall and free drainage as indicated by the soils in the study area are the main factors limiting the availability of grazing and consequently the ability to sustain wildlife. *Aristida adscensionis* is a ‘strong competitor’ in community 1 (Table 5.5) and is known (van Oudtshoorn 2012) to increase under heavy grazing conditions in dry areas and warrants monitoring. ‘Weak’ grass competitors could indicate species under pressure in each community. They should be monitored for their intrinsic and indicator values. *Eragrostis lehmanniana,* which is a ‘weak competitor’ in communities 1 and 3 could turn out to be valuable in the grass component and would also warrant monitoring.

The PHYTOSET program generated the percentage that each growth form contributed to the total canopy cover in each community. The amenability of data in PHYTOSET procedures being ordinal was manifested yet again.

The analysis was helpful in providing an overview of the state of dynamic interplay between woody and herbaceous species per community in the study area. Comparative percentages of growth forms are shown in Figure 5.13. Repetition of this analysis would be useful in the passage of time for overall monitoring. It would assist management to identify areas on which to focus closer attention.

CHAPTER 7: CONCLUSION

7.1 ACHEIVEMENT OF AIMS

The study demonstrates that PHYTOSET procedures were less complicated than those of Braun-Blanquet. Two different additional programmes were used to bolster the Braun-Blanquet classification. BECVOL was used to aid description and scree plotting of PCoA to deal with the non-iterative nature of the Braun-Blanquet classification.

Greater objectivity was applied in using PHYTOSET procedures as the data used for the basis of the maps were generated by an image itself, whereas the physiognomic map in the Braun-Blanquet approach depended on interpretation of what had been seen on an image and then drawing by hand. Similar mapping units in the case of PHYTOSET were shown in terms of outcomes of the classification of a digital image itself; whereas the physiognomic map required the vegetation classification of Braun-Blanquet procedures before the proposed map areas could be related to one another.

PHYTOSET field work was less time consuming in that assessment required only 18 relevés compared with 35 for Braun-Blanquet. PHYTOSET data were processed to show growth form characteristics of the vegetation communities, whereas time had to be spent on BECVOL to derive sufficient data about woody growth forms to be able to describe communities adequately.

Both approaches yielded usable outcomes for modelling and ranch management. These will serve the management purposes of Evelyn Game Ranch. However, neither was sufficiently superior to allow disregard for the other. There is therefore a case for using both methods in a synergetic way.

7.2 SYNERGY

7.2.1 Introduction

Leopold (1940) contends that conservation is a house divided. He states that there is a need to thoroughly work out what the differences are when there is contention and that in the end mutual respect is often as good as agreement. He points out that in the pursuit of knowledge, often one's opponent is one's best teacher.

In the past, traditional classification and ordination methods were regarded as antagonistic. However, differences have been resolved and the different approaches are accepted as complementary (Chytrý et al. 2011). PHYTOSET is based on classification of data that are iterative from the outset. Thus differences from Braun-Blanquet classification are inevitable.

The idea of synergy as applied to the two approaches to plant community demarcation and floristic analysis in the study is to demonstrate an appreciation for different approaches. The application of a combination may be more useful than either approach would be on its own.

7.2.2 Background

Stereo photographic aid to physical mapping has brought out details of areas that deserve specific management consideration. This level of detail is sacrificed in the process applied to the construction of the Google image based map.

Both Braun-Blanquet and PHYTOSET procedures produced data from which information useful to wildlife management may be developed. However, the output is different to the extent that marrying the two was not possible. However, elements of each approach could be helpful to the other. The cost of applying both in their entirety to a particular property would be unnecessarily high, possibly to the point of unaffordability.

7.2.3 Basis of synergy

In 6.2.2 it was explained that the riparian vegetation where it occurred in narrow strips along streambeds would have been merged with adjoining units in the filtration process with the application of PHYTOSET procedures. While that loss of identity at the scale of 1:9 000 was not considered significant, management may have a particular interest in the riverine areas as a whole. In such a case a stereographic map and intense sampling could be included in the process. The same approach could be adopted for the quarry sites and old lands in the study area.

Braun-Blanquet procedures did deal with such areas as the final physiographic-physiognomic map (Figure 5.10) was drawn to include them in their entirety and the areas concerned were specifically sampled. The riverine community and quarry sites and old lands community are two of the five communities emanating from Braun-Blanquet procedures that did not show as such in the three communities emanating from PHYTOSET. With the exception of these two communities there is a considerable measure of correlation of the final vegetation map (Figure 5.11) and the three community PHYTOSET map (Figure 5.12). This is shown in an overlay of the two (Figure 7.1). Although the detail produced by both approaches was dealt with in results and discussion, it is important to show the extent of this correlation in detail before concluding on synergy.

Google picks up intense colour for community 2 (magenta on Google map (Figure 5.12) and horizontal red on Google overlay (Figure 7.1)). It corresponds well with the *Kirkia acuminata – Melinis repens* Tall closed woodland on flat rocky outcrops (diagonal red on Stereo overlay (Figure 7.1)) and ~25% of Stereo-Megatab *Pupalia lappacea – Acacia nigrescens* Riparian thicket, part of but not all the most wooded (diagonal blue on stereo overlay). On the differential table (Table 5.1) these two groups are next to each other. They are also next to one another in ordination space (Figure 5.4). There is a small quarry in the North-western corner shown as *Acacia tortilis – Enneapogon cenchroides* Short open woodland on old fields and borrow pits (diagonal brown on stereo overlay) in community 2. Google map suggested community 2 (magenta on map and horizontal red on Google overlay) has several small islands of community 3 (brown on Google map and horizontal green on Google overlay), whereas this area is uniformly *Kirkia acuminata – Melinis repens* Tall closed woodland on flat rocky outcrops (diagonal red on stereo overlay).

Google appears to pick up the least intense colour for community 1 (grey on the Google map and horizontal black on Google overlay). It corresponds very well with the *Boscia albitrunca – Commiphora edulis* Short closed woodland on sandy soils (diagonal green on stereo overlay) in the centre and east and where Google community 1 (grey on Google map and horizontal black on Google overlay) occurs in the west. However the *Boscia albitrunca – Commiphora edulis* Short closed woodland on sandy soils (diagonal green on stereo overlay) far exceeds community 1 (grey on the Google map and horizontal black on Google overlay) in the west. Community 1 (grey on the Google map and horizontal black on Google overlay) corresponds with ~50% of *Acacia tortilis – Enneapogon cenchroides* Short open woodland on old fields and borrow pits (diagonal brown on stereo overlay) throughout the study area. *Boscia albitrunca – Commiphora edulis* Short closed woodland on sandy soils and *Acacia tortilis – Enneapogon cenchroides* Short open woodlands on old fields and borrow pits are alongside each other in the differential table (Table 5.1).

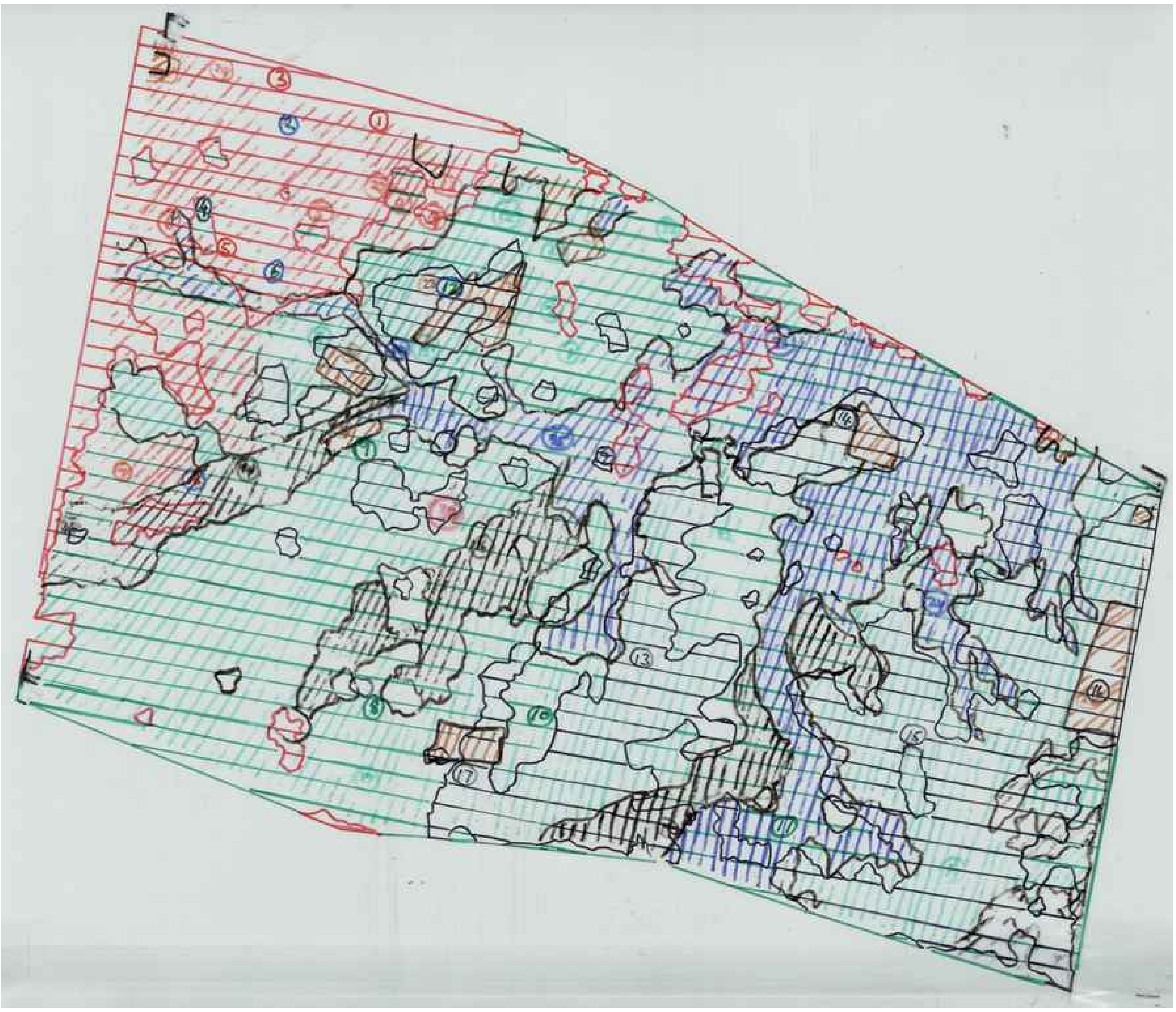


Figure 7.1: Overlay: Image of Google and Stereo maps traced on to acetate sheets.

Google community 3 (brown on map and horizontal green on Google overlay) contains ~90% of the *Terminalia prunioides – Colophospermum mopane* Tall closed shrubland of dry water courses (diagonal black on stereo overlay). It also contains the South-western part of *Boscia albitrunca – Commiphora edulis* Short closed woodland on sandy soils (diagonal green on stereo overlay), that is extensive and ~ 50% of the smaller North-western part of *Boscia albitrunca – Commiphora edulis* Short closed woodland on sandy soils (diagonal green on stereo overlay). ~50% of *Acacia tortilis – Enneapogon cenchroides* Short open woodlands on old fields and borrow pits (diagonal brown on stereo overlay) falls into community 3 (brown on Google map and horizontal green on Google overlay). These are old lands and quarried areas and while distinct, they are not extensive. ~70% of the *Pupalia* *lappacea – Acacia nigrescens* Riparian thicket (diagonal blue on stereo overlay) falls into community 3 (brown on Google map and horizontal green on Google overlay).

Google community 3 (brown on map and horizontal green on Google overlay) has parts of all the Stereo-Megatab groups.

The vegetation map (Figure 5.11) shows 33.85 ha granite outcrops and 46.83 ha old fields and borrow pits. It is probable that the approximately 15% of pixels at the extremes of the histogram referred to in the method for PHYTOSET procedures would have included those representing these features. Therefore representation of their areas on the final Google satellite image map (Figure 5.12) would be very limited, if present at all. There could well have been merit in reducing the extent of the extremes that were virtually eliminated from consideration as described in methods for PHYTOSET procedures. On the other hand, in overall significance for management of such an area the small pockets and strips of terrain were not many. The physiographic map (Figure 5.11) showing these features may be useful in terms of division of the property for wildlife management purposes. For example, the granite outcrops that are a rocky spine running North / South in the centre of the ranch.

7.2.4 **Conclusion on synergy**

The question is whether or not objective programmatic stratification with explanation of methodology is more reliable than subjective treatment of raw data to fit a subjectively drawn map on an aerial photograph.

The subjectively drawn map has areas far separated and several small areas were not sampled. Relating or distancing such areas is open to error. On the other hand, programmatic classification relates or distances such separated areas objectively and decisively.

It is suggested that synergy of the two approaches is a solution, with the better elements of each applied to a project. While the programmatically generated map has an advantage regarding objectivity, the detail from the stereo photographically based map can be superimposed on it. This will facilitate management of chosen elements within the context of the programmatically mapped areas in which they are located.

Better options are likely to emerge. Objective satellite image stratification by ISO clustering is already in use for mapping (Xie et al. 2008) and may develop in a way that would obviate the need for synergies as described by producing results that would suffice on their own. The same may be said of the OptimClassing method (Tichý et al. 2010) based on objectively determined faithful species associations that are clustered into partitions indicating mapping areas. Iterative data and objective classifications characterise these approaches.

REFERENCES

ACOCKS, J.P.H. 1953. *Veld types of South Africa, Map sheet.* Government Printer, Pretoria.

ACOCKS, J.P.H. 1975. *Veld types of South Africa. Memoirs of the Botanical Survey of South Africa.* No. 40. Government Printer, Pretoria.

ALIBER, M., Maluleke, T., Manenzhe, T., Paradza, G. & Cousins, B. 2013. *Land reform and Livelihoods. Trajectories of change in northern Limpopo Province, South Africa.* HSRC Press, Cape Town.

BARBOUR, M.G., Burk, J.H. & Pitts, W.D. 1980. *Terrestrial plant ecology*. Benjamin/ Cummings, Menlo Park, California.

BOND, W.J. & Van Wilgen, B.W. 1996. *Fire and Plants*. Chapman & Hall, London.

BOTHMA, J. du P. 2002. Objectives. In Bothma, J. du P. (Ed.) *Game Ranch Management.* Van Schaik Publishers, Pretoria.

BOTHMA, J. du P., Van Rooyen, N. & Van Rooyen. M.W. 2004. Using diet and plant resources to set wildlife stocking densities in African savannas. *Wildlife Society Bulletin*. 32: 840–851.

BRAUN-BLANQUET, J. 1932. *Plant Sociology*. Translated, revised and edited by Fuller, G.D. & Conrad, H.S. McGraw-Hill Book Company, Inc., New York & London.

CHIEF DIRECTORATE OF SURVEYS AND MAPPING. 1996. *1:50 000 full coverage topo-cadastral sheet 2229BD KAMKUSI*. Government Printer, Pretoria.

CHYTRÝ, M., Schaminée, J.H.J. & Schwabe, A. 2011. Vegetation survey: a new focus for Applied Vegetation Science. *Applied Vegetation Science.* 14: 435-439.

DIRECTORATE OF HYDROLOGY. 1999. 1:2 000 000 Drainage regions of the Republic of South Africa. Department of Water Affairs and Forestry, Pretoria.

DUGMORE, H. 2010. Save the land: keep more animals. *Farmer's Weekly* 13 August 2010: 42 – 45.

EDWARDS, D. 1983. A broad-scale structural classification of vegetation for practical purposes. *Bothalia* 14: 705-712.

ESLER, K.J., Milton, S.J. & Dean, W.R.J. 2006. (Eds.) *Karoo Veld: ecology and management.* Briza Publications, Pretoria.

FOURIE, G. 2011. Realise a higher income on your game farm. *Game and Hunt.* 17: 69-71.

GEO-LOGIC MAPPING. 2013. Adapted extract from the digital 1:50 000 scale National Topographic Map Series sheet 2229BD KAMKUSI. Geo-logic, PO Box 7352, Noorder-Paarl.

GOOGLE EARTH. 2013. Google Earth/layers/primary database/historical imagery/12/2007, co-ordinates 22˚ 17’ 19” to 22˚ 19’ 37” S and 29˚ 48’ 51” to 29˚ 51’ 35”

HENNEKENS, S.M. & Schaminée, J.H.J. 2001. TURBOVEG, a comprehensive data management system for vegetation data. *Journal of Vegetation Science*. 12: 589-591.

HENNEKENS, S. M. 2012. *Turboveg for Windows*. Version 2. 15-2-2012. http://www.synbiosys.alterra.nl/turboveg/tvwin.pdf

JORDAAN, J.J. 1999. Bush control: general aspects and practical considerations*. Farm Planning Course for ARID. 6-17 September 1999. Trompi Seleka Agricultural College.* Towoomba Agricultural Development Centre, Bela-Bela.

KRIEK, J. 2011. Far better asset growth with rare species. *Game and Hunt.* 17: 78.

LAND TYPE SURVEY STAFF. 2003a. Land type map 2228 Alldays. Agricultural Research Council, Institute for Soil, Climate & Water, Pretoria.

LAND TYPE SURVEY STAFF. 2003b. Land types of the maps 2228 Alldays & 2230 Messina. *Memoirs of the Agricultural Natural Resources of South Africa. No.* 37. Agricultural Research Council, Institute for Soil, Climate & Water, Pretoria.

LEOPOLD, A. 1940. *The essential Aldo Leopold quotations and commentaries*. Edited by Meine, C. & Knight, R. L. 1999. University of Wisconsin, Madison.

LOW, A.B. & Rebelo, A.G. 1998. 2 (Eds.) *Vegetation of South Africa, Lesotho and Swaziland*. Department of Environmental Affairs and Tourism, Pretoria.

MALAN, O.G. & Westfall, R.H. 1987. A new strategy for vegetation mapping with the aid of Landsat MSS data. *Advances in Space Research* 7: 97-103.

McNAUGHTON, S.J & Georgiais, N.J. 1986. Ecology of African grazing and browsing mammals. *Annual Review of Ecology and Systematics.* 17: 39-65.

MUCINA, L. & Rutherford, M.C. 2006. 9 (Eds.) The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19, South African National Biodiversity Institute, Pretoria.

MUCINA, L., Rutherford, M.C. & Powrie, L.W. 2005. *Vegetation map of South Africa, Lesotho and Swaziland, 1:1 000 000 scale sheet maps*. South African National Biodiversity Institute, Pretoria.

MÜNKEMÜLLER, T., Bugmann, H. & Johst, K. 2009. Hutchinson revisited: Patterns of density regulation and coexistence of strong competitors. *Journal of Theoretical Biology*. 259: 109-117.

NATIONAL AGRICULTURAL MARKETING COUNCIL (NAMC). 2006. *Report on the investigation to identify problems for sustainable growth in South African wildlife ranching.* Report 2006-03. NAMC. Pretoria.

ORLAND, B., Budthimedhee, K. & Uusitalo, J. 2001. Considering virtual worlds as representations of landscape realities and as tools for landscape planning. *Landscape and Urban Planning.* 54: 139-148.

PANAGOS, M.D. 1999. Preliminary data for determination of herbaceous layer dry matter production per unit square area for incorporation into PHYTOTAB-PC program suite. Unpublished report to Agricultural Research Council, Range and Forage Institute, Pretoria.

PEEL, M.J.S. 1989. *Determinants of veld composition on a number of ranches in the north-western Transvaal*. MSc Thesis. University of Pretoria, Pretoria.

PODANI, J. 2001. *SYN-TAX 2000 Computer programs for data analysis in ecology and systematics.* Scientia publishing, Budapest

SCOTT, J.D. 1955. Principles of pasture management. In Meredith, D. (Ed.) *The Grasses and Pastures of South Africa.* Central News Agency, Johannesburg.

SMITH, B. 2006. *The farming handbook*. University of KwaZulu-Natal Press, Scottsville & The Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen.

SHEPPARD, S.R.J. & Cizek, P. 2009. The ethics of Google Earth Imagery: crossing thresholds from spatial data to landscape visualisation. *Journal of Environmental management.* 90: 2102-2117.

SMIT, G.N. 1996. BECVOL: Biomass Estimates from Canopy VOLume (version 2) – Users Guide. University of the Free State, Bloemfontein

SOUTH AFRICA SOIL CLASSIFICATION WORKING GROUP. 1991. *Soil classification -a taxonomic system for South Africa. Memoirs on the Agricultural Natural Resources of South Africa No. 15.* Department of Agricultural Development, Pretoria.

SOUTH AFRICAN WEATHER SERVICE. 2009. Electronic rainfall data for 1966 to 2008 supplied on 21st August 2009.

STARFIELD, A.M. &. Blelock, A.L. 1991 *Models for conservation and wildlife management.* Burgess Publishing, Edina, Minnesota.

STARFIELD, A.M., Smith, K. A. &. Blelock, A.L. 1994. *How to model it, problem solving for the computer age.* Burgess Publishing, Edina, Minnesota.

STUART–HILL, C.G. 1989. Some problems with using proportional species composition. In Danckwerts, J.E. & Teague, W.R. (Eds.) *Veld management in the Eastern Cape.* Pasture Research Section, Eastern Cape Region, Stutterheim.

TAINTON, N.M. 1981. *Veld and Pasture Management in South Africa.* Shuter & Shooter, Pietermaritzburg.

TERRAMETRICS & Google Earth. 2012a. TruEarth® 15-meter Global Satellite Imagery Features 2012 http://www.truearth.com/support/faqs_content_google.htm (accessed 23 June 2012)

TERRAMETRICS & Google Earth. 2012b. http://truearth.com/products/TE_15m_features.htm (accessed10 October 2012)

TICHÝ, L. 2002. JUICE, software for vegetation classification. *Journal of vegetation Science.* 13: 451-453

TICHÝ, L., Chytrý, M., Hájek, M., Talbot, S.S. & Botta-Dukát, Z. 2010. OptimClass: Using species-to-cluster fidelity to determine the optimal partition in classification of ecological communities. *Journal of Ecological Science.* 21: 287-299

VAN DER MAAREL, E. 2007. Transformation of cover-abundance values for appropriate numerical treatment – Alternatives to the proposals by Podani. *Journal of Vegetation Science.* 18: 767-770

VAN OUDTSHOORN, F. 2012. *Guide to Grasses of southern Africa.* Briza Publications, Pretoria.

VAN ROOYEN, N. 2002. Veld management in the savannas. In Bothma, J. du P. (Ed.) *Game Ranch Management.* Van Schaik Publishers, Pretoria.

VISSER, N. 2005. 'n Ekologiese studie van en 'n natuurlewebestuursplan vir die Honnet-Natuurreservaat, Noordelike provinsie. MSc dissertation, University of Pretoria, Pretoria.

WAYNE, L. 2005. *Metadata in action: expanding the utility of geospatial metadata.* Federal Geographic Data Committee, Reston, Virginia. http://www.fgdc.gov/metadata/metadata-business-case (accessed 23 February 2010)

WERGER, M.J.A. 1974. On concepts and techniques applied in the Zürich-Montpellier method of vegetation survey. *Bothalia.* 11, 309-323.

WESTFALL, R.H. 1992. Objectivity in stratification, sampling and classification of vegetation. PhD. Thesis, University of Pretoria, Pretoria.

WESTFALL, R.H. 2008. PHYTOSET: A program package for vegetation mapping, sampling and analysis. Agricultural Research Council, Irene.

WESTFALL, R.H. & Malan, O.G. 1986. A method for vegetation stratification using scale related vegetation-enhanced satellite imagery. *Bothalia.* 16: 263-268.

WESTFALL, R.H. & Panagos, M.D. 1988. The plant number scale – an improved method of cover estimation using variable-sized belt transects. *Bothalia.* 18: 289-291.

WESTFALL, R.H. & Van Staden, J.M. 1996. Primary divisions of the biomes of South Africa. *South African Journal of Science* 92:373-375.

WESTFALL, R.H., Van Staden, J.M., Panagos, M.D., Breytenbach, P.J.J. & Greeff, A. 1996. *Scale-related Vegetation Sampling*. Agricultural Research Council, Range and Forage Institute, Irene.

WHITE, G. C. 2001. Perspectives. Why take calculus? Rigor in wildlife management. *Wildlife Society Bulletin.* 29: 380-386.

XIE, Y., Sha, Z. & Yu, M. 2008. Remote sensing imagery in vegetation mapping: a review. *Journal of Plant Ecology.* 1: 9-23.