TOWARDS FORMALIZED ADAPTIVE MANAGEMENT IN SUCCULENT VALLEY BUSHVELD

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ABSTRACT

This study was designed to provide the means for implementing formal scientific vegetation management in the succulent valley bushveld of the eastern Cape, South Africa.

Nowhere in the world has a detailed, effective and practical veld management system being developed entirely from research, and even the most successful management systems rely heavily on the intuition of people. A process, formally called 'adaptive management', combines this intuition with scientific testing and the overall objective of this study was to provide a framework for formalized adaptive management in succulent valley bushveld.

On analyzing the process of adaptive management, the following knowledge 'tools' were identified: (i) a management system for immediate implementation; (ii) a technique for vegetation assessment; (iii) a technique for monitoring vegetation change; (iv) a technique for monitoring forage use and recovery; (v) a list of key forage species; (vi) a model to set initial stocking rates; (vii) a method of recording essential information; and (viii) a database of ecological principles.

Providing these 'tools' became the goals of this study. These topics covered almost all facets of rangeland science, and the approach was to address these in a 'top down' manner, rather than sub-optimize by specializing on any one component.

Most of the 'tools' were achieved to a greater or lesser extent and are presented as a series of publications. However, a central tool, that for monitoring vegetation change, remains outstanding despite comprehensive testing of a range of traditional botanical methods. Indeed, critical review revealed that this 'missing tool' is a problem which is common in all vegetation communities in South Africa - despite the impression created by vegetation researchers that adequate techniques are indeed available. This is serious because land managers are not able to evaluate the impact of their efforts and the government is unable to monitor the effectiveness of their research and extension services, costing millions of public monies annually. The implication also, is that vegetation cannot be managed scientifically (management implies monitoring).

Either formal adaptive management is not practicable, or researchers are operating from an inappropriate paradigm; specifically that of providing techniques for their research projects and claiming that these (or derivatives of these) are adequate for farm or regional scale monitoring.

More generally, research has often become an end in it's self, with research quality being judged by criteria which are of little significance to the real world and which damage efficiency. Perhaps, the real value of vegetation research, lies in the experiential learning which the researcher gains, not the inevitably parochial results.

PREFACE

This thesis is presented as a series of publications, both published and unpublished, as well as reports which have been produced over a period of eight years. The inevitable consequence is that literary and presentation style varies and details/thinking in some papers have become redundant (or are not yet fully mature). I make no apology for this. Indeed my intention is for the thesis to record a process. Because it is a process, there are however, some gaps. Whilst I have made every attempt to cover each topic as broadly as possible, my further input had to be terminated at some point. Inevitably, this point is a value judgement.

Another unavoidable consequence of a series of articles published over time, is the repetition of material; e.g. description of the vegetation, references and some non-redundant text which may be repeated in successive articles covering the same topic. I considered removing this (especially the latter), but there were also good reasons to leave the format as it is (e.g. to illustrate a process and for efficiency with publication). In the end I decided to leave the thesis as a series of independent articles, and consequently I request the reader to forgive the repetition.

I declare, furthermore, that this thesis is the result of my original work, unless specifically stated to the contrary in the text. It has not been submitted for any degree or examination at any other university.

G.C. STUART-HILL

FOREWORD

'RULES OF THE GAME'

In this dissertation, I have aligned myself with the strategy of allowing the land manager to define his own land use objectives. However, the study originated from within the traditional agricultural paradigm of domestic stock farming and as a consequence, the dated works reflect this thinking. When I do, in the later works, lapse into making value loaded statements (e.g. veld degradation) this may be done either: from the viewpoint of a specific land user; or where the land use option leads to a decrease in overall vegetation cover. I have selected cover in place of soil loss as it is an easier parameter to monitor and because it has been shown to be positively correlated with soil protection (Anon 1976).

As we do not know what the needs of future generations will be, it is perhaps wise to take a conservative approach to land use. Consequently, I have adopted the approach that it is best to maintain those aspects of the vegetation which, if lost, will not regenerate within a human life span. If the actions of the land manager lead to a reduction in total vegetation cover or irreversible change in the vegetation (the 'rules of the game'), then I believe that mechanisms should exist whereby society be informed of the consequences so that they (through their elected leaders) can take appropriate action. It is important to realize, however, that under certain socio-economic conditions, even the most well-intentioned land user will unavoidably break the 'rules'. In such cases, society may be forced to reassess the these and be prepared to bear the consequences.

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CHAPTER 1

INTRODUCTION

1.1 THE DESIRE

Ultimately we aspire to have management systems for land users which are compatible with the conservation ideal. Conservation, as opposed to preservation, means "wise use" and is defined by the World Conservation Strategy (WCS) as the management of the biosphere so that it may yield the greatest sustainable benefit to present generations whilst maintaining its potential to meet the needs and aspirations of future generations (WCS, 1980).

1.2 THE PROBLEMS

While noble in intent the WCS definition has a number of problems which affect its implementation (see Mentis 1985). How do we know apriori, what the needs and aspirations of future generations will be. "Greatest sustainable benefit" is of course, a value judgement and will depend on the viewpoints and objectives of the various sectors of the "present generation". For example, a traditional tribal pastoralist may have the objective of maximizing animal numbers and not products (Brown, 1969). A commercial pastoralist, on the other hand, may seek maximum financial profit. A tax-paying town dweller may enjoy fishing at the coast and consequently object to excessive siltation of estuaries caused by land managers who profit at the expense of top-soil.

Even if we consider only commercial pastoralism, we soon notice how widely operator objectives can vary. For example, a farmer could operate with either cattle, sheep, goats, game or various combinations of all these. He also has the option of adopting various systems of management such as: high and low stocking rates, rotational grazing or continuous grazing, burning or not burning, as examples. None of the above are necessarily harmful to the vegetation and consequently, none should be condemned out of hand. Rather, it is the specific timing, combinations and/or magnitude of each which may lead to undesirable vegetation change.

It follows, that the combinations of enterprises and management systems is almost infinite. Consequently, it would be an extremely complex, tedious and expensive task to determine, through research, the optimum timing, combination and magnitude of each so as to produce a management formula. Importantly, this task is made even more difficult due to the added complexity of having different species (each behaving uniquely), different plant communities and constantly changing environmental conditions.

Because of this complexity, a detailed, effective and practical management procedure cannot be developed entirely from research. In the eastern Cape thornveld, where more that 50 scientific articles devoted to veld management have been published (one of the most researched veld types in southern Africa), the most practicable management system developed thus far (Danckwerts 1984), whilst incorporating some scientific predictions, relies mostly on the intuition and experience of successful farmers and scientists.

It may even be concluded that research is a waste of time and money, especially when we see land users earning a good living whilst doing their veld no harm. Could the management solution lie with these people? Should we not simply copy the 'leading farmers'? Yes and no! Often the perception is created that successful land users are wealthy because they implement conservation practises. However, it has been shown that these individuals were often wealthy to start with and it is because of their wealth that they are able to implement altruistic conservation (Grossman 1988). Most land users are not in a position to spend large amounts of money on, for example, soil reclamation works, but does this mean that they are not conservation farmers? Remember, conservation means wise use! I suggest that the 'leading farmers' are those who manage with specific objectives in mind and to achieve these they monitor both the performance of their animals (and hence profits) and their veld. These farmers have the answer; by having objectives and periodically monitoring goal attainment, they are able to identify successes and failures. With appropriate monitoring programmes and an understanding of the ecosystem (derived from research), they can adapt their management system accordingly. Essentially, they practise a system formally call "Adaptive Management" (Walters & Hilborn 1978; Holling 1978).

1.3 THE OBJECTIVE

The overall objective of this study was to provide a framework for formalized adaptive management in the succulent valley bushveld of the eastern Cape (see Paper [P 0.1] for a description of this vegetation type).

The approach was firstly, to describe an interpretation of adaptive management, and from this description, identify the 'tools' that a land-manager would require to formally implement the system. Providing these tools became the goals of this study.

CHAPTER 2

ADAPTIVE MANAGEMENT

2.1 DESCRIPTION

Adaptive management, in the active sense, is an approach whereby a manager would specifically implement various actions to learn how the system responds, thereby learning to manage. In the more passive (and applied) sense, adaptive management is the term used to describe the system of modifying management by learning through mistakes and successes. It is useful in situations where few facts are known but where management decisions cannot be delayed while research is being conducted (Walters & Hilborn, 1978; Holling, 1978). Adaptive management is thus particularly relevant to veld management where few quantitative management guidelines are available.

Mentis (1985) provided a generalized algorithm for scientific management (Figure 2.1) which is firmly based on the paradigm of adaptive management.

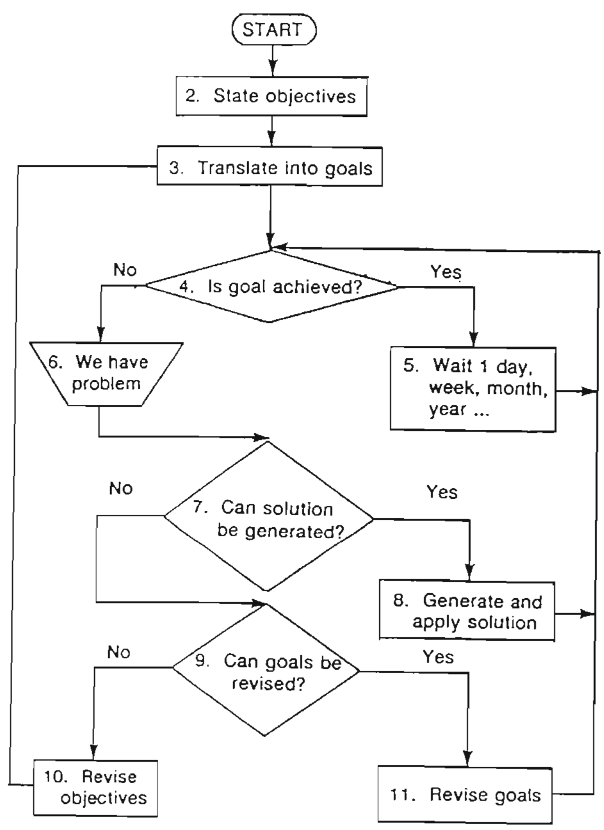

Figure 2.1 A generalized algorithm for scientific management (Mentis 1985).

This can be expanded into a more applicable veld management algorithm (see Figure 2.2 as an example).

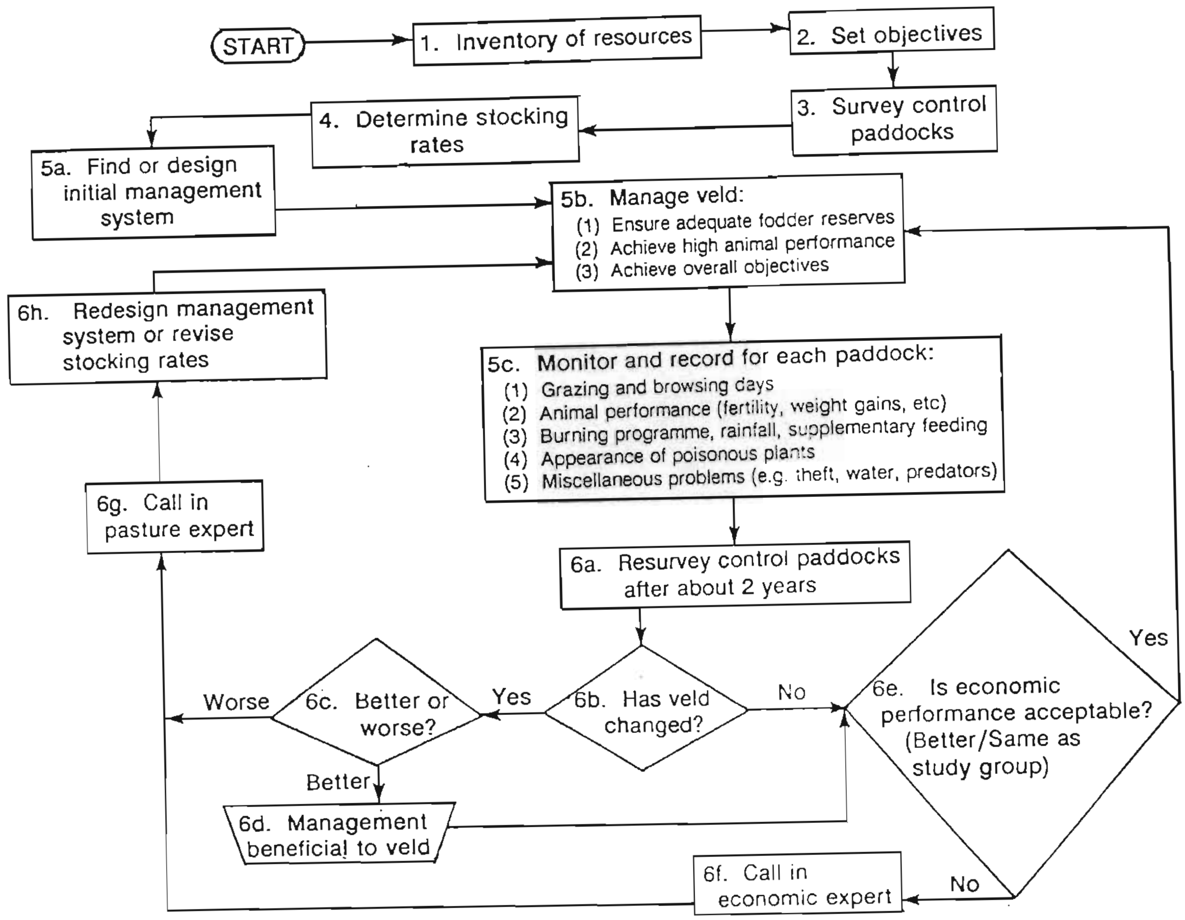

Figure 2.2 Generalized procedure for adaptive veld management.

A grazier beginning to use adaptive management may go through the following seven phases (Figure 2.2).

1) Undertake an inventory of the natural resources on the property.
2) Decide on his objectives and translate these into operational goals (e.g. what is the desired animal performance, what veld condition, etc.)
3) Identify and survey sites representing each veld type on the property so that vegetation change can be monitored.
4) Determine stocking rates with quantitative methods, if available, or through educated estimates.

5) Select a veld management system according to the best (objective and subjective) knowledge currently available. For example, a grazier could adopt: published veld management guidelines (e.g. Danckwerts & Teague, 1989), an expert system based on scientific predictions, his neighbours management program, or a new system devised by himself. This will serve as a starting system which can, in time, be modified or replaced depending on its performance. While managing according to the system adopted, all management and environmental impacts should be recorded (e.g. the grazing, browsing and burning programme; rainfall; forage availability before and after each period of occupation; miscellaneous occurrences such as the appearance of poisonous plants; and animal performance such as weight gains, fecundity, etc).

6) Periodically resurvey the monitoring sites and compare the veld condition with what it was previously. This allows the performance of the grazing/browsing system to be evaluated in terms of both animal productivity (i.e. fecundity, weight gains and profitability as described above) and vegetation change. If the veld has deteriorated, or the animal/economic performance is low compared to previous experience or study group figures, the manager is then able to return to the management and environmental records and discover what went wrong and thereby, devise a new management strategy. During this analysis it may become apparent that the goals are unattainable and this would necessitate changing the goals or perhaps even the objectives.

7) Finally, return to phase (5) and repeat the whole process.

It is evident, that, if the process continues long enough, and is formalized (by being written down or computerized), then a model specially adapted for the property could evolve. This will be useful as the knowledge it contains can be passed from one manager to another with limited loss of information.

2.2 ROLES OF RESEARCHERS, LAND-MANAGERS AND SCIENTIFIC ADVISORS

Three types of people will in all likelihood be required to implement formalized adaptive management. These are: land-managers; scientific advisors (e.g. extension officers and consultants) and research workers.

The role of a research worker may be to:

i) develop techniques to monitor vegetation change (phases 3 and 6);

ii) develop predictive models to determine initial stocking rates (phase 4) and help construct management systems phase 5);

iii) develop an understanding of the ecosystem, thereby assisting managers and scientific advisors to interpret and overcome problems (phase 6);

iv) discover new and more efficient methods of resource conservation (phase 2); and

v) present research results in a usable form.

The role of the manager is to develop a unique grazing/browsing system for the property and continually modify it according to new circumstances and information.

The advisor's role is to assist the manager with the technical aspects of each step, assimilate new information, inform the land user of the various options available, inform researchers as what work is required, and thereby serve as the coordinating body between research and management.

Let us examine a simple example to see how formalized adaptive management could work in practice.

We assume that the manager has, as one of his goals, "The vegetation condition index must not deviate by more than 10% from the initial score of 80". After proceeding through phases 1 to 5, he finds (during phase 6) that his veld condition index has changed beyond acceptable limits. A cursory glance at his records shows that this has occurred despite the fact that he has had the same stocking rate, has been implementing the same system of rotational grazing and has burnt his veld at the same frequency as those neighbours who have not experienced unacceptable vegetation change. He calls in a scientific advisor who, <u>in examining his detailed management records</u>, finds that although burning frequency is the same, he has been burning during the growing season while all his neighbours have been burning during the dormant season. The advisor recalls a researcher having found that burning veld while it is growing changed it, whereas burning during the dormant period had little adverse effect. Applying this <u>ecological principle</u>, the advisor is able to advise the manager to consider a change in the burning schedule. The manager, after evaluating the advice to see whether it is compatible with the rest of his farming enterprise, may implement the change.

This is a very elementary example. But from this, it is evident that with veld monitoring, adequate records and some ecological principles, the manager was able to <u>identify</u> a problem, <u>learn</u> from his mistake and <u>adapt</u> management accordingly. Without these, he would not have been able to make any constructive progress other than have a vague feeling that the veld was deteriorating.

Adaptive veld management depends on four equally important monitoring programmes:
i) measuring vegetation change;
ii) measuring animal performance (thereby linking management to financial performance);
iii) recording the environmental conditions; and
iv) recording the management actions that are being applied.

These monitoring and record keeping programmes should be balanced in that, for example, equal emphasis should be placed in recording vegetation change as in recording the rainfall. By definition, <u>if you are not monitoring the vegetation then you cannot claim to be managing it.</u>

In addition to these monitoring programs, it is essential that we have some understanding of the important ecological processes. This knowledge will be required to extract, from the environmental and management records, the reasons for failure to achieve goals (e.g. "the vegetation is changing beyond acceptable limits") and to suggest appropriate corrective action.

2.3 TOOLS REQUIRED FOR ADAPTIVE VELD MANAGEMENT

From analysis of Figures 2.1 and 2.2 the following 'Tools' are necessary to implement formalized adaptive veld management.

1. A management system for immediate implementation.

   This should not be presented as the only correct management system. Rather it is a suggestion which individual land users can adopt in the absence of their own.

2. Technique for vegetation inventory.

   The technique should be a rapid survey technique which is descriptive and has a resolution adequate for planning purposes. I refer to this as veld or vegetation assessment.

3. Technique for monitoring vegetation change.

   The technique should have high repeatability and efficiency, and be acceptable to land managers. I refer to this as veld or vegetation monitoring.

4. Technique for monitoring forage use and recovery.

   This is required for management feedback in the short-term and the technique must monitor degree of utilization and forage accumulation so that farmers can decide when an area of veld should be burnt, is ready to be grazed or when animals should be removed from a paddock. I refer to this as forage assessment.

5. List of key species.

   In multi-species communities it is inevitable that utilization levels will differ between species. Consequently the manager should know those plants that are important to his objectives and understand why they are important. I call these plants key species.

6. A model to set initial stocking rates.

   This model should integrate, at the very least, rainfall and vegetation condition. Importantly, it should clearly state that it's predictions are not absolute but rather intended to be used as initial values which can be adapted with experience.

7. A method of recording essential information.

   Here the emphasis must be on balanced record keeping and only information which is useful should be collected. It must be clearly stated why each piece of information is being collected; e.g. why collect rainfall data?

8. A database of ecological principles.

   The ecological principles must be relevant to management by contributing an understanding of the system. Full understanding is unachievable and a library, database or expert systems of ecological principles (which can continually be updated) is probably the best that can be achieved.

2.4 GOALS OF THIS STUDY.

As mentioned in Chapter 1, providing these Tools became the goals of this study. It is obvious, from perusal of these goals, that the study is extremely broad (encompassing almost all the facets of the discipline of rangeland science) and consequently, runs the risk of superficial treatment of any single component. To avoid this, whilst maintaining the "top-down" approach which system analysis demands (Ahituv & Neumann 1986), I concentrated on a few of the adaptive management tools and devoted less effort to others. It follows that the adaptive management framework presented in this dissertation is not complete (nor will it ever be), but in the spirit of adaptive management, is itself presented for immediate implementation, identification of further applied research needs and later improvement.

CHAPTER 3

PROVIDING THE TOOLS FOR ADAPTIVE MANAGEMENT IN SUCCULENT BUSHVELD

While project design is a sequential process, it is necessary to recognise that the implementation of the steps may be undertaken concomitantly. In addition there is also a degree of iteration in that, as we discover something new, it may become necessary to change, delete, add or reassess the importance attached to each goal. A consequence of this is that some of the work/thinking is rendered redundant by later work. This Chapter is a summary of the progress achieved so far.

Because the Chapter is designed to describe how the various articles fit into the broad picture, the details of each have been left in the publications themselves. However, to avoid the necessity of having to continually refer back to this chapter, the relevant text is repeated on the introductory pages of each section.

3.1 INTRODUCTORY WORK

Before providing the tools for adaptive management, it was necessary to define the extent and nature of the vegetation type. The unpublished paper: **An agriculturalists view of the nature and extent of succulent bushveld [P 0.1]**, is the product of that effort. This study, as with all classifications, relies heavily on the objectives for classification. As such, it may offend classical botanists who are used to traditional quantitative avenues of classification. I have considered issues of real concern to graziers (i.e. forage source and sustainability) and based the classification on these attributes.

Despite this 'new classification', it has been necessary to use the original classification convention in those publications destined for strictly botanical journals. This has led to some inconsistency in the thesis but hopefully this article will at least serve to cross reference the various naming conventions.

3.2 A MANAGEMENT SYSTEM FOR IMMEDIATE IMPLEMENTATION [TOOL 1]

The next goal was to provide the management system which land users could implement immediately (Tool 1). The first product of this goal was a section in a book entitled: **Management of veld types: succulent valley bushveld [P 1.1]**. This recipe was given reluctantly to serve as an initial guideline for those who have no management plan. It is heavily biased towards domestic stock farming and consequently has a very narrow market. On reflection, it was decided not to upgrade this recipe (even for those rare individuals who may request one) because the effort in developing such a system does not warrant the amount of times it will be used. Furthermore, a management plan rests on objectives which are value judgements and it follows that these plans will be personalized for each property and land manager. This Tool was eventually achieved by emphasising the principles that managers should be aware of (see the section in a second book: **Management of different types of veld: succulent bushveld [P 1.2]**). The reader should be aware that the second article repeats some material from the first. I apologise for this, but deleting the first would have removed the apportunity of illustrating a process.

3.3 A TECHNIQUE FOR VEGETATION INVENTORY [TOOL 2]

An essential part of scientific management and land use planning is an inventory of resources (Figure 2.2). Consequently, it was necessary to develop a system whereby succulent bushveld (in different states) could be quantified in some objective and repeatable manner. Using the terminology of the time, the intention was to develop a method of assessing veld condition (Tool 2).

Providing this tool became the next goal and the first product was the published paper: **Towards a method of assessing the veld condition of the valley bushveld in the eastern Cape [P 2.1]** (the co- authors assisted in selecting the sampling approach and in addition, C.J.G le Roux advised on statistical analysis). At the time the approach was innovative in that it broke from the tradition of using species response categories (decreasers and increasers) and calculating score as some percentage deviation from the 'ideal'. It was nevertheless naive and later modified (see the section of a book, entitled: **Monitoring vegetation change and assessing veld condition: Assessing the condition (ecological status) of valley bushveld [P 2.2]**) where the vegetation score came to represent an index (now called ecological status), devoid of value judgement and describing the position which the site occupies along a gradient of floristic similarity. The philosophy developed further, and was crystallised in an invited published paper: **An alternative approach to veld condition assessment in the non-grassveld regions of South Africa [P 2.3]** (the co-author of this paper contributed the review of vegetation assessment in the karoo). The sections of relevance to this dissertation are the Introduction, the review of thicket assessment methods, and all sections thereafter.

While the philosophy and theoretical procedure for scoring veld was being developed, a means of actually assessing vegetation in the field was devised. The approach was a formalized visual method with multiple operators. It was tested and found to be acceptable and Tool 2 was thereby provided (see the published paper: **Towards visual assessment of succulent valley bushveld [P 2.4]**). Not included in the paper was a discussion of the difference between 'subjective' and 'visual' methods. My impression is that many people confuse the two, some even believing that they are the same. A useful analogy is that of determining a length of string. A subjective approach would return measurements of "long or short" (obviously not repeatable between operators), whereas a visual method would return estimates of length in millimetres, centimetres, or metres (or other measurable units). This could be done in the conventional sense by placing a ruler next to the piece of string or by estimating the length by simply looking at it whilst refering to a repeatable index 'embedded' in the mind. Visual methods are not subjective methods!

3.4 A TECHNIQUE FOR MONITORING VEGETATION CHANGE [TOOL 3]

Providing Tool 3 (a technique for vegetation monitoring) was more problematical and hinged on evaluating the repeatability and efficiency of the survey technique. The first attempt was informal (unpublished report: **Repeatability of bushveld assessment: informal analysis [P 3.1]**) and showed that the survey method initially used (the point-centred-quarter method) was not sufficiently sensitive for farm scale monitoring.

This result led to the initiation of a series of experiments to test the repeatability and efficiency of a number of traditional botanical survey methods. The approach was neutral and conventional; i.e. establishing relationships between repeatability (error) and sampling effort. See the following unpublished papers:

- i) **Evaluation of the point-centred-quarter method of sampling kaffrarian succulent thicket [P 3.2];**
- ii) **Evaluation of a belt transect method of sampling kaffrarian succulent thicket [P 3.3];**
- iii) **Repeatability of the Domin-Krajina cover-abundance scale in kaffrarian succulent thicket [P 3.4];** and
- i) **The 'Bubble' technique for sampling kaffrarian succulent thicket [P 3.5] (parts 1, 2 & 3).**

Essentially, the philosophy was to provide the above relationships so that, by defining <u>apriori</u> a level of precision suitable for their requirements, users could then determine what sampling effort they would need. In this paradigm, the <u>same</u> sampling technique is used by all users but at different sampling intensities depending on the required precision. This approach had its roots in grassveld monitoring and led to a host of technique studies (Mentis 1984; Walker 1987; Hardy 1986). An implicit assumption with this philosophy, is that land managers require (for adaptive management) a <u>less</u> sensitive vegetation monitoring technique than researchers (Hardy & Walker 1991). This I challenged in a paper entitled: **Vegetation monitoring for adaptive management: is a paradigm shift required? [P 3.6]**, where I argued that the converse is true. This is because land managers need to be pro-active and adapt their management before irreparable damage occurs. Researchers, on the other hand, merely want to quantify the response to some applied treatment. People have assumed that because managers seek an 'easy' method, it follows that they are happy with a less sensitive technique.

All of the conventional botanical methods tested in this study were found to be too tedious and/or insensitive for pro-active farm scale monitoring. Of the methods tested, the 'bubble method' (using frequency measures) was the most useful and could be used for research based monitoring. The reason for the failure of all these classical methods is probably that their very nature depends on the death (or severe reduction in size) of individual plants. To a land user, this is not sufficiently sensitive as he needs to take appropriate action before losing valuable plants.

The failure of this research effort to produce Tool 3 prompted a paradigm shift and the emphasis has turned to monitoring attributes of individual plants which give early warning of their imminent demise[1]. To do this, however, requires a detailed understanding of the growth and reaction to defoliation of key plant species. Future research should concentrate on the demography of this vegetation type and, in particular, on understanding how individual plants are killed by defoliation so that critical attributes of the plants can be identified for monitoring.

It is important to note that if this 'new paradigm' is also unable to produce Tool 3 (a monitoring technique for proactive adaptive management), then the implication is that adaptive management may not be tenable. If this fails, what scientific approach to vegetation management is possible? The consequence could be that the vegetation cannot be managed scientifically or at least, cannot be managed in a pro-active manner.

3.5 TECHNIQUE FOR MONITORING FORAGE USE AND RECOVERY [TOOL 4]

Tool 4, a method for monitoring forage, was not seriously addressed in this study because:

i) of logistical limitations;
ii) it is only necessary for the implementation of rotational grazing which, in succulent bushveld, is untested;
iii) if the stocking rates are 'correct' then monitoring forage utilization and regrowth is not really necessary; and
iv) there is already an informal visual method which monitors the development of a 'browse line' (for utilization) and length of current shoot growth on *P. afra* (for recovery).

Nevertheless, a method of monitoring twig utilization on *P. afra* and *G. robusta* was briefly evaluated and found to be inappropriate, even for research efforts (see the unpublished

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[1] An example is perhaps the 'skirting' phenomenon of *P. afra* (reported in the published paper entitled: "Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa") and is paralleled by the aerial tillering phenomenon observed in *Themeda triandra* (Tainton 1981).

paper: **Evaluation of a non-destructive technique to monitor utilization and recovery of two shrub species in succulent bushveld [P 4.1]**).

3.6 A LIST OF KEY FORAGE SPECIES [TOOL 5]

Tool 5, a list of key forage species, was also not a priority as this had previously been researched by Aucamp (1979). However, while evaluating productivity, Aucamp did not formally consider palatability or acceptability. To address this limitation, a 'first approximation' type investigation was undertaken resulting in the unpublished paper: **The goat preference rating of shrubs in the succulent bushveld of the eastern Cape [P 5.1]**. It is important to note that while there exists a differentiation in the palatability of the shrub species in this vegetation type, almost all species will be utilized to extinction if animals are forced to. It follows that when viewed globally, there may be a relatively small variation in absolute palatability between shrubs of the succulent bushveld.

The results of this investigation were then used in a pilot study which aimed to initiate research into understanding goat selectivity. The unpublished research note (**Relationships between some commonly assayed plant chemicals and shrub acceptability (to goats) in the succulent bushveld of the eastern Cape [P 5.2]**) details the results.

3.7 A MODEL TO SET INITIAL STOCKING RATES [TOOL 6]

A model to set initial stocking rates (Tool 6) was provided in the published paper: **Carrying capacity of the succulent valley bushveld of the eastern Cape [P 6.1]** (the co-author initiated the field work). This model should be viewed as a first approximation which should be tested and upgraded where necessary. A formal test of the model has been started and is currently the responsibility of F.O. Hobson[2]. The essential preliminary result after three years of treatment, is that while the vegetation at the high stocking rates (i.e. two and three times greater than recommended by the model) is showing visible signs of damage, the goats' productivity (measured with mass gain) continues at control levels (pers comm. F.O. Hobson). Despite this new experimental effort, further on-farm testing is required.

A lesson from the published study was that the research effort was not worth the information obtained, especially in view of the rather nebulous concept of carrying capacity and the temporal and spatial limitations of the predictions. I suggest that future work of this nature should be more holistic, the experimental effort going into increasing the range of sites and variables

[2] Dohne Research Centre, P Bag X15, Stutterheim, 4930.

under test, rather than on the backbreaking and inefficient efforts to objectively monitor plant utilization and recovery.

By way of generalizing the results, and in an attempt to discover a unifying relationship to predict carrying capacity in the woody vegetation communities of the eastern Cape, the model developed for the false thornveld of the eastern Cape (Acocks 1975, veld type number 21) was used to predict the carrying capacity as measured in the above experiment. The result was surprisingly good, given the major differences between the two vegetation types (see the unpublished paper: **Can a common model be used to determine carrying capacity in false thornveld and succulent valley bushveld: a preliminary investigation? [P 6.2]**).

3.8 A METHOD OF RECORDING ESSENTIAL INFORMATION [TOOL 7]

Tool 7, a model of recording essential environmental and management information, is not specifically provided in this dissertation. It is a complex study which would have received superficial treatment given the resources at my disposal. The complexity comes from the myriad of land-use possibilities, time scales and variables and ideally, each property should have a tailor-made monitoring system. By way of example, however, an elementary information monitoring system is suggested for a national park in the unpublished report: **A vision for ecological monitoring in a National Park [P 7.1].**

3.9 DATABASE OF ECOLOGICAL PRINCIPLES [TOOL 8]

Tool 8, a database of ecological principles, is also not fully provided in this dissertation (as expected). Nevertheless, a paper was produced which reported on a preliminary community based investigation. The approach was to examine pattern in the community and develop hypotheses describing how the succulent bushveld responds to impact. The study consisted of a three way comparison between the treatments: 'elephant grazing', 'goat grazing' and 'no grazing' (reported in the published paper: **Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa [P 8.1]**). The results implied that the succulent bushveld was changing in sympathy with the change in utilization regime; from that dominated by elephant to that of small domestic stock (mostly goats). The results illustrated that the vegetation is adapted to tolerate elephant impact and not goat farming! This initiated an interest in a basic biological principle, seldom if ever articulated, upon which all of pasture/veld/range/grassland science rests and against which vegetation management efforts inevitably work. IF THE DEFOLIATION REGIME, UNDER WHICH A PARTICULAR VEGETATION TYPE EVOLVED SHOULD BE CHANGED, THEN THE VEGETATION WILL CHANGE IN SYMPATHY WITH THE 'NEW' REGIME. Veld 'degradation' (change away from some agro-ecological 'ideal') is inevitable with modern farming practices and is a symptom of the changing defoliation regime. This principle is so simple, but more often than not it is ignored. Bush clearing efforts are a good example and this, together with the results of the above publication, led to the paper (in press): **Farmland elephant: a solution to degradation in the woody vegetation communities of southern Africa [P 8.2].**

3.10 FURTHER WORK

It is obvious that this study has failed to produce all the tools required for formalized adaptive veld management in succulent bushveld. It is still necessary to develop and test:

i. a vegetation monitoring system for proactive adaptive management (Tool 3); and
ii. a system of recording essential environmental and management information (Tool 7).

Assuming that these are provided, it will then be necessary to formally implement an adaptive management system on various properties and monitor the performance of such systems.

I believe that future work with respect to Tool 8 (ecological principles) should concentrate on the demography of this vegetation type and, in particular, developing an understanding of how individual plants are killed by defoliation. My suggestion for integrating future vegetation work in a manner that is useful to managers is described in the last paper of the thesis: **Framework for the development of a management orientated vegetation model [P 0.2].**

CHAPTER 4

CONCLUDING REMARKS

Perhaps the most important conclusion from this study is my questioning the practicability of adaptive vegetation management in succulent valley bushveld. This has arisen because of my inability to find an efficient land-manager orientated, and proactive vegetation monitoring technique on which adaptive management rests. It could be argued that the methods tested are able to achieve repeatable results, but with considerable effort. The counter to this argument is that without exception, land managers cannot afford the degree of effort required with these conventional botanical methods. It is no wonder that few land managers monitor their veld. I agree that it is too soon to discard the philosophy of adaptive management, but honest reflection will conclude that, to date, there are no good examples where formal pro-active adaptive veld management is been successfully practised. The impression I have, is that we pay lip service to adaptive management and get away with it because its flexible nature is such that its failure can be easily ignored. If, for argument sake, a suitable monitoring technique cannot be found, what becomes of adaptive management, and what alternatives are there?

One view is that biological systems operate randomly in response to stochastic events; i.e. they do not have a predetermined end point. Why should veld management be any different? Objective orientated vegetation management implicity supports the philosophy of adapting the vegetation to meet the requirements of a predefined need, rather than vice versa. What if (when) the need changes? Perhaps management effort should be designed to take responsible advantage of vegetation change when it occurs, rather than trying to adapt management to achieve a specific vegetation vision. 'Locking onto' a specific vegetation endpoint (e.g. open savanna) could even cost opportunities (e.g. clearing encroaching bush instead of converting it into a useful resource).

What of vegetation research? Perhaps there is room for a return to the lassa fair approach to vegetation science based on a mixture of science and art - called 'gut feel'. Big biological breakthroughs (e.g. Darwin 1901; Clements 1916) came from this paradigm. 'Modern biological scientists' must deny this inherent attribute and thereby forgo innovative opportunities because they have been constrained by a system which has a preoccupation with turning biology into a hard science. The scientific system demands absolute accuracy despite the biological 'law' of diminishing returns. For example, scientists waste a massive proportion of their time on irrelevant detail ensuring that a single paper is 'perfect', instead of writing additional papers. Better still, the extra time could be used to develop 'gut feel' through experimentation (in the broadest sense) and innovative observation. If this assessment is true, and I am aware of the untested dogmas which may result in soft sciences (not that these don't appear with monotonous regularity in conventional science), then this can have far reaching implications for research. For example, the tangible results of the research project may be less important than the experience which the project gives the researcher. As such, biological research projects could be designed in such a way that they maximize the experiential learning of the scientist even if this means that the experiments do not strictly conform to the expectations (value judgements) of the current scientific system.

ACKNOWLEDGEMENTS

In addition to the various people acknowledged in each article, I am also extremely grateful to the following organisations and people.

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Jock Danckwerts for logistic support, his personal interest, argumentative but constructive advice and for an extremely enjoyable working atmosphere during the first five years of this study.

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My parents, for their support and encouragement, and for the years of sacrifice which have allowed me the opportunities denied to so many.

To Jenny, my wife, for the sacrifices, love and support during this seemingly endless task.

Finally, to my Parents, Jenny and Dave Grossman for the ruthless harassment which has resulted in the completed thesis.

REFERENCES

Acocks J.P.H. 1975. Veld types of South Africa. 2nd edition. Mem. Bot. Surv. S. Afr. No. 40.

Ahituv N. & Neumann S. 1986. Principles of information systems for management. 2nd edition, Wm. C. Brown Publishers, Dubuque, Iowa.

Anon 1976. Soil loss estimator for southern Africa. Bulletin of Natal Agricultural Research Institute. No. 7, Pietermaritzburg.

Aucamp A.J. 1979. Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke. DSc. Agric. thesis. Univ. of Pretoria.

Brown D.L. 1969. A study of the animal and crop production systems and potential of the Bantu Ciskei territories. D.Sc. thesis, Univ. Orange Free State, Bloemfontein.

Clements F.E. 1916. Plant succession. An analysis of the development of vegetation. Carnegie Inst. Washington. No. 242.

Danckwerts J.E. 1984. Towards improved livestock production off sweet grassveld. Ph.D. thesis. Univ. of Natal, Pietermaritzburg.

Danckwerts J.E. & Teague W.R. Veld management in the eastern Cape. Govt. Printer, Pretoria.

Darwin C. 1901. The origin of species. 6th edition, John Murray, London.

Grossman D. 1988. Relations between ecological, sociological and economic factors affecting ranching in the North-Western Transvaal. Ph.D. thesis, Univ. Witwatersrand, Johannesburg.

Hardy M.B. 1986. Grazing dynamics in Highland Sourveld. M.Sc. Agric. thesis, Dept. Grassland Science, Univ. of Natal, Pietermaritzburg.

Hardy M.B. & Walker R.S. 1991. Determining sample size for assessing species composition in grassland. J. Grassl. Soc. South. Afr. 8(2): 70-73.

Holling C.S. 1978. Adaptive environmental assessment and management. Wiley, New York.

Mentis M.T. 1984. Monitoring in South African grasslands. S.A. Nat. Sci. Prog. Report, No. 91. CSIR, Pretoria.

Mentis M.T. 1985. Conserving rangeland resources. J. Grassl. Soc. South. Afr. 2(3): 27-31.

Tainton N.M. 1981. (Ed) Veld and pasture management in South Africa. Pietermaritzburg: Shuter & Shuter.

Walters C.J. & Hilborn R. 1978. Ecological optimisation and adaptive management. Annual review of ecological systems. 9: 157-188.

Walker R.S. 1987. Monitoring species composition in mountain catchment grasslands. M.Sc. Agric. thesis, Dept. Grassland Science, Univ. of Natal, Pietermaritzburg.

WCS 1980. The World Conservation Strategy: living resource conservation. IUCN, Switzerland.

PAPER INDEX

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INTRODUCTORY WORK

[P 0.1] An agriculturist's view of the nature and extent of succulent bushveld

INTRODUCTORY WORK

Before providing the tools for adaptive management, it was necessary to define the extent and nature of the vegetation type. The unpublished paper: **An agriculturalists view of the nature and extent of succulent bushveld [P 0.1]**, is the product of that effort. This study, as with all classifications, relies heavily on the objectives for classification. As such, it may offend classical botanists who are used to traditional quantitative avenues of classification. I have considered issues of real concern to graziers (i.e. forage source and sustainability) and based the classification on these attributes.

Despite this 'new classification', it was been necessary to use the original classification convention in those publications destined for strictly botanical journals. This has led to some inconsistency in the thesis but hopefully this article will at least serve to cross reference the various naming conventions.

AN AGRICULTURIST'S VIEW OF THE NATURE AND EXTENT OF SUCCULENT BUSHVELD

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ABSTRACT

This paper examines the Sub-Tropical Thicket communities of the eastern Cape (alias - 'Valley Bushveld') from the viewpoint of a land user, not a botanist. As such it concentrates on features which are of concern to managers (i.e. forage production and sustainable utilization).

After reviewing the present classifications, the name 'Succulent Bushveld' is proposed for all those vegetation communities where: i) trees and shrubs are the forage production base; ii) bush encroachment is not a feature; iii) a dominant perennial grass sward cannot be encouraged with bush clearing and iv) succulent shrub species (e.g. Portulacaria afra, Euphorbia spp. & Crassula spp.) are/were an important part of the community.

Typically this vegetation occurs in hot, dry (rainfall 225 to 500mm), frost-free areas at low altitude (usually below 500m but never above 1100m) between the Kei and Gouritz river valleys. Dominant in river valleys, it changes, from one valley to another as one progresses up the coast towards Transkei, and within a single river valley with increasing distance from the coast. The change is generally reflected in greater species diversity, high tree densities, more grass and higher growth habit of the bush as one moves down the valleys towards the coast and eastwards from one river valley to the other.

Included under the name 'Succulent Bushveld', are portions of Acocks's: Fish River scrub [Nr. 23c]; Addo Bush [Nr. 23d(i)]; Sundays River scrub [Nr. 23d(ii)]; Gouritz River Scrub [Nr. 23e]; Noorsveld [Nr. 24] and Spekboomveld [Nr. 25]. The Succulent Bushveld is also similar to Cowling's 'Kaffrarian Succulent Thicket', except that it excludes the non-succulent portions of the Kei river valley bushveld [Acocks Nr. 23b]. It is similar to Everard's Xeric and Mesic Succulent Thickets but differs in that it includes the Noorsveld and the Spekboomveld.

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INTRODUCTION

Vegetation classification is traditionally the domain of phytosociological botanists who classify vegetation on the basis of the evolutionary relationships of floristics. Such classifications, while extremely useful with respect to understanding the development of the vegetation, are not necessarily useful to land managers. This paper attempts to evaluate past classifications of the succulent thicket vegetation types in the eastern Cape from the viewpoint of a land user, not a botanist and consequently, concentrates on the functional features of the vegetation types which are of concern to land managers: i.e. forage production and sustainable utilization.

BACKGROUND

On the eastern seaboard of the Cape province exists a variety of vegetation communities within which woody plants are a characteristic and important component (see Acocks 1975). Most of this vegetation may be classed as typical savanna, where the herbaceous layer is dominated by perennial grasses and the successional trend is towards increased bush: i.e. 'bush encroachment' is a feature of these communities. In past commercial agriculture, the woody plants were treated as weeds and great effort was expended in attempting to rid the veld of these plants. In more recent times, and in contrast to other parts of southern Africa, these woody communities now form an important forage source for browser based farming enterprises. Broadly, the utilization philosophy in these eastern Cape savannas' concentrates on conserving (utilizing wisely) the herbaceous layer whilst damaging (controlling) the woody layer because the latter has strong recuperative powers.
In contrast, the vegetation community known locally as 'Valley Bushveld' is functionally different to the savannas because the herbaceous layer is dominated by ephemeral plants and the successional drift towards increased bush is so slow that for all practicable (land use) purposes, it does not exist. The management philosophy in this vegetation is one of maintaining the shrub component because it is potentially the most productive and if lost, does not regenerate within a human lifespan at least.

Unfortunately, locals (with parochial insight) have simply adopted the term 'Valley Bushveld' to refer to all of the dense woody vegetation where succulents, in particular <u>Portulacaria afra</u>, are common. This has resulted in endless confusion - at best with Valley Bushveld-proper (in Natal), and at worst, with savanna. This confusion needs to be eliminated because the differences are of vital concern to management and can be summarized as follows.

i) The shrub component of the succulent varieties of Valley Bushveld (unlike non-succulent Valley Bushveld or savanna) will not regenerate (within a human lifespan) following severe disturbances.

ii) It is not possible to establish and maintain a stable and highly productive grass sward in the succulent varieties of Valley Bushveld, even with bush clearing.

LITERATURE REVIEW

The name 'Valley Bushveld' comes from Acocks (1975) and refers to the densely wooded vegetation found in the major river valleys of the eastern seaboard of South Africa. This classification intended to group together vegetation with the same utilization potential, but at least two distinct plant communities (a dense scrub dominated by succulents and a very dense savanna or bushveld not dominated by succulents) are grouped together under the same name (Valley Bushveld).

Acocks (1975) did account for this to some extent by dividing the Valley Bushveld [Veld type Number 23] into six variations as follows:

i) Valley Bushveld proper, northern variation, [23a] which extends from the Tugela River valley southwards as far as the Great Kei River;
ii) Valley Bushveld proper, southern variation, [23b] which extends from the Great Kei to the Kabeljauw's valley;
iii) The Fish River scrub, [23c] in the Lower Great Fish River valley;
iv) The Addo Bush [23d(i)];
v) The Sundays River scrub, [23d(ii)] in the wide flat lower Sundays River valley; and
vi) The Gouritz River Scrub [23e].

Cowling (1984), in a conventional botanical study, revised Acocks's classification for the eastern Cape and included all except the northern variation [23a] into a syntaxonomic - synecological 'order' called Kaffrarian Succulent thicket which falls into a 'class' called Subtropical Transitional thicket. He identified another order in this class called Kaffrarian thicket and this contains the grass-bush communities of the eastern Cape [Acocks veld type numbers 2, 76, 21, 46 & 47]. He hypothesised that it was possible to include within the Subtropical Transitional Thicket a third order, Karroid Succulent thicket and this would encompass Acocks's Noorsveld [24], Spekboomveld [25] and Karroid broken veld (of the little Karoo) [26b]. A schematic breakdown of Cowling's (1984) proposed classification is presented in Figure 1.

Insert Figure 1

Everard (1987) further subdivided each of Cowling's Kaffrarian thickets into xeric and mesic sub-orders (Figure 1) but made no attempt to relate these to Acocks's (1975) veld types. Importantly, the vegetation map which Everard presented (Figure 2) conflicts with that of Acocks's (Figure 3).

Insert Figure 2
Insert Figure 3

The former shows more variation within one river valley than between river valleys. This is probably reflected in an increase in 'wetness' as one moves down the rivers towards the coast so that the vegetation in, for example, the Fish river valley changes from Xeric Succulent thicket in the interior, to Xeric Kaffrarian thicket near the coast. It is also evident that the interior of the Fish and Sundays river valleys have similar bush communities (i.e. Xeric Succulent thicket).

DISCUSSION

Although I am more comfortable with Everard's (1987) classification than with Acocks's, it has a limitation in that it does not consider the Noorsveld or the Spekboomveld. This omission, together with the suggestion by Acocks (1975) that the Spekboomveld is a karroid vegetation type (despite Palmer (1990) showing its subtropical affinity), could imply that the Xeric Succulent thicket (300 - 400 mm $rain.yr^{-1}$) and the Mesic Kaffrarian thicket (700 - 800 mm $rain.yr^{-1}$) are more similar to each other than the former is to Spekboomveld (300 - 250 mm $rain.yr^{-1}$) or Noorsveld (225 - 300 mm $rain.yr^{-1}$). Cowling (1984) suggested that these two veld types could also be included into the Subtropical Transitional Thicket as a third order, Karroid Succulent thicket. I suggest, however, that on the basis of rainfall, the same differential bush species (*Portulacaria afra*, *Scotia afra*, *Pappea capensis* and *Grewia robusta* - Acocks, 1975; Everard, 1987; Palmer, 1989), the absence of a stable and productive grass sward, and the irreversible nature of change in these veld types, that the succulent thickets defined by Cowling (1984) and Everard (1987), and Acocks's Noorsveld [24] and Spekboomveld [25], should be incorporated into a single functional veld type. I suggest that these veld types be collectively known as 'Succulent Bushveld' (or Succulent Thicket).

Because of the historical and local connections with the name 'Valley Bushveld', it is probably unwise (for the applied scientist) to reject this name totally. Consequently, when the Noorsveld [24] and Spekboomveld [25] (which do not occur in valleys) are excluded, then the name 'Succulent Valley Bushveld' would be appropriate. It is convenient to subdivide this group into four divisions on the basis of rainfall, the relative dominance and occurrence of diagnostic species and production potential. A suggested division is given in Figure 4 although naturally this requires testing.

Insert Figure 4

Formal description

Succulent Bushveld (or Succulent Thicket) occurs along the south-eastern seaboard of the Cape Province in hot, dry (rainfall 225 to 500mm), frost-free areas at low altitude (usually below 500m but never above 1100m) between the Kei and Gouritz river valleys (data from Acocks, 1975; Cowling, 1984; Everard, 1987; Palmer, 1989; Palmer, 1990; Palmer, unpublished data and Ag met.reports). The vegetation changes, from one river valley to another, as one progresses northwards up the coast, and within a single river valley with increasing distance from the coast. The change is generally reflected in greater species diversity, high tree densities, more grass and higher growth habit of the bush as one moves down the river valley towards the coast and eastwards from one river valley to the other.

Growth forms are diverse and include: leaf and stem succulent shrubs, trees, vines and herbs; large and small-leaved microphyllous and orthophyllous shrubs; stunted trees, grasses; forbs; and geophytes (Cowling, 1984). Succulents contribute 20 - 30% relative cover (Cowling, 1984) and the high incidence of succulents, spines and vines reflects extreme specialization (Bews, 1925): for example, the abundance of CAM species (P.afra, C. ovata and Aloe spp) indicates an adaptation to hot, dry days followed by cool nights (Kluge & Ting, 1978).

Palmer (1990) proposed that the succulent thickets (Succulent Bushveld) evolved after 18 000 BP (the Last Glacial Maximum) and were most extensive during the warmer wetter periods which occurred between 14 000 and 10 000 BP. Conditions then became progressively drier until 6 000 BP, whereafter similar climatic conditions to those currently experienced prevailed (Scholtz, 1986). Palmer, et al (1988) argued that this vegetation is able to survive the present arid conditions by growing in clumps within which the plant/soil environment is modified and moisture is conserved. Destruction of these communities leads to irreversible change given the present arid conditions and consequently the succulent bushveld is informally called a relic vegetation. Whatever the mechanism, it remains an inherent feature of this vegetation that once destroyed, it seems unable to regenerate within a human lifespan.

CONCLUSION

It should be borne in mind that, as with any classification, there are intergrades. Drawing lines between groups is subjective and does not reflect reality. The resolution of classification will depend on the objectives for classification. When mapping these, misunderstandings inevitably arise when the resolution of the vegetation map is different to the resolution required by the user. The result of such misunderstanding is that a particular user rejects the map/classification as being worthless. Another problem with mapping is that these are often unable to accurately represent the variation on the ground - this being particularly severe in the Succulent Valley Bushveld as a result of the broken topography.

In an attempt to avoid this problem I suggest a 'vital attributes' approach (perhaps contained in an expert system) to identify the type of vegetation and hence utilization potential at any given site. It is my opinion that vegetation maps are for explanation and illustration, not prediction.

REFERENCES

Acocks J.P.H. 1975. Veld types of South Africa, 2nd edition. Mem. Bot. Sur. S. Afr. No 40. Government Printer, Pretoria.

Agmet records. Dohne Research Station, South Africa.

Bews J.W. 1925. Plant forms and their evolution in South Africa. Longmans, London.

Cowling R.M. 1984. A syntaxonomic and synecological study in the Humansdorp region of the fynbos biome. Bothalia, 15, 175-227.

Everard D.A. 1987. A classification of the subtropical transitional thicket in the eastern Cape, based on syntaxonomic and structural attributes. S. Afr. J. Botany, 53, 329-340.

Kluge M. & Ting I.P. 1978. Crassulacean acid metabolism: analysis of an ecological adaptation. Springer, Berlin.

Palmer A.R. 1989. The vegetation of the karoo nature reserve, Cape province. I. a phytosociological reconnaissance. S. Afr. J. Bot. 55: 215-230.

Palmer A.R. 1990. A qualitative model of vegetation history in the eastern Cape midlands, South Africa. J. Biogeography. 17: 35-46.

Palmer A.R., Crook B.J. & Lubke R.A. 1988. Plant/soil interactions on the Andries Vosloo Kudu Reserve, Cape province. S. Afr. J. Bot. 54: 309-314.

Scholtz A. 1986. Palynological and palaeobotanical studies in the southern Cape. M.A. thesis, Univ. Stellenbosch, Stellenbosch.

FIGURE CAPTIONS

Figure 1. Schematic breakdown illustrating the relationships between the classifications of the thicket vegetation communities of the eastern Cape made by Acocks (1975), Cowling (1984) and Everard (1987).

Figure 2. A map showing the extent of the four thicket types in the eastern Cape identified by Everard (1987).

Figure 3. A map showing the extent of three arid thicket vegetation types in the eastern Cape identified by Acocks (1975).

Figure 4. A suggested agricultural classification of Succulent Bushveld in the eastern Cape. Everard's Kaffrarian Succulent Thicket and Cowling's Karroid Succulent Thicket (see Figure 1 for the respective Acocks veld types) are equivalent to the Succulent Valley Bushveld and Karroid Succulent Bushveld respectively.

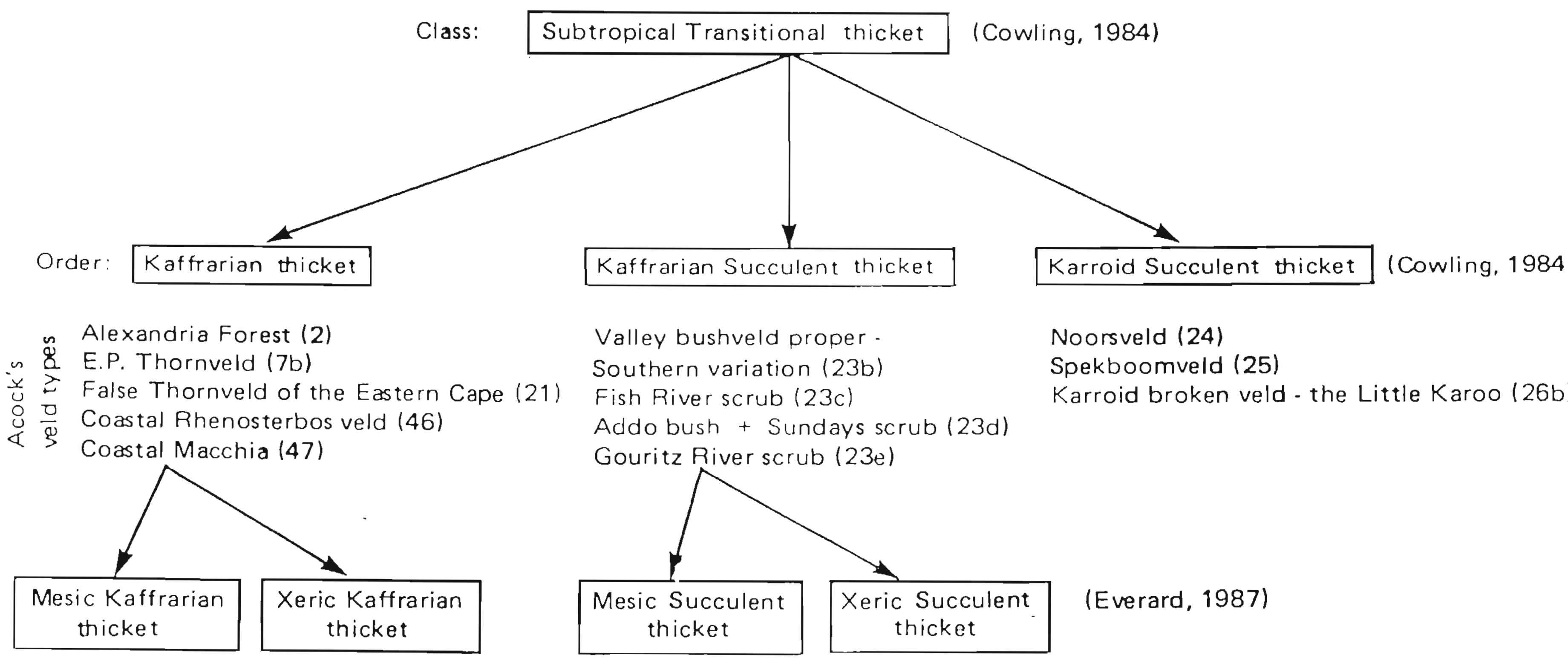

Class:
Subtropical Transitional thicket
(Cowling, 1984)
Order:
Kaffrarian thicket
Kaffrarian Succulent thicket
Karroid Succulent thicket
(Cowling, 1984)
Acock's veld types
Alexandria Forest (2)
E.P. Thornveld (7b)
False Thornveld of the Eastern Cape (21)
Coastal Rhenosterbos veld (46)
Coastal Macchia (47)
Valley bushveld proper -
Southern variation (23b)
Fish River scrub (23c)
Addo bush + Sundays scrub (23d)
Gouritz River scrub (23e)
Noorsveld (24)
Spekboomveld (25)
Karroid broken veld - the Little Karoo (26b)
Mesic Kaffrarian thicket
Xeric Kaffrarian thicket
Mesic Succulent thicket
Xeric Succulent thicket
(Everard, 1987)

Figure 1

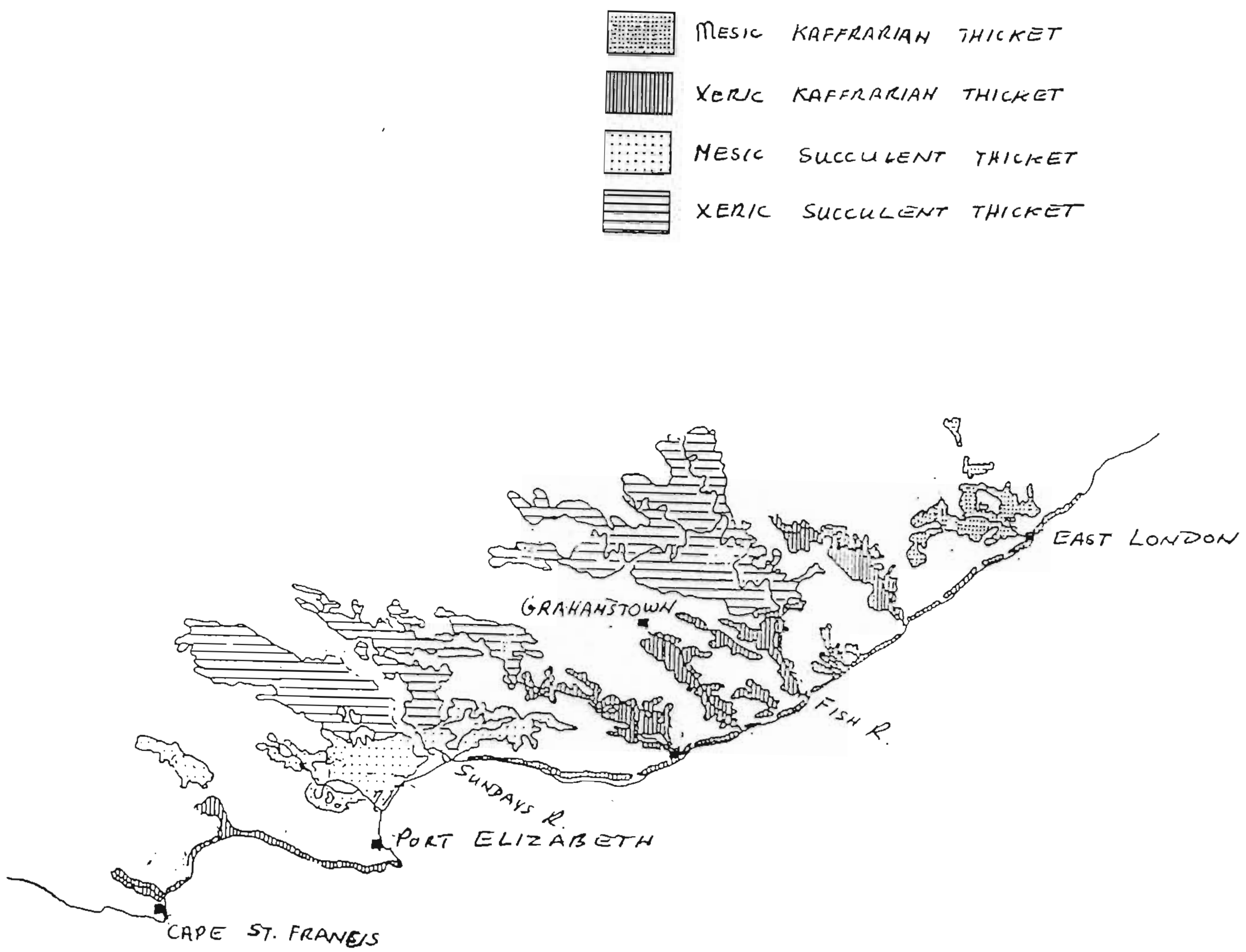
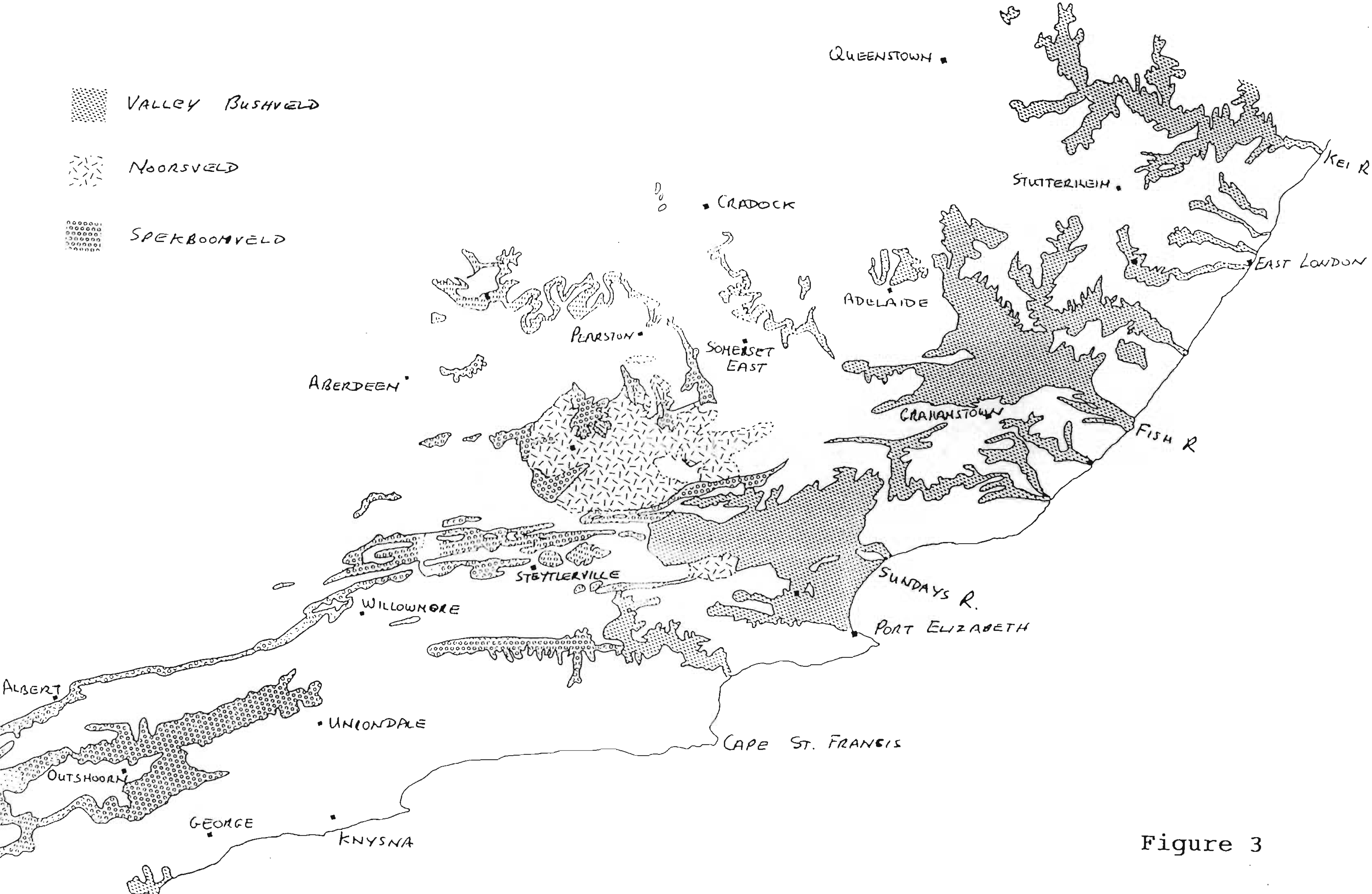

MESIC KAFFRARIAN THICKET
XERIC KAFFRARIAN THICKET
MESIC SUCCULENT THICKET
XERIC SUCCULENT THICKET
EAST LONDON
GRAHAMSTOWN
FISH R.
SUNDAYS R.
PORT ELIZABETH
CAPE ST. FRANCIS

Figure 2



VALLEY BUSHVELD
NOORSVELD
SPEKBOOMVELD
QUEENSTOWN
KEI R.
STUTTERHEIM
CRADOCK
EAST LONDON
ADELAIDE
PEARSTON
SOMERSET EAST
ABERDEEN
GRAHAMSTOWN
FISH R
STEYTLERVILLE
SUNDAYS R.
WILLOWMORE
PORT ELIZABETH
ALBERT
UNIONDALE
CAPE ST. FRANCIS
OUTSHOORN
GEORGE
KNYSNA

Figure 3

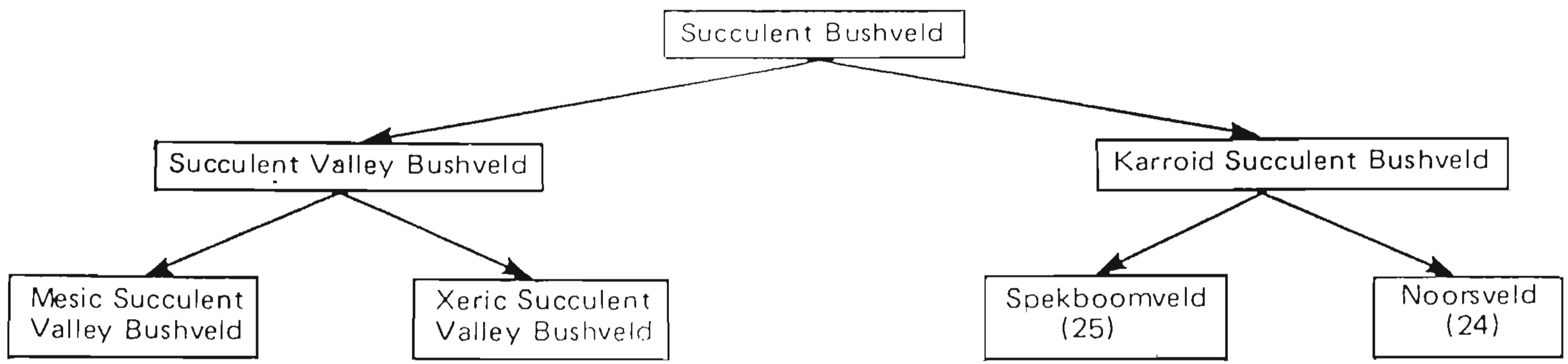

Succulent Bushveld
Succulent Valley Bushveld
Karroid Succulent Bushveld
Mesic Succulent Valley Bushveld
Xeric Succulent Valley Bushveld
Spekboomveld (25)
Noorsveld (24)

Figure 4

TOOL 1

MANAGEMENT SYSTEM FOR IMMEDIATE IMPLEMENTATION

[TOOL 1]

A MANAGEMENT SYSTEM FOR IMMEDIATE IMPLEMENTATION

ORIGINAL BRIEF

This should not be presented as the only correct management system. Rather it is a suggestion which individual land users can adopt in the absence of their own.

RESULT

The first product of this goal was a section in a book entitled: **Management of veld types: succulent valley bushveld [P 1.1]**. This recipe was given reluctantly to serve as an initial guideline for those who have no management plan. It is heavily biased towards domestic stock farming and consequently has a very narrow market. On reflection, it was decided not to upgrade this recipe (even for those rare individuals who may request one) because the effort in developing such a system does not warrant the amount of times it will be used. Furthermore, a management plan rests on objectives which are value judgements and it follows that these plans will be personalized for each property and land manager. This Tool was eventually achieved by emphasising the principles that managers should be aware of (see the section in a second book: **Management of different types of veld: succulent bushveld [P 1.2]**). The reader should be aware that the second article repeats some material from the first. I apologise for this, but deleting the first would have removed the opportunity of illustrating a process.

ERRATA & CLARIFICATION NOTES

This publication appeared in a semi-popular book published in 1989 by the Government Printer, Pretoria. The numbering convention for sections, figures and tables refers to the book, not the thesis.

Specific errors (excluding punctuation and those as a result of changing information or philosophy) are as follows.

Pg. 167	Col. 1	Ln. 42	"only" should precede "once the plants ..."
Pg. 171	Col. 1	Ln. 19	"step 41" should read "step 40"
Pg. 174	Col. 1	Ln. 8	"step 17" should read "step 18"
Pg. 174	Col. 1	Ln. 20	"step 17" should read "step 18"

[P 1.1]

Veld management in the Eastern Cape

Editors
J.E. Danckwerts and W.R. Teague

CONTENTS

10.4 SUCCULENT VALLEY BUSHVELD

G.C. Stuart-Hill

10.4.1 Introduction

There are very little quantitative data available that can serve as a basis for the development of a management plan for the Succulent Valley Bushveld. Aucamp (1979) produced a dissertation in which the production potential of the Succulent Valley Bushveld was assessed. A portion of this work investigated the growth of *P. afra* and its reaction to defoliation. This is a relatively limited input when compared with veld types such as the False Thornveld and the Dohne Sourveld. Aucamp and Tainton (1984) published a booklet entitled *Veld Management in the Valley Bushveld of the Eastern Cape* in which a management programme, based on the results of Aucamp (1979), was presented. The present author has used this work extensively in this Section.

This Section begins by reviewing the major biological principles that management should consider in the Succulent Valley Busveld. It then describes some farming enterprises that appear to have potential in this vegetation type. Finally, it presents a management plan that can serve as a starting point for an adaptive management programme.

10.4.2 Principles to consider in management of Succulent Valley Bushveld

(i) The climate is characterised by an unreliable, low rainfall - averaging less than 500 mm a year. It is estimated that there is a 25% chance of the area receiving less than 80% of its long-term average annual rainfall in any year (Aucamp & Tainton, 1984). This aridity is compounded by extremely high temperatures.

(ii) The shrub component of the vegetation is the production base. If damaged through over-utilisation, the woody layer will not recover and, consequently, bush encroachment is not a phenomenon experienced in this veld type. It is important to appreciate that if bush is removed it is not, as in other bushveld types, replaced by more productive grassland.

(iii) The herbaceous layer is not a reliable source of forage as it fluctuates widely with environmental conditions. It is sparse and predominantly non-perennial and although it normally has little commercial value (except after a series of good rains) it is ecologically important in enhancing infiltration and reducing run-off and soil erosion. This is shown by run-off and soil erosion data obtained with a rainfall simulator (Scheltema, unpublished data) which illustrates that cutting the herbaceous material results in a dramatic increase in run-off and soil loss (Table 10.4.1).

It is advisable therefore, that no farming enterprises be based entirely on this resource.

(iv) Degradation of this vegetation is characterised by loss of almost all plants occurring in the veld

TABLE 10.4.1 - The role of standing herbaceous material in reducing run-off and soil erosion in the Succulent Valley Bushveld. These were determined from two runs (a wet and a dry) with a rainfall simulator on a Swartland soil with a slope of between 7,8 and 8,2%. "Rainfall" intensities were 83,82 mm/h and 67,43 mm/h for the dry and wet runs respectively

Treatment	Dry run			Wet run		
	Minutes before run-off	After 60 min Run-off %	After 60 min Soil loss t/ha	Minutes before run-off	After 60 min Run-off %	After 60 min Soil loss t/ha
Uncut	> 83	0	0	12	21	0,57
Cut	12	12	1,66	3	54	1,53

type. The result of extreme degradation is bare ground.

(v) There appears to be little or no recruitment of woody species in the Succulent Valley Bushveld. To maintain the productivity of this vegetation it is essential that every plant be kept alive as the loss of even a single plant usually represents a loss in total productivity. This can be achieved by lenient defoliation and, more importantly, by allowing the plants to recover to at least their pre-defoliation levels. It is inevitable, however, that on occasion some plants will die, and consequently it will be necessary to provide for this, either by allowing some recruitment or, at the very least, allowing the remaining plants to increase in size. At present the mechanisms of shrub recruitment through seeding in the Succulent Valley Bushveld are not known, and this requires urgent investigation. It probably occurs after certain episodic events and, logically, one would expect that management after these will be crucial to the survival of the seedlings.

Allowing remaining plants to increase in size so as to compensate for the loss of a plant is inadequate, but current management recommendations use this approach because: (i) we do not know how to encourage seedling survival: and (ii) *P. afra*, the dominant (and desirable) species, is able to propagate vegetatively provided its branches are allowed to become long enough so that they rest on the ground, where they can take root and eventually become new individuals.

In the past, before commercial pastoralism, elephants were probably a dominant defoliating agent in the Succulent Valley Bushveld. It is of interest that these animals, although having an enormously destructive impact on individual *P. afra* plants, do not appear to stop this plant from reproducing vegetatively (personal observation). Elephants appear to browse *P. afra*, "from the top downwards" and this contrasts with goats that browse *P. afra* "from the side inwards" (Fig. 10.4.1).

The browsing habit of elephant would allow the lower-side branches to root and propagate despite severe damage to the upper canopy. By contrast, goats would be defoliating these branches and this would prevent them from establishing new individuals. The sudden change in defoliation regime with the introduction of commercial pastoralism, means that this vegetation is not adapted to the type or intensity of browsing to which it is now subjected. The inevitable result is that it will change -

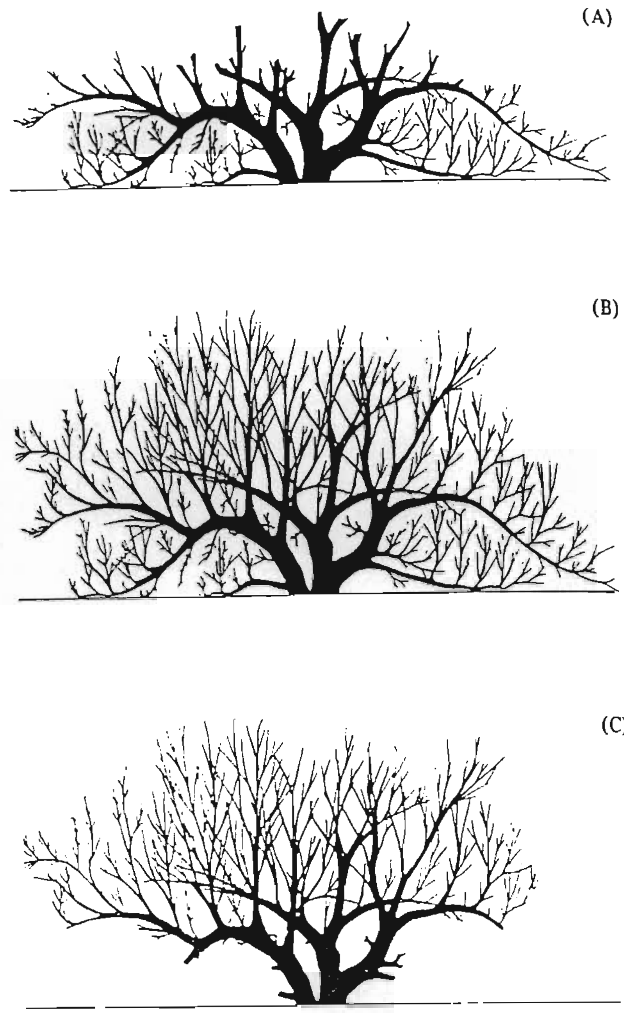


FIG. 10.4.1 - Hypothetical effect elephant browsing (A), no browsing (B) and goat browsing (C) have on the growth habit of *P. afra*

unfortunately it changes to a state that is less productive and ecologically unsound.

It may be worth noting that with the removal of avian and mammalian predators, small herbivores (e.g. rodents and Hyrax species) have been allowed to increase in number. This may be having a detrimental effect on the survival of seeds and seedlings and therefore on the recruitment of shrubs.

(vi) The annual productivity of this vegetation is low (Aucamp, 1979) and goats, if forced to do so, are able to consume years of accumulated growth within a short period. If this occurs, a large amount of twigs will be removed and this represents a loss of meristematic tissue (i.e. growing points). It follows that in order to recover from this form of utilisation, shrubs, unlike grasses, have to regenerate growth sites before lost foliage can be replaced. This would require extremely long rest periods. As a consequence, it is hypothesised that the management principle of "sacrificing" a camp following good rains in order to allow plants in other camps a period of undisturbed growth (Section 10.1), is not applicable to this veld type.

(vii) After defoliation, the recovery of shrubs in this vegetation can be extremely variable, and depends on defoliation intensity, season of defoliation and prevailing environmental conditions during the recovery period. For example, *P. afra*, following 50% leaf removal, has been known to take between 30 days (Aucamp, 1979) and 18 months (Stuart-Hill, unpublished data) to recover to its pre-defoliated state. This means that it is extremely difficult to apply a rotational system with fixed periods of occupation and absence. Preferably, recovery should be monitored on the plant and only once the plant has recovered (be it in 1 or 24 months) should it be browsed.

Farmers generally do not observe their plants and, for planning purposes, prefer to have fixed rotational systems. If these inefficient systems must be adopted, then it is necessary that the periods of absence be long. Aucamp and Tainton (1984) recommended that between 211 and 275 days be allowed following defoliation intensities of 25-50%. This intensity of defoliation is recommended as it would appear that *P. afra*, at least, is stimulated to produce more forage with these levels of utilisation (Aucamp, 1979). It is evident that many other browse species respond in a similar manner to lenient defoliation (Garrison, 1953; Cook & Goeble, 1962; Lay 1965; Ferguson & Basile, 1966; Teague, 1987).

(viii) Provided the Succulent Valley Bushveld is not greatly overstocked, both Boer and Angora goats are able to select a diet that permits good animal performance (Aucamp, 1979). Indeed, these animals are able to slowly destroy the vegetation whilst still gaining mass. It follows, therefore, that the condition of the animal should not be used as a measure of overbrowsing. Consequently, if destocking is necessary as a result of a loss in animal performance, then the land operator should be aware that he has already damaged the vegetation and should allow for this in his future planning. This attribute of the vegetation nevertheless confers an advantage to a farmer who bases his rotational browsing system on the recovery of the key shrubs (principle vii) - i.e. he only allows a camp to be regrazed once the plants have recovered to their predefoliated levels. As soon as such a land operator finds himself in the situation where he has no camps that have recovered, then he knows his property is overstocked. He will then have time to off-load (sell) some of the stock before they lose condition. A further advantage is that, as most farmers do not manage their veld in this manner, he would be selling his stock at a time when few others are.

(ix) Although goats will utilise almost all of the species in this vegetation type, the palatabilities of the various bush species do differ (Stuart-Hill, unpublished data). Indeed, it appears that the most desirable species will be over-utilised before the less desirable species have even been browsed. Forcing goats to utilise all species to the same level is unrealistic because they will over-utilise and even physically damage the branches of desirable species before utilising the less desirable species (the author has observed that branches of *P. afra* in excess of 70 mm in diameter have been broken off during lenient browsing). It follows that this vegetation should be so managed that the desirable/palatable species are utilised at their "optimum" level.

10.4.3 Current and potential farming systems

Since environmental conditions in the Succulent Valley Bushveld are too arid for cultivated pastures, livestock production is usually based entirely on the veld. However, if a farmer has irrigated lands, a useful system would be to establish cultivated pasture on these with the objective of removing the animals from the veld onto the pastures during critical growth stages (e.g. after each significant rain) to allow the bush a chance to grow undisturbed.

This would increase productivity and ultimately raise the carrying capacity of the bushveld. Another enterprise that has potential in areas where the bush has been eliminated through past mismanagement, is to establish saltbush. These are productive and hardy, and can be used either to relieve nutritional bottle-necks, or as an enterprise on their own.

Since the primary forage source is browse, it follows that browsers should be the main enterprise. The only domestic browser is the goat and both Angora and Boer goats are popular and profitable farming enterprises in this vegetation. Some land operators are opting for a game enterprise in which the dominant browsers are kudu and bushbuck and the income is derived from hunting fees and/or the products of these animals. A useful, financially attractive and aesthetically pleasing system is a combination of game and domestic stock into a single enterprise.

Sheep (e.g. Dorpers) may also be considered as they do some browsing, although they will probably destroy the little herbaceous vegetation before using significant amounts of browse. It is thus preferable to run goats alone and thereby lessen the pressure on the herbaceous vegetation. This recommendation is based on the run-off and soil erosion data shown in Table 10.4.1.

After a series of exceptionally good rains, a considerable amount of herbaceous vegetation may be produced. When this occurs, the grass could be used with grazers brought in on an *ad hoc* basis. It is emphasised, however, that the herbaceous vegetation does not provide a constant fodder supply and, consequently, managing grazers on a permanent basis in the Valley Bushveld is a hazardous exercise.

Finally, it appears that there may be a potential for ostrich farming in areas where the bushveld has been severely damaged through past mismanagement. However, there is little information regarding the potential or suitability of this enterprise.

10.4.4 A veld management system for consideration

There is certainly more than one way of managing veld to achieve profit without harming the resource. The question that will probably always remain unanswered is, which system is the most efficient? The management system presented here attempts to

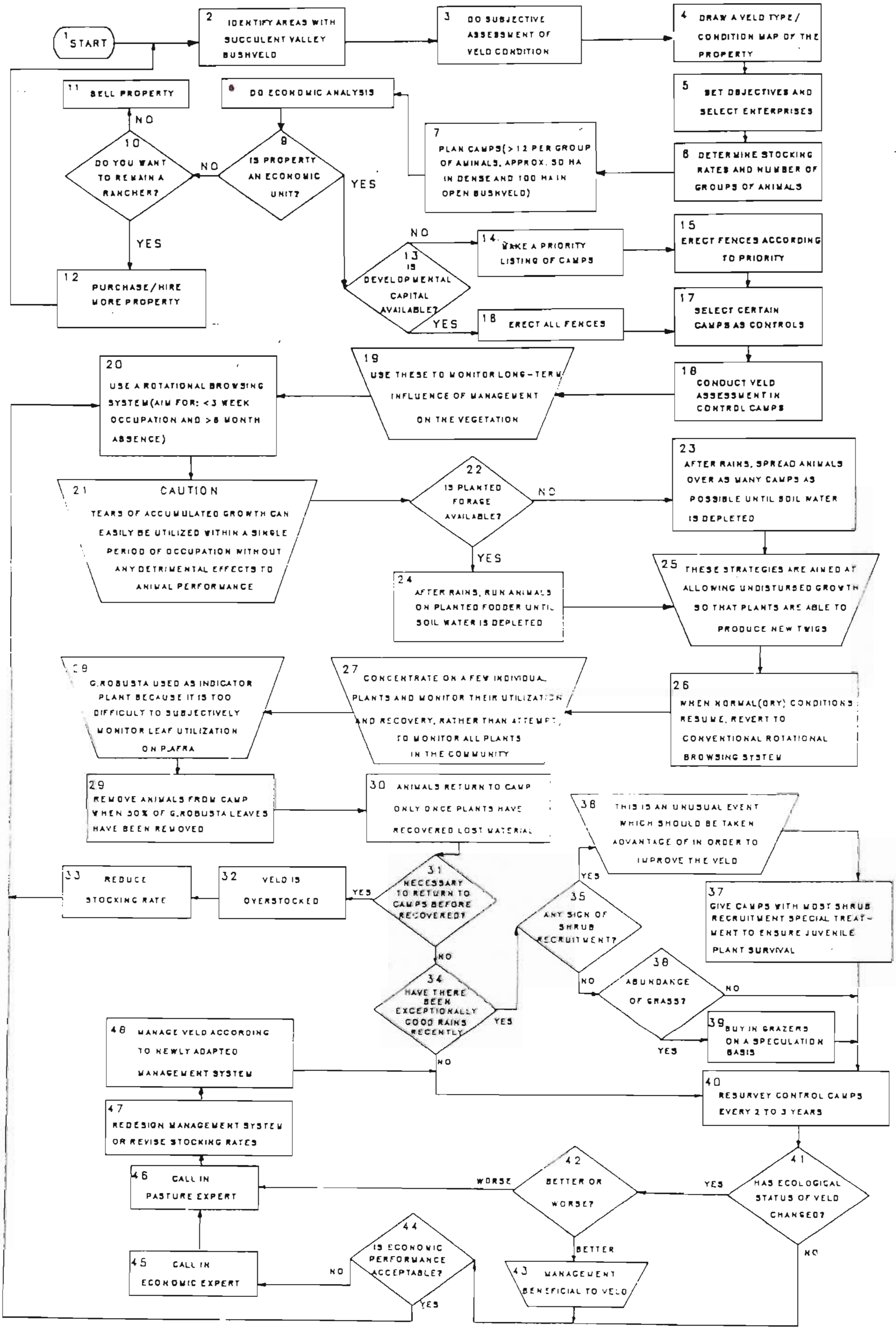


FIG. 10.4.2 - An algorithm illustrating a management system for Succulent Valley Bushveld

incorporate the ecological principles discussed earlier (Section 10.4.2) and is presented as a model for testing and modification, refinement and, if necessary, rejection. It is intended as an initial step in adaptive management, i.e. to provide a starting management system for Succulent Valley Bushveld where none exists (Fig. 2.1, step 5a). The system is illustrated as an algorithm (Fig. 10.4.2) and assumes that the user is farming domestic browsers for profit.

The prevention of resource deterioration is a non-negotiable attribute of this management model and, consequently, it may not be economically viable on many properties in the veld types that are too small for sustained commercial pastoralism. It is the opinion of the author that attempting to develop a management system for these properties, is a worthless exercise.

The management system presented (Fig. 10.4.2 is derived from some research results, but relies also on successful farming operations and on the intuition of pasture scientists.

A step by step explanation of Fig. 10.4.2 follows.

1. Start

2. Identify areas with Succulent Valley Bushveld

It is important to identify these areas on a farm because they can be confused with dense non-succulent bushveld which has different management options and requirements (Section 8.5.2).

3. Do subjective assessment of veld condition

In this vegetation type. objective assessment is tedious and time-consuming. If the objective is merely to do an inventory (i.e. assess what is there) then structured subjective estimates are probably adequate. This can be done by inspecting recent aerial photographs and placing areas with different appearances into different categories. This should be backed up by using a team of experienced assessors to class, in the field, these categories into different condition/ecological classes.

4. Draw a veld type/condition map of the property

Veld type, in this context, refers to plant communities that are likely to have different production potential, palatabilities and sensitivities to degradation. In the Succulent Valley Bushveld, the ecological status (condition) of the vegetation is probably of overriding importance with respect to productivity, palatability and sensitivity and it is important that areas of similar ecological status be mapped together. Further classification should be done on the basis of soil types (especially depth), aspect, catenal position and irrigable lands. This step is necessary to assist in setting objectives, selecting enterprises and developing a management plan (step 5).

5. Set objectives and select enterprises

In this step the farmer must clearly define his personal objectives in terms of income, time, likes and dislikes. With these in mind, and considering the natural and financial resources, the various farming enterprises should be selected (e.g. Angora goats will be the main enterprise and will be supported by game farming, 50 ha of irrigated lucerne, and 20 ha of saltbush plantation). It is also important that the land operator should state what veld condition/ecological status he considers as optimum, and what performance he expects from his individual enterprises. Without doing this, the farmer has no way of measuring his progress, and cannot, therefore, apply adaptive management (Chapter 2).

6. Determine stocking rates and number of groups of animals

An approximate index of the average long-term browsing capacity for the Valley Bushveld in various conditions is illustrated in Fig. 10.4.3.

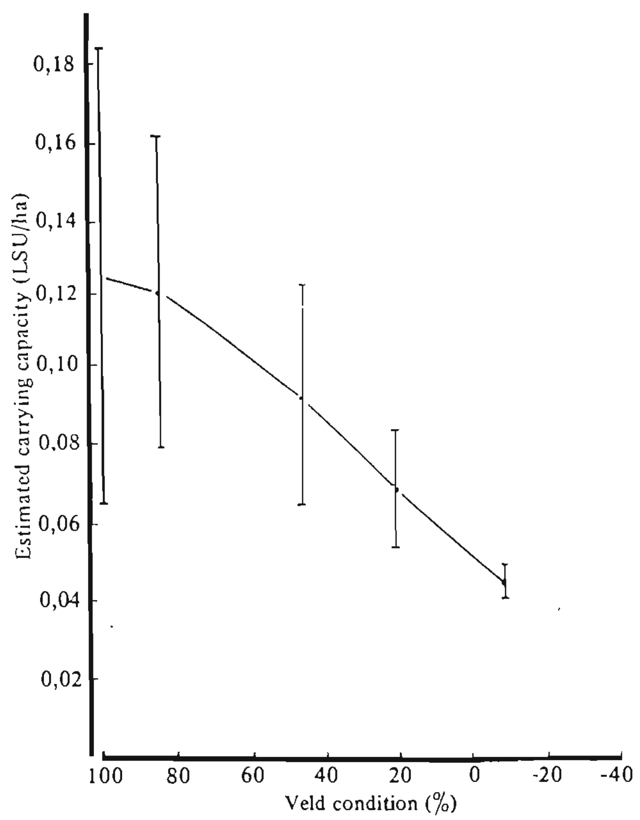


FIG. 10.4.3 - The relationship between the ecological status (veld condition) and carrying capacity in the Sundays River Valley as estimated by six leading farmers. The vertical bars represent the standard errors

This graph shows the relationship between veld condition score and browsing capacity and was developed from subjective estimates of carrying capacity, by a group of leading farmers of the Xeric Succulent Valley Bushveld (Kirkwood District). The veld condition was determined by the technique described in chapter 8.5 (Stuart-Hill, unpublished data). As an initial value, the carrying capacity of a sample site of Valley Bushveld in the Sundays River Valley can be obtained from the graph. It would appear that the carrying capacity of the Mesic Succulent Bushveld may be slightly higher.

It has been estimated in the Fish Valley, from grazing records of 17 years, that an average annual stocking rate of 0,19 LSU/ha has not harmed the condition of a site of Succulent Valley Bushveld scoring 100% (Stuart-Hill, unpublished data). This represents a 50% increase over the mean estimated carrying capacity of Xeric River Valley bushveld scoring 100% and may serve as a rule of thumb when estimating carrying capacity of the Mesic Succulent Valley Bushveld (i.e. multiply the carrying capacity obtained from Fig. 10.4.3 by 1,5). It should be appreciated that these values are not to be considered as hard and fast rules, but should rather be used in the interim until more objective methods of estimating grazing capacity become available, or if adaptive management shows that they should be adjusted.

The most desirable stocking ratio will vary according to the objectives of the land operator and according to the condition of the vegetation. In dense bushveld, it is recommended that stocking rates be adjusted so that the total number of animal units are made up of: 85% goats and 15% kudu. In open bushveld where herbaceous vegetation becomes relatively more important, the stocking ratio may be made up of: 80% goats, 5% kudu and 15% sheep/cattle (Aucamp & Tainton, 1984). It is important to appreciate that the Succulent Valley Bushveld has a fairly high stocking rate of kudus (approx. 0.083 LSU/ha), and this should be accounted for when setting stocking rates.

Once the farmer is aware of the number of animals he can run on the property, he can determine the number of flocks that he will require. These should be kept to the minimum practicable number in order to facilitate fewer camps on the property (every extra group of animals will require at least 12 extra camps).

7. Plan camps

In addition to fencing off the "veld types" identified in step 4, the property should have sufficient camps to facilitate proper rotational grazing. It is suggested that at least 12 camps are necessary per group of animals (Aucamp & Tainton, 1984).

The recommended camp size is 40 - 50 ha in the dense bushveld and 80 - 100 ha in the open bushveld (Aucamp & Tainton, 1984).

Camps that follow the shape of the areas identified in step 4 are biologically more acceptable than the funnel-shaped camps provided by wagon-wheel layouts. The latter, however, provide considerable advantages in water provision and stock management and therefore may be extremely useful where conditions permit. Wagon-wheel layouts should be established only where the topography is such that it is possible to separate veld types and to provide a central hub area in such a position that its surroundings will not be severely eroded by the inevitable concentration of stock trampling around the hub (Aucamp & Tainton, 1984). A further disadvantage of wagon-wheel camps is that they are long and narrow (especially in large layouts) and the animals are reluctant to walk long distances in this vegetation when they can severely defoliate nearby plants without suffering nutritional stress.

8. Do economic analysis

Having determined the number of animals the property can carry (step 6), and the requirements for production (step 5) and camping (step 7), the operator can determine the theoretical profitability of the property. The manager will then be in a position to determine whether the property is large enough to fulfil his personal financial requirements in an average year.

9. Is property an economic unit?

10. Do you want to remain a rancher?

If the property is not adequate to fulfil the owner's financial requirements, he must decide whether he wishes to remain a pastoralist.

11. Sell property

If the owner does not wish (or cannot afford) to remain a rancher, it would be advisable to sell the property and invest in an alternative enterprise.

12. Purchase or hire more property

Should the owner of a subeconomic unit wish to remain a rancher, it is necessary that he either purchase or hire more property in which case he should begin again at step 2.

13. Is developmental capital available?

14. Make a priority listing of camps

If there are not sufficient funds immediately available to erect all planned fences and watering systems, then this should be done according to priority. The most important fences are those that separate different plant communities. In this veld type, it means separating veld with different conditions (or ecological statuses) - the bigger the difference the more of a priority is the separation. Camps that enjoy the lowest priority are those that break up a uniform area to reduce camp size or create more paddocks.

15. Erect fences according to priority

As development capital becomes available, the fences with the highest priority rating should be erected first.

16. Erect all fences

If sufficient developmental capital is immediately available then all fences and watering systems planned in step 7 should be erected.

17. Select certain camps as controls

The objective method of vegetation assessment is expensive and tedious. Consequently, it is not practicable to do veld condition surveys in all camps on the property. Certain camps should be chosen to represent the major plant communities identified in step 4. These will be known as control camps and should receive no special treatment in relation to the other non-control camps.

18. Conduct veld assessment in control camps

Conduct detailed vegetation surveys in the control camps according to the technique described in Section 8.5.

19. Use control camps to monitor long-term influence of management on the vegetation

Detailed records of any management activity or environmental perturbation must be kept for each of the control camps. When these camps are resurveyed (step 41), any change in the condition of the vegetation can be interpreted in terms of the management applied and/or the environmental conditions experienced (Chapter 2). If the management of the control camps has been the same as the management on the non-control camps, then it may be assumed that the dynamics of the former represent that of the latter.

20. Use a rotational browsing system

Although there are no data that illustrate that rotational browsing systems are superior to continuous browsing systems, the former is recommended for the following reasons:

(i) It allows a degree of control over area-selective grazing. This can be severe as goats seem to prefer sparsely-bushed areas. In time, these areas become over-utilised while the densely bushed areas are under-utilised.

(ii) It allows a degree of control over the intensity and frequency of defoliation of the key browse species. At this stage it is not certain whether it is necessary to control this as certain browse species appear to have the ability to become unpalatable when browsed (Van Hoven, 1984; Rhoades, 1985). They may be able, therefore, to control the intensity and frequency with which they are defoliated, provided the herbivores are allowed a free choice. This requires testing, especially with goats, since these appear to be less sensitive to secondary plant metabolites than wild herbivores (Malechek & Provenza, 1983).

(iii) It allows for strategic treatments to be implemented, e.g. allowing an extra-long rest after exceptional rains to encourage shrub recruitment.

(iv) It allows for easier stock management, e.g. stock mustering (finding animals in small camps is easier than finding them in large camps), control of predators and parasites.

It is true that the above [except point (iii)] could be achieved in a multi-camp system regardless of whether continuous or rotational browsing is applied. The essential reason for recommending rotational over continuous browsing is that the former allows the manager to control, when, where and how intensively his animals will browse, thus giving him a better chance of manipulating the vegetation.

Early browsing of regrowth will reduce the rate at which defoliated plants will recover. Consequently, animals should not remain in a camp until regrowth has developed sufficiently to permit it to be rebrowsed. Within reason, therefore, the shorter the period of occupation, the better. In doing so, however, the subsequent rest period becomes shorter as the rotation from one camp to the other speeds up. During fast growing periods, the period of occupation should be short but need not be reduced below about 7 - 10 days (Aucamp & Tainton, 1984). During slow growing periods, however, the period of occupation can be extended to approximately 60 days (to lengthen the period of absence in other camps) without the danger of browsing regrowth.

A long period of absence is desirable in this veld as rains are infrequent and sporadic, and it is proposed that rests without rains do not constitute a recovery period. It is, at the very least, necessary to allow enough time for the plants to recover to their pre-defoliated condition. Unless this is done, individual plants will in time become smaller, their vigour will decline and eventually they will die. This will lead to veld deterioration since shrub replacement through seedling establishment does not appear to occur under current agricultural systems. It is not unreasonable to accept that the required period of rest depends on the degree of utilisation that is employed. The lower the intensity of utilisation, the shorter need the period of rest be. So, for example, if 50% of the leaf material is removed from spekboom under normal climatic conditions, a rest period of about 275 days, on average, is required to allow the browsed plants to recover to their pre-utilised condition. Where utilisation is less severe (say 30% leaf removal), the rest period can be reduced to about 210 days (Aucamp, 1979).

21. Caution - years of accumulated growth can be utilised within a single period of occupation

The quality of Succulent Valley Bushveld is high and goats are able to severely damage the vegetation within a short period without significantly affecting animal performance (Aucamp, 1979). Unlike grasses that retain their meristematic regions out of reach of grazing animals, the meristematic regions of shrubs are exposed to herbivory. These are protected either by secondary plant metabolites, or by being associated with highly lignified material (i.e. wood). It follows that if browsers are able, or are forced, to ignore the protective attempts of the shrubs, then they can inflict severe damage on the plants' total meristematic material. There is a limit to the amount of physical damage that grazers can inflict on grasses, even if they are forced to overgraze. It is more likely that grasses die through overgrazing because of a rundown in vigour rather than physical damage. Shrubs die, however, because of: (i) a rundown in vigour, (ii) a loss of meristematic tissue and (iii) loss of bark (i.e. "ring barking"). This would mean that palatable shrubs are more sensitive to over-utilisation than grasses and extreme caution should be applied when utilising these plants, especially in this vegetation where annual productivity is low.

22. Is planted forage available?

It is strongly recommended that extra forage be planted on all properties in this veld type. This refers to irrigated pastures (where possible) or plantations of drought resistant crops (e.g. saltbush). Having these available is advantageous because: they can be used as a drought reserve; they can be used to increase the carrying capacity of the property; and, most importantly, they allow pressure to be removed from the veld at critical times. Cultivated forage should be viewed as an aid in managing veld rather than as an enterprise on its own - despite the short-term advantages that intensive systems appear to have.

23. After rains, spread animals over as many camps as possible

If cultivated forage is not available, then, after significant rains have fallen (i.e. rains of sufficient size to support growth for at least one week), it is proposed that the rotational grazing system should be abandoned and the animals spread over as large an area as possible. The intention here, where no cultivated forage is available, is to allow lenient defoliation of the key browse species so that they are given a chance to grow new twigs and on these produce and protect new meristematic material.

24. After rains, run animals on cultivated fodder until soil water is depleted

When cultivated forage is available, then for the same reason as given in step 23, animals should be removed from the actively growing veld onto the cultivated fodder. These fodder sources (especially when irrigated) should receive rests during the period when the animals are on the veld, in the normal rotational system.

25. These strategies are aimed at allowing undisturbed growth so that plants are able to produce new twigs

The meristematic regions for the production of browse (leaves, flowers, pods, etc.) are generally borne on young twigs. If these are never allowed to establish, then it means a loss in the potential for forage production. It is proposed that, in this veld, where growth generally occurs in short bursts following rains, removing or reducing browsing pressure during these times is advantageous because it would allow new twigs to grow. Furthermore, it will give these young twigs a chance to become less susceptible to browsing (e.g. by becoming more lignified).

26. When normal (dry) conditions resume, revert to conventional rotational browsing system

27. Concentrate on a few individual plants and monitor their utilisation and recovery rather than attempt to monitor all plants in the community

The time to move animals into and out of a camp should depend on the state of the key browse plants. It is the opinion of the author that, to monitor the recovery of the vegetation, single plants should be marked and monitored and these used to represent the dynamics of the vegetation. Obviously these should be selected with care, but if the most sensitive key species are used as the indicator plants, then a measure of safety is immediately incorporated. Trying to monitor the recovery and utilisation of all plants (i.e. get an average idea) in the community is more open to the problems of the operator trying to assimilate too much detail, and "finding proof" for his preconceived ideas.

28. Grewia robusta *is used as the indicator plant*

Although the most dominant forage plant in good and moderate Succulent Valley Bushveld is *P. afra* (Aucamp, 1979), *G. robusta* is used as the indicator plant as this species is more responsive to perturbations and it is easier to subjectively monitor utilisation and regrowth on it than on *P. afra*. There are some preliminary indications that *Euphorbia bothea* could be a superior indicator plant but this requires further investigation (Stuart-Hill, unpublished data).

29. Remove animals from camp when 50% of G. robusta *leaves have been removed*

It has been established throughout the world, that moderate levels of defoliation appear to stimulate the production of many browse species (Garrison, 1953, Cook & Goeble, 1962, Lay, 1965, Ferguson & Basile, 1966, Teague, 1987). It has been illustrated that the same occurs for *P. afra* (Aucamp, 1979). Stuart-Hill (unpublished data) has found that during a period of occupation with goats when 50% of *G. robusta* leaves have been removed, *P. afra* has been defoliated by approximately 30 - 40%. This has been identified as a desirable intensity with which to defoliate *P. afra* (Aucamp, 1979).

30. Animals return to camp only once plants have recovered lost material

In the rotation of animals through the camps, the objective is to enable the individual plants to recover to their pre-defoliated state before they are rebrowsed. This rule should never be broken.

31. Necessary to return to camps before recovered?

If found that it is necessary to return to camps before the plants have recovered lost forage, then the current stocking rate is too high in relation to prevailing conditions (e.g. may be experiencing a severe drought).

32. Veld is overstocked

33. Reduce stocking rate

If the property is overstocked, the owner should sell as many non-breeding and non-replacement animals as necessary. This should not be delayed, even though in the veld type animal performance will not suffer while the veld is overstocked i.e. resist the temptation to hang on to stock in the hope that conditions and prices will improve. Prices are likely to decrease if the environmental conditions remain dry, as the average land operator, who does not monitor the recovery of the vegetation, will become aware that he is overstocked only at a much later time than a farmer applying the principles outlined in steps 29 to 32. Indeed, this is probably one of the few vegetation types where the farmer can determine that his property is overstocked before he causes it damage or before animal performance suffers.

34. Have there recently been exceptionally good rains?

The Succulent Valley Bushveld is almost certainly an event-driven system, i.e. only under exceptionally rare circumstances is the system prone to positive change. The vegetation in this veld type is water limited and it is argued, therefore, that these events occur during seasons which experience exceptionally high rainfall. If we desire (as we should) to improve the productivity of the vegetation, then it is necessary that we take advantage of these events.

35. Any sign of shrub recruitment?

An artifact of misuse of the vegetation is a loss of individual plants. If there is a chance of replacing these "lost plants" then it should be grasped. The recruitment of shrubs appears to occur only rarely and these occurrences should be identified so as not to lose the opportunity of attempting positive change on the few occasions when the ecosystem is prone to change.

36. This is an unusual event which should be taken advantage of to improve the veld

See discussion in step 35.

37. Give camps with most shrub recruitment special treatment to ensure juvenile plant survival

It is not normally practicable to give all camps on a property "special treatment" (e.g. rests of 3 - 4 years). Certain camps, which require rehabilitation and which have the most chance of achieving it (i.e. have the most shrub recruitment), should be set aside until the juvenile shrubs are resistant to browsing. It is not certain how long this would take, and will almost certainly vary depending on subsequent environmental conditions, but the land operators should be prepared to rest the camps for at least 3 - 4 years - possibly more. This is not as bad as it would at first appear, because in the normal browsing system recommended here, no camps are allocated extra long rests as is the case in the grassveld. There, it is recommended that a third of a farm should receive "special treatment" (i.e. yearly rests) in addition to the normal period of absence it receives during the grazing rotation (Section 10.1).

Further, it would seldom be necessary to implement these special rests as these events occur rarely (possibly every 8 plus years). In reality, therefore, this strategy does not constitute removing large tracts of land from the productive system on a regular basis. Rather it recognises the event-driven nature of the system, the rarity of these events and the necessity of attempting change when the system is on the few occasions prone to change. However, it does constitute implementing a major resting programme on these special occasions. Farmers should be aware and make provision for this. It is unlikely that land owners with small properties will be able to implement this strategy as they will not be able to live off the portions of their property remaining in the productive system.

38. Abundance of grass?

It frequently (but not always) occurs that, during unusually "wet" seasons, a high biomass of herbaceous material accumulates. This is almost always temporary and represents a valuable bonus to a grazier.

39. Buy in grazers on a speculation basis

As farmers following this strategy will be largely farming browsers, it will be necessary for them to buy in grazers (cattle or sheep), on an *ad hoc* basis, to utilise the extra grass. Because of the unreliable nature of this forage source, these animals should never be kept as a permanent enterprise, except possibly where nucleus breeding herd/flocks are kept on irrigated pastures. It is also possible to utilise this herbaceous material with goats, provided this is done before it dries out. Another option is to leave this material for soil protection and the enhancement of infiltration (C. Scheltema, pers. comm.). If the herbaceous layer is to be utilised, it is recommended that the grass be allowed to seed before it is grazed - it appears that the cattle perform better on the dry grass than they do on the green grass (M. Swart, pers. comm.).

40. Resurvey control camps every 2 to 3 years

This is vital to the success of adaptive management which, in Chapter 2, we decided was the only practicable system of veld management. To monitor the effect of management (and environmental conditions) on the vegetation, it is necessary to resurvey the control camps assessed in step 17. These surveys are tedious (taking a two-man survey team one day per camp), but the costs are negligible in terms of the costs of managing the entire system: e.g. surveying 10 control camps every 2 years represents 1,60% of a manager's time - assuming he works a 6-day week! Weighing this against the importance of knowing if the management system is harming or benefitting the vegetation, illustrates that this step represents time and effort well spent.

41. Has ecological status of veld changed?

This is determined by comparing the current survey results with those from step 17. Any *significant* difference means that the vegetation has changed. This may be either irrelevant, beneficial or detrimental depending on the type of change - i.e. along which environmental gradient, and in which direction the vegetation has moved (Section 8.5). In agricultural systems, we are concerned with a change in "ecological status" because it represents, amongst other things, a change in the current and potential forage productivity.

42. Better or worse?

This refers to the direction of change along the relevant environmental gradients.

43. Management beneficial to veld

Care must be taken when coming to this conclusion as change, for the better, may also be as a result of favourable environmental events that may mask the influence of management. Novelli & Strydom (1987) in a wildlife situation, have shown that grazing had little effect on the density of karoo grass when compared with the influence of seasonal rainfall.

44. Is economic performance acceptable?

This can be determined by comparing the economic performance of the farm with that of other similar farms. This facility already exists in the form of study groups.

45. Call in economic expert

If the economic performance of the property is significantly less than that of similar properties, the cause should be identified, possibly with the help of an expert in these matters.

46. Call in pasture expert

This should be done if the ecological status of the control camps has deteriorated (steps 41 and 42). If the property is not performing as it could economically (step 44), then a pasture expert should be consulted before implementing changes that may adversely affect the vegetation.

47. Redesign management system or revise stocking rates

If the economic performance is poor or the veld has deteriorated, it is necessary that the management system be revised and this may involve setting new stocking rates. This step should be considered positively as it is a critical process in adaptive management - i.e. learning from past mistakes.

48. Manage veld according to newly-adapted management system

References

AUCAMP, A.J., 1979. Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke. D.Sc. Agric. Thesis, Univ. Pretoria.

AUCAMP, A.J. & TAINTON, N.M., 1984. Veld management in the Valley Bushveld of the Eastern Cape. Pretoria: Government Printer.

COOK, C.W. & GOEBELL, C.J., 962. The association of plant vigour with physical stature and chemical content of desert plants. *Ecology* 32(3): 343-546.

FERGUSON, R.B. & BASILE, J.V., 1966. Topping stimulates twig growth. *J. Wildl. Mgmt* 30: 339-341.

GARRISON, G.A., 1953. Effects of clipping on some range shrubs. *J. Range Mgmt* 6: 309-317.

LAY, D.W., 1965. Effects of periodic clipping on yield of some common browse species. *J. Range Mgmt* 18: 181-184.

MALECHEK, J.C. & PROVENZA, F.D., 1983. Feeding behaviour and nutrition of goats on rangelands. *World Animal Review* 3: 38-48.

NOVELLI, P. & STRYDOM, G., 1987. Monitoring the response of vegetation to use by large herbivores: An assessment of some techniques. *S. Afr. J. Wildl. Res.* 17.4: 109-117.

RHOADES, D.F., 1985. Offensive-defensive interactions between herbivores and plants: their relevance in herbivore population dynamics and ecological theory. *Am. Nat.* 125(2): 205-238.

SCHELTEMA, J.C.. (Unpublished data.) The effect of defoliating the herbaceous layer on run-off and soil loss in the Valley Bushveld. Dohne Research Station, Stutterheim.

STUART-HILL, G.C.. (Unpublished data.) The browsing and grazing capacity of the Valley Bushveld in the eastern Cape region. Research facet D.5411/36/1/1. Dohne Research Station, Stutterheim.

TEAGUE, W.R., 1987. Defoliation and browse production of *Acacia karroo* Hayne in the Eastern Cape, South Africa. Ph. D. Thesis, Univ. Witwatersrand, Johannesburg.

SWART, M.L. Personal communication.

VAN HOVEN, W., 1984. Trees' secret warning system against browsers. *Custos* 13(5): 5-16.

[P 1.2]

CLARIFICATION NOTES

This article will appear in a book to be published during 1994, edited by N.M. Tainton & A.J Aucamp. The numbering convention for sections, figures and tables refers to this book and not the thesis.

THE MANAGEMENT OF DIFFERENT TYPES OF VELD

13.5 Succulent bushveld

G.C. STUART-HILL

13.5 Succulent Bushveld

13.5.1 Geographical distribution and extent

The term 'Valley Bushveld' was coined by Acocks (1975) and refers to the densely wooded vegetation found in the major river valleys of the eastern part of South Africa. Acocks (1975) went on to sub-divide the valley bushveld [Veld type Number 23] into six variations as follows:

i) Valley bushveld proper, northern variations, [23a] which extends from the Tugela river valley southwards as far as the Great Kei river;
ii) Valley bushveld proper, southern variation, [23b] which extends from the Great Kei to the Kabeljauw's valley;
iii) The Fish river scrub, [23c] in the lower Great Fish river valley;
iv) The Addo bush [23d(i)] and
v) The Sundays river scrub, [23d(iii)] in the wide flat lower Sundays river valley; and
vi) The Gouritz river scrub [23e].

This classification intended to group together vegetation with the same utilization potential but, from a management viewpoint, at least two distinct plant communities are grouped together under the same name, Valley Bushveld: a dense scrub-thicket dominated by succulents and very dense savanna or bushveld not dominated by succulents, This distinction is important because:

i) the shrub component of succulent bushveld (unlike non-succulent bushveld) will not regenerate (within a human lifespan) following severe disturbances; and
ii) it is not possible to establish and maintain a stable and highly productive grass sward in the succulent bushveld, even with bush clearing.

Three of Acocks's other veld-types (Noorsveld [24], Spekboomveld [25] and Karroid broken veld (of the little karoo) [26b]) also have these two characteristics and for management can all be considered variations of succulent bushveld. In this section we concentrate on the management of the succulent bushveld types which are largely confined to the eastern Cape. The management of non-succulent valley bushveld is the same as for the arid savannas' (see section 14.5).

13.5.2 Present condition

The current condition of the succulent bushveld ranges from good to extremely poor. The invasion of prickly pear (<u>Opuntia ficus-indica</u>), blue-bush (<u>Pteronia incana</u>), honey-thorn (<u>Lycium oxycarpum</u>), slaaibos (<u>Zygophyllum morgsana</u>) and various karoo bushes over large areas and the disappearance of valuable browse species such as spekboom (<u>Portulacaria afra</u>) is an indication that the carrying capacity has been exceeded or that incorrect management systems have been applied (Aucamp & Tainton 1984; Stuart-Hill <u>et al.</u> 1986). The succulent bushveld types are extremely sensitive to over stocking and have become degraded over large areas (Hoffman & Everard 1987; Hoffman 1989, Hoffman & Cowling 1990). When the shrub component is damaged or destroyed by over-browsing, it is replaced by a form of "false dwarf karroid veld composing karoo shrublets" (Aucamp & Tainton 1984) interspersed by umbrella shaped Pappea capensis trees. In severe situations even these plants are eliminated and only the umbrella shaped P. capensis trees remain. This is serious as it represents an irreversible loss of a unique vegetation type, and the community which replaces it is unstable, prone to soil erosion and is able to support fewer stock than dense succulent bushveld (Stuart-Hill & Danckwerts 1988).

13.5.3 Management

There are little quantitative data available which can serve as a basis for the development of a management plan for this veld type. Aucamp (1979) produced a dissertation in which the production potential of the succulent bushveld was assessed. A portion of this work investigated the growth of P. afra and its reaction to defoliation and this has been extensively used by Aucamp and Tainton (1984) to propose a management programme for the succulent bushveld. This work has in turn been used extensively in this section but a more flexible approach has been adopted, incorporating the work by Stuart-Hill (in prep.).

We begin by reviewing the major biological principles that managers should consider, we then discuss some farming enterprises that appear to be suitable for this vegetation and finally, present a management plan that can serve as a starting point for an adaptive management programme.

13.5.3.1 Principles to consider in management of succulent bushveld

i) The climate is characterized by a largely non-seasonal, low and unreliable rainfall regime - averaging less than 500 mm a year. It is estimated that there is a 25 % chance of the area receiving less than 80 % of its long-term average annual rainfall in any year (Aucamp & Tainton, 1984). This aridity is compounded by extremely high temperatures in summer.

ii) The shrub component of the vegetation is the production base. If damaged through over-utilization, the woody layer will not recover and, consequently, bush encroachment is not a phenomenon experienced in this veld type. It is important to appreciate that removal of the woody plants does not, as in other bushveld types, lead to a grassland which is more productive than the shrubs.

iii) The herbaceous layer is not a reliable source of forage as it fluctuates widely with environmental conditions. It is sparse and predominantly non-perennial and although it normally has little commercial value (except after a series of good rains) it is ecologically important in enhancing infiltration and reducing soil erosion (Table 13.5.1). It is advisable therefore, that no farming enterprises be based entirely on this resource.

INSERT TABLE 13.5.1

iv) Goats will utilize almost all of the shrub species in this vegetation. The palatabilities of the species do nevertheless differ and the most desirable are over-utilized before the less desirable species have even been browsed (Stuart-Hill unpublished data). Forcing goats to utilize all species to the same degree is unrealistic because they severely defoliate and physically damage the branches of desirable species before utilizing the less desirable species (branches of P. afra in excess of 70 mm in diameter are broken off during 'lenient' browsing with goats). It follows that this vegetation should be managed so that the desirable (palatable and productive) species are utilized at their 'optimum' level.

v) The vegetation is adapted to defoliation by a range of indigenous animals, in particular elephant and degrades if these are replaced by domestic ungulates even if these are stocked at the same rates as the mix of indigenous herbivores (Stuart-Hill 1992). The dominant succulent shrub, P. afra, is well adapted to tolerate severe upper canopy elephant damage because it reproduces vegetatively from procumbent lower side-branches which in healthy plants, form a 'skirt' around the base of the plant. Goats at high densities prevent this 'skirt' from developing as they browse "from the side inwards" (Figure 13.5.1). The other woody shrubs tolerate elephant damage to their canopies by coppicing (Stuart-Hill 1992). Managers should ensure that there is always a 'skirt' of rooted side-branches around each P. afra plant and that the coppice of woody plants is allowed to become established.

INSERT FIGURE 13.5.1

vi) The annual productivity of this vegetation is low (Aucamp, 1979) and goats, if forced to do so, are able to consume years of accumulated growth within a short period. If this occurs, a large amount of twigs will be removed and this represents a loss of meristematic tissue (i.e. growing points). It follows that to recover from this degree of utilization, shrubs (unlike grasses) have to regenerate growth sites before lost foliage can be replaced. This requires extremely long rest periods (Aucamp 1979; Teague 1987) and as a consequence, it is hypothesised that the management principle of 'sacrificing' a camp following good rains in order to allow plants in other camps a period of undisturbed growth (Danckwerts 1984), is not applicable to this veld type.

vii) After defoliation, the recovery of shrubs can be extremely variable, and depends on defoliation intensity, season of defoliation and prevailing environmental conditions during the recovery period. For example, P. afra, following 50% leaf removal, has been known to take between 30 days (Aucamp 1979) and 18 months (Stuart-Hill 1993) to recover to its pre-defoliated state. This means that it is extremely difficult to apply a rotational system with fixed periods of occupation and absence. Preferably, recovery should be monitored on the plant and only once the plant has recovered (be it in 1 or 24 months) should it be re-browsed. Farmers generally do not monitor their plants and, for logistic reasons, prefer to have fixed rotational systems. If these sub-optimal systems must be adopted, then it is necessary that the periods of absence be long. Aucamp and Tainton (1984) recommended that between 211 and 275 days be allowed following defoliation intensities of 25 to 50%. This intensity of defoliation is recommended as P. afra appears to be stimulated to produce more forage with these levels of utilization (Aucamp 1979): a response similar to that found in other browse species (Garrison 1953; Cook & Goebell 1962; Lay 1965; Ferguson & Basile 1966; Teague 1987).

viii) If Boer and Angora goats are not greatly overstocked they are able to select a diet that permits good animal performance (Aucamp 1979). Indeed, these animals are able to destroy the vegetation whilst still gaining in weight. It follows, therefore, that the condition of the animal should not be used as a measure of over-browsing. Consequently, if destocking is necessary as a result of a loss in animal performance, then the land operator should be aware that he has already damaged the vegetation and should account for this in future planning.

ix) Although mass gemination of seed occurs periodically, there appears to be little or no recruitment of woody species through this source. Palmer (1990) implies that this vegetation is a relic community from a wetter and warmer period (between 12000 and 6000 years ago) able to persist by growing in 'bush clumps' within which the micro-climate is so modified as to allow seedling establishment during the present more arid conditions. Seedling recruitment in degraded bush is as a consequence impossible and to maintain productivity of this vegetation, it is essential that every plant be kept alive. This can be achieved to some extent by very lenient defoliation but inevitably plants die, and it is necessary to provide for this, by either allowing some recruitment or (at the very least) allowing the remaining plants to increase in size. At present the mechanisms of shrub recruitment through seeding in the succulent bushveld are poorly understood (La Cock 199????). It probably occurs after certain 'episodic' events and, logically, one would expect that management after these will be crucial to the survival of the seedlings.

It may be worth noting that with the reduction of avian and mammalian predators, small herbivores (e.g. rodents and Hyrax) have probably increased in number and this may be having a detrimental effect on the survival of seeds and seedlings, and thus on the recruitment of shrubs. An interesting theory is that the flightless dung beetle (Circellium bacchus), dependent on elephant dung and having largely disappeared along with these herbivores, may have been a vector for seedling establishment through its habit of burying balls of elephant dung, possibly of which contains seed (Stuart-Hill 1992).

x) Burning is not recommended in this vegetation although it may be an option to consider in those exceptional cases where an impenetrable spiny thicket of Maytenus spp. and Azima tetracantha develops (in moist sites). No research has been done on this but circumstantial evidence from an accidental fire in the Kirkwood district shows that the reduction in cover of these shrubs has led to an increase in forage production. Veld burning in the succulent bushveld should nevertheless, be viewed in an experimental light and with extreme caution.

13.5.3.2 Current and potential farming systems

Since environmental conditions in the succulent bushveld are too arid for cultivated pastures, livestock production is usually based entirely on the veld. However, if a farmer has irrigated lands, a useful system would be to establish planted pasture on these with the objective of removing the animals from the veld onto the pastures during critical growth stages to allow the bush a chance to grow undisturbed (e.g. after each significant rain). This will increase productivity and ultimately raise the carrying capacity of the bushveld. Another enterprise that has potential in areas where the bush has been eliminated through past mismanagement, is to establish salt bush plantations (Atriplex nummularia). Once established, these are productive and hardy, and can be used to relieve nutritional bottle-necks, or as an enterprise on its own.

Since the primary forage source is browse, it follows that browsers will be the main enterprise. The only domestic browser is the goat and both Angora and Boer goats are popular and profitable farming enterprises in this vegetation. Some land operators are opting for a game enterprise in which the dominant browsers are kudu and bushbuck and the income is derived from hunting fees and/or the products of these animals. A useful, financially attractive and aesthetically pleasing system is a combination of game and domestic stock into a single enterprise. It may even be possible for the larger land owners to introduce elephant into their system as hunting and tourism can be very lucrative. Elephant are retained by relatively cheap electrical fencing and do less damage to the floristics of the vegetation than the goats (Stuart-Hill in press.).

Sheep (e.g. Dorpers) may also be considered as they do browse to some extent. They will, however, probably destroy the little herbaceous vegetation before using significant amounts of browse. In view of this and the run-off and soil erosion data shown in Table 13.5.1, it is preferable to avoid large numbers of sheep. After a series of exceptionally good rains, a considerable amount of herbaceous vegetation may be produced. When this occurs, grazers could be brought in on an ad. hoc basis. It is emphasised, however, that the herbaceous vegetation does not provide a constant fodder supply and managing grazers on a permanent basis in succulent bushveld is hazardous.

Finally, it appears that there may be a potential for ostrich farming. However, this is limited to areas where the bushveld has been severely damaged because in dense bush, the skin (the most valuable part of the bird) becomes excessively scratched and loses value. There is, however, little information regarding the potential or suitability of these animals but observations are that they are extremely heavy feeders in relation to bodymass.

13.5.4 A veld management system for consideration

There is certainly more than one way of managing veld to achieve profit without harming the resource. The question that will probably always remain unanswered is, which system is the most efficient? While any management system should attempt to incorporate the ecological principles discussed earlier (section 13.5.3.1), each property will have a unique system depending on resources and objectives. It follows that an adaptive management should be followed (Walters & Hilbron 1978). Essentially this involves setting rather specific objectives with respect to economic and biological factors, and periodically monitoring progress towards these whilst recording relevant management actions and environmental perturbations. The details of the system suggested here, revolve around the dominant farming practise in the region: i.e. domestic stock farming for profit. It is worth noting that whilst a management system may attempt to use only scientifically derived information, inevitably it will rely heavily on evidence from successful farming operations and on the intuition of experienced people.

Setting objectives

The land-user needs to clearly define his personal objectives in terms of income, time, likes and dislikes, etc. With these in mind, and considering the natural and financial resources, the various enterprises should be selected (e.g. Angora goats will be the main enterprise supported by game farming, 50 ha of irrigated lucerne, and 20 ha of salt-bush). It is important also, to state what veld condition is considered as optimum, as well as what performance is expected from each enterprise (e.g. mass gain, weaning percentage, gross margin). Without doing this, the farmer will have no way of measuring performance and cannot, therefore, implement formal adaptive management.

The prevention of resource deterioration should be a non-negotiable attribute of any management model and, consequently, it may be a hard fact that many properties in this veld type are too small for sustained commercial pastoralism.

Resource inventory

Common to all management systems is the requirement for a basic inventory of the resource. From the vegetation viewpoint, it is essential to differentiate areas of succulent bushveld from dense non-succulent bushveld because of the inherently different management options and requirements (Section 13.5.1).

In this vegetation type, objective assessment is tedious and time-consuming (Stuart-Hill in prep.) so to inventorize vegetation condition, structured visual estimates of veld condition are recommended (Stuart-Hill 1991). Veld condition in this context, refers to plant communities that are likely to have different production potential, palatabilities and sensitivities to degradation. In succulent bushveld, the 'ecological status' (condition) of the vegetation is probably of overriding importance with respect to these attributes and it is important that areas of similar ecological status be mapped together. Further classification should be done on the basis of soil types (especially depth), aspect, catenal position and irrigable lands. This step is necessary to assist in setting objectives, selecting enterprises, determining stocking rates and thereby developing a management plan.

<u>Stocking rates and ratios</u>

The relationship between vegetation condition, rainfall and the economic carrying capacity for the succulent bushveld is illustrated in Figures 13.5.2 and 13.5.3 and Table 13.5.2.

INSERT FIGURES 13.5.2 & 13.5.3
INSERT TABLE 13.5.2

This was developed in the Sundays river valley (Kirkwood district) to determine initial stocking rates for the xeric succulent bushveld (Stuart-Hill & Aucamp 1993). The carrying capacity of mesic succulent bushveld may be slightly higher. Seventeen years of grazing records from a site in the Fish river valley, showed that an average annual stocking rate of 0,19 LSU/ha did apparently not harm vegetation condition (Stuart-Hill, unpublished data). This represents a considerable increase over the mean estimated carrying capacity of Xeric succulent bushveld and is probably due to the more perennial grass sward in these areas. It should be appreciated that these values are not hard and fast rules but rather as starting points which can be adjusted as adaptive management proceeds.

The most desirable stocking ratio will vary according to the objectives of the land operator, current season rainfall and according to the condition of the vegetation. In dense bushveld, it has been recommended that stocking rates be adjusted so that the total number of animal units are made up of: 85% goats and the rest the naturally occurring kudu. In open bushveld where herbaceous vegetation becomes relatively more important, the stocking ratio may be made up of: 80% goats, 5% kudu and 15% sheep/cattle (Aucamp & Tainton 1984). It is important to appreciate that the succulent bushveld has a fairly high stocking rate of kudus (approx. 0,083 LSU/ha), and this should always be accounted for when setting stocking rates.

Infrastructure

Fencing off the 'veld types' is recommended if the intention is to farm with domestic stock as it reduces area selection. For rotational grazing, it has been suggested that at least 12 camps are necessary per group of animals (Aucamp & Tainton 1984) but given the low productivity of this vegetation this degree of camping is unlikely to be economically feasible.

The ideal camp size is 40 to 50 ha for dense bushveld and 80 to 100 ha for open bushveld (Aucamp & Tainton 1984). These sizes are designed to promote uniform utilization of the vegetation spatially, and to aid in mustering but again economic constraints will dictate camp size.

Camps that follow the natural boundaries of areas of different potential are biologically more acceptable than traditional paddock layout or the funnel-shaped camps of wagon-wheel systems. A further disadvantage of wagon-wheel camps is that inevitably they are long and narrow. Because animals are reluctant to walk long distances in this vegetation, they severely defoliate nearby plants without suffering nutritional stress and degrade the hub area. Wagon-wheels do however, provide considerable advantages in water provision and stock management and, therefore, are extremely useful where conditions permit: i.e. where the topography is such that it is possible to separate veld types and the central hub area is in a position where it will not be severely eroded by the inevitable concentration of stock trampling around the hub (Aucamp & Tainton 1984).

Monitoring

Monitoring goal attainment is central to adaptive management. Vegetation surveys for monitoring veld condition change should be conducted in strategic places on the property according to the techniques described in Section 8.4. These surveys can be tedious and easily postponed (indefinitely), but the costs are negligible in terms of the costs of managing the entire system. Weighing these against the importance of knowing if the management system is harming or benefitting the vegetation, inevitably illustrates that this step represents time and effort well spent.

Care must, however, be taken when interpreting reasons for change, for the extent and nature of vegetation change will depend on both management and on the environmental conditions which have been experienced. Novellie and Strydom (1987), for example, have shown that grazing had little effect on the density of karoo grass when compared with the influence of seasonal rainfall.

For this reason detailed records of any management activity or environmental perturbation must be kept. When the monitoring sites are resurveyed, any change in the condition of the vegetation can then be interpreted in terms of the management applied and/or the environmental conditions experienced.

Management

There are no data that illustrate that rotational browsing systems are superior to continuous browsing systems. Indeed, Mentis (199???) has shown that these are seldom justified on the basis of pure economics. However, rotational grazing has a number of distinct disadvantages for domestic stock farming which bear mentioning.

i) It allows a degree of control over area selective grazing which can be severe as goats seem to prefer sparsely-bushed areas. In time, these areas become over-utilized while the densely bushed areas are under-utilized.
ii) It allows a degree of control over the intensity and frequency of defoliation of the key browse species.
iii) It allows for strategic treatments to be implemented, e.g allowing an extra-long rest after exceptional rains in order to encourage shrub recruitment.
iv) It allows for easier stock management, e.g. stock mustering (finding animals in small camps is easier than finding them in large camps) and the control of predators and parasites.

While it is true that the above (except point iii) could be achieved in a multi-camp system regardless of whether continuous or rotational browsing is applied, the essential reason for most people recommending rotational over continuous browsing is probably that the former allows the manager to control, when, where and how intensively animals will browse. This gives the land operator a better chance of manipulating the vegetation.

Early browsing of regrowth reduces the rate at which defoliated plants recover (Aucamp 1979). Consequently, it is normally recommended that animals do not remain in a camp until regrowth has at least replaced material previously browsed. Within reason, therefore, the shorter the period of occupation, the better. In doing so, however, the subsequent rest period becomes shorter as the rotation from one camp to the other speeds up. During fast growing periods, the period of occupation should be short but need not be reduced below about 7 to 10 days (Aucamp & Tainton 1984). During slow growing periods, however, the period of occupation can be extended to approximately 60 days (in order to lengthen the period of absence in other camps) without the danger of browsing regrowth.

Long periods of absence are desirable as rains are infrequent and sporadic. It is proposed that rest periods without rain, do not constitute recovery periods and it is at least necessary to allow enough time for the plants to recover to their pre-defoliated condition otherwise they become progressively smaller and eventually die. The required period of rest is dependent on the degree of utilization: the lower the intensity of utilization, the shorter the period of rest. So, for example, if 50 % of the leaf is removed from spekboom under normal climatic conditions, a rest period of about 275 days is required to allow the browsed plants to recover to their pre-utilized condition. Where utilization is less severe (say 30 % leaf removal), the rest period can be reduced to about 210 days (Aucamp 1979).

A word of caution, however, is that years of accumulated growth can be utilized within a single period of occupation because the forage quality of succulent bushveld is high and remains high even in old growth. Goats can, therefore, severely damage even well rested vegetation without their performance being significantly effected (Aucamp 1979).

The time to move animals into and out of a camp should depend on the state of the key browse plants. Trying to monitor the recover and utilization of all plants (i.e. get an average idea) in the community is susceptible to the problems of the operator trying to assimilate too much detail, and 'finding proof' for his preconceived ideas. It would appear that based on abundance, palatability, productivity and sensitivity to over-utilization, P. afra and G. robusta are the most appropriate indicator plants. The length of the young (red) shoots of P. afra can be used as an indicator of recovery following defoliation and the presence of a well developed 'skirt' of rooted side-branches can be used as an index of 'health' of the community (Stuart-Hill 1992). It is easier to visually monitor utilization on G. robusta than on P. afra, and defoliation of this species can be used to determine when animals should be removed from a camp. Grewia robusta responds rapidly to environmental perturbations and is also useful as an indicator of current growing conditions. There are some preliminary indications that Euphorbia bothea could also be a useful indicator of utilization but this requires further investigation (Stuart-Hill, unpublished data).

Moderate levels of defoliation appear to stimulate the production of many browse species (Garrison 1953; Cook & Goebell 1962; Lay 1965, Ferguson & Basile 1966; Teague 1987) and this also applies for the dominant forage shrubs in this vegetation type (Aucamp 1979). Stuart-Hill (1993) found that, during periods of occupation with goats, when 50 % of G. robusta leaves have been removed, P. afra will normally have been defoliated to an intensity of approximately 30 to 40% - a desirable intensity with which to defoliate P. afra (Aucamp 1979).

In rotating animals through the camps, the rule which should be applied is that the individual plants should recover to their pre-defoliated state before they are re-browsed. This may not occur on occasion depending on prevailing conditions (e.g. the area may be experiencing a drought) but if the rule is broken repeatedly, then this suggests that the carrying capacity estimate should be adjusted.

If the property is overstocked, the owner should sell as many non-breeding and non-replacement animals as is necessary. This should not be delayed, even though animal performance will not initially suffer. Farmers should resist the temptation to retain stock in the hope that conditions and prices will improve. Prices will decline further if conditions remain dry. This is because most land operators do not monitor the vegetation and consequently only become aware that they are overstocked at a much later stage than farmers applying the principles outlined above. Indeed, this is probably one of the few vegetation types where the grazier can determine that the property is overstocked before irreparable damage or before animal performance suffers.

Special strategies

It is recommended that extra forage crops be planted on all properties in this veld type because they can be used as a drought reserve, to increase the carrying capacity of the property and most importantly, they allow animals to be removed from the veld at critical times. Such plantings may comprise irrigated pastures (where possible) or plantations of drought resistant crops (e.g salt-bush, spineless cactus and Agave spp.). Planted forage in these areas should be viewed as a synergistic aid to manage veld rather than as an enterprise on its own.

After significant rains (i.e. rains of sufficient size to support growth for a least one week), any rotational grazing system should be abandoned and the animals spread over as large an area as possible. If planted forage is available, then animals could instead be removed from the actively growing veld onto the planted fodder which in turn can be rested when the animals return to the veld. The reasoning behind these strategies is to allow undisturbed growth so that plants are able to take advantage of the growth spurts following rains. The removal or reduction of browsing pressure during these times is advantageous because it allows new twigs to grow and become lignified thereby becoming less susceptible to browsing.

It is not normally practicable to regularly give all camps on a property 'special rests' (e.g. seeding or vigour rests of three to four years). In any case, the succulent bushveld is almost certainly an event-driven system: i.e. only under exceptionally rare circumstances is the system able to improve in response to improved management. An artifact of misuse of this vegetation is a loss of individual plants and if there is a chance of replacing these then it should be grasped whenever it occurs. The recruitment of shrubs appears to occur only rarely: i.e. following exceptional rains. These occurrences should be identified so as to promote recruitment on the few occasions where the ecosystem is prone to such change.

Camps with the most shrub recruitment following such events should be set aside until the juvenile shrubs are resistant to browsing. It is not certain how long this need be, and will almost certainly vary depending on subsequent environmental conditions, but the land operator should be prepared to rest the camps for at least three to four years - possibly more. This is not as bad as it first appears, because in the browsing system recommended here, no camps are regularly allocated extra long rests as, for example, in grassveld (Danckwerts 1984). Furthermore, as these events occur rarely (>8 years), it would seldom be necessary to implement these special rests. In reality, therefore, this strategy does not constitute removing large tracts of land from the productive system on a regular basis. Rather it recognises the event-driven nature of the system, the rarity of these events and the necessity of attempting change when the system is on the few occasions prone to change. However, it does involve implementing a major resting programme on special occasions and farmers should be aware and make provision for this. However, it is unlikely that land owners with small properties will be able to implement this strategy as they will not be able to live off the remaining portions of their property.

The occasional wet periods also provide an opportunity for the re-establishment of plants such as P. afra which can be readily grown from cuttings. This is a very expensive process and the plants require extensive rests before they can be browsed (Hobson, Stuart-Hill & Swart in prep.).

During unusually 'wet' seasons, a high biomass of herbaceous material may accumulate. While this accumulation is always temporary, it represents a valuable bonus to a grazier. As farmers in this vegetation mostly use browsers, it may be necessary for them to buy in grazers (cattle or sheep) on an ad. hoc basis. Because this forage source is unreliable, these animals should never be kept as a permanent enterprise except possibly where a small breeding herd/flock can be maintained on irrigated pastures or at very low densities. It is also possible to utilize this herbaceous material with goats, but this should be done before it dries out. Another option is to leave this material for soil protection and the enhancement of infiltration (Table 13.5.1). If the herbaceous layer is to be utilized, it is recommended that the grass be allowed to seed before it is grazed as this builds up the seed bank and rather surprisingly, cattle perform as well on the dry grass as they do on the green grass (M. Swart, pers, comm.).

References

Acocks, J.P.H., 1975. Veld types of South Africa. 2nd edition. Mem. Bot. Surv. S. Afr. No. 40.

Aucamp, A.J., 1979. Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke. DSc. Agric. thesis, Univ. of Pretoria.

Aucamp, A.J., & Tainton, N.M., 1984. Veld management in the Valley Bushveld of the eastern Cape. Government Printer, Pretoria

Cook, C.W. & Gable, C.J., 1962. The association of plant vigour with physical stature and chemical content of desert plants. Ecology. 32(3): 343-546.

Danckwerts, J.E., 1984. Towards improved livestock production off sweet grassveld. Phd. thesis, Univ. of Natal.

Ferguson, R.B. & Basile, J.V., 1966. Topping stimulates twig growth. J. Wildl. Mgmt. 30: 339-341.

Garrison, G.A., 1953. Effects of clipping on some range shrubs. J. Range. Mgmt. 6: 309-317.

Hobson, F.O., Stuart-Hill, G.C. & Swart, M.L. in prep. Establishment of spekboom: preliminary results. Dohne Research station, South Africa.

Hoffman, M.T., 1989. Vegetation studies and the impact of grazing in the semi-arid eastern Cape. Ph.D. thesis, Univ. of Cape Town.

Hoffman, M.T., & Cowling, R.M., 1990. Desertification in the lower Sundays river valley, South Africa. J. Arid Envir., 19, 105-117.

Hoffman, M.T., & Everard, D.A., 1987. Neglected and abused: the eastern Cape subtropical thickets. Veld and Flora.

La Cock, G.D. 1992. Regeneration through seeding of shrubs in the xeric succulent thicket of the eastern Cape. M.Sc. thesis, Rhodes Univ., Grahamstown.

Lay, D.W., 1965. Effects of periodic clipping on yield of some common browse species. J. Range. Mgmt. 18: 181-184.

Malechek, J.C. & Provenza, F.D., 1983. Feeding behaviour and nutrition of goats on rangelands. World Animal Review. 3: 38-48.

Mentis, M.T. 1991. Are multi-paddock grazing systems economically justifiable? J. Grass. Sac. South. Afr. 8(1): 29-44.

Novellie, P. & Strydom, G., 1987. Monitoring the response of vegetation to use by large herbivores: an assessment of some techniques. S. Afr. J. Wildl. Re. 17(4): 109-117.

Palmer, A.R., 1990. A qualitative model of vegetation history in the eastern Cape midlands, South Africa. J. Biogen., 17, 35-46.

Rhodes, D.F., Offensive-defensive interactions between herbivores and plants: their relevance in herbivore population dynamics and ecological theory. The Amber. Na. 125 (2): 205-238.

Scheltema, J.C., unpublished data. The effect of defoliating the herbaceous layer on run-off and soil loss in the Valley Bushveld. Dohne Research Station, Stutterheim.

Stuart-Hill, G.C. & Aucamp, A.J., 1993. Carrying capacity of the succulent valley bushveld of the eastern Cape. Afr. J. Range. For. Sci. 10(1): 1-10.

Stuart-Hill, G.C., 1992. Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa. J. Applied Ecol. 29: 699-710.

Stuart-Hill, G.C., in prep. Towards a formalized adaptive management framework in succulent bushveld. Ph.D thesis. Univ. Natal, Pietermaritzburg.

Stuart-Hill, G.C., Aucamp, A.J., Le Roux, C.J.G. & Teague, W.R., 1986. Towards a method of assessing the veld condition of the Valley Bushveld in the Eastern Cape. J. Grass. Sac. South. Afr. 3(1):19-24.

Stuart-Hill, G.C. & Danckwerts J.E., 1988. Influence of domestic and wild herbivores on the future of the Succulent Valley Bushveld. Pelea. 7: 45-56.

Teague, W.R., 1987. Defoliation and browse production of Acacia karroo Hayne in the eastern Cape, South Africa. Ph. D. thesis. Univ. of Wits., Johannesburg.

Van Hoven, W., 1984. Trees' secret warning system against browsers. Custos, 13 (5): 5-16.

Walters, C.J. & Hilborn, R. 1978. Ecological optimisation and adaptive management. Annual review of ecological systems. 9: 157-188.

Table 13.5.1 The role of standing herbaceous in reducing run-off and soil erosion in the succulent bushveld. These were determined with a rainfall simulator on a wet and a dry Swartland soil with a slope of between 7 and 8%. 'Rainfall' intensities were 84 and 67 mm hr^{-1} for the dry- and wet-runs respectively (Scheltema unpublished data).

Treatment	Dry-run: minutes before run-off	Dry-run: after run-off %	Dry-run: 60 min soil loss t ha^{-1}	Wet-run: minutes before run-off	Wet-run: after run-off %	Wet-run: 60 min soil loss t ha^{-1}
uncut	>83	0	0	12	21	0.57
cut	12	12	1.7	3	54	1.53

Table 13.3.2 Combined predicted carrying capacity (LSU 1000ha^{-1}) of grazers and browsers in succulent bushveld for different ecological statuses and for various rainfall seasons. Predictions were derived from interpolation using linear Kriging (Stuart-Hill & Aucamp 1993).

Rain	Ecological status (%)										
(mm)	-10	0	10	20	30	40	50	60	70	80	90	100
240	1	4	9	15	23	31	41	52	63	73	78	79
250	2	6	11	17	25	33	43	54	66	77	81	81
260	8	11	16	22	29	38	47	57	67	76	81	83
270	15	18	22	28	35	43	51	60	68	75	81	84
280	21	25	29	35	41	48	55	63	70	76	81	85
290	28	31	36	41	47	53	60	66	72	78	83	86
300	35	38	42	47	52	58	64	70	75	80	84	87
310	41	44	48	53	58	63	69	74	78	83	87	89
320	42	46	54	59	64	69	73	78	82	86	87	90
330	45	51	56	59	64	74	78	74	83	87	90	93
340	51	55	61	61	65	72	75	81	84	90	89	92
350	56	60	65	71	74	87	89	81	91	92	94	96
360	61	67	81	85	89	91	92	93	94	96	97	99
370	73	78	85	90	93	95	96	96	96	97	100	104
380	73	80	89	96	99	101	101	101	100	99	102	108
390	74	83	93	103	107	108	109	108	106	103	106	113
400	76	87	98	109	116	119	120	118	116	113	114	117
410	78	90	104	117	127	132	133	130	126	122	121	122
420	76	91	110	127	139	146	147	142	134	129	127	128
430	72	92	116	139	150	160	161	151	141	132	131	134
440	77	96	119	140	153	162	163	155	146	138	135	137
450	88	102	120	136	148	156	157	154	148	143	140	139

FIGURE CAPTIONS

Figure 13.5.1 The hypothetical effect no browsing (a), elephant browsing (b) and goat browsing (c) has on the growth habit and ability to vegetatively propagate of P. afra (Stuart-Hill 1992).

Figure 13.5.2. Relationship between ecological status of succulent bushveld, and average grazing, browsing and grazing plus browsing capacity measured over the experimental period.

Figure 13.5.3 Carrying capacity (browsing capacity plus grazing capacity) of succulent bushveld as predicted from Kriging where the independent variables are rainfall and vegetation condition (ecological status). The predicted relationships are shown in three-dimensions (a) and as a contour plot (b) (Stuart-Hill & Aucamp 1993).

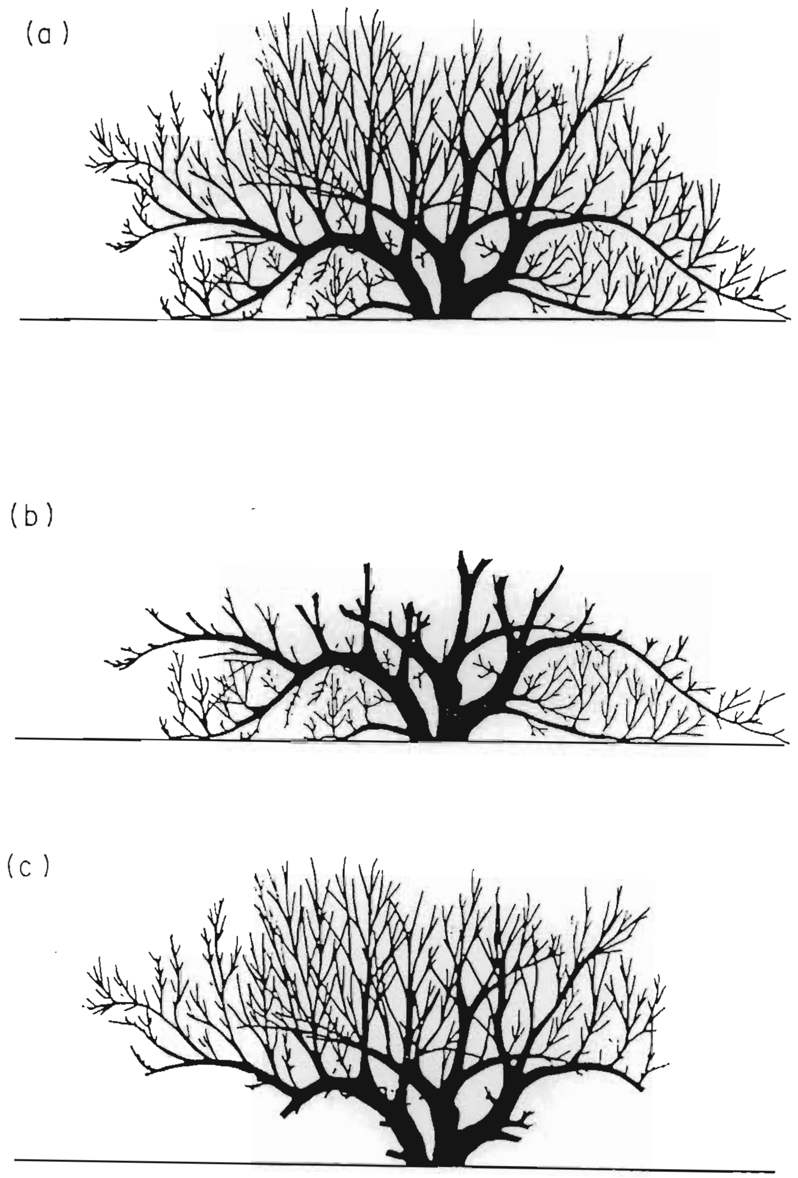
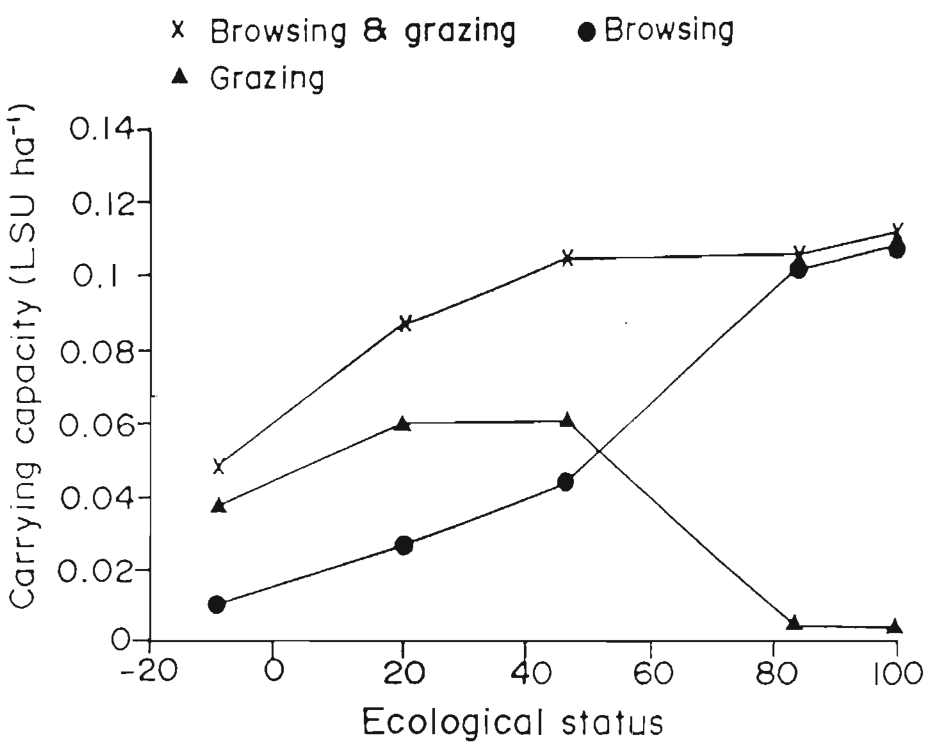
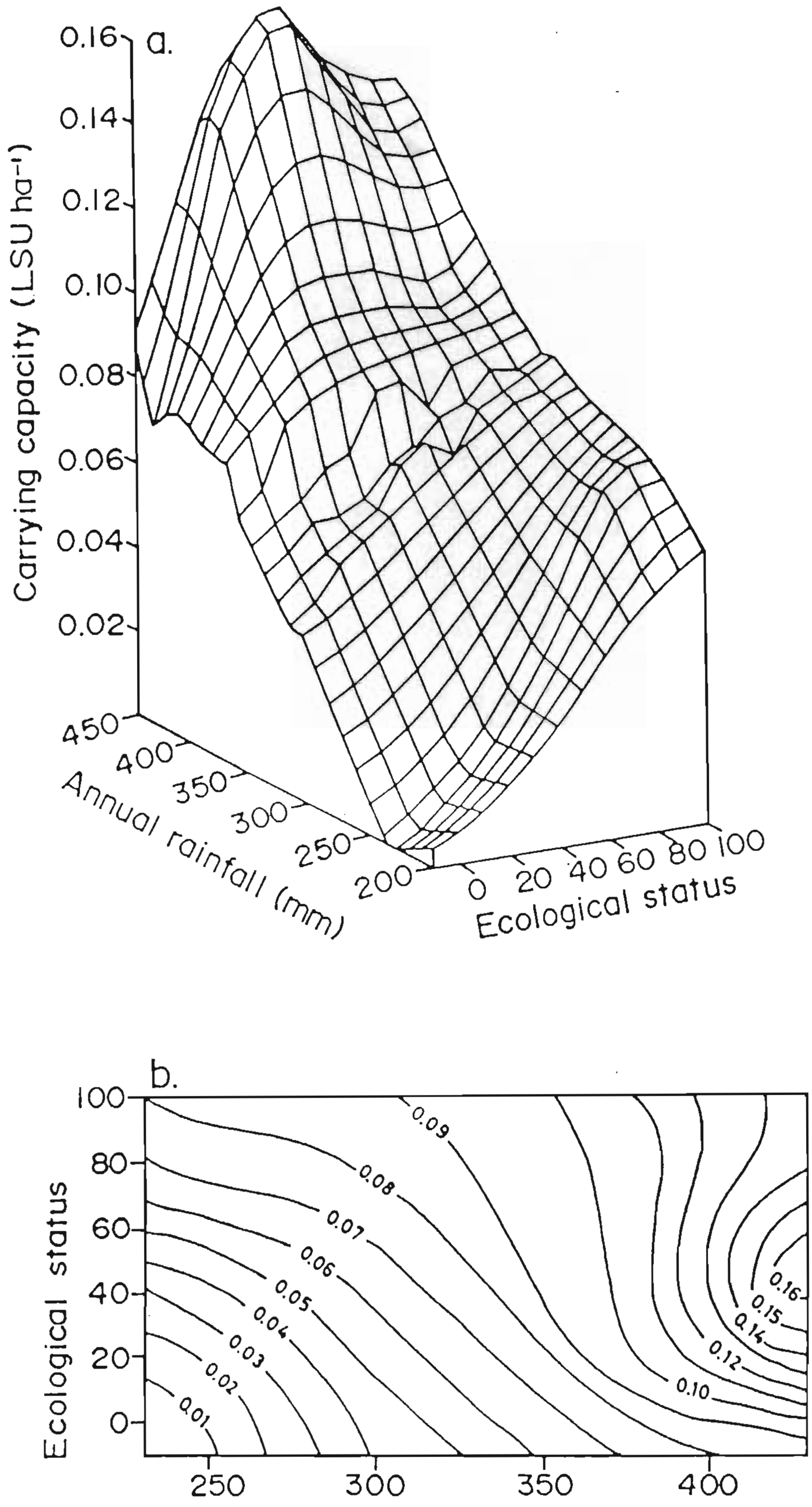


Figure 13.5.1.


x Browsing & grazing
● Browsing
▲ Grazing
Carrying capacity (LSU ha-1)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-20
0
20
40
60
80
100
Ecological status

igure B.5.2


a.
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
Carrying capacity (LSU ha⁻¹)
450
400
350
300
250
200
Annual rainfall (mm)
0 20 40 60 80 100
Ecological status
b.
100
80
60
40
20
0
Ecological status
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.16
0.15
0.14
0.12
0.10
250 300 350 400
Annual rainfall (mm)

TOOL 2

A TECHNIQUE FOR VEGETATION INVENTORY

[TOOL 2]

A TECHNIQUE FOR VEGETATION INVENTORY

ORIGINAL BRIEF

The technique should be a rapid survey technique which is descriptive and has a resolution adequate for planning purposes. I refer to this as veld or vegetation assessment.

RESULT

The first product was the published paper: **Towards a method of assessing the veld condition of the valley bushveld in the eastern Cape [P 2.1]** (the co- authors assisted in selecting the sampling approach and in addition, C.J.G le Roux advised on statistical analysis). At the time the approach was innovative in that it broke from the tradition of using species response categories (decreasers and increasers) and calculating score as some percentage deviation from the 'ideal'. It was nevertheless naive and later modified (see the section of a book, entitled: **Monitoring vegetation change and assessing veld condition: Assessing the condition (ecological status) of valley bushveld [P 2.2]**) where the vegetation score came to represent an index (now called ecological status), devoid of value judgement and describing the position which the site occupies along a gradient of floristic similarity. The philosophy developed further, and was crystallised in an invited published paper: **An alternative approach to veld condition assessment in the non-grassveld regions of South Africa [P 2.3]** (the co-author of this paper contributed the review of vegetation assessment in the karoo). The sections of relevance to this dissertation are the Introduction, the review of thicket assessment methods, and all sections thereafter.

While the philosophy and theoretical procedure for scoring veld was being developed, a means of actually assessing vegetation in the field was devised. The approach was a formalized visual method with multiple operators. It was tested and found to be acceptable and Tool 2 was thereby provided (see the published paper: **Towards visual assessment of succulent valley bushveld [P 2.4]**). Not included in the paper was a discussion of the difference between 'subjective' and 'visual' methods. My impression is that many people confuse the two, some even believing that they are the same. A useful analogy is that of determining a length of string. A subjective approach would return measurements of "long or short" (obviously not repeatable between operators), whereas a visual method would return estimates of length in millimetres, centimetres, or metres (or other measurable units). This could be done in the conventional sense by placing a ruler next to the piece of string or by estimating the length by simply looking at it whilst referring to a repeatable index 'embedded' in the mind. Visual methods are not subjective methods!

ERRATA & CLARIFICATION NOTES

Specific errors (excluding punctuation and those as a result of changing information or philosophy) are as follows.

Pg. 21	Col. 1	Fig. 1	In the species key, the second reference to the species codes "EUPH" and "CROV" should read "BRIL" and "AZTE" respectively.
Pg. 21	Col. 1	Ln. 5	"may only be obvious" should read "may be indicative of deeper"
Pg. 21	Col. 2	Ln. 10	The absence of <u>Rhus lucida</u> in Figure 1 is because it was so uncommon that it could not be displayed on the Figure.

J. Grassl. Soc. sth. Afr. (1986). **3**,*1: 19-24*

TOWARDS A METHOD OF ASSESSING THE VELD CONDITION OF THE VALLEY BUSHVELD IN THE EASTERN CAPE
BENADERING VAN 'N METODE OM VELDTOESTAND IN THE VALLEIBOSVELD VAN DIE OOS-KAAP TE BEPAAL

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ABSTRACT

Currently, no technique is available for assessing the condition of Valley Bushveld in the Eastern Cape. The objective of this investigation was to develop a method of scoring bushveld according to its productive condition. It was established, through principal component analysis that, while bushveld condition is negatively related to the percentage of *Lycium austrinum*, it is positively related to tree density, foliage volume below 1,5 m, the percentage of *Portulácaria afra*, *Euphorbia* spp. and *Schotia afra*. Furthermore, it was established that species such as *Brachylaena ilicifolia*, *Rhigozum obovatum*, *Zygophyllum morgsana* and *Azima tetracantha* are indicative of important differences within the Valley Bushveld. From these variables a tentative technique was developed to score the condition of Valley Bushveld.

UITTREKSEL

Daar is tans geen tegniek beskikbaar om die toestand van Vallei-bosveld in die Oos-Kaap te bepaal nie. Die doel van hierdie ondersoek was om 'n metode daar te stel om bosveld volgens sy produktiewe toestand te bepaal. Deur hoof komponente analise is vasgestel dat bosveld toestand negatief gekorrelleer is aan die persentasie digtheid van Lycium austrinum *en positief aan boom digtheid, blaarvolume onder 1,5 m, en die digtheid persentasies van* Portulacaria afra, Euphorbia *spp. en* Schotia afra. *Daar is ook gevind dat verskeie soorte soos* Brachylaena ilicifolia, Rhigosum obovatum, Zygophyllum morgsana *en* Azima tetracantha *belangrike verskille binne die Valleibosveld aandui. 'n Tegniek is tentatief vanaf hierdie veranderlikes ontwikkel om die veldtoestand van Valleibosveld te bepaal.*

Additional index words: Principal component analysis, cluster analysis, browse, tree density, species composition.

INTRODUCTION

The Valley Bushveld (Veld Type 23: Acocks, 1975) is the single largest veld type in the Eastern Cape region. The major portion of this approximately two million ha is considered by pasture scientists to be in poor condition. There exists, however, a vast difference of opinion within the farming community, and between some farmers and scientists as to what constitutes Valley bushveld in good or poor condition. It follows that if awareness programmes by scientists are to have any success, then it must be clearly stated what characteristics ideal Valley Bushveld should possess. Furthermore, an objective technique must be made available so that the condition of any bushveld site can be quantified according to its carrying capacity. The overall objective, therefore, is to develop a repeatable technique that would objectively score the condition of Valley Bushveld in terms of its carrying capacity.

At present the constraint in achieving this objective is the lack of plant productivity data. However, it has been determined, from experience, that bushveld with high tree densities, with no well-developed browse line (below 1,5 m for goats) and an abundance of *Portulacaria afra* can support more stock on a sustained basis than bushveld with low tree densities having well-developed browse lines and little or no *P. afra* (Aucamp, 1979). It was assumed, therefore, that variables which are positively correlated to tree density, amount of forage below 1,5 m and *P. afra* are indicative of Valley Bushveld in good condition.

PROCEDURE

The study was conducted on three sites in the Valley Bushveld. Sites 1 and 3 were on the J C Steyn Prison Farm (approximately eight km apart) in the Kirkwood district and Site 2 on the farm Blaaukrantz in the Uitenhage district. At Sites 1 and 2, five camps were subjectively selected to cover a range of conditions varying from that perceived to be very good to very poor veld. At Site 3, the bushveld had never been utilized by domestic stock and it was considered to be in a "pristine" condition. Only a single sample was surveyed at this site.

The quadrat method survey, devised by Cottam & Curtis (1956), was used (120 points/camp) to determine the number of plants of each tree species per ha (N), tree density per ha and species composition. In the same survey additional measurements per plant encountered were: height of lowest leaves (H); mean canopy radius (R); and the optical density (OD) of twigs and leaves below the browse line. The latter was estimated at intervals of 10, 30, 50, 70 and 90% of the potential leaf and twig density for that species. (Andrew, Noble & Lange, 1979; Lensing & le Roux, 1982). For each camp, browseable volume per species per ha (BV) was calculated from:

$$BV = \frac{(\sum_n (1.5 - H) \times \Pi r^2 \times OD/100) \times N}{n}$$

where n = number of plants encountered per species; and total browseable volume of all species per ha (TBV) was calculated from:

$$TBV = \Sigma_s BV$$

where s = number of species encountered.

Factors accounting for the variability between camps and sites were identified by performing a principal component analysis (PCA) with the BMDP programme - P4M (Frane, 1983). Two ordinations were performed, each with a different set of variables. The first analysis used percentage species composition of the 14 most abundant species, TBV and tree density while the second used BV of the same 14 species and tree density.

Where it was necessary to compare sites, a cluster analysis was performed using the BMDP programme - P2M (Engelman, 1983). The variables used in the comparison were percentage species composition (of the 14 most abundant species), TBV and tree density.

RESULTS AND DISCUSSION

In the first PCA, where the 16 variables comprised percentage species composition, TBV and tree density, three factors (principal components) were identified and together they accounted for 76,1% of the total variation. The second PCA, based on BV and tree density, identified the same three factors which together explained 76% of the total variability. The resulting factors and eigen values in this case were very similar to those of the analysis based primarily on percentage species composition. As the two ordinations essentially produced the same result, only the PCA incorporating percentage species composition, TBV and tree density was used.

Regarding this ordination, it was found that the first factor accounted for 39% of the total variation and was characterised by high positive eigen vectors for density (0,966), *P.afra* (0,926), TBV (0,900), *Euphorbia* spp. (0,742) and *Schotia afra* (0,700) but a highly negative coefficient for *Lycium austrinum* (-0,809) (Table 1).

Table 1 *Eigen vector values and factors from principal component analysis in Valley Bushveld.*

Variables	Factor		
	1	2	3
Portulacaria afra	0,926	0.089	0.075
Euclea undulata	0,661	0,449	0,457
Maytenus heterophylla	0,506	-0,317	0.093
Azima tetracantha	-0,354	-0,865	0,131
Schotia afra	0,700	-0,290	-0,224
Pappea capensis	0,327	0,339	-0,658
Rhigozum obovatum	-0,507	0,760	-0,321
Rhus lucida	-0,143	-0,237	0,818
Brachylaena ilicifolia	0,349	0,804	-0,080
Lycium austrinum	-0,809	-0,488	-0,108
Crassula ovata	0,501	0,536	0,285
Zygophyllum morgsana	-0,597	0,678	0,056
Euphorbia spp.	0,742	-0,481	-0,147
Grewia robusta	-0,089	0,504	0,448
Tree density	0,966	-0,004	0,134
TBV	0,900	-0,239	-0,216
Sum of eigen vector values	6,235	4,067	1,885
Variance accounted for by Factor (%)	39,0	25,4	11,8
Cumulative variance accounted for (%)	39,0	64,4	76,2

As we assume that the condition of bushveld is positively related to its density, browseable volume and amount of *P.afra*, then presumably Factor 1 describes "bush condition". Within this factor, species with negative eigen vectors indicate bushveld in poor condition, whilst species with positive eigen vectors are indicators of bushveld in good condition. The variables identified above are termed "condition indicators".

The second factor was responsible for 24,4% of the total variation (Table 1). It has positive eigen vectors for *Brachylaena ilicifolia* (0,804), *Rhigozum obovatum* (0,760) and *Zygophyllum morgsana* (0,678), while the eigen vector for *Azima tetracantha* (-0,865) was highly negative. In the field it had been subjectively noted that there existed a quantity of *B. ilicifolia* in every camp at Sites 2 and 3, but in none of the camps at Site 1. This observation was tested against the raw species composition data (Figure 1, p 21).

Furthermore, the other two species with high positive eigen vectors (*R.obovatum* and *Z.morgsana*) both occurred in abundance at Site 2, and the former at Site 3, but were relatively rare at Site 1. This inferred that Factor 2 could describe compositional differences between sites. From this it follows that, if species with positive coefficients are indicative of the bushveld type at Sites 2 and 3, then species with highly negative eigen vectors (*A tetracantha*) are indicative of the bushveld type at Site 1. This was not refuted by the raw data in Figure 1. The species listed above are termed "indicator species" as they are indicative of site differences. The validity of the interpretation of Factor 2 ("site differences") was tested by conducting a cluster analysis to see if the sites were different.

It is evident from the resulting dendrogram (Figure 2) that, on the basis of the data analysed, the bushveld at the three sites differed.

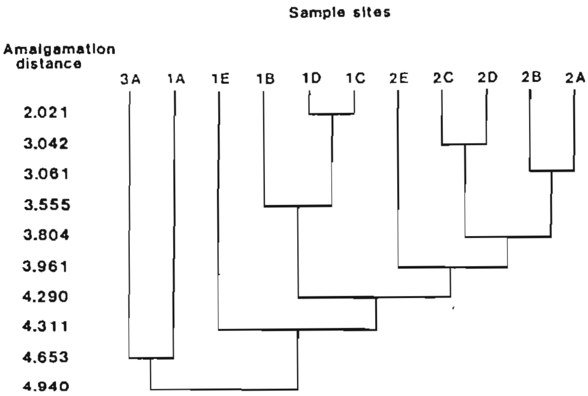
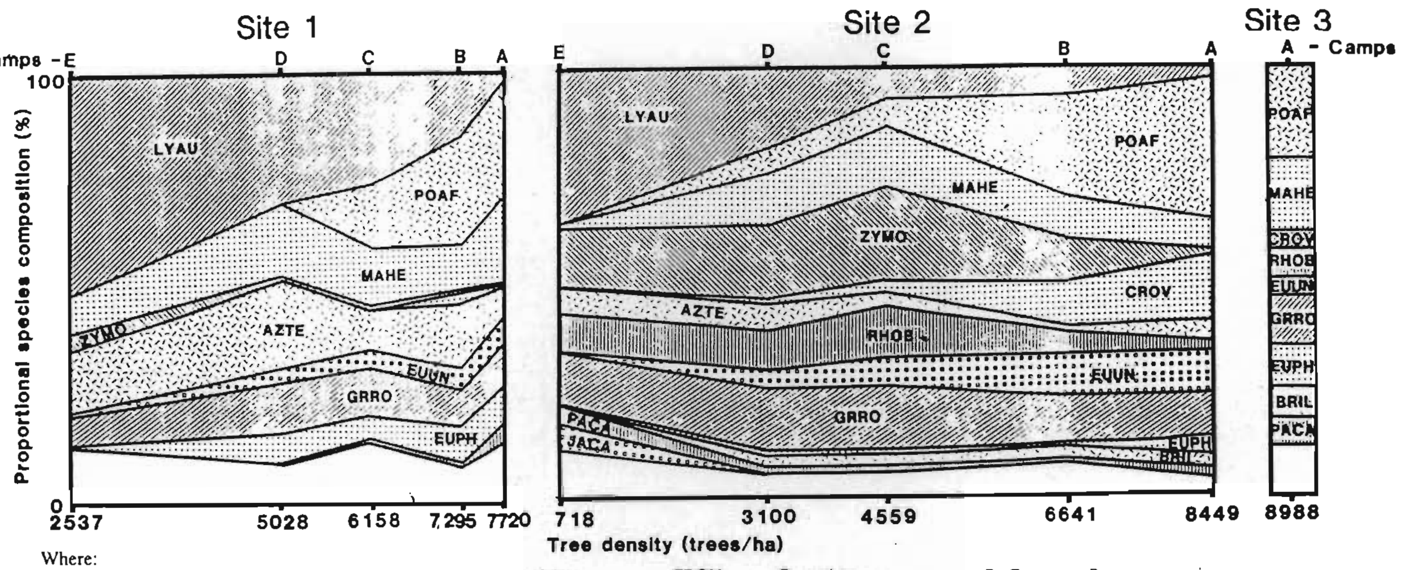


Figure 2 *The relationship between 11 camps at three sites on the basis of species composition, tree density and total browseable volume below 1.5 m per ha (TBV).*

These differences were so marked that, despite the vast differences in tree density and TBV, the camps at Site 2 were more closely related to each other than to any of the camps at Sites 1 or 3. To test the interpretation of Factor 2 still further, it was argued that, if the four "indicator species" were removed from a cluster analysis of samples, then there should remain little or no differences between sites. This was done and the resulting dendrogram (Figure 3) illustrates that the large difference between sites previously obtained (Figure 2) no longer existed.



Where:

LYAU	- *Lycium austrinum*	EUUN	- *Euclea undulata*	CROV	- *Crassula ovata*	PACA	- *Pappea capensis*
POAF	- *Portulacaria afra*	GRRO	- *Grewia robusta*	CROV	- *Azima tetracantha*	JACA	- *Jatropha capensis*
MAHE	- *Mytenus heterophylla*	EUPH	- *Euphorbia* spp	RHOB	- *Rhigozum obovatum*		
ZYMO	- *Zygophyllum morgsana*	EUPH	- *Brachylaena ilicifolia*				

Figure 1 *Changes in the proportional composition of species with tree density at Sites 1, 2 and 3.*

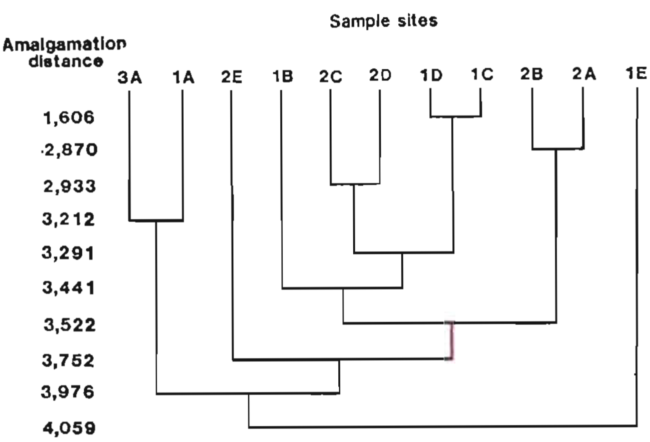


Figure 3 *The relationship between 11 camps at three sites, after "site identifier" species were removed from the cluster analysis which yielded Figure 2.*

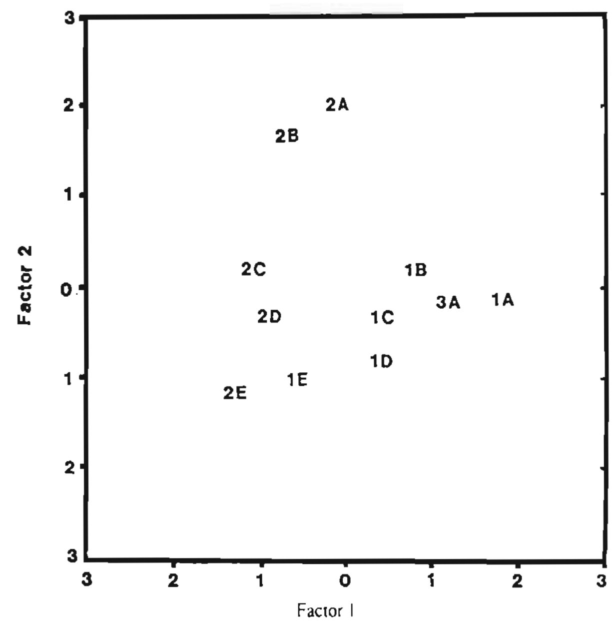


Figure 4 *Positions of camps (A to E) at three sites (1, 2 and 3) on the first (Factor 1) and second (Factor 2) principal components.*

It could be a solution simply to ignore these species, especially in view of their relatively small contribution to total species composition (Figure 1), and treat the data from all sites as from a single population. However, this may be unwise because the presence or absence of these species may only be obvious differences between sites. For example, a species such as *P. afra*, although occurring equally at both sites, may be very different below 1,5 m or have a different productive potential at Site 2 than at Site 1. This argument is corroborated by Figure 4 which illustrates that, if Factor 2 was ignored and the veld condition assessed according to Factor 1 alone, then the best camps at Site 2 could score approximately the same as the worst camps at Site 1.

In reality this conclusion would enjoy little support from both local farmers and scientists alike. It is absolutely essential, therefore, that both Factors 1 and 2 are considered in the assessment of the condition of Valley Bushveld.

The third factor accounted for 11,8% of the total variation (Table 1). It had a high positive eigen vector (0,818) for *Rhus lucida* and a negative eigen vector for *Pappea capensis* (-0,658). This would indicate that these two species are at the opposite ends of the gradient described by Factor 3. It is apparent that both *R.lucida* and *P.capensis* make up a relatively small proportion of the total species composition (Figure 1). From raw data it was calculated that *P.capensis* on average, has a browseable volume of approximately 0,013 m² per plant whilst *R.lucida* plants were somewhat larger contributing 0,720 m² per plant. This is corroborated by field observation where *R lucida* plants are larger below 1,5 m than *P.capensis* plants. The latter are characteristically umbrella-shaped with little or no foliage below 1,5 m. On the basis of the preceding argument, it would appear that Factor 3 may describe plant size below 1,5 m. However, it is the opinion of the authors that Factor 3 cannot be described with any degree of certainty and the above interpretation is merely presented as an hypothesis for testing.

The results of the PCA were used to score bushveld according to its condition. It involved two stages. Firstly, the bushveld type was identified according to the composition of "indicator species", and secondly, bush condition was scored according to the relative magnitude of the "condition indicators"

Bushveld type was identified from sample site scores obtained by summing the scores for each "indicator species". The latter were derived by multiplying the percentage composition of each "indicator species" with the eigen vector associated with that species in Factor 2 (Table 2).

The negative sample site scores are indicative of the bushveld type at Site 1 (Kirkwood bushveld type), whereas the positive scores indicate the bushveld type at Site 2 (Uitenhage bushveld type). It will be noted that Site 3 has a positive score and, consequently, for assessing condition, is considered to be of the same bushveld type as Site 2.

Bushveld condition was characterised by summing the scores obtained by the "condition indicators" at each sample site. These scores were obtained by multiplying the measured variable (percentage species composition of each "condition identifier" species, TBV and tree density) with its relevant eigen vector as pertaining to Factor 1 (Table 3).

The total condition score for each sample site was expressed as a percentage of the highest total score obtained in the relevant bushveld type. The sample sites with the highest scores in each bushveld type were thus regarded as benchmarks (Table 3). It is evident that TBV and tree density are essentially the only variables determining bush condition score. With the method used, percentage species composition had little influence on scoring and can therefore be eliminated from the scoring process. This step can be defended in that species composition was found to be strongly correlated with both TBV and bush density ($r = 0{,}835$ and $r = 0{,}9082$ respectively). Furthermore, it was evident, by ignoring the differences between bushveld types and scoring all the sample sites in relation to a single benchmark, that the camps were ranked according to bushveld condition in approximately the same order as they would have been, had they been subjectively allocated a ranking according to the conceptual model as described at the start of this paper. It is further of note that this ranking was dissimilar and vastly superior to the ranking order given by Factor 1 alone in Figure 4. However, ignoring the differences between bushveld types is in direct conflict with the argument presented previously for the inclusion of Factor 2 into the scoring process. It appears, therefore, that somehow the impact of "site differences" was accounted for in the scoring of bushveld condition. This probably was when the TBV variable was scored because it is apparent that TBV also had a slightly negative (-0,239) eigen vector for Factor 2 ie it is a weak indicator of bushveld type. However, in the scoring process it would have a significant contribution because of its absolute magnitude. Presumably, therefore, Factor 2 can be left out of the scoring process, provided TBV is measured and presented for scoring.

Table 2 *Scoring sample sites according to Valley Bushveld type. Camps A to E at each site were subjectively selected to represent decreasing bushveld condition. Negative scores are indicative of Kirkwood bushveld (Site 1) while positive scores indicate Uitenhage bushveld (Sites 2 and 3).*

"Indicator species" (x)	Eigen vector value from Factor 2 (y)	Score (xy)										
		Site 1					Site 2					Site 3
		A	B	C	D	E	A	B	C	D	E	A
A. tetracantha (%)	-0,865	-5,2	-13,0	-8,7	-14,7	-13,7	-4,3	-0,9	-2,6	-5,2	-6,1	0
R. obovatum (%)	0,760	0,8	0	-0,8	0	5,3	2,3	4,6	9,1	7,6	6,8	5,3
B. ilicifolia (%)	0,804	0	0	0	0	0	2,4	3,2	3,2	2,4	0	5,6
Z. morgsana (%)	0,678	0	0	0,7	0,7	2,7	0,7	8,1	18,6	12,2	10,2	0
TOTAL SCORE		-4,4	-13,0	-7,2	-14,0	-5,0	1,1	15,0	25,3	17,0	10,9	10,9

Table 3 *Scoring sample sites according to bushveld condition, where all the "condition indicators" were measured. Camps A to E were subjectively selected to represent decreasing bushveld condition at Sites 1 and 2.*

	"Condition indicators" (X)	*Eigen vector value from Factor 1* (y)	Score (XY)										
			Kirkwood bush type					Uitenhage bush type					
			1A	1B	1C	1D	1E	2A	2B	2C	2D	2E	3A
Species Composition (%)	*L. austrinum*	-0,81	-2	-12	-22	-24	-42	-6	-5	-6	-15	-30	0
	P. afra	0,93	26	24	14	1	0	31	21	7	5	0	20
	S. afra	0,70	4	1	1	1	1	1	1	0	0	0	1
	Euphorbia spp	0,74	7	7	4	5	0	3	0	0	1	0	7
	Tree density (Plants/ha)	0,97	7488	7075	5973	4876	2461	8195	6442	4422	3007	696	8718
	TBV (m^3/ha)	0,90	5093	4539	2273	1026	434	2533	1680	846	734	36	4490
	Total score		12616	11634	8243	5885	2854	10757	8139	5269	3732	702	13236
	Condition scores within bushveld type (%)		100	92	65	47	23	81	61	40	28	5	100
	Overall condition score (%)		95	88	62	44	22	81	61	40	28	5	100

To improve the efficiency of assessing bushveld condition it would be desirable to eliminate TBV as measuring this parameter is extremely time-consuming. However, as has been pointed out, it is absolutely essential in determining bushveld condition and, consequently, cannot simply be ignored in the scoring process. A regression analysis was performed on the data from Site 1 where the dependent variable was TBV and the independent variable was tree density. Similarly, a regression analysis was performed on the combined data of Sites 2 and 3. These groupings were made according to the site scores which established that Sites 2 and 3 were of the same bushveld type but of a different type from Site 1 (Table 2). The most significant relationship is presented for each bushveld type (Figure 5).

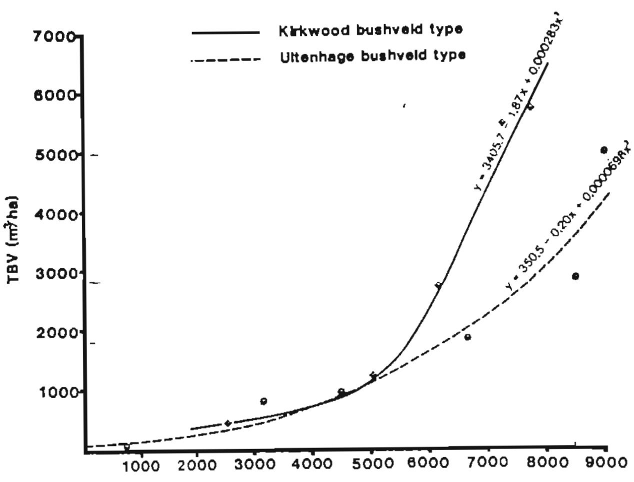


Figure 5 *The relationship between total browseable volume below 1.5 m (TBV) and tree density for the Kirkwood (Site 1) and Uitenhage (Sites 2 and 3) bushveld types.*

There was a strong relationship between tree density and TBV ($r = 0,996$ and $r = 0,900$ for Site 1 and for Sites 2 and 3 respectively). This enables TBV to be calculated instead of being measured. It is noteworthy that the large differences in browseable volume between similar tree densities at Site 1 and at Sites 2 and 3, corroborate the argument posed previously that it is important to distinguish between bushveld types. Calculated browseable volume (CTBV) was determined with the equations pertaining to each bushveld type and this was used to replace TBV in the bushveld scoring process. Thus "site differences" (Factor 2) is incorporated into the assessment of Valley Bushveld condition because it identifies the equation to be used in the determination of CTBV. The assessment of bushveld condition by using CTBV instead of TBV is presented in Table 4.

This method was successful in that similar scores were obtained as when TBV was used (Table 3), the major difference being that the benchmark changed from Site 3 in the original assessment to Camp A at Site 1. This was considered unimportant as the differences between these camps in terms of the scores were negligible. Over the entire spectrum of sample sites the scores derived using CTBV instead of TBV were acceptable in view of the time that would be saved in the field by not having to measure the latter parameter.

CONCLUSION

Of the three variables considered to determine the productive condition of Valley Bushveld, tree density and TBV were shown to be extremely important. The direct influence of species composition on the scoring of bushveld condition was unimportant, inferring that it can be dropped altogether from this type of bushveld assessment. This presumably was because species composition is related to both bush density and TBV and is being accounted for by these two variables in the scoring process. However, species composition is important in determining CTBV, the latter replacing TBV in the proposed scoring technique. Briefly, the procedure for this technique is: (i) measure tree density; (ii) measure species composition; (iii) identify bushveld type by scoring from "indicator species"; (iv) select the appropriate equation and estimate CTBV from tree density; (v) score veld according to tree density and CTBV; and (vi) express condition as a percentage of the benchmark. If this technique is to be applicable to all situations in this veld type, it needs to be ascertained, over a wide range of conditions (eg sites with different age structures), whether CTBV is a reliable predictor of TBV. Furthermore, it is necessary to test in these situations, whether species composition always influences the estimation of CTBV.

In addition to the above, it is recommended that additional variables (eg plant palatability, plant digestibility, plant production potential, soil type, altitude and rainfall) should be investigated to establish the influence they have on bushveld condition. Most importantly, a reliable index of browsing capacity must be developed so that the conceptual model of ideal Valley Bushveld can be objectively tested.

ACKNOWLEDGEMENTS

We are very grateful to our colleagues for their assistance with the botanical surveys; to Mr E Kingman and Mr A Fourie for their help in processing and analysing data and to Mr G Barnes and Mrs M McMaster for their editorial comments.

Table 4 *Scoring sample sites according to bushveld condition, where species composition and bushveld type are ignored and TBV is replaced by CTBV. Camps A to E were subjectively selected to represent decreasing bushveld condition at sites 1 and 2.*

"Condition indicators" (X)	Eigen vector value from Factor 1 (y)	Score (XY)										
		Site 1					Site 2					Site 3
		A	B	C	D	E	A	B	C	D	E	A
Tree density (Plants/ha)	0,97	7488	7075	5973	4876	2461	8195	6442	4422	3007	696	8718
CTBV (m³/ha)	0,90	5237	4325	2346	1030	428	3278	1890	800	361	219	3772
Total Score		12725	11400	8319	5906	2889	11473	8332	5222	3368	915	12490
Condition score(%)		100	90	65	46	23	90	65	41	26	7	98

REFERENCES

Acocks, J.P.H., 1975. Veld types of South Africa. 2nd edition. *Mem. Bot. Surv. S. Afr. No. 40.*

Andrew, M.H., Noble, I.R., & Lange, R.T., 1979. A non-destructive method for estimating the weight of forage on shrubs. *Aust. Range. J.*, **1(3)**: 225-231.

Aucamp, A.J., 1979. Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke. D.Sc. Agric. thesis. Univ. van Pretoria.

Cottam, G. & Curtis, J.T., 1956. The use of distance measures in phytosociological sampling. *Ecology*, **37**: 451-460.

Engelman, L., 1983. Cluster analysis of cases. In *BMDP statistical software*. Eds.: Dixon, W.J., Brown, M.B., Engelman, L., Frane, J.W., Hill, M.A., Jennrich, R.I. & Toporek, J.D. Berkeley: Univ. of California Press, 456 pp.

Frane, J., 1983. Factor analysis. In *BMDP statistical software*. Eds.: Dixon, W.J., Brown, M.B., Engelman, L., Frane, J.W., Hill, M.A., Jennrich, R.I. & Toporek, J.D. Berkeley: Univ. of California Press, 480 pp.

Lensing, J.E. & le Roux, C.J.G., 1982. Herbage availability inventories in rock hyrax habitat in southern South West Africa. *Madoqua*, **13 (1)**: 45-57.

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[P 2.2]

ERRATA & CLARIFICATION NOTES

This publication appeared in a semi-popular book published in 1989 by the Government Printer, Pretoria. The numbering convention for sections, figures and tables refers to the book, not the thesis. In addition, the genus of some species may not be included on first reference because this would have been done earlier in the book.

Specific errors (excluding punctuation and those as a result of changing information or philosophy) are as follows.

Pg. 105	Col. 2	Ln. 15	"within the 10m interval" should read "at each 10m interval"
Pg. 106	Col. 1	Table	I emphasize that these values were for explanation only. Despite the qualifier in the caption, I would avoid doing this in future.
Pg. 107	Col. 1	Ln. 49	This analogy is perhaps appropriate in a semi-popular article but I would not place it in a scientific document.

Veld management in the Eastern Cape

[P 2.2]

Editors
J.E. Danckwerts and W.R. Teague

CONTENTS

8.5 ASSESSING THE CONDITION/ ECOLOGICAL STATUS OF VALLEY BUSHVELD

G.C. Stuart-Hill

8.5.2 Procedure for assessing Succulent Valley Bushveld

There are two very distinct phases of assessing the vegetation at a site.

(i) The basic data which describe the relevant aspects of the vegetation have to be collected (and stored in a readily retrievable manner) - the *survey phase*.

(ii) The data collected during the survey phase are processed and condensed into as few descriptive terms as necessary (e.g. a single value describing veld condition, browse availability or veld type). This we will call the *computational phase*.

It follows that, in the computational phase, there may be a number of different techniques depending on the operator's objective. For example, an extension officer wishing to quantify, in general terms (for farm planning), the condition of the vegetation may use a different technique to a scientist who wants to monitor short-term change as a result of a particular grazing or resting treatment. It is extremely desirable that the data collected during the survey phase be as complete as possible. This would allow for a number of objectives to be met from one particular set of data, allow an assessor to relate his results to those of others working at more or less detailed levels and, most importantly, to prevent the data from becoming obsolete if subsequent research shows that extra parameters are required for intelligible interpretation (e.g. see Section 8.2).

Naturally one must be reasonable about collecting "extra survey data" as vegetation surveying is a costly and time-consuming effort. A rule of thumb may be to collect data at one level more intensively than you require provided it does not overly strain your survey resources.

We now discuss in detail the survey phase and this will be followed by a discussion of the computational phase of vegetation assessment in the Succulent Valley Bushveld.

8.5.2.1 *The survey phase*

It is important to appreciate that surveying the vegetation and determining the ecological index are two separate procedures. Vegetation assessment is the survey where the raw data are collected in the field. Determining the ecological index (or veld condition) is a mathematical exercise using some or all of the raw data collected during the surveys. It is highly likely that as we learn more about the vegetation, our method of arriving at an ecological index may change. Therefore, it is desirable (especially at this stage where techniques are tentative) that the survey data be collected in such a manner that they are of sufficient quality and cover a range of variables so that if (when) different procedures for determining veld condition are developed then it is possible to re-estimate the scores using the new technique, without having to resurvey the vegetation. This is vital as veld continually changes and a new survey, if conducted after some time, will yield different results.

To arrive at an index of the ecological status (condition) of the veld we require basic data which describe the vegetation. The survey method currently used is a derivative of the point-centred-quarter method (Cottam & Curtis, 1956), although it is currently being evaluated against the transect method (Section 8.4). The intention in this phase is to collect data which describe the agro-ecologically important attributes of the vegetation. It has subjectively been decided that, species composition, density (of both the bush and the grass), volume of bush per ha, volume of bush below 1,5 m/ha, average height of the community, the average height of lowest browseable material in the community as well as some detailed information regarding each plant species (heights, importance values, etc.), adequately describe the Succulent Valley Bushveld.

The specific steps taken in assessing Valley Bushveld are listed and described below.

Step (1) Select site to be assessed

If one of the objectives in surveying the veld is to monitor change, then:

(i) avoid sites where the vegetation is very variable or patchy. If this cannot be done, then increase the number of sample points; and

(ii) do not include into a single survey more than one camp.

If the objective of surveying the veld is merely for inventory or predictive purposes, then it is not necessary to follow the above rules. It is advisable, however, to follow these rules as the data are then available for monitoring purposes should the objective change.

Step (2) Describe site

It is essential for clear interpretation of the survey data, that the abiotic and biotic factors that may have an effect on the vegetation also be recorded. These include climatic and edaphic characteristics, aspect, slope and past management (where this is known).

Step (3) Layout transects

Transect layout with the objective of surveying Valley Bushveld for monitoring vegetation change should be consistent between sample dates (i.e. permanently marking transects or even sample points).

Step (4) Record basic data parameters

Walk along the transect in a *straight line* (this may be very difficult in thick bush) and, at 10-m intervals, mark a right-angled cross in the ground or make a placement of a pre-made iron cross. The latter may be spun and dropped so that the precise position and orientation of the cross is random, within the 10-m interval. In each of the quarters, record on an appropriate data sheet the following parameters:

(i) the nearest bush species (common name - species code filled in later);

(ii) the distance to the centre of the nearest bush;

(iii) the height of the top of the canopy;

(iv) the height of the lowest part of the canopy;

(v) the radius of the canopy;

(vi) a subjective estimate of the density of living twigs in the volume described by (iii), (iv) and (v);

(vii) the ~~nearest grass species (if present~~ within 5 m); and

(viii) the distance to the nearest grass plant. (Note: if the distance to the nearest grass plant is greater than 5 m, then write down 5,00 in the appropriate column and write "BARE" (for bare ground) into the species code column.

Step (5) Analyse grass data

The data pertaining to the grass layer can easily be managed by hand in the following manner:

(i) Determine grass species composition by adding up the number of times each species was encountered and expressing this as a % of the total number of observations. Include a dummy species "BARE" to represent bare ground.

(ii) Determine grass density by calculating the average distance ($\bar{d}$), squaring this and dividing the answer into 10 000:

$$\text{i.e. grass plants/ha} = \frac{10\,000}{\bar{d}^2} \qquad \text{(after Phillips, 1959)}$$

It should be pointed out that the formula used by Lamacraft *et al.* (1983) differs from the above, but no explanation could be found as to why this is so. This requires further investigation but in the meantime the original formula will be used.

Step (6) Prepare bush data for capture and analysis by computer

Codes for each species are made up from the first two letters of the generic and first two letters of the specific name (e.g. *Schotia afra* = SCAF). These are to be entered in the appropriate places on the data sheets. A list of all the species encountered plus their codes must accompany the data sheets. It is absolutely essential that no blanks be left in the data sheets. Species that cannot be identified should be entered as *zzzz*, although this should be used as a last resort.

Step (7) Analysis of bush data

This step involves determining the primary variables describing the Valley Bushveld from the raw basic data. It is possible, by using the procedure described in step 5, to estimate species composition and density of the bush by hand. It is, however, an immense task to determine the other variables (i.e. total bush volume, volume of bush below 1,5 m, etc.) by hand, and these are best calculated with a computer. This process involves two FORTRAN programs. The first checks the data for errors (e.g. unspecified species codes or upper height smaller than lower height) and the second estimates, for six camps at a time, total bush density, average height of the canopy, average height of the lowest part of the canopy, total volume of all bush, total volume of all bush below 1,5 m and total volume of all bush below 1,5 m - corrected for the density of living twigs. The second computer program further estimates plant density, average height, average height of the lowest part of the canopy, volume below 1,5 m (corrected and uncorrected), total volume, relative density (i.e. species composition), relative frequency, relative dominance (based on: total volume, volume below 1,5 m - corrected; and volume below 1,5 m - uncorrected) and importance value (based on: total volume, volume below 1,5 m - corrected, and volume below 1,5 m - uncorrected) for *each bush species* encountered.

These are the data which describe various aspects of the vegetation on the survey site.

Number of samples

At present we are fairly confident that the parameters which we measure are describing most of the important aspects of the vegetation. At this stage, however, it is not certain if the present technique is sensitive enough to usefully monitor change and further research is still required before this can be accepted with certainty. This research hinges mainly around the number of samples which are required to obtain repeatable results for each parameter. Eventually we will end up with a table such as the example given in Table 8.5.1. *NOTE: This table is an example only and the number of points are at this stage wild guesses for illustrative purposes only and, consequently, should NOT be used at all.*

TABLE 8.5.1 - The number of point-centered-quarters required to obtain 10% repeatability when surveying various parameters in different camp sizes in the Valley Bushveld of the Eastern Cape (an example!)

Parameter	Camp size (ha)		
	20	20-200	200
Bush density	150	300	350
Grass density	50	100	150
Sp. Compo-bush	120	200	250
Sp. Compo-grass	100	120	180
Total bush Vol.	250	420	550
Availab. bush Vol.	260	430	560
Vol. of sp. 1	300	600	700
Vol. of sp. 2	280	520	620
Vol. of sp. 3	310	610	715
etc.	x	x	x
VCS (technique I)	150	300	800

8.5.2.2 *The computational phase*

The procedure laid out below is a tentative one and is presented to illustrate the scoring principle and serve as a basis on which to build and modify. It is by no means claimed that it is faultless and final. It is almost certain that modification will be made as more information becomes available. The following procedure has been developed and has had limited (and inadequate) testing in the Sundays River Valley of the Xeric Succulent Valley Bushveld.

8.5.2.2.1 *Theoretical background*

The technique for quantifying the ecological status (veld condition) of a sample of Succulent Valley Bushveld is at present under investigation and consequently the details of the assessment procedure should be regarded as tentative. However, the principles will probably not change and these are described below.

Very few pasture research programmes (i.e. utilisation studies) have been undertaken in this vegetation and, consequently, management principles are largely based on guesswork. Indeed, there is even a difference of opinion within the farming community, and between some farmers and scientists as to what constitutes poor and good Succulent Valley Bushveld. Pasture scientists, extension officers and most of the farming community believe that high bush densities with no well-developed browse line and an abundance of *P. afra* are indicative of Succulent Valley Bushveld in "good condition". This assumption is made because vegetation in this status:

(i) is supposed to be what the vegetation was like prior to commercial pastoralism,
(ii) is reputed to carry more stock than open (less dense) Succulent Valley Bushveld, and
(iii) if damaged through over-browsing, undergoes irreversible change by firstly developing a well-defined browse line (i.e. the trees taller than 1,5 m become umbrella-shaped), secondly the *P. afra* dies out along with most of the other bush species and this leads to a dramatic (and permanent) reduction in bush density.

Certain farmers favour more open Succulent Valley Bushveld because they claim (probably correctly) that:

(i) animal management is easier in open than in dense bushveld, and
(ii) animal performance (per individual) is higher in this type of veld.

Their perception of bushveld condition is understandably objective orientated and open or "broken" Valley Bushveld is, for them, veld in good condition. This difference in perception may also result because of the confusion between Succulent Valley Bushveld and non-Succulent Bushveld. In the latter, where grass increases with bush clearing, it may well be beneficial in terms of forage production to "open up" the bush.

The technique for assessing the ecological status of veld in the Succulent Valley Bushveld (which is still in the process of being refined) attempts to avoid this dispute by assessing the position of a sample site along an environmental gradient. The gradient which appears to be dominant within this vegetation, is "history of grazing/browsing intensity", although naturally there are other gradients which affect the Valley Bushveld (Stuart-Hill *et al.*, 1986). The technique attempts to score sites which have been hardly used by herbivores on one end of the gradient while sites which have been heavily over-utilised are scored on the other end. Sites with a history of moderate herbivore usage are situated in between these two extremes.

For convenience, we could express the position of any sample site along this gradient as a percentage of one of the ends. It had been decided, because it is possible to move (i.e. change) from dense to open bush but not vice versa, to express distance along the gradient in relation to those sites with a history of a low-level grazing or browsing (i.e. dense Valley Bushveld). It follows then that dense Valley Bushveld will have high ecological status scores (i.e. 70-100%) while open Valley Bushveld will have low ecological status scores (i.e. < 20%).

It must be pointed out immediately that no assumption has at any time been made regarding the usefulness of this bush. Rather the technique merely positions the sample site along a gradient. It is then up to the individual land operator to decide what score is "optimum" for his particular set of objectives. For example, a game ranger in the Addo Elephant Park may want very dense bush as his "optimum" because such bush has a high carrying capacity and density is not a problem for the movement of elephants: i.e. he may aim for a score of 100%. A farmer who has very valuable stud goats which must each produce to their optimum (i.e. optimise production/animal at the expense of production/ha) may select a score of, say, 70% as his "best veld". This would contrast with a film-maker who wants desert scenes for his cowboy films and he may select, for example, a score of 5%.

What must be appreciated in selecting and working towards a particular veld condition score as the optimum for a certain purpose, is: (i) the irreversible nature of change in this vegetation type: i.e. if the operator (or his descendants) should for some reason or other decide to change the objectives (e.g. farming enterprise) and therefore require a different score as optimum, he/they may be unable to achieve it; and (ii) the ecological hazard (e.g. potential for soil erosion) of the selected score.

The two important principles which emerge from the above are that:

(i) the technique scores the sample sites along an ecological gradient, i.e. "history of grazing/browsing intensity"; and
(ii) the technique does not assume, in the scoring process, that a certain veld condition is optimum.

It is for these reasons that in the Valley Bushveld we prefer to refer to the score as the ecological status of the veld rather than the veld condition.

8.5.2.2.2 *Scoring Bushveld subtype*

It is possible, once a site has been surveyed, to objectively decide whether a sample site belongs to one or other of the Succulent Bushveld subtypes. This can serve as a test for the pre-survey predicted bushveld type classification made by the expert system (Section 8.5.1). It is done by scoring each sample site according to the abundance of the "site indicators" (i.e. those species which are diagnostic of the various bushveld types). Sample site scores are obtained by summing the scores determined for each "site indicator". These are derived by multiplying the percentage composition of each of the "site indicators" with its eigen vector value associated with the gradient describing differences between sites.

As an example we take data from two grazing gradient surveys done in the Succulent Valley Bushveld, one on the J.C. Steyn prison farm and one on the farm Blaaukrantz. From ordination analyses of these data, it was established that an abundance of *R. obovatum* (granaat), *B. ilicifolia* (bitterblaar) and *Z. morgsana* (slaaibos) appeared to be diagnostic of bushveld in the Uitenhage District of the Sundays River Valley whereas an abundance of *A. tetracantha* (byangel) is indicative of the bushveld at Kirkwood (Stuart-Hill *et al.*, 1986). The essential difference (apart from the species composition differences) between these two subtypes of the Xeric Succulent Bushveld appears to be that at the same

TABLE 8.5.2 - Scoring sample sites according to Valley Bushveld sub-type. Sites have been selected to represent a range of bushveld conditions. Negative sample site scores are indicative of Kirkwood bushveld while positive scores indicate Uitenhage bushveld

"Site indicators" (X)		Eigen vector value for sites (Y)	Score (XY)										
			Kirkwood					Uitenhage					
			1	2	3	4	5	6	7	8	9	10	11
A. tetracantha	(%)	-0,865	-5,2	-13,0	-8,7	-14,7	-13,7	-4,3	-0,9	-2,6	-5,2	-6,1	0
R. obovatum	(%)	0,760	0,8	0	-0,8	0	5,3	2,3	4,6	9,1	7,6	6,8	5,3
B. ilicifolia	(%)	0.804	0	0	0	0	0	2,4	3,2	3,2	2,4	0	5,6
Z. morgsana	(%)	0,678	0	0	0,7	0,7	2,7	0,7	8,1	18,6	12,2	10,2	0
Sample site scores			-4,4	-13,0	-7,2	-14,0	-5,0	1,1	15,0	25,3	17,0	10,9	10,9

TABLE 8.5.3 - Scoring sample sites according to bushveld condition. Negative scores indicate bushveld in such a degraded state that browse can no longer be considered as the main forage source

"Conditioner indicators" (X)	Eigen vector value for condition (Y)	Score (XY)										
		Kirkwood bush type					Uitenhage bush type					
		1	2	3	4	5	6	7	8	9	10	11
Species composition												
L. austrinum	-0,81	-2	-12	-22	-24	-42	-6	-5	-6	-15	-30	0
P. afra	0,93	26	24	14	1	0	31	21	7	5	0	20
S. afra	0,70	4	1	1	1	1	1	1	0	0	0	1
Euphorbia spp.	0,74	7	7	4	5	0	3	0	0	1	0	7
BD/137,74	0,97	54	51	44	35	17	59	47	32	22	5	63
TBV/56,59	0,90	90	80	41	18	8	45	30	15	13	1	79
Total score		**179**	**151**	**82**	**36**	**-16**	**133**	**94**	**48**	**26**	**-24**	**170**
Condition scores within bushveld type (%)		100	84	46	20	-9	78	55	28	15	-14	100
Condition scores overall bushveld types (%)		100	84	46	20	-9	74	53	27	15	-13	95

plant density, the subtype at Kirkwood has a greater volume of bush below 1,5 m than the Uitenhage subtype. Negative sample site scores, obtained in this manner, are indicative of the bushveld type at Kirkwood whereas the positive scores indicate the bushveld type at Uitenhage. This procedure is illustrated in Table 8.5.2.

8.5.2.2.3 *Scoring ecological status*

Scoring sample sites according to their ecological positions along a grazing/browsing gradient is achieved by summing the scores obtained for each "condition indicator". The "condition indicators" were identified in the Xeric Succulent Valley Bushveld (Stuart-Hill *et al.*, 1986) and are the relative abundance of *P. afra* (spekboom), *S. afra* (boerboon) and *Euphorbia* species (noors), tree density (BD) and volume of bush below 1,5 m - corrected (TBV) as indicators of under-utilised bushveld and the percentage of *L. austrinum* (kareedoring) as the indicator of over-utilised bushveld. The score for each condition indicator is obtained in the same manner as described for identifying bushveld subtypes. This procedure is illustrated, for the same sample sites as previously, in Table 8.5.3.

8.5.3 **Conclusion**

Assessing the ecological status of Valley Bushveld with this technique (or any other objective technique) is a tedious and time-consuming process (it will take two operators one day to assess one site of Succulent Valley Bushveld).

It is recommended that, for farm planning and estimation of stocking rates, structured subjective estimates of the ecological status of this vegetation should be used. The role of objective techniques in this vegetation is to monitor change in the vegetation over time. This is best achieved by intensively surveying a few camps, to ensure that change can be measured, rather than inadequately surveying all the camps on the property. These camps, called "control camps", should be used to represent veld condition change over the whole property.

References

ACOCKS, J.P.H., 1975. Veld types of South Africa. (2nd edition.) *Mem. bot. Surv. S. Afr.* No. 40.

COTTAM, G. & CURTIS, J.T., 1956. The use of distance measures in phytosociological sampling. *Ecology* 37: 451-460.

COWLING, R.M., 1984. Asyntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome. *Bothalia* 15(1.2): 175-227.

EVERARD, D.A., 1987. A classification of the subtropical transitional thicket in the eastern Cape, South Africa, based on syntaxonomic and structural attributes. *S. Afr. J. Bot.* 53: 329-340.

LAMACRAFT, R.R., FRIEDEL, M.H. & CHEWINGS, V.H., 1983. Comparison of distance based density estimates for some arid rangeland vegetation. *Aust. J. Ecol.* 8: 181-187.

PHILLIPS, E.A., 1959. Methods of vegetation survey. Henry Holt & Co., Inc., U.S.A.

STUART-HILL, G.C., AUCAMP, A.J., LE ROUX, C.J.C. & TEAGUE, W.R., 1986. Towards a method of assessing the veld condition of the valley bushveld in the eastern Cape. *J. Grassld Soc. sth. Afr.* 3(1): 19-24.

An alternative approach to veld condition assessment in the non-grassveld regions of South Africa

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Traditional veld condition assessment methods score veld either in terms of its 'state of health' or its value for a specific land-use objective. This is problematic and we propose that 'veld condition' should simply be a descriptive index, devoid of value judgement. The index should convey multivariate information about the current state of the vegetation at a site in the same way that a cow's breed, sex or age (all descriptive indices) convey multivariate information about that cow, to which different people can attach a value. We propose that the position which a sample site occupies in multivariate space (from ordination analysis) should be its descriptive index (or condition). Different land-users can then all use the same descriptive index, but may interpret it differently, depending on their objectives. It should be noted that simply using multivariate statistics to analyse floristic data does not mean that the vegetation is being assessed according to the approach outlined in this paper.

Die kondisie van veld word tradisioneel bepaal in terme van 'gesondheidtoestand' daarvan of die waarde daarvan vir 'n spesifiek bepaalde benuttingsdoelwit. Dit lei tot komplikasies en ons stel voor dat veldkondisie 'n beskrywingsindeks, vry van waarde toekenning, moet wees. Die indeks moet inligting omtrent die huidige toestand van veld in 'n gebied oordra in die selfde wyse waarop 'n koei se teellyn, geslag of ouderdom (almal beskrywende indekse) omvattende inligting daaromtrent oordra, waarvan mense verskillende waardetoekennings kan heg. Ons stel voor dat die posisie van die perseel binne 'n multivarierende omgewing (van uit ordinasie analise) die kondisie indeks is. Verskillende landverbruikers kan dan van dieselfde beskrywingsindeks gebruik maak maar nagelang van hulle doelwitte verskillend interpreteer. Daar moet besef word dat deur eenvoudig multivariasie statistiek te gebruik om floristiese data te analiseer, nie beteken dat die plantegroei volgens die multivariasie benadering in die studie omskryf, beoordeel word nie.

Additional index words: Condition, ecological status, karoo, savanna, thicket, vegetation assessment

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Introduction

When in this paper we refer to veld condition assessment we are specifically considering once-off assessment with the express objective of providing information for management and planning (e.g. setting sustainable stocking rates, evaluating erosion hazard, siting fences to separate veld with different management requirements, assessing the potential for various enterprises). Veld condition assessment is, therefore, a form of vegetation inventory and 'condition' is an index of the current state of the veld (in terms of species composition and structure) — usually related to some a priori land-use value.

The non-grassveld regions tend to occur in the drier parts of South Africa and can be broadly classed into savanna (trees and grass), karoo (arid shrublands) and thicket (dense woody and succulent bushveld with little grass). In these regions the vegetation consists of (one or all of) a herb layer (usually dominated by grasses), a shrub layer and a tree component. As with grassveld, the composition and structure of each of these components varies. In addition, the ratio between these components varies and this adds an extra and complicating dimension to veld assessment. A further complication is that the vegetation is frequently used by land owners with different animal types (e.g. browsers and grazers) and who have different management objectives (game farms, cattle farms, goat farms and nature reserves). Veld condition cannot, therefore, simply be indexed according to its usefulness for a single a priori land-use.

This paper begins by briefly reviewing techniques of assessing veld in each of three non-grassveld regions of South Africa. We then evaluate the concept of veld condition as presently used and end by discussing the theory of an alternative approach.

Review of current methods

Savanna

Savanna is grassveld which has a woody component that can vary in density. Traditionally these regions were utilized with domestic grazers (either cattle or sheep) but it was soon recognized that if the woody component became too dense, then grass productivity would be lowered, accessibility reduced and as a consequence, animal productivity would suffer. Assessment techniques, therefore, are concerned with measuring the herbaceous layer (using a grassveld technique) and in addition, determining the density of woody plants (from counts in transects).

In a semi-arid savanna of the eastern Cape a model to predict grazing capacity from the grassveld condition score was developed, and tree density was incorporated as a factor which reduced the grazing capacity in accordance with the competitive influence trees have on sward productivity (Danckwerts 1981; Aucamp *et al.* 1983). Teague *et al.*

(1981) introduced a refinement where the height of the tree was measured and converted into an index of tree competitiveness called a 'tree equivalent'. At the same time, the principle of using trees as fodder for browsers (goats) was formalized (Aucamp & Barnard 1980) and each tree was then also considered in terms of 'browse units', the number depending on the height of the tree, the height of its canopy and its palatability. Grazer carrying capacity was determined as previously, but tree equivalents instead of tree density was used to correct grazer stocking rates to account for the competitive effect of trees. Browser carrying capacity was determined from the number of browse units and this varied according to catenal position and average annual rainfall (Teague 1987). Stuart-Hill (1985) then introduced a modification which reduced the predicted carrying capacity to account for the dietary overlap of cattle and goats.

More recently, attempts have been made to improve the accuracy of measuring woody phytomass (aerial) and researchers turned to using canopy volume (derived from various formulas) as this was found to be more closely correlated with phytomass than tree height, tree equivalents or browse units (Teague 1987; Smit 1989; Stuart-Hill in prep. b). Hobson & De Ridder (1991) found, however, that these attributes had poor repeatability between operators and advised that tree height (or stem basal dimensions) should rather be used, provided that a curvilinear relationship between height and competitiveness be adopted. 'Browse' on the other hand was best measured using a volumetric measure called 'partial spherical volume'. It is important to note that these results were from single-stemmed trees and the same may not apply with multi-stemmed trees. This needs to be tested.

Smit (1989) added a third descriptive index (of the woody component) to the existing 'competitive' and 'browse' indices which he called a 'canopy sub-habitat index'. This was based on the percentage area covered by tree canopies and was intended to quantify the potential influence that trees may have in changing grass composition beneath their canopies.

Apart from Smit (1989), most of this work was done in the eastern Cape where *Acacia karroo* is the dominant woody plant. Du Toit (1968) showed that sward species composition was not influenced by *A. karroo* density and this appears to differ markedly from other savanna types where trees do influence the composition of the sward. It is argued, however, that the 'eastern Cape' approach would account for this through the independent measurement of the grass sward. Veld assessment in eastern Cape savanna essentially determines the 'condition' of the grass layer, and separately quantifies the composition and amount (either density, canopy volume, tree/browse units or cover) of the woody layer. Two scores for each savanna site are, therefore, developed: one describing the sward and the other, the woody layer.

A major limitation for using the eastern Cape approach in other savanna types is that while *A. karroo* at low densities seems to promote grass production (Stuart-Hill & Tainton 1989), and this results in a gradual decline in grass productivity with increasing tree biomass (Aucamp *et al.* 1983), grass productivity in some other savannas of South Africa decreases immediately with increasing tree density (Donaldson & Kelk 1970).

Karoo

Karoo vegetation refers to a complex mixture of dwarf shrubs, grasses, shrubs and ephemerals with trees occurring along water courses and on some hills and mountains. The predominance of dwarf shrubs (karoo bushes) characterizes the karoo.

Repeated subjective reports of veld degradation and decline in animal productivity prompted Tidmarsh & Havenga (1955) to develop the first technique to quantify karoo veld. Plant cover was used to quantify relative dominance as this measure was presumed to be better than frequency or density. Since basal cover is less subject to variation (e.g. by grazing) than canopy cover, basal cover was chosen as the basis for measuring karoo vegetation. To overcome possible bias from clustered distribution of species and individual plants, Tidmarsh & Havenga (1955) developed the wheel-point survey method. Based on binomial theory, basal cover at a species level could be determined from systematic points covering the area to be sampled. The precision of measurement is dependent on the cover and the number of points sampled. To obtain measures of acceptable precision *c.* 1 000–2 000 points are required, taking *c.* 1.5–2.5 h. In tall scrub, woodland or in rocky terrain the wheel apparatus was unwieldy and Roux (pers. comm. to Tidmarsh & Havenga 1955) achieved point sampling by using a marked chain that could be systematically moved to provide the number of sampling points needed.

Despite the logical justification of using basal cover as a parameter to accurately quantify karoo vegetation, the wide canopy to base ratio of constituent species means that basal cover values do not accurately reflect dominance between species. To overcome this, Roux (1963) developed the descending-point method of vegetation survey that, in addition to recording basal cover, measures canopy spread, canopy cover, canopy layering and height of plants. Plant density can also be obtained at a species level by dividing the cover of a species by the mean canopy spread of individuals of that species. The descending-point method developed out of the wheel-point method and involves the same sampling and statistical procedures but is not impeded by rocky terrain. The detailed measurements taken with the descending-point make the data versatile (e.g. calculation of phytographs and canopy density) but the technique is more tedious than the wheel-point.

Apart from subjective association of grazing value and usefulness of the species, both the wheel-point and descending-point methods of the 1950s and 1960s do not formally rate veld condition or usefulness. The first attempt to evaluate karroid veld in terms of usefulness involved classifying species into functional groups (e.g. climax grasses, palatable karoo bushes, unpalatable karoo bushes and shrubs, pioneer grasses, poisonous plants, etc.) and indexing these according to their forage importance (Van den Berg & Roux 1974). Together with the contribution of each group to the composition of the vegetation, the indices were used to compute a single score for a site and based on certain norms, a site could then be placed in a condition class (e.g. very poor, poor, fair, good, excellent) (Van den Berg & Roux 1974).

Vorster (1980) showed that canopy cover was a better comparative estimator of dominance in karoo veld than either basal cover or frequency, and using this parameter developed the Ecological Index Method (EIM). Species canopy cover is measured using a point survey and the species are allocated into 'ecological groups' based on successional status (decreasers, increaser IIa, b & c and invaders): the EIM inherently assumes that the response of karoo species to grazing intensity is a direct reversal of plant succession. The percentage cover for each group is then multiplied by an 'ecological index' and the products are then summed to obtain a veld condition index (Vorster 1982). This is then compared with the score obtained for a benchmark (the assumed 'ideal veld') and based on the percentage deviation from the benchmark, a site is placed in a condition class (excellent, fair, poor or very poor). The carrying capacity of a sample site is then assumed to be the carrying capacity of the benchmark, less the percentage deviation in scores.

It is noteworthy that the EIM (based on actual plant cover) combines cover with botanical composition to provide a single indicator of veld condition that is quick and easy to measure. The technique does, however, have theoretical limitations. Species are placed subjectively into ecological groups and species within a group are multiplied by the same 'usefulness' index, i.e. it assumes that all species within an ecological group have the same response to grazing and have the same forage value. The EIM assumes that the response of karoo species to grazing intensity is a direct reversal of plant succession and that the 'climax' veld is 'optimal' for animal production.

Thicket

True thicket vegetation is confined to the eastern seaboard of southern Africa and is commonly known as Valley Bushveld (Acocks 1975). This vegetation should not be confused with savanna where bush encroachment has resulted in the woody component becoming extremely dense. In a pristine state, thickets are dominated by woody plants and the grass layer is insignificant. In succulent varieties of thicket (Cowling 1984; Everard 1987) the difference is greater as the shrub component (unlike savanna) will not regenerate following severe disturbances and it is not possible to establish and maintain a stable and highly productive grass sward in Succulent Bushveld, even with bush clearing.

Up until the mid-1980s, the vegetation was assessed destructively in terms of above-ground phytomass (Penzhorn *et al.* 1974; Aucamp 1979). This is an extremely tedious method and was only used by researchers. Botanists later used the Braun-Blanquet technique to survey the vegetation for classification purposes (Palmer 1981; Cowling 1984; Everard 1987). Early attempts by agriculturalists to survey this extremely dense and tangled vegetation non-destructively, concentrated on using the 'transect method' developed for the thornveld savannas of the eastern Cape. Aucamp (Dohne Research Centre, Stutterheim, pers. comm. 1985) soon abandoned this approach because of the difficulty with transect layout in the dense bush and adopted the point-centred-quarter method (Cottam & Curtis 1956).

Stuart-Hill *et al.* (1986) ordinated data obtained from the point-centred-quarter method and developed a tentative technique which scored veld according to bushveld sub-type and 'condition', the latter related to an assumed degradation gradient. This approach changed somewhat in that it was necessary to separate 'condition' from 'usefulness'. The score came to represent an index (called ecological status) which describes the position of the community along a gradient of floristic similarity derived from an ordination (of species composition, plant density and canopy volume) that, coincidently, appears to be related to past 'grazing' intensity (Stuart-Hill 1989a). The technique scores sites which have been hardly used by herbivores on one end of the gradient while sites which have been heavily utilized are scored on the other end. Sites with a history of moderate herbivore usage are situated in between these two extremes. Stuart-Hill (1989a) points out that no assumption is made regarding the usefulness of any ecological status. Rather it is up to the individual land-user to decide what score is 'optimum' for his particular set of objectives. This was quantified experimentally for goats and cattle in the Succulent Bushveld for different rainfall seasons (Stuart-Hill 1989b).

It should be noted that Stuart-Hill (1989a) ignored the grasses on the basis that the herb layer (in this vegetation) is insignificant in relation to the woody layer. Grass density is *c.* 1–2% of the density of true grasslands.

Stoltz & Hoffman (1989) tested the Karoo's Ecological Index method (Vorster 1982) and concluded that while it adequately surveyed the vegetation the technique was of limited use as species had to be subjectively allocated into 'ecological groups'. They recommended that the technique developed by Stuart-Hill *et al.* (1986) would be more appropriate.

Stuart-Hill (in prep. a) recommends two complimentary methods for once-off assessments (inventory) of Succulent Bushveld. The first is an objective means of deriving ecological status (Stuart-Hill 1989a) and is primarily required for assessing reference sites which are necessary for training teams of assessors to recognize different ecological statuses. The second is a rapid visual technique (Stuart-Hill 1991) recommended for quantification of ecological status at an operational level. Teams of qualified assessors (those who have been shown to have little bias and adequate accuracy) first inspect sites where the ecological status has been objectively determined. Here they standardize the field appearance of these sites against a series of reference photographs thereby developing the scale of ecological status in their minds. The teams then visit the site/s to be assessed and each operator privately estimates the ecological status. Once all the operators have made their estimates, the average is calculated and is used as the score for that site. The greater the team size, the greater the precision of the estimate. As an example, twelve 'qualified' operators would be required in an assessment team to distinguish 10% ($P \leq 0.05$) differences in ecological status. Limitations of this visual method are that: (a) the reference sites have to be exhaustively surveyed and this has to be repeated on a regular basis as they change with time; (b) it is absolutely vital that the assessors should, from time to time, recorrelate their conceptual scale of ecological status with sites where ecological status has recently been objectively measured; (c) transporting and accommodating large teams of surveyors is relatively expensive; and (d) it is only really useful for estimating specific attributes of the vegetation (e.g. ecological status, cover or density).

Critique of veld condition

Veld condition has been defined in a number of different ways but usually it is concerned with the 'state of the health' of the vegetation: what the vegetation should be like under normal climate and optimum management (Bailey 1945; Parker 1954; Short & Woolfolk 1956; Tueller & Blackburn 1974; Tainton 1981). Essentially veld condition is evaluated in terms of expressions such as 'excellent, good, fair or poor'.

Aside from the obvious difficulty of defining 'normal climate', 'optimum management' and 'healthy veld', we believe that there is a philosophical shortcoming with 'veld condition' which scientists (especially locally) have neglected in their attempts to refine methods of vegetation assessment. The different states that the vegetation can assume are not all equal, and for a specific set of objectives some conditions are more desirable than others. Take for example an extreme situation where the land-use objective is to provide desert scenes for filming cowboy films. Here, the most desirable (good) veld in the eyes of the operator (film maker) would be severely denuded and eroded. Commercial farmers, on the other hand, would say that good veld is that which consistently produces high amounts of palatable and nutritious forage, despite Walker's (1980) warning that its resilience (ability to recover following stress) could be lowered. In contrast to production-orientated pastoralism, ideal veld for communal grazing lands would have a high resilience even if this is at the expense of short-term forage production (Danckwerts 1989).

These examples are extreme, but even within commercial pastoralism, veld in 'good condition' incorporates a value judgement. A goat farmer would require high numbers of trees and shrubs and this conflicts with a cattle farmer who requires few or no trees with lots of tall grass. The latter, in turn, is different to the short, ephemeral-dominated woodland which is ideal for impala on game farms. It is also evident that even for a specific enterprise, the 'ideal' veld can be different in a wet season to that in a dry season (Stuart-Hill 1989b).

It follows from the foregoing that there is no one ideal state for veld. In an attempt to alleviate this problem the approach has been to use different techniques for different objectives, and a host of techniques have evolved which Hurt (1989) broadly classified into two philosophies, viz. an ecological approach (based on successional theory) and a forage production approach. None of these techniques have been globally accepted, with scientists either firmly accepting or rejecting the various techniques based on their own objectives of assessment.

Successional theory is just that, theory. Veld condition is a value judgement and as this cannot be tested, it is really beyond the realms of science! It may be argued, however, that veld condition is valuable for communication. Scientists all 'know', for example, that Natal grasslands in 'good condition' are dominated by *Themeda triandra.* Without a simple descriptive index of the current state of the vegetation, communication between land operators would be almost impossible. We propose then, that veld condition should simply be a descriptive index which conveys multivariate information about the current state of the vegetation at a site. This is the same principle as using a cows's breed, sex or age (all descriptive indices) to convey multivariate information about that animal to which different people can attach a value judgement. It follows that each land-user should use the same descriptive index but they may interpret it differently depending on their viewpoints/objectives.

Multivariate approach to assessing veld

If veld condition is simply an index for description (to aid communication) then it should not be necessary to invoke value judgement or successional theory. We believe that this can be achieved by using multivariate statistical procedures. These objectively ordinate sites (samples) in multidimensional space according to their similarity in species composition (or by whichever variables the veld is being quantified). The reader may argue that the interpretation of the causal factors resulting in the distribution of sites along the various ordination axes is subjective. It may well be, but unlike the numerous researchers who have used multivariate techniques in veld condition assessment, we submit that this interpretative step can be eliminated if the purpose is merely to assess (index) a sample site in relation to all other sites.

Our suggestion, then, is that a sample site should be assessed in terms of its similarity (floristically or structurally) to all other sites, and its position in multivariate space should be the index (or 'condition') which inherently describes the state of the vegetation. It is without value judgement.

Terminology is difficult. 'Veld condition' should not be used because, as mentioned earlier, how is condition defined? The term also has historical connections which could lead to confusion between traditional scores and those scores indicating position in multivariate space. We hesitantly suggest the term 'ecological status', but nevertheless invite the reader to develop a more suitable term. The term should refer specifically to the position that a sample site occupies in multivariate space and which can be located by using one or more scores, each describing the position of the site on the respective axes within this space. It should not inherently contain value judgement. The term 'ecological status' could be criticized as being nebulous and it is unashamedly so. The reader should not attempt to find a meaning from the words used.

The first step in developing a multivariate technique for assessing ecological status is to provide a multidimensional cloud of possible states which the vegetation may express itself as. This can be achieved by ordinating a number of sites which represent the greatest floristic variation expected in the area in which the assessment technique will eventually be used. To do this, increasing numbers of sites are intentionally chosen to represent the extremes of possible vegetation states. These are added to an existing data set and subjected to ordination analysis. This is repeated until the 'cloud' no longer changes with the addition of new samples. At this point, any site encountered in the study area will lie within the bounds of the multidimensional cloud. It is true that some sites may be in atypically favoured locations and the vegetation of the rest of the sites may never be able to reach a certain part of the multidimensional cloud. This is unimportant. The sites are different and that is all that is required of a technique which simply sets out to assess the current state of the vegetation.

The ecological status of a sample site could be determined by adding it to the existing data matrix and ordinating it along with all the other sites. This is not an ideal approach as it may result in a change to the cloud of points as the ordination rearranges all sites to account for the 'new arrival'. Some multivariate techniques (e.g. discriminant function analysis) maintain the original ordination and merely position the new site within the existing cloud. The latter is preferable but the former could be used if only a few new sample sites are added, the original data matrix is large and the sample site will lie within the multidimensional cloud.

Traditionally, veld has been scored along a single 'axis' and this is logical if one is scoring its usefulness from the viewpoint of a specific operator requirement (e.g. a commercial cattle farmer). By contrast, the multivariate approach deals with multidimensional space, where more than one axis of similarity is produced and it becomes possible to determine, for each sample site, a number of scores along each one of the many axes. Note that the score on each axis would describe the site with regard to the attributes (species or structure) correlated with that axis. Humans struggle to visualize more than three dimensions and as the axes beyond the first three normally account for little variation, these can probably be ignored. A given site can, therefore, be easily placed within conceptual three-dimensional multivariate space by using the positions on the first three axes as coordinates for that site (Figure 1).

Conceptually, using three dimensions to index veld is elementary, but in practice, there are problems associated with having three scores to describe the vegetation: it is difficult to simultaneously grasp the significance of all three scores at once, and it becomes unwieldy when wanting to illustrate relationships between ecological status and (as examples) carrying capacity or erosion hazard. Mathematically this should present little trouble as carrying capacity (for example) could be predicted from ecological status, using three scores as independent variables in a multiple regression relationship.

The simplest approach would be to have a single score (position on the axis accounting for most of the variation). This can be related to, for example, an estimate of carrying capacity (or soil loss, habitat suitability, etc.) either mathematically with regression or descriptively using simple graphs (Figure 2). This approach would be acceptable to field workers as they are accustomed to considering veld condition along a single dimension. If however, the first axis does not account for a considerable proportion of the total variation, then a single score would be of little value.

Using two scores to index vegetation at a sample site is probably a reasonable compromise as it is not too difficult

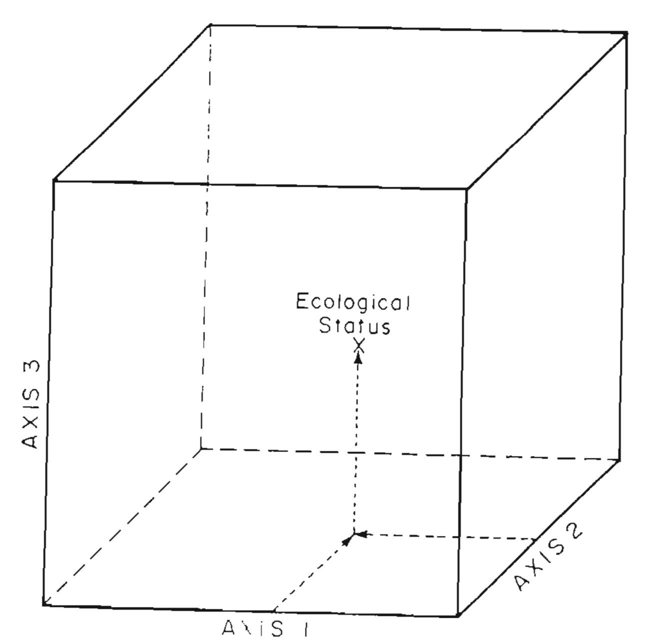

Figure 1 Conceptual 3-dimensional plot showing ecological status as a position in multivariate space.

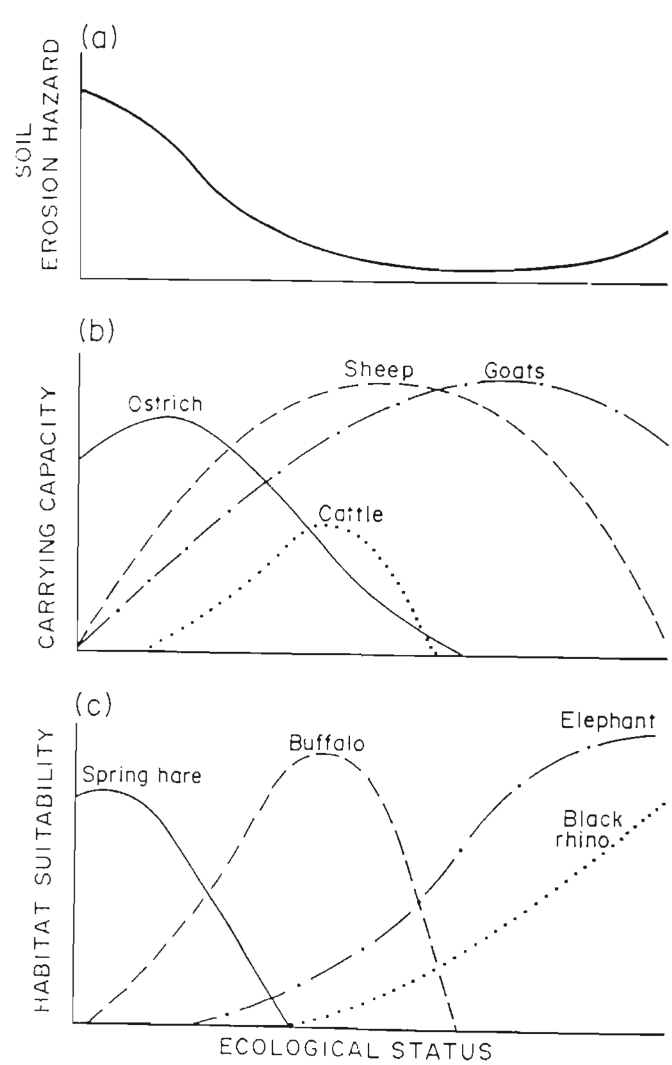

Figure 2 One-dimensional plot of ecological status showing conceptual relationships with: soil loss (a); carrying capacity (b); and habitat suitability (c) for different animal types.

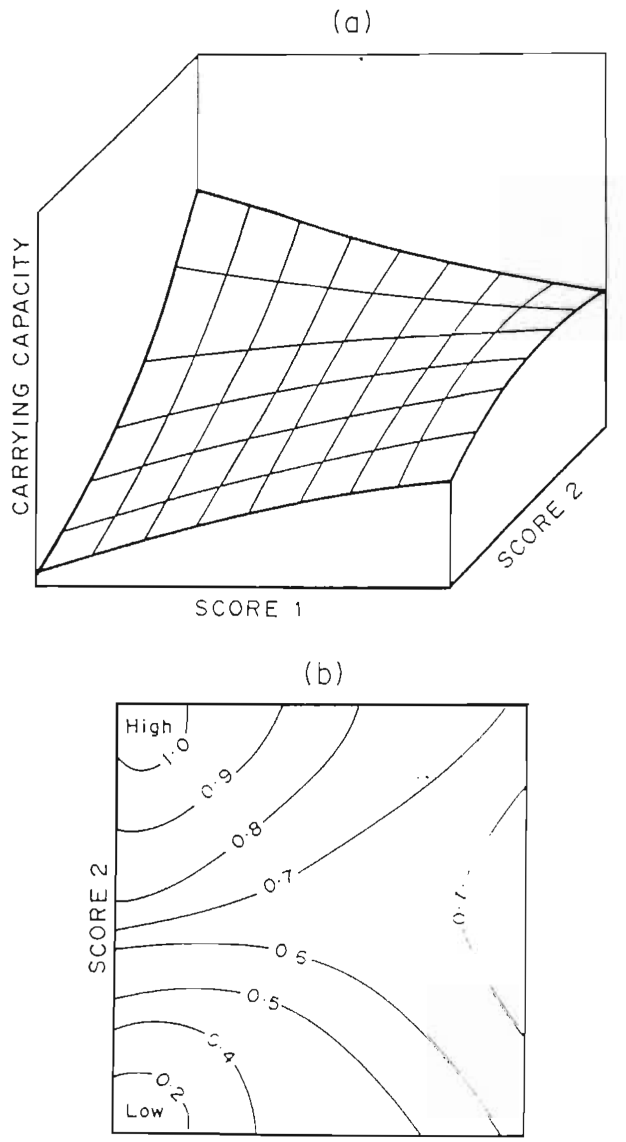

Figure 3 Conceptual 2-dimensional plot of ecological status showing predicted carrying capacity as a surface plot (a) and as a contour plot (b).

to visualize the vegetation in two dimensions and the relationship with (for example) carrying capacity could be easily developed mathematically or illustrated as a response surface (Figure 3).

The final choice as to the number of dimensions to use rests on the resolution required during veld assessment and importantly, on the precision of the techniques employed to collect the primary data.

Conclusions

Carrying capacity, soil loss, habitat suitability, etc. are alleged to be influenced by, amongst other variables, the composition (in terms of species and structure) of the vegetation. Veld assessment is, therefore, necessary for planning farms, catchments or nature conservation areas. Existing assessment techniques classify the condition of vegetation in terms of its 'state of health' or its value in terms of a specific land-use objective. The non-grassveld regions are invariably used for a number of different land-use options (e.g. goat, cattle, sheep, ostrich and game farming, and conservation) each of which requires a different state of the vegetation as 'optimum'. Because each sample of veld is unique in its species composition and structure, it is multivariate, and this causes problems as land-users require some method of condensing these complex data into easily conceivable univariate, bivariate or trivariate indices which broadly describe the vegetation at a resolution useful to him.

We propose a multivariate approach of reducing the dimensionality of complex vegetation data so that the index derived inherently describes the main attributes of the veld at a sample site. However, simply using multivariate statistical techniques to analyse floristic data does not mean that the vegetation is being assessed according to the multivariate approach outlined in this paper. We are suggesting that the position which the site occupies in multivariate space should be the score which that site is allocated, period. It is not at all essential to try to understand what factors have caused the site to be in that position, provided the objective is merely to assess the current state of the vegetation. Central to our approach is that different land-users will all use the same descriptive index, but interpret it differently depending on their objectives. We are proposing, therefore, that veld condition (ecological status) is simply a descriptive index which conveys multivariate information about the current state of the vegetation at a site. This is similar to the way a cow's breed, sex or age (all descriptive indices) conveys multivariate information about it, which different people can attach a value judgement to: like, dislike, useful, useless, etc.

At present the assessment technique for thicket vegetation is being developed along these lines and it would be very easy for the karoo regions to be assessed in this manner. The savanna regions may be somewhat more problematic as two very different vegetation components have to be integrated into a single ordination analysis. Theoretically there should be no problem with doing this. Indeed, the current approach is a primitive version of the multivariate approach as it assesses a savanna site in terms of two axes: one for the composition of the grass layer and one for the quantity of the woody layer.

The scores derived using the proposed approach should be related to various indices of usefulness. If no relationships can be established, then this means that vegetation condition is not important and there is no real need for assessing vegetation nor, indeed, for monitoring it.

References

Acocks J.P.H. 1975. Veld types of South Africa. 2nd edn. *Mem. Bot. Surv. S. Afr.* 40.

Aucamp A.J. 1979. *Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke.* D.Sc. Agric. thesis, Univ. Pretoria.

Aucamp A.J. & Barnard H.H. 1980. Die ontplooiing van die veekundepotensiaal van die droë Gras-Bosgemeenskappe in die Oos-Kaap. *Proc. Grassl. Soc. sth. Afr.* 15: 137–140.

Aucamp A.J., Danckwerts J.E., Teague W.R. & Venter J.J. 1983. The role of *Acacia karroo* in the False Thornveld of the eastern Cape. *Proc. Grassl. Soc. sth. Afr.* 18: 151–154.

Bailey R.W. 1945. Determining trend of watershed condition essential to success in management. *J. Forestry* **43:** 733–737.

Cottam G. & Curtis J.T. 1956. The use of distance measures in phytosociological sampling. *Ecol.* **37:** 451–460.

Cowling R.M. 1984. A syntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome. *Bothalia* **15:** 175–227.

Danckwerts J.E. 1981. *A technique to assess the grazing capacity of sweetveld with particular reference to the False Thornveld of the Ciskei.* M.Sc. Agric. thesis, Univ. Natal.

Danckwerts J.E. 1989. Introduction. In: Danckwerts J.E. & Teague W.R. (eds). *Veld management in the eastern Cape.* Govt. Printer, Pretoria.

Donaldson C.H. & Kelk D.M. 1970. An investigation of the veld problems of the Molopo area: I. Early findings. *Proc. Grassl. Soc. sth. Afr.* **5:** 50–57.

Du Toit P.F. 1968. A preliminary report on the effect of *Acacia karroo* competition on the composition and yield of sweet grassveld. *Proc. Grassl. Soc. sth. Afr.* **3:** 147–149.

Everard D.A. 1987. A classification of the subtropical transitional thicket in the eastern Cape, South Africa based on syntaxonomic and structural attributes. *S. Afr. J. Bot.* **53:** 329–340.

Hobson F.O. & De Ridder C.H. 1991. Quantifying indices of potential competitiveness and browse productivity of single-stemmed *Acacia karroo* in south-eastern Africa. *J. Grassl. Soc. South. Afr.* **8:** 1–8.

Hurt C.R. 1989. *Relationships between range condition score and long-term stocking rates applied to two vegetation types in Natal.* M.Sc. Agric. thesis, Univ. Natal.

Palmer A.R. 1981. *A study of the vegetation of the Andries Vosloo Kudu Reserve, Cape Province.* M.Sc. thesis, Rhodes Univ., Grahamstown.

Parker K.W. 1954. Application of ecology in the determination of condition and trend. *J. Manage.* **7:** 14–23.

Penzhorn B.L., Robbertse P.J. & Oliver M.C. 1974. The influence of the African elephant on the vegetation of the Addo National Park. *Koedoe* **17:** 137–158.

Roux P.W. 1963. The descending-point method of vegetation survey. A point sampling method for the measurement of semi-open grasslands and karoo vegetation in South Africa. *S. Afr. J. Agric. Sci.* **6:** 273–288.

Short L.R. & Woolfolk E.J. 1956. Plant vigour as a criterion of condition. *J. Manage.* **9:** 66–69.

Smit G.N. 1989. Quantitative description of woody plant communities: Part 1. An approach. *J. Grassl. Soc. South. Afr.* **6:** 186–191.

Stoltz C.W. & Hoffman M.T. 1989. Can the ecological index method be used to assess condition of Valley Bushveld? *Dohne Agric.* **11(1):** 23–24.

Stuart-Hill G.C. 1985. *Competitive interactions between* Acacia karroo *and the grass sward in the False Thornveld of the eastern Cape.* M.Sc. Agric. thesis, Univ. Natal.

Stuart-Hill G.C. 1989a. Assessing the condition (ecological status) of Valley Bushveld. In: Danckwerts J.E. & Teague W.R. (eds). *Veld management in the eastern Cape.* Govt. Printer, Pretoria.

Stuart-Hill G.C. 1989b. Carrying capacity of the Succulent Valley Bushveld. *Dohne Agric.* **11(2):** 6–7.

Stuart-Hill G.C. 1991. Towards visual assessment of Succulent Valley Bushveld. *J. Grassl. Soc. South. Afr.* **8:** 63–69.

Stuart-Hill G.C. in prep. (a). Veld condition assessment: Succulent Bushveld. In: Tainton N.M. & Aucamp A.J. (eds). 2nd edn. *Veld and pasture management in South Africa.*

Stuart-Hill G.C. in prep. (b). *Towards a framework for formalized adaptive management in the Succulent Valley Bushveld of the eastern Cape.* Ph.D. thesis, Univ. Natal.

Stuart-Hill G.C. & Tainton N.M. 1989. The competitive interaction between *Acacia karroo* and the herbaceous layer and how this is influenced by defoliation. *J. Appl. Ecol.* **26:** 285–298.

Stuart-Hill G.C., Aucamp A.J., Le Roux C.J.G. & Teague W.R. 1986. Towards a method of assessing the veld condition of the Valley Bushveld in the eastern Cape. *J. Grassl. Soc. South. Afr.* **3(1):** 19–24.

Tainton N.M. 1981. (ed.). *Veld and pasture management in South Africa. Shuter & Shooter,* Pietermaritzburg.

Teague W.R. 1987. *Defoliation and browse production of Acacia karroo* Hayne in the eastern Cape, South Africa. Ph.D. thesis, Univ. Witwatersrand.

Teague W.R., Trollope W.S.W. & Aucamp A.J. 1981. Veld management in the semi-arid bush grass communities of the eastern Cape. *Proc. Grassl. Soc. sth. Afr.* **16:** 23–28.

Tidmarsh C.E.M. & Havenga C.M. 1955. The wheel-point method of survey and measurement of semi-open grasslands and karoo vegetation in South Africa. *Bot. Surv. S. Afr. Mem.* **29.** Govt. Printer, Pretoria.

Tueller P.T. & Blackburn W.H. 1974. Condition and trend of the big sagebrush/needlethread habitat type in Nevada. *J. Manage.* **27:** 36–40.

Van den Berg J.A. & Roux P.W. 1974. Handleiding vir die evaluasie van veld met behulp van 'n keurkaart. Unpub. report, Dept. Agric., Middleburg.

Vorster M. 1980. *Eienskappe wat 'n rol speel by veldevaluering in die Oostelike karroo.* M.Sc. Agric. thesis, Univ. O.F.S.

Vorster M. 1982. The development of the ecological index method for assessing veld condition in the karoo. *Proc. Grassl. Soc. sth. Afr.* **17:** 84–89.

Walker B.H. 1980. Stable production versus resilience: a grazing management conflict? *Proc. Grassl. Soc. sth. Afr.* **115:** 79–83.

Towards visual assessment of succulent valley bushveld

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Visual vegetation assessment was tested for repeatability and accuracy and compared with an objective survey technique for time and cost efficiency. Eighteen operators first inspected a range of sites where ecological status was known. Using these for reference, they then visually inspected and independently estimated the ecological status of 15 other sites. Single operators could not reliably visually assess ecological status. Repeatability was, however, obtained by using the mean from a group of operators' independently-derived estimates. In the worst case, fifteen randomly-chosen operators would be necessary in an assessment team to distinguish 10% differences in ecological status ($P \leq 0.05$). On average, however, only eight operators would be necessary for this degree of precision. A number of operators were found to be biased and they should be removed from assessment teams. Conservative relationships between precision and operator team size are provided for users of this technique who may require a precision other than 10%, or who are limited by the number and type of operators at their disposal. For farm planning and possibly even monitoring change on a farm or regional scale, the visual method is a viable and efficient replacement for current objective techniques.

Visuele bepaling van plantegroei toestand was vir herhaalbaarheid en akkuraatheid getoets, en met 'n objektiewe opname tegniek vergelyk vir tyd en koste doeltreffendheid. Agtien operateurs het eers 'n reeks persele besigtig waar die toestand bekend was. Met hierdie as verwysing, het hulle 15 ander persele besigtig en die ecologiese toestand onafhanklik beraam. 'n Operateur kon nie op sy eie 'n betroubare beraming van toestand maak nie. Herhaalbaarheid was, nietemin, behaal deur die gemiddelde waarde van 'n span se onafhanklike beramings te bereken. In die mees ongunstige geval word 15 operateurs benodig om 'n 10% verskil in toestand te bepaal ($P \leq 0.05$). In die algemeen, word net agt operateurs benodig vir hierdie vlak van herhaalbaarheid. 'n Getal operateurs was bevooroordeeld en dit is belangrik dat hulle van opname spanne verwyder moet word. Konserwatiewe verwantskappe tussen herhaalbaarheid en span grootte is vir gebruikers van hierdie tegniek, wie miskien 'n herhaalbaarheid ander as 10% vereis, of in getalle en tipe operateurs beperk is, verskaf. Vir plaas beplanning en miskien ook die monitering van veldtoestand op plaas of streek vlak, is hierdie visuele metode 'n lewensvatbare en doeltreffende vervanging van die huidige objektiewe tegnieke.

Additional index words: Accuracy, efficiency, range monitoring, repeatability, vegetation assessment, veld condition

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Introduction

Assessing the ecological status of the succulent valley bushveld (Stuart-Hill & Danckwerts 1988) with any of the current objective techniques (Stuart-Hill *et al.* 1986a; Stuart-Hill 1989; Stoltz & Hoffman 1989) is a tedious and time-consuming process (e.g. one site of 2 ha takes two operators approximately one day). It was proposed that, for farm planning and resource evaluation at least, structured visual estimates of ecological status could be used instead of tedious objective methods (Stuart-Hill *et al.* 1986b).

The objective of this study was to determine whether visual assessment of ecological status was a viable alternative technique for rapid veld evaluation.

Definition of ecological status

The technique for evaluating the ecological status of veld in the succulent valley bushveld (which is still in the process of being refined) attempts to position a sample site along an environmental gradient (Stuart-Hill 1989). The gradient which appears to be dominant within this vegetation is 'history of grazing/browsing intensity', although as one would expect, there are other gradients which affect the succulent valley bushveld (Stuart-Hill *et al.* 1986a). The technique scores sites which have hardly been used by herbivores on one end of the gradient while sites which have been heavily utilized are scored on the other end. Sites with a history of moderate herbivore usage are situated in between these two extremes. Dense succulent valley bushveld has high ecological status scores (i.e. 70–100%) while open bushveld has low ecological status scores (i.e. <20%).

It must be pointed out that the technique merely positions the sample site along a gradient and no assumption is made regarding the usefulness of this bush. It is up to the individual land operator to decide what score is 'optimum' for his particular set of objectives. For example, a game ranger in the Addo Elephant Park may want very dense bush as his 'optimum' because such bush has a high carrying capacity, and density is not a problem for the movement of elephants, i.e. he may aim for a score of 100%. A farmer who has very valuable stud goats which must each produce to their optimum (i.e. optimize production animal^{-1} at the expense of production ha^{-1} may select a score of say 70% as his 'best veld'. This would be in contrast with a cattle farmer who wants fewer trees and he may select, for example, a score of 35%.

Field procedure

The study was undertaken in the succulent variety of Acocks's (1953) valley bushveld in the Kirkwood district of the eastern Cape. Five *reference sites* were surveyed using the point-centred-quarter method and their ecological status was determined (Stuart-Hill 1989). These sites were chosen to represent a gradient from high to low status and had scores of 90, 45, 20, 0 and −10%. A further five sites were surveyed and the ecological statuses determined. The former sites were for training the operators and the latter, together with ten other (unsurveyed) sites, were for testing the surveyor's ability to visually assess ecological status (i.e. *test sites*). The field procedure comprised two phases.

1. Training phase

Eighteen operators with various biological training backgrounds were taken to the five reference sites. The operators were given the scores of each site and were then allowed approximately 10 minutes per site, during which time they walked through the vegetation while I explained to them why the site had a particular score. Emphasis was placed on the abundance of *Portulacaria afra*, bush density and volume as indicators of high ecological status and *Lycium oxycarpum* as the indicator of low ecological status. It was explained that the grass layer was to be ignored during the exercise and emphasized that ecological status was not necessarily positively correlated with agricultural usefulness and is thus independent of a manager's objectives (Stuart-Hill 1989).

A series of photographs of each reference site was available and the operators were encouraged to relate each photograph with the field appearance of the vegetation. These photographs were meant as an aid only and emphasis was placed on the field appearance of each site. All sites had recently experienced above-average rains and the shrubs were very lush. This was pointed out to the operators and they were warned not to be misled by the vegetation's current leafiness.

2. Evaluation phase

After inspecting all the reference sites and developing the scale of ecological status in their minds, the operators were driven through the fifteen 5-ha test sites on the back of two trucks. These camps were intentionally selected to represent the entire ecological status range and were divided into four categories to test various types of surveying procedure (Table 1).

Each operator was required to independently allocate and record scores for each camp using the relevant assessment procedure (Table 1). The operators were not allowed to discuss their score during the exercise. While the whole exercise was based on anonymity the operators were, however, asked to indicate their level of tertiary training in the botanical sciences and their current occupation. This was necessary to determine whether training and or occupation influenced the operators' ability to visually evaluate ecological status.

Table 1 Four procedures of visually assessing the vegetation and the number of sites surveyed with each method

Assessment procedure	Number of sites
Walk through the vegetation and assess	3
Drive past and assess	5
Observe vegetation from a long distance (*c*. 600 m)	4
Observe vegetation from a short distance (*c*. 100 m)	3

Once all the camps had been assessed a brief discussion (*c*. 5 minutes) was allowed before reassessing each site. During the latter 'run', the route was reversed, starting at the last and ending at the first site.

Data analysis

The terms 'repeatability' and 'precision' may be used interchangeably throughout this article and refer to the 'disagreement' between operators. They are quantified as either standard errors (*SE*) or least significant differences (*LSD*), the latter being used to identify real difference between ecological status scores (i.e. the difference in ecological status not due to variation between operators). 'Accuracy' is used to refer to the difference between the scores derived visually and those derived from objective vegetation surveys.

Ecological status can also be derived from the mean of the individual estimates made by a team of operators. In this case the size of the team will have a critical influence on the repeatability of the scores. In this study, the relationship between team size and repeatability was determined in three ways:

1. The site that had the poorest repeatability between operators was chosen to represent the worst situation, and the *LSD* ($P = 0.05$) was determined for increasing numbers of randomly-chosen operators;
2. average precision was quantified by determining the above relationship from the site whose precision was the closest to the mean of all sites (to illustrate the 'normal' situation); and
3. to be conservative, yet not unrealistic, the site whose precision was closest to the mean of the worst three sites was used to generate relationships between *LSD* and team size for four different probability levels.

The precision of the various assessment procedures (Table 1) was evaluated by analysis of variance (AOV) (unequal replications where each method represented a treatment). The overall improvement of precision in the repeat assessment was evaluated in the same AOV.

To examine the assessment ability of operators for all sites, all the data were subjected to principal components analysis (PCA) and cluster analysis, where operators were samples. Groups of operators were identified from the cluster analysis and their accuracy was evaluated. This led to a basis for operator rejection as a number appeared to be biased (i.e. their scores consistently differed from the scores obtained from the objective surveys of the test sites). The data were then re-analysed for the remaining operators in an attempt to provide improved relationships between team size and error. The latter could be used when qualified operators (in contrast to randomly-selected operators) visually estimated ecological status.

Results and Discussion

1. Differences in precision of the assessment procedures

There were no significant differences ($P \leq 0.05$) in the precision of the four assessment procedures described in Table 1. For precision then, it probably does not matter whether the operators walk through the site, drive past it, or study it from a distance when estimating ecological status scores.

2. Improvement in precision during the evaluation phase

There was no consistent improvement in precision when the same sites were assessed for the second time. Precision did, however, change in a remarkable pattern (Figure 1).

All the sites assessed at the beginning and the end of the exercise showed relatively large improvements in precision (13–40%). The AOV did not identify a significant difference because this improvement was negated by the worsening precision in the middle range of camps. I can not give a reason for this phenomenon. Perhaps it was because of an increase in 'agreement' between inexperienced and experienced operators after the former had seen the entire ecological status range (the first and last sites generally also represented either ends of the ecological status gradient).

Although no improvement in precision between the first and repeat assessment was detected with the AOV, it is evident that precision initially decreased and then 'stabilized' as the assessment exercise progressed (Figure 2). It may be wise then to give the operators some practice before being put into an assessment team and it appears that at least three 'test' sites should be assessed before operators are used in the field (Figure 2).

3. Relationship between ecological status and precision

The relationship between precision and ecological status was evaluated during the second assessment to avoid confounding with the change in precision over time (i.e. once precision had stabilized).

A scatter plot between precision and ecological status revealed no relationship at all. It is apparent therefore, that the technique will be equally sensitive for all ecological statuses (i.e. as a group, the operators were able to assess veld with a high or low ecological status with equal precision).

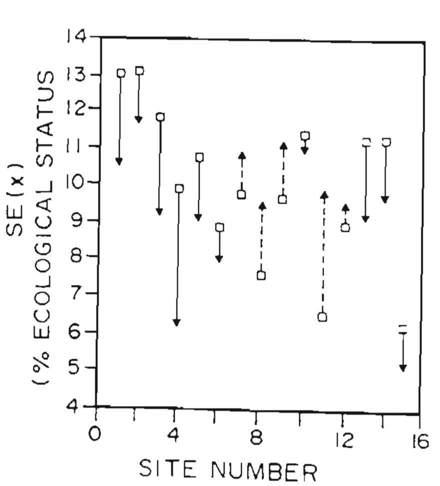

Figure 1 Influence of a repeat assessment on the error of estimating ecological status on all the sites: error during the first assessment (□); and reduction (↓) and increase in error (↑) with the repeat survey.

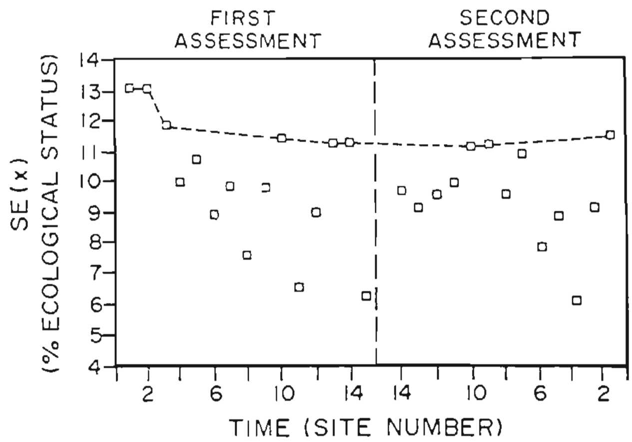

Figure 2 The change in repeatability (error) obtained at each site in relation to the order in which they were assessed. The broken line represents the 'upper-error' boundary over the assessment period.

4. Relationship between precision and team size

In the worst case the number of randomly-selected operators required to obtain a specified *LSD* (with 95% confidence) is illustrated in Figure 3. This figure can also be used to determine the difference in ecological status which can be proved to be significant ($P \leq 0.05$) given a fixed number of

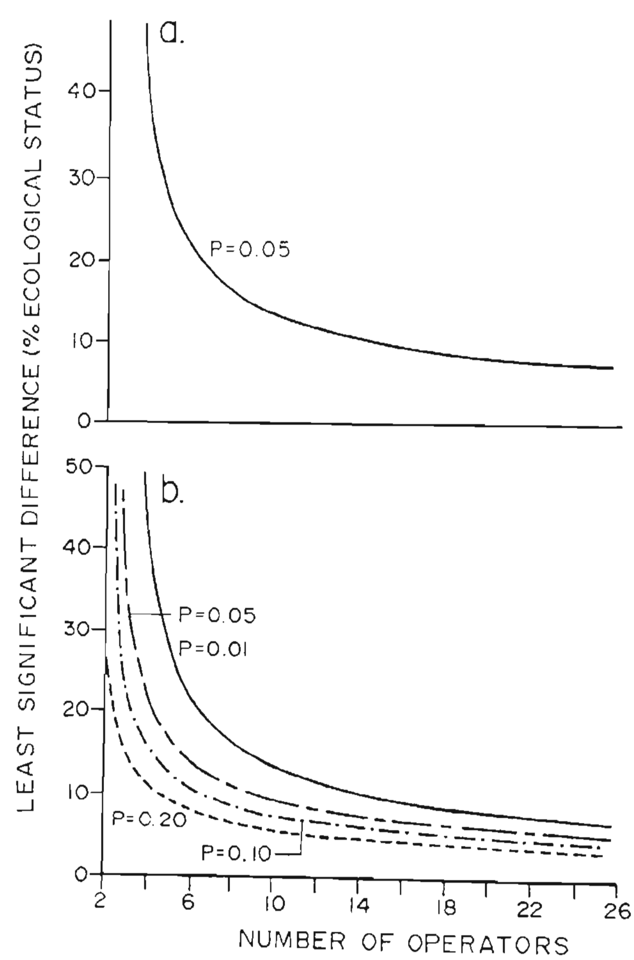

Figure 3 The improvement in precision of assessing ecological status with increasing numbers of arbitrarily-selected operators in a team: on the site where repeatability was worst (a), and on a site with average repeatability (b).

randomly-selected operators. For example, 15 operators would be required, in an assessment team, to distinguish 10% differences in ecological status ($P \leq 0.05$), or, given 10 operators in a team, 13% differences can be distinguished ($P \leq 0.05$).

As this was derived from the site with the worst precision, and no operators have been excluded on the basis of their assessment ability, the situation described in Figure 3 is extremely conservative. If it can be accepted that the precision on the 15 sites represents that which would occur in the veld type generally, the relationship between team size and precision, derived from the site with its precision closest to the mean of all sites, can be used (Figure 3). Notice how now only nine operators are required to distinguish 10% ($P \leq 0.05$) differences in ecological status (Figure 3).

Even though it has been demonstrated that repeatability is possible with visual veld assessment, it would be dangerous to leave the analysis at this point as the operators may be yielding a biased result. A marksman who has good grouping but misses the bull is repeatable but inaccurate, he is biased. Uncorrected, the marksman is worthless. Similarly a repeatable but biased estimation of ecological status is worth little.

5. Bias/accuracy

The cluster analysis identified a main group of operators while the rest of the assessments were ungrouped (i.e. *c.* equally dissimilar at the chosen level of aggregation). All the assessments made by pasture scientists were in this main group. The first two axes produced by the PCA did not reveal intelligible variations in the data. The third PCA axis, however, appeared to represent a separation with respect to the bias with which operators assess veld with high ecological status (Figure 4).

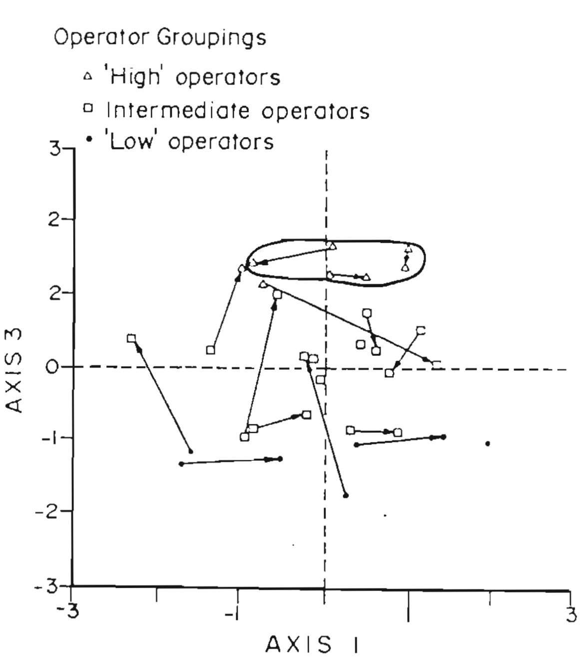

Figure 4 Scatter of operators along PCA axes one and three. Arrows indicate change in position from the first assessment to the second assessment. The operators circled are pasture scientists and symbols without arrows represent operators who did not participate in the repeat survey.

Table 2 The average score per site for each of the operator groups (n is the number of estimates)

Site number	All ('Random') operators n=34	Pasture scientists n=5	'High' operators n=8	'Low' operators n=7	'Qualified' operators n=36
1	57	62	65	53	57
2	66	80	82	50	70
3	75	82	84	64	79
4	47	57	54	41	49
5	62	75	67	56	63
6	73	85	82	68	75
7	42	47	41	43	41
8	32	42	33	31	33
9	51	57	55	49	52
10	31	37	34	31	32
11	24	27	23	25	23
12	36	32	35	39	35
13	16	20	18	16	15
14	14	12	13	16	13
15	−14	−13	−14	−18	−13

To test this interpretation, the operators whose assessments were at the extreme ends of axis 3 (Figure 4) were removed from the main data matrix, and the mean ecological status for each site was recalculated for each of these 'high' and 'low' operator groups (Table 2).

For most of the test sites, there was no true measure of ecological status with which to evaluate bias (accuracy) and the mean estimates of the pasture scientists (n = 5) were used as an estimate of the 'true' ecological status (Table 2). This was assumed on the basis that the pasture scientists understood both the concept of ecological status (Stuart-Hill 1989) and how it is derived (bias could arise where the assessor evaluates veld in terms of his preconceived idea of usefulness — remember that ecological status is independent of operator objectives). To test this assumption, the mean ecological status derived from the pasture scientists and the rest of the operators was compared with the 'true' values determined from the five test sites which were surveyed (Stuart-Hill 1989). As the pasture scientists were less biased than the rest of the operators (Table 3), it is probably reasonable to use the mean of their estimates as the 'true' ecological status. The reader should bear in mind that all further discussions relating to accuracy rest on the assumption that the pasture scientists were not biased.

The estimates of ecological status by the group at the positive end of axis 3 ('high' operators) differed very little from these 'true' ecological statuses: the largest difference being 9% (Figure 5a).

Consequently, the 'high' operators had little bias. The estimates from the operators at the negative end of axis 3, however, deviated greatly from the 'true' values (Figure 5b). These 'low' operators underscored veld which had an ecological status of greater than *c.* 40%, to the extent that the highest mean score that they obtained was a mere 68%. By contrast, the pasture scientists and other groups obtained highest mean scores of 85% and 84%, respectively. The

Table 3 Testing the accuracy of pasture scientists (n=3) against all other operators (n=13) in their ability to visually assess ecological status (ES)

Site number	Objectively derived ES	[1]Mean visual estimates of ES: Pasture scientists (n=3)	Other operators (n=14)
2	79	80 (1)	68 (−11)
5	79	75 (−4)	60 (−19)
7	54	47 (−7)	41 (−13)
12	20	32 (12)	39 (19)
15	0	−13 (−13)	−13 (−13)

[1]Values in brackets indicate bias

influence of these 'low' operators was significant in that when they were included with all operators they reduced the highest (mean) score to 75%. This has serious implications as their inclusion in assessment teams implies that visual veld evaluation will be inaccurate at high ecological status.

A comparison of the operators' qualifications and occupations between the 'high' and 'low' groups revealed some interesting (and perhaps meaningful) trends. The 'low' group consisted of two animal scientists, one nature conservation officer, one extension officer and an operator who did not specify either his formal botanical training or occupation. The 'high' group consisted of all the pasture scientists, one extension officer and two operators who did not record either occupation or training. During discussions with some of the operators from the 'low' group (after the exercise), it became apparent that a number of individuals were still attempting to score 'usefulness' instead of ecological status, despite the pains taken during the training phase to point out the distinction. It is interesting to note the improvement in accuracy of a number of the operators during the second assessment (Figure 4). Possibly these operators, once having seen the range in ecological status, were happy to give sites with higher status larger scores.

With the foregoing in mind, all the 'low' operators were rejected from the data set and the remaining operators were considered to have 'qualified' as visual bushveld operators. The relationship between team size (of qualified operators) and precision (*LSD*) for four probabilities was developed from the mean of the three sites with the worst precision (Figure 6).

These relationships (Figure 6) are conservative yet realistic and are useful for determining either:

a. the precision (*LSD*) obtainable at four significance levels, given a number of operators; or
b. the number of operators required to visually assess vegetation given a level of precision and significance.

These results show that meaningful visual assessment of bushveld is certainly possible. Although a single operator cannot be used to visually assess bushveld to within a reasonable degree of precision (Figures 4, 5 & 8), surprisingly small *LSDs* with good probabilities can be achieved by using the mean estimate from even relatively small assessor teams.

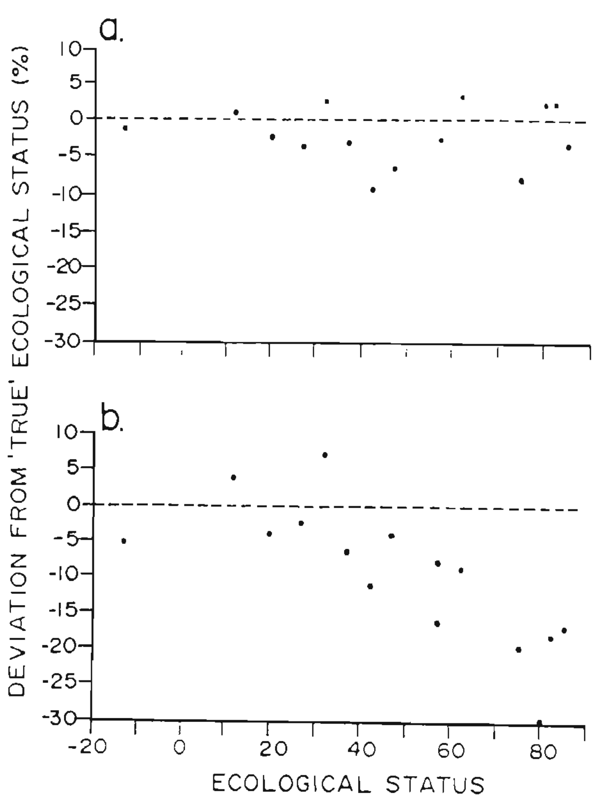

Figure 5 The deviation in mean estimates (at each site) from the 'true' ecological status (determined by pasture scientists) for each of the 'high' (a) and 'low' (b) groups of operators.

6. Efficiency

A simple measure of efficiency of a technique is the time it takes to achieve a specified level of repeatability and accuracy. It is estimated that it will take *c.* 36 man-minutes to visually assess each site (*LSD* = 10%; $P \leq 0.05$). The objective survey technique, measured to the same confidence of precision, will take *c.* two man-days. The visual

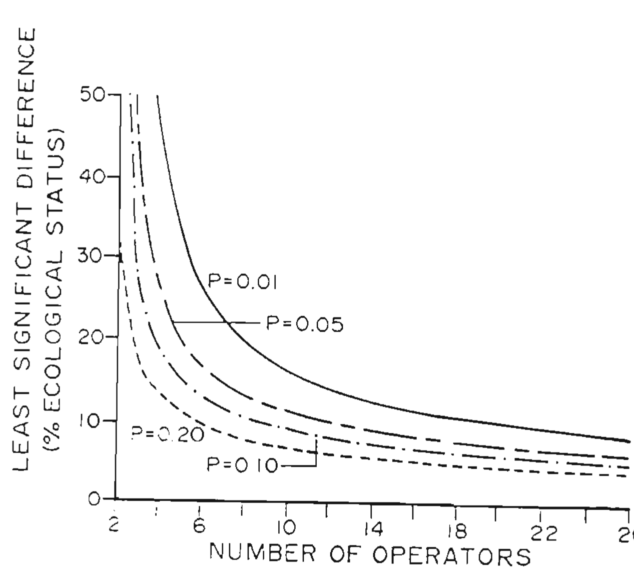

Figure 6 The relationship between repeatability and increasing numbers of 'qualified' operators for four probability levels using the mean precision of the worst three sites.

Table 4 The approximate costs of surveying and analysing one site with an objective technique so that *LSD* in ecological status of 10% can be proved significant (*P*=0.05)

	R
1. Technician salary[1] (2 man-days @R90 day^{-1})	180
2. Data typist[1] (½ day @R56 day^{-1})	28
3. Computer analysis	5
4. Professional salary[1] (⅙ day @R150 day^{-1})	25
Total	238

[1]Obtained from Department of Agriculture where salaries were extracted from the middle of the appropriate scales. The rates per *working day* were calculated by dividing the annual salary by 231 — the number of working days an average employee would work in a year

technique is, therefore, considerably more time-efficient than the objective survey technique.

Efficiency may, however, also be measured in terms of cost and this could include operator salaries, transport, accommodation, analysis charges and equipment costs. The approximate costs of analysing one site using the survey approach are presented in Table 4.

To achieve the same level of precision (*LSD* = 10%; $P \leq 0.05$) using the visual technique, 12 operators would be required. They would, however, have to be trained at sites already surveyed and a portion of the cost of training, and surveying these reference sites, must be written off as a cost to each site assessed. Naturally, the amount costed to each site will depend on how many sites the trained operator will eventually assess before re-surveying becomes necessary. The assumptions used to determine the cost of surveying the reference sites are presented in Table 5.

It has been estimated that a 10% change in ecological status represents *c*. 9% change in long-term grazing capacity (Stuart-Hill 1989). A nomogram is presented which links team size with the average differences in long-term grazing capacity which can be distinguished (Figure 7).

A particular land manager can select how many operators are required to show changes in ecological status which are meaningful for his set of objectives. Added to this nomogram are estimates of costs for two groups of operators who

Table 5 Assumptions of the costs of surveying and analysing four reference sites and preparing the assessment aids (e.g. photographs of sites)

	R
1. Technician salary (8 days @R90 day^{-1})	720
2. S&T (8 days @R42 day^{-1})	336
3. Transport (700 km @44c km^{-1})	308
4. Photographs, albums etc.	34
5. Data typist salary (2 days @R56 day^{-1})	112
6. Computer analysis	15
7. Professional salary (½ day @R150 day^{-1})	75
Total	1 600

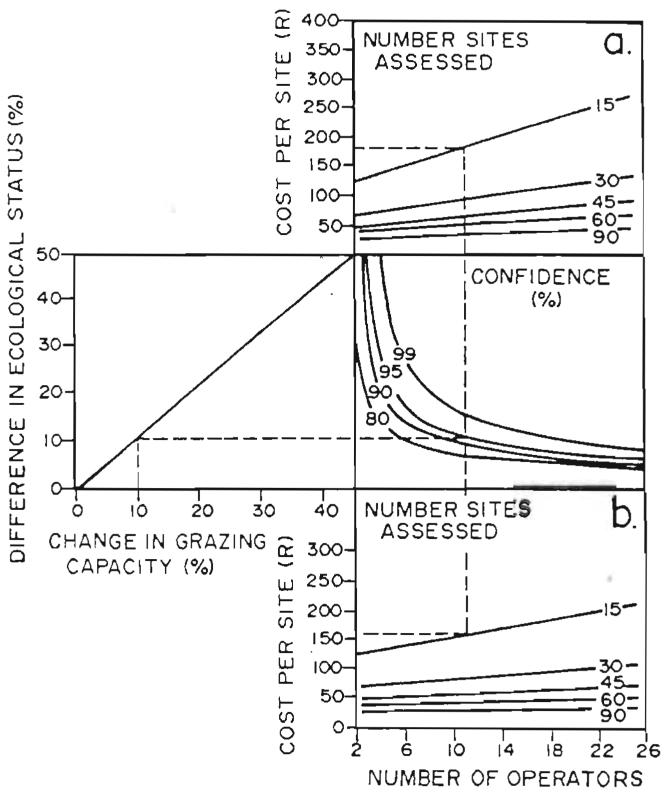

Figure 7 A nomogram to determine the inter-relationships between cost of surveying and the differences in productivity potential ('grazing capacity') which can be identified using structured visual veld assessment. For qualified operators who (a) earn *c*. R100 day^{-1}; and (b) earn *c*. R50 day^{-1}.

receive different pay packages. The relationships between costs and number of operators were derived from the assumptions outlined in Table 6. The nomogram allows the basic cost per site (excluding transport to and from the survey area and accommodation) to be linked to the differences in productivity which can on average be shown to be significant at various levels of probability.

The most comprehensive comparison of efficiency between the objective and visual techniques is summarized in Figure 8.

Table 6 The assumptions used in determining the cost of visually assessing a site with various numbers of operators as presented in the nomograph (Figure 7)

Cost per site = Ta[1] + Tr + Sa[2]

where: Ta = portion of costs of *Assessing* the reference sites and *Training* the operators;

Tr = portion of costs of *Transport* between reference and assessed sites (100 km @44c km^{-1} (car: 4 passengers) or @54c km^{-1} (truck: 8 passengers); and

Sa = portion of *Salary* of operators

[1]Determined for various numbers of sites surveyed before retraining and reassessment of the reference sites

[2]Determined for various pay categories of operators based on salary scales provided by the Department of Agriculture

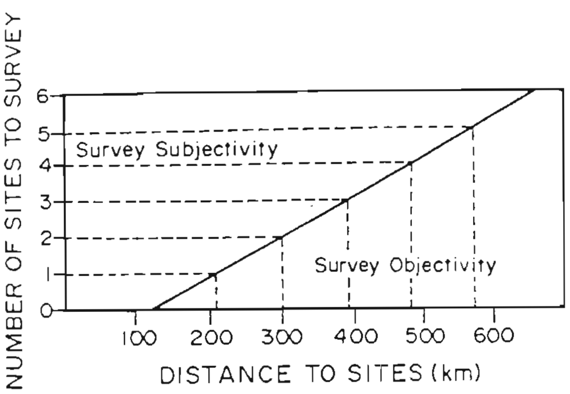

Figure 8 The influence of distance to the sites and the number of sites required to be assessed on the choice between the objective and visual methods in order to show differences of 10% in ecological status ($P \leq 0.05$).

Conclusion

Visual veld assessment was found to be accurate and repeatable, and considerably more time and cost efficient than objective methods. The decision of whether to select the objective or visual technique rests on the number of sites to be surveyed and the distance which has to be travelled to get to the survey area. The objective technique has the advantage of using little transport (i.e. four operators per car). The visual method requires much transport (e.g. three cars per assessment team of 12) but has the advantage of being able to assess many sites in a day and this saves on accommodation costs.

Limitations of this visual method are that: 1. the reference sites have to be exhaustively surveyed and this has to be repeated on a regular basis as they change with time; 2. it is absolutely vital that the assessors should, from time to time, recorrelate their conceptual scale of ecological status with a range of sites where ecological status has recently been objectively measured; 3. transporting and accommodating large teams of surveyors is relatively expensive; and 4. it is only really useful for estimating univariate attributes of the vegetation (e.g. ecological status, cover or density).

The main benefits of an objective technique, which are not readily quantifiable in terms of efficiency, are: 1. it yields multivariate data (e.g. species composition, browseable volume, plant density); 2. it will not be adversely influenced by biased operators; and 3. it is less likely to be influenced by events such as very high rainfall which may cause operators to overestimate ecological status.

The final decision of which technique to use naturally depends on the objectives of assessment but it is evident that, for farm planning and possibly even monitoring change on a farm or regional scale, the visual method is a viable replacement for current objective techniques.

References

Acocks J.P.H. 1953. Veld Types of South Africa. *Mem. Bot. Surv. S. Afr.* **28.**

Stoltz C.W. & Hoffman M.T. 1989. Can the ecological index method be used to assess condition of valley bushveld? *Dohne Agric.* 11(1): 23–25.

Stuart-Hill G.C. 1989. Assessing the condition of valley bushveld. In: Danckwerts J.E. & Teague W.R. (eds). *Veld management in the eastern Cape.* Govt. Printer, Pretoria, pp. 103–108.

Stuart-Hill G.C., Aucamp A.J., Le Roux C.J.C. & Teague W.R. 1986a. Towards a method of assessing the veld condition of the valley bushveld in the eastern Cape. *J. Grassl. Soc. South. Afr.* 3: 19–24.

Stuart-Hill G.C., Danckwerts J.E. & King P.G. 1986b. A veld condition map: a workable alternative to the grazing capacity map in its present form. Dohne Research Station, Stutterheim. Unpublished report.

Stuart-Hill G.C. & Danckwerts J.E. 1988. Influence of domestic and wild animals on the future of succulent valley bushveld. *Pelea* 7: 45–56.

TOOL 3

A TECHNIQUE FOR MONITORING VEGETATION CHANGE

[P 3.1] Repeatability of bushveld assessment: informal analysis

[P 3.2] Evaluation of the point-centred-quarter method of sampling kaffrarian succulent thicket

[P 3.3] Evaluation of a belt transect method of sampling kaffrarian succulent thicket

[P 3.4] Repeatability of the Domin-Krajina cover-abundance scale in kaffrarian succulent thicket

[P 3.5.1] Evaluation of the 'Bubble' technique for sampling kaffrarian succulent thicket: 1. Technique development

[P 3.5.2] Evaluation of the 'Bubble' technique for sampling kaffrarian succulent thicket: 2. Evaluation of frequency measurements

[P 3.5.3] Evaluation of the 'Bubble' technique for sampling kaffrarian succulent thicket: 3. Evaluation of cover based measurements

[P 3.6] Vegetation monitoring in South Africa: is a paradigm shift required?

[TOOL 3]

A TECHNIQUE FOR MONITORING VEGETATION CHANGE

ORIGINAL BRIEF

The technique should have high repeatability and efficiency, and be acceptable to land managers. I refer to this as veld or vegetation monitoring.

RESULT

Providing this tool was problematical and hinged on evaluating the repeatability and efficiency of the survey technique. The first attempt was informal (unpublished report: **Repeatability of bushveld assessment: informal analysis [P 3.1]**) and showed that the survey method initially used (the point-centred-quarter method) was not sufficiently sensitive for farm scale monitoring.

This result led to the initiation of a series of experiments to test the repeatability and efficiency of a number of traditional botanical survey methods. The approach was neutral and conventional; i.e. establishing relationships between repeatability (error) and sampling effort. See the following unpublished papers:

- i) **Evaluation of the point-centred-quarter method of sampling kaffrarian succulent thicket [P 3.2]**;
- ii) **Evaluation of a belt transect method of sampling kaffrarian succulent thicket [P 3.3]**;
- iii) **Repeatability of the Domin-Krajina cover-abundance scale in kaffrarian succulent thicket [P 3.4]**; and
- iv) **The 'Bubble' technique for sampling kaffrarian succulent thicket [P 3.5] (parts 1, 2 & 3).**

Essentially, the philosophy was to provide the above relationships so that, by defining apriori a level of precision suitable for their requirements, users could then determine what sampling effort they would need. In this paradigm, the same sampling technique is used by all users but at different sampling intensities depending on the required precision. This approach had its roots in grassveld monitoring and led to a host of technique studies (Mentis 1984; Walker 1987; Hardy 1986). An implicit assumption with this philosophy, is that land managers require (for adaptive management) a less sensitive vegetation monitoring technique than researchers (Hardy & Walker 1991). This I challenged in a paper entitled: **Vegetation monitoring for adaptive management: is a paradigm shift required? [P 3.6]**, where I argued that the converse is true. This is because land managers need to be pro-active and adapt their management before irreparable damage occurs. Researchers, on the other hand, merely want to quantify the response to some applied treatment. People have assumed that because managers seek an 'easy' method, it follows that they are happy with a less sensitive technique.

All of the conventional botanical methods tested in this study were found to be too tedious and/or insensitive for pro-active farm scale monitoring. Of the methods tested, the 'bubble method' (using frequency measures) was the most useful and could be used for research based monitoring. The reason for the failure of all these classical methods is probably that their very nature depends on the death (or severe reduction in size) of individual plants. To a land user, this is not sufficiently sensitive as he needs to take appropriate action <u>before</u> losing valuable plants.

The failure of this research effort to produce Tool 3 prompted a paradigm shift and the emphasis has turned to monitoring attributes of individual plants which give early warning of their imminent demise[1]. To do this, however, requires a detailed understanding of the growth and reaction to defoliation of key plant species. Future research should concentrate on the demography of this vegetation type and, in particular, on understanding how individual plants are killed by defoliation so that critical attributes of the plants can be identified for monitoring.

It is important to note that if this 'new paradigm' is also unable to produce Tool 3 (a monitoring technique for proactive adaptive management), then the implication is that adaptive management may not be tenable. If this fails, what scientific approach to vegetation management is possible? The consequence could be that the vegetation cannot be managed scientifically or at least, cannot be managed in a pro-active manner.

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[1] An example is perhaps the 'skirting' phenomenon of <u>P. afra</u> (reported in the published paper entitled: "<u>Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa</u>") and is paralleled by the aerial tillering phenomenon observed in <u>Themeda triandra</u> (Tainton 1981).

INTERNAL REPORT

REPEATABILITY OF BUSHVELD ASSESSMENT: INFORMAL ANALYSIS

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(March 1987)

The repeatability of the current technique of assessing various parameters in Valley Bushveld appears to be in doubt. Four sites previously surveyed were re-surveyed. Tree density, total volume, uncorrected browseable volume and corrected browseable volume were estimated for each of the surveys and the results are presented in Table 1.

INSERT TABLE 1.

It is evident that the repeatability of measuring these parameters is extremely poor.

The imprecision of the data obtained by the current survey is also reflected in the bushveld condition scores (table 2).

INSERT TABLE 2.

It must be stressed, that these poor results do not cast doubt on the procedure for determining condition score (Stuart-Hill *et al.* 1986). Rather, the poor repeatability of the scores is as a result of the poor input (survey) data.

RECOMMENDATIONS

1) The repeatability of each survey parameter needs to be tested. It is probably best to determine relationships between repeatability and the number of sample points in order to evaluate how much extra sampling effort will be needed to obtain an acceptable degree of repeatability. Note, that it is most likely that different numbers of samples may be required for each parameter.

2) Stop all further surveys especially where the objective is to monitor change, until we have determined how many points are required. It *may* not be necessary to stop those surveys where the objective is merely to determine what the condition of the vegetation is because the technique was able to distinguish between the different vegetation conditions (see Tables 1 & 2 and note the relatively consistent trends *between camps*).

SUGGESTED RESEARCH PROCEDURE

Take one 'fairly typical' camp and conduct very intensive surveys in this camp (eg > 1 000 points). This will take approx. 20 man days. Run computer program "NUMOBS" on the various parameters and this will yield relationships between sampling effort (number of points) and repeatability (see the approach suggested by Mentis 1984). Information such as that shown below (an example for illustrative purposes only!) can then be extracted from these curves.

If you want 10% precision then you:

- require 150 points for bush density;
- require 250 points for species composition;
- require 300 points for bush volume; and
- require 350 points for monitor change in volume of P. afra.

REFERENCES

Mentis M.T. 1984. Monitoring in South African grasslands. S.A. Nat. Sci. Prog. Report, No. 91. CSIR, Pretoria.

Stuart-Hill G.C. Aucamp A.J. Le Roux C.J.G. & Teague W.R. 1986. Towards a method of assessing the veld condition of the Valley Bushveld in the Eastern Cape. J. Grassl. Soc. South. Afr. 3(1): 19-24.

Table 1. The repeatability of various parameters surveyed with 120 points at four sites in the Valley Bushveld

	Sites	1st survey	2nd survey	Increase (%)
Bush density (plants/ha)	1	8449	11541	36
	2	6641	7231	9
	3	4559	6007	32
	4	3100	3308	7
Total volume (m^3/ha)	1	8150	17792	118
	2	7339	11305	54
	3	4677	6484	39
	4	3148	1841	-42
Browse volume (m^3/ha)	1	6870	12626	84
	2	5086	8486	67
	3	3320	4961	49
	4	2430	1275	-47
Corrected Browse volume (m^3/ha)	1	2814	3632	29
	2	1868	2555	37
	3	940	1547	39
	4	816	388	-52

Table 2. The repeatability of Valley Bushveld scores of four sites in the Uitenhage district from survey data where 120 points were taken per camp.

Sites	1st survey	2nd survey	Increase (%)
1	81	110	35
2	61	71	16
3	40	55	38
4	28	27	4

EVALUATION OF THE POINT-CENTRED-QUARTER METHOD OF SAMPLING KAFFRARIAN SUCCULENT THICKET

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ABSTRACT

The objective was to evaluate the efficiency and repeatability of the point-centred-quarter method.

The parameter which was most efficiently sampled was species composition (relative density), with 90% replicate similarity being achieved with 100 point-centred-quarters. However, this technique cannot be recommended, even for research purposes, because: (i) the technique is extremely time consuming (i.e. it takes c. 14.2 man hours to record 100 samples); (ii) it is difficult to identify individual plants because of the multi-stemmed nature of the vegetation; and (iii) there are mathematical constraints to determining density from distance based methods.

INTRODUCTION

After having rather blindly used a derivative of a point-centred-quarter (PCQ) method (Cottam & Curtis 1965) in an investigation to develop a method of assessing the vegetation (Stuart-Hill et at 1986), I turned my attention to evaluating the survey technique itself. The first step was a crude informal approach whereby some of the sites originally surveyed were simply resurveyed (Stuart-Hill 1987). The results showed that while the technique was able to distinguish differences between the sample sites, the values for each of the survey parameters varied greatly.

The objective of this study was to briefly evaluate the use of the PCQ method in Kaffrarian Succulent Thicket (Cowling 1984) otherwise known as Valley Bushveld, southern variation (Acocks 1975). The focus of the study was to establish relationships between repeatability (error) and increasing sampling intensity for various parameters of the vegetation. Most of these parameters were univariate (eg number of species encountered, average canopy height, total shrub volume, etc) while one,

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species composition (i.e. relative density), was multivariate. It was possible to obtain more than one measure of species composition (e.g. relative volume), but for simplicity this was not pursued in this study. It follows that this investigation is not comprehensive and it may suffer from this shortcoming.

PROCEDURE

The approach was to select a site and saturate it with sampling points, far in excess of that which would normally be practicable. These data then served as a data bank from which various sized samples were drawn and analysed.

Site

A 2ha site was located in the Andries Vosloo Kudu Reserve approximately 2km from the Fish River. The site was selected with the following prerequisites in mind. It had to:

i) be representative of Kaffrarian Succulent Thicket;
ii) be in moderate condition (moderately dense) so that results could be extrapolated to other sites where the condition was 'better' or 'worse' - it was decided not to repeat the test at various veld conditions because of a lack of manpower;
iii) have adequate species diversity;
iv) be typically heterogeneous with regard to 'bush-clumping'; and
v) be on a moderate slope so that the operators would be under 'normal' stress.

The site was 100 x 200m and situated with its longest edge adjacent to a road (for easy orientation while surveying) and permanently marked.

Pre-survey training

The operators were a mixture of experienced and inexperienced personnel, but all had a relatively high level of academic training (minimum of a diploma). All operators had moderate species identification abilities but it was necessary to group together certain species as these were difficult to distinguish in the field.

The pre-survey training was brief (15 minutes) as the intention was to rigorously test the technique. The philosophy was to provide test results that would be applicable to persons wanting to use the technique but who would have no more information than that obtained from reading the technique description or having a telephone conversation.

The following points were emphasised during training.

i) How to distinguishing a single multi-stemmed plant from a group of closely growing single stemmed plants.

ii) The distance from the centre of the cross was measured to the centre of nearest the plant, not the nearest rooted portion.
iii) The measurements describing the canopy were the average measurements and isolated twigs were treated as outliers.
iv) The twig density estimate was independent of the leafiness of the shrub (a shrub with no leaves could potentially score 10 for twig density).
v) The leaf density estimate was independent of the size of the plant or the twig density of its canopy. Thus a plant could potentially score 10 for leaf density even if it was very small or had a very sparse twig density.
vi) It was, stressed that the entire exercise was a test of the technique and not a test of individuals. Consequently the test was conducted anonymously and operators were encouraged to proceed with the speed and care with which they would survey a site in practice.
vii) Herbaceous plants were to be excluded.
viii Operators were told to walk in a straight line even if this meant forcing their way through shrub clumps.
ix) The points were to be placed 10m apart regardless of whether this was under or on top of a shrub.
v) Unknown species were to be recorded as such, given a unique code and a sample taken for subsequent identification.
vi) Woody seedlings less than 10cm in height were excluded.

Survey procedure

The assessors were divided into 5 operator pairs each having one experienced and one inexperienced assessor. In total 560 sample points (four readings at each point) were taken in a stratified random manner. It took a total of eight hours to finish the survey and this included a number of short breaks. The individuals in each operator pair took turns measuring and recording, and these changes were made on an informal basis.

In each of the four quarters at every point, the following data parameters were recorded:
i) the nearest shrub species greater than 10cm tall;
ii) the distance to the centre of the nearest bush;
iii) the height of the top of the canopy;
iv) the height of the lowest part of the canopy;
v) the radius of the canopy;
vi) a subjective estimate of the density of living twigs in the canopy below 1,5m; and
vii) a subjective estimate of the leafiness of a representative twig taken from the canopy below 1,5m.

STATISTICAL ANALYSIS

A technique for monitoring vegetation change should be robust enough to withstand error due to operator differences. Indeed it is regarded as irrelevant for long-term monitoring techniques as operators will inevitably be replaced over the years. Consequently, repeatability within operators was not quantified but rather included into the error variance. I suggest that this should not be seen as a limitation to the testing of this technique, as it results in a stricter test because error due to operators' is incorporated into the results.

Number of species

The species codes in the raw data file were randomly sorted, following which, a second computer program determined the relationship between the number of observations and number of species encountered. This was repeated 15 times for each sample size and the mean plotted to illustrate the effectiveness of increased sampling in determining species richness.

Parameters describing canopy structure

These measures of the shrub community included: average canopy height; average lower canopy height; average shrub radius; total canopy volume; and browseable canopy volume (see definitions in Stuart-Hill et al. 1986).

The relationship between sampling repeatability and sampling effort (number of points) was determined by pooling all the data and calculating the mean and population SE(x). From the latter, the SE(mean) was determined for each sample size and plotted against increasing sampling effort. This procedure was repeated for each parameter.

Index of plant density

The average distance (d) from the point to the centre of the nearest plant was converted to density (Den) using the formula (Cottam & Curtis 1965):

$$Den = 10000/d^2 \quad [plants/ha]$$

where d is in m.

It follows that distance is an index of plant density and its repeatability was determined in the same manner as that for the parameters describing canopy structure.

Species composition (relative density)

All the data were pooled and from this 'artificial' parent population (of 560 point centred quarters), 15 random samples of a particular sample size were drawn. Species composition for each sample was determined and a similarity matrix between samples constructed. The mean similarity was then determined from the off-diagonal terms in the matrix along with the SE(mean) and this plotted against the particular sample size. This was repeated for samples of different sizes (see Hardy & Walker 1991). A relationship reflecting the similarity in species composition from replicate samples of increasing sampling effort was ultimately constructed.

It will be noted that the relationship was not constructed beyond 400 PCQ's as the risk of duplicate sampling became excessive, especially if the 'parent' population did not accurately represent the variation in the true population.

RESULTS

Number of species

The first 100 placements of the PCQ apparatus yielded 80% (24 species) of the 30 species encountered during the study (Figure 1). In the next 200 points, another four species were found (i.e. 93%) and thereafter extra species were encountered at an extremely slow rate.

INSERT FIGURE 1

This method of determining species richness is highly inefficient and cannot be recommended. It does, however, illustrate that the improvement in measuring number of species beyond 100 points is not worthy of the extra effort.

Parameters describing canopy structure

A very rapid decline in error was obtained after only 50 PCQ's but significant improvements in error were still being achieved with sampling in excess of 200 to 250 PCQ's (Figure 2).

INSERT FIGURE 2

The sampling effort required for even 200 points, however, is extremely high (c. 28,4 operator hours).

Distance : the index of plant density

As with the other univariate parameters mean distance was most efficiently sampled at approximately 225 point centred quarters (Figure 3).

INSERT FIGURE 3

Species composition (relative density)

Relatively good replicate similarity (85%) was obtained after only 50 point centred quarters but this improved even more up to about 200 points, whereafter further sampling resulted in a slow linear improvement in repeatability (Figure 4).

INSERT FIGURE 4

DISCUSSION AND CONCLUSION

The PCQ method, while being capable of producing relatively repeatable results, is highly inefficient. It's best attribute is determining species composition and it's worst is determining species richness.

Determining shrub density may appear to be relatively repeatable but other workers warn one off distanced based measures of density (Lamacraft, Friedel & Chewings 1983) because they tend to be biased, especially in vegetation which is not randomly distributed. From this study, two additional problems with the distance based measure were identified. These were the difficulty of identifying individual plants because of their multi-stemmed growth habitat; and that, because of the shape of the relationship between distance and density, the distance based method of detecting plant density is less sensitive at high plant densities than at low plant densities.

The PCQ method appears to have little practicable value in adaptive veld management and even for research purposes, its inefficiency is such that it cannot be recommended for sampling Kaffrarian Succulent Thicket.

ACKNOWLEDGEMENTS

I am extremely grateful to the Department of Agriculture for financial support, Pete Burdett for his friendly co-operation in allowing us to use the Andries Vosloo Kudu Reserve and most of all, to the following people who were the operators: D. Deckker, C. De Ridder, L. Du Toit, O. Grobler, H. Lourens, H. Oosthuizen, B. Ras, C. Scheltema and M. Swart.

REFERENCES

Cottam G. & Curtis J.T. 1956. The use of distance measures in phytosociological sampling. Ecology. 37: 451-460.

Hardy M.B. & Walker R.S. 1991. Determining sample size for assessing species composition in grassland. J. Grassl. Soc. South. Afr. 8(2): 70-73.

Lamacraft R.R., Friedel M.H. & Chewings V.H. 1983. Comparisons of distance based density estimates for some arid rangeland vegetation. Aust. J. Ecol. 8: 181-187.

Stuart-Hill G.C. Aucamp A.J. Le Roux C.J.G. & Teague W.R. 1986. Towards a method of assessing the veld condition of the Valley Bushveld in the Eastern Cape. J. Grassl. Soc. South. Afr. 3(1): 19-24.

Stuart-Hill G.C. 1987. Repeatability of bushveld assessment: informal analysis. Unpubl. Report. Dohne Research Station, Stutterheim.

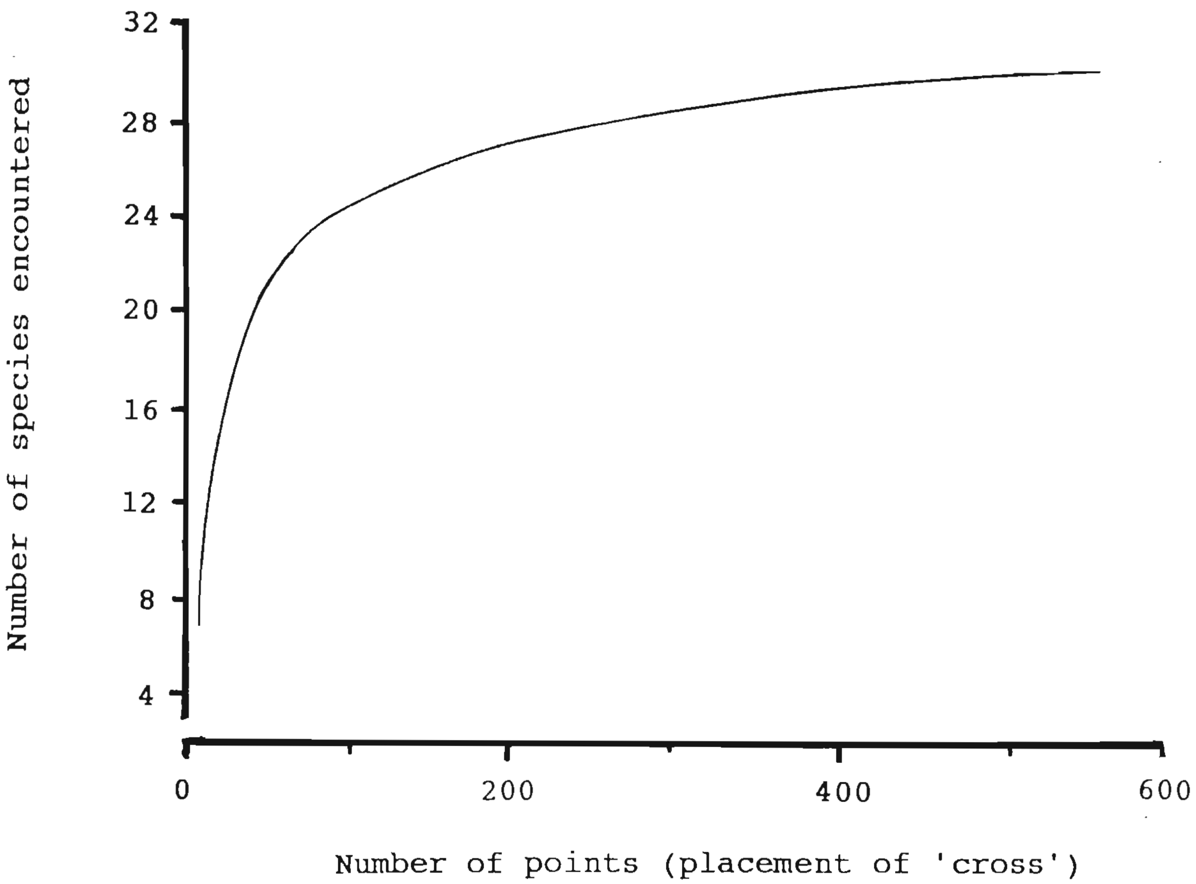
FIGURE CAPTIONS

Figure 1. The relationship between sampling effort (number of points) and the number of species encountered with the point-centred-quarter method.

Figure 2. The relationship between sampling effort (number of points) and repeatability of measures of: average canopy radius (a); average canopy height (b); average lower canopy height (c); total canopy volume (d); and browseable canopy volume (e).

Figure 3. The relationship between sampling effort (number of points) and repeatability of determining average distance to the centre of the nearest shrub (a parameter reflecting density).

Figure 4. Replicate similarity (percentage similarity) of determining species composition (relative density) with increasing numbers of point centred quarters. Variation was determined from 15 randomized samples taken at each sample size, from a parent population of 560 point centred quarters.



32
28
24
20
16
12
8
4
Number of species encountered
0
200
400
600
Number of points (placement of 'cross')

Figure 1

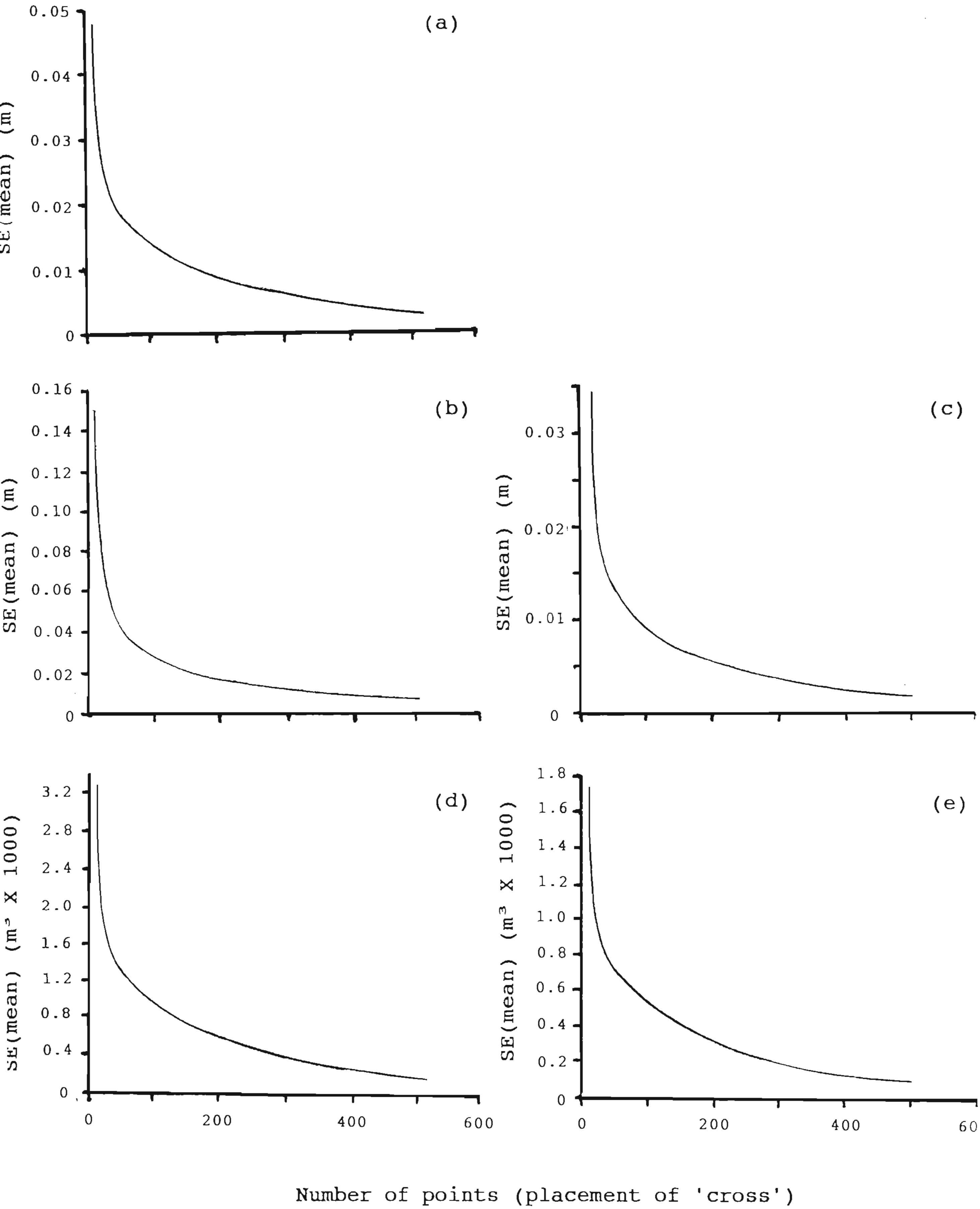

(a)
SE(mean) (m)
0.05
0.04
0.03
0.02
0.01
0
(b)
SE(mean) (m)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
(c)
SE(mean) (m)
0.03
0.02
0.01
0
(d)
SE(mean) (m³ X 1000)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
(e)
SE(mean) (m³ X 1000)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
200
400
600
60
Number of points (placement of 'cross')

Figure 2

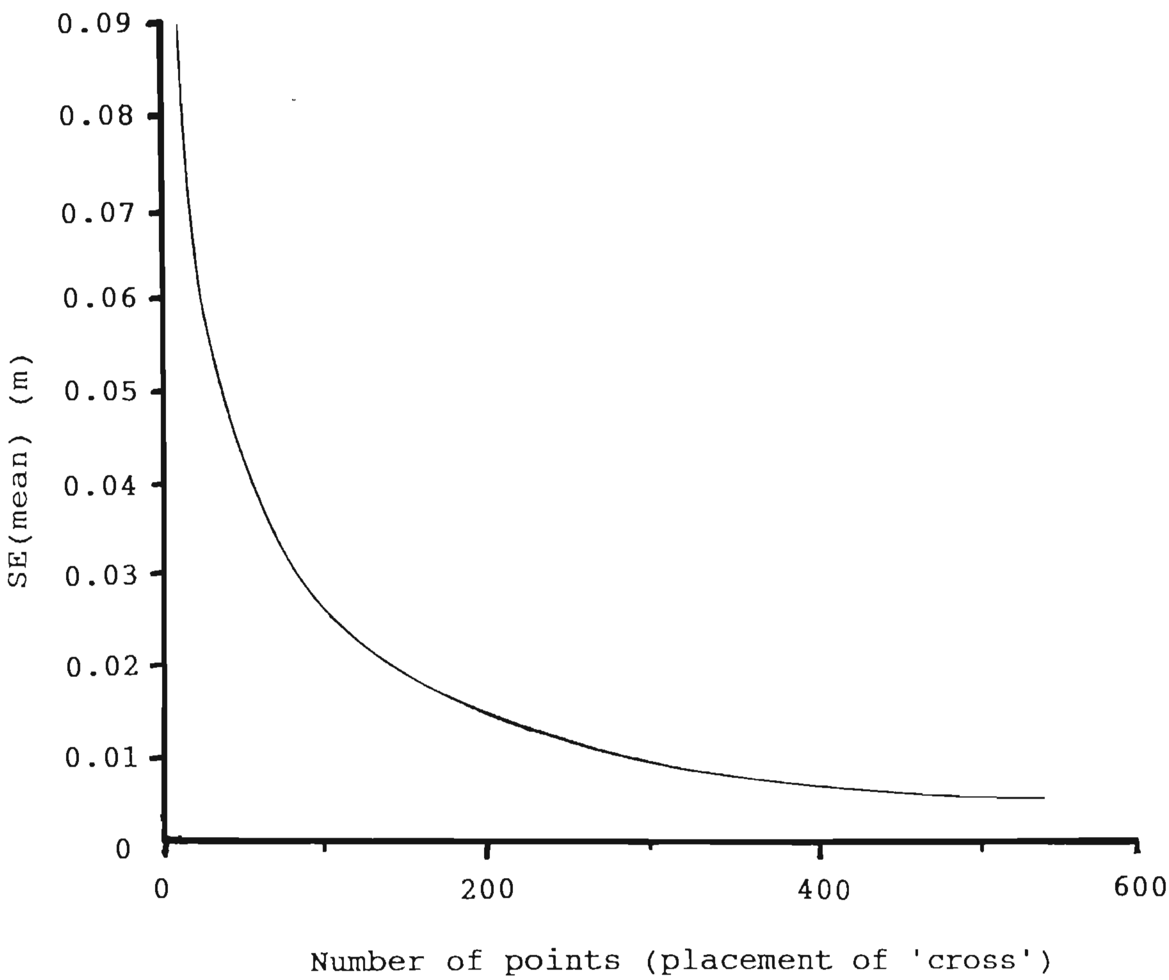
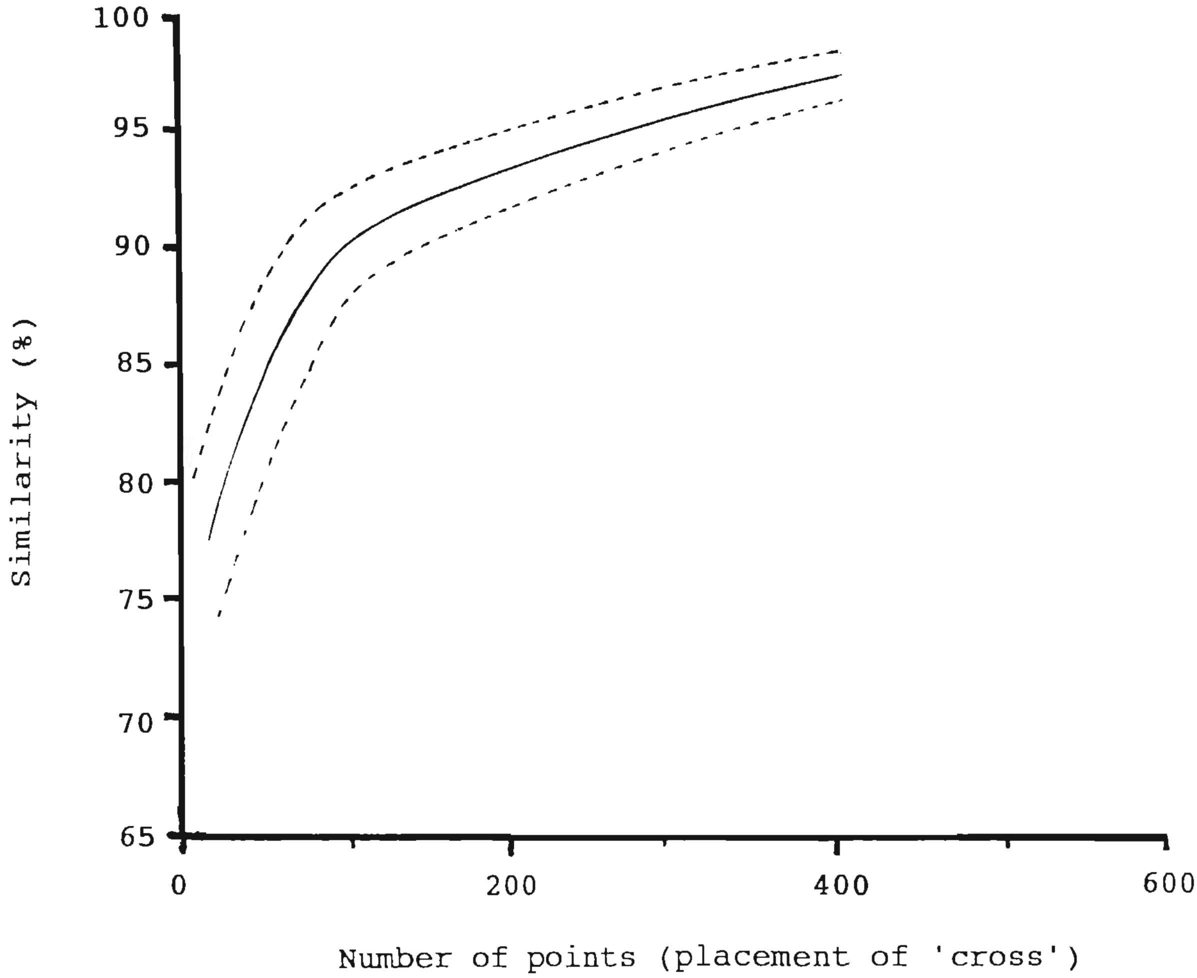

0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
SE(mean) (m)
0
200
400
600
Number of points (placement of 'cross')

Figure 3



100
95
90
85
80
75
70
65
Similarity (%)
0
200
400
600
Number of points (placement of 'cross')

Figure 4

EVALUATION OF A BELT TRANSECT METHOD OF SAMPLING KAFFRARIAN SUCCULENT THICKET

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ABSTRACT

The objective was to evaluate the efficiency and repeatability of the belt transect survey method, measuring eight parameters, in this dense and tangled vegetation.

Finding 85% of the species eventually determined with an exhaustive transect survey, took c. 7.5 man hours (MH). Determining shrub density, average canopy height, average lower canopy height and average canopy radius would require c. 7.5 MH before the 'law of diminishing returns' would discourage further sampling. Lower canopy height was the most efficiently surveyed parameter and would require c. 2 MH to get error to within 10% of the final estimate. Measuring the various canopy volumes would require c. 10 MH (and even here the coefficient of variation would still be greater than 10%). This is probably due to multiplicative errors in calculating these parameters. To determine a reasonable replicate similarity for species composition (i.e. 85%) would require c. 10 man hours.

This technique cannot be recommended for Kaffrarian Succulent Thicket as it is too inefficient, even for researchers.

INTRODUCTION

The objective of this study was to evaluate the use of the belt transect method in Kaffrarian Succulent Thicket (Cowling 1984) otherwise known as Valley Bushveld, southern variation (Acocks 1975). After having used (Stuart-Hill <u>et at</u> 1986) and discarded (Stuart-Hill in prep.) the point centred quarter (PCQ) method (devised by Cottam & Curtis 1965), I turned my attention to evaluating a conventional belt transect (2m wide) survey method as used in the neighbouring False Thornveld of the eastern Cape (Teague 1989).

The approach was to establish relationships between repeatability (error) and increasing sampling intensity for various parameters measured by the technique (e.g. number of species encountered,

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shrub density, average canopy height, average lower canopy height, average canopy radius, total canopy volume, and browseable canopy volume, shrub density and species composition).

PROCEDURE

The site

The 2ha site (the same one used to evaluate the PCQ method) was located in the Andries Vosloo Kudu Reserve approximately 2km from the Fish River. It was selected with a number of prerequisites in mind (as described in Stuart-Hill in prep.) designed to make the site as representative of the vegetation type as possible. It was 100 X 200m, permanently marked and situated with its longest edge adjacent to a road for easy orientation while surveying.

Survey procedure

The site was 'saturated' with transects (2m wide) well in excess of that which could normally be applied in practise. The idea was to use this sampling effort to estimate the variance of the true population and these data could then serve as a data bank from which various sized samples could be drawn and analyzed.

Twenty five random numbers between 10 and 190 were drawn and these represented the transect starting points along the road-side edge of the plot. The transect starting point from the road was determined by walking into the plot (at right angles to the road) for ten meters, and then walking an extra number of paces as determined by the same random number but now divided by 10 (i.e. between one and 19). The transects were each 20 m long but recorded as two 10m contiguous transects which ran at right angles to the road. In total 30 transects with a total length of 600m were surveyed.

There were five operator pairs who each surveyed six transects. On average it took two operators 30($\pm$ 8.8) minutes per 20m transect which translates to 3 man minutes per meter of transect, excluding breaks. The individuals in each operator pair took turns measuring and recording, and these changes were made on an informal basis.

The following parameters were recorded on each shrub (greater than 10cm tall) encountered in the transect:

i) the height of the top of the canopy;
ii) the height of the lowest part of the canopy;
iii) the radius of the canopy;
vi) a subjective estimate of the density of living twigs in the canopy below 1,5m; and
vii) a subjective estimate of the leafiness of a representative twig taken from the canopy below 1,5m.

Pre-survey training

The operators had all completed tertiary level education. The pre-survey training was brief (10 minutes) as the intention was to rigorously test the technique. The philosophy was to provide test results that would be applicable to persons wanting to use the technique but who would have no more information than that obtained from reading the technique description or having a telephone conversation.

The following points were emphasised during training.

i) If any portion of a plant was rooted in the transect then it was counted. This tends to bias the measures of canopy volume and plant density upwards, but I felt that it was preferable to sacrifice accuracy in favour of repeatability.

ii) The measurements describing the canopy were the average measurements and isolated twigs were treated as outliers.

iii) The twig density estimate was independent of the leafiness of the shrub (a shrub with no leaves could potentially score 10 for twig density).

iv) The leaf density estimate was independent of the size of the plant or the twig density of its canopy. Thus (a plant could potentially score 10 for leaf density even if it was very small or had a very sparse twig density).

v) It was, stressed that the entire exercise was to be conducted anonymously as it was a test of the technique not individuals and the operators were encouraged to proceed with the speed and care with which they would survey a site in practice.

vi) Herbaceous plants were excluded.

vii) Unknown species were to be recorded as such, given a unique code and a sample taken for subsequent identification. While all operators had moderate species identification abilities, it was necessary to group those species which were difficult to distinguish in the field.

STATISTICAL ANALYSIS

The error as a result of operator differences was not quantified as it was assumed that, in practice, operators will inevitably be replaced in any long term survey programme. I suggest that this should be seen as a strength because it results in a stricter test.

The analytical approach was similar to that taken in evaluating the PCQ method (Stuart-Hill in prep.), except that randomization was done on the transects themselves; i.e. each 20m transect was treated as a sampling unit. To increase sampling effort involved randomly selecting a number of transects and merging them to give the required transect length (i.e. transect length represents sampling effort).

Number of species

Fifteen transects were randomly selected, and merged to give the appropriate length (this started at 20m and ended at 400m in multiples of 20). The number of species in each composite transect was counted, following which the mean and SE(x) for the 15 transects (at each transect length) was determined. Ultimately a relationship between length of transect (sampling effort) and number of species encountered was constructed to illustrate the effectiveness of increased sampling in determining species richness.

Univariate parameters

These measures of the shrub community included: shrub density, average canopy height; average lower canopy height; average shrub radius; total canopy volume; and browseable canopy volume (see definitions in Stuart-Hill et al. 1986).

As before, fifteen transects were randomly selected, and merged to give an appropriate transect length. The mean for each parameter was determined for each of these 15 transects. The mean of these means and, importantly, the SE(mean) was then determined. This was repeated for each transect length (starting at 20m and ending at 400m in multiples of 20) so that eventually a relationship between SE(mean) and transect length could be constructed for each parameter.

Species composition (relative density)

As above, fifteen transects were randomly selected, and merged to give an appropriate transect length. The species composition for each composite transect was determined for each of these 15 transects and a similarity matrix between samples constructed. The mean similarity was then determined from the off-diagonal terms in the matrix along with the SE(mean) and this plotted against the particular sample size. This was repeated for each transect length (starting at 20m and ending at 400m in multiples of 20) so that eventually a relationship between replicate similarity and transect length could be constructed (similar to the approach used by Hardy & Walker 1991).

RESULTS

Number of species

The first 24 species were found after 150m of transect (taking 7.5 man hours) and this represented 85% of the 28 species found. Significantly, the total was two less than found by the PCQ method (Stuart-Hill in prep.). It took an extra 50m before the next species was encountered (Figure 1).

INSERT FIGURE 1

As with the PCQ method, this method of determining species richness is highly inefficient and cannot be recommended.

Univariate parameters

Except for the canopy volume parameters, all the univariate parameters experienced a rapid decline in error with the first 50m of transect (Figure 2).

INSERT FIGURE 2

The size of the errors, relative to the actual measurement (i.e. the coefficient of variation), shows that lower canopy height was the most efficiently sampled parameter, requiring c. 60m of transect to get error to within 10% of the measured value (Figure 3).

INSERT FIGURE 3

The volumetric measures were considerably less repeatable, probably because of the increase in variation as a result of multiplicative errors. Measuring these would require c. 10 man hours and even here, the coefficient of variation would still be greater than 10% (Figures 2 & 3).

Sampling beyond c. 150 to 200m would not dramatically improve repeatability and the required sampling effort is such (c. between 7.5 and 10 man hours respectively) that the belt transect method cannot be recommended for these parameters.

Species composition (relative density)

Reasonable replicate similarity (85%) was obtained after c. 200m of transect but this would take c. 10 man hours (Figure 4).

INSERT FIGURE 4

CONCLUSION

The belt transect method, while being capable of producing relatively repeatable results, is even less efficient than the PCQ method (Stuart-Hill in prep.). Consequently I cannot recommend it's use even for research purposes.

ACKNOWLEDGEMENTS

I am extremely grateful to the Department of Agriculture for financial support, Pete Burdett for his friendly co-operation in allowing us to use the Andries Vosloo Kudu Reserve and most of all, to the following people who were the operators: D. Deckker, C. De Ridder, L. Du Toit, O. Grobler, H. Lourens, H. Oosthuizen, B. Ras, C. Scheltema and M. Swart.

REFERENCES

Acocks J.P.H. 1975. Veld types of South Africa (2nd edition). Mem. Bot. Surv. S. Afr. No. 40.

Cottam G. & Curtis J.T. 1956. The use of distance measures in phytosociological sampling. Ecology. 37: 451-460.

Cowling R.M. 1984. Asyntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome. Bothalia. 15(1&2): 175-227.

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Stuart-Hill G.C. in prep. Evaluation of the point centred quarter method of sampling Kaffrarian Succulent Thicket.

Teague W.R. 1989. Monitoring vegetation in thorn/grass communities. In: Veld management in the eastern Cape, (Eds: J.E. Danckwerts & W.R. Teague). Govt. Printer, Pretoria.

FIGURE CAPTIONS

Figure 1. The relationship between sampling effort (length of 2m wide transect) and the number of species encountered.

Figure 2. The relationship between sampling effort (length of 2m wide transect) and repeatability of measures of: shrub density (a); average canopy radius (b); average canopy height (c); average lower canopy height (d); total canopy volume (e); and browseable canopy volume (f).

Figure 3. The relationship between sampling effort (length of 2m wide transect) and the coefficient of variation of measures of various univariate parameters describing the community.

Figure 4. Replicate similarity (percentage similarity) of determining species composition (relative density) with increasing length of a 2m wide transect.

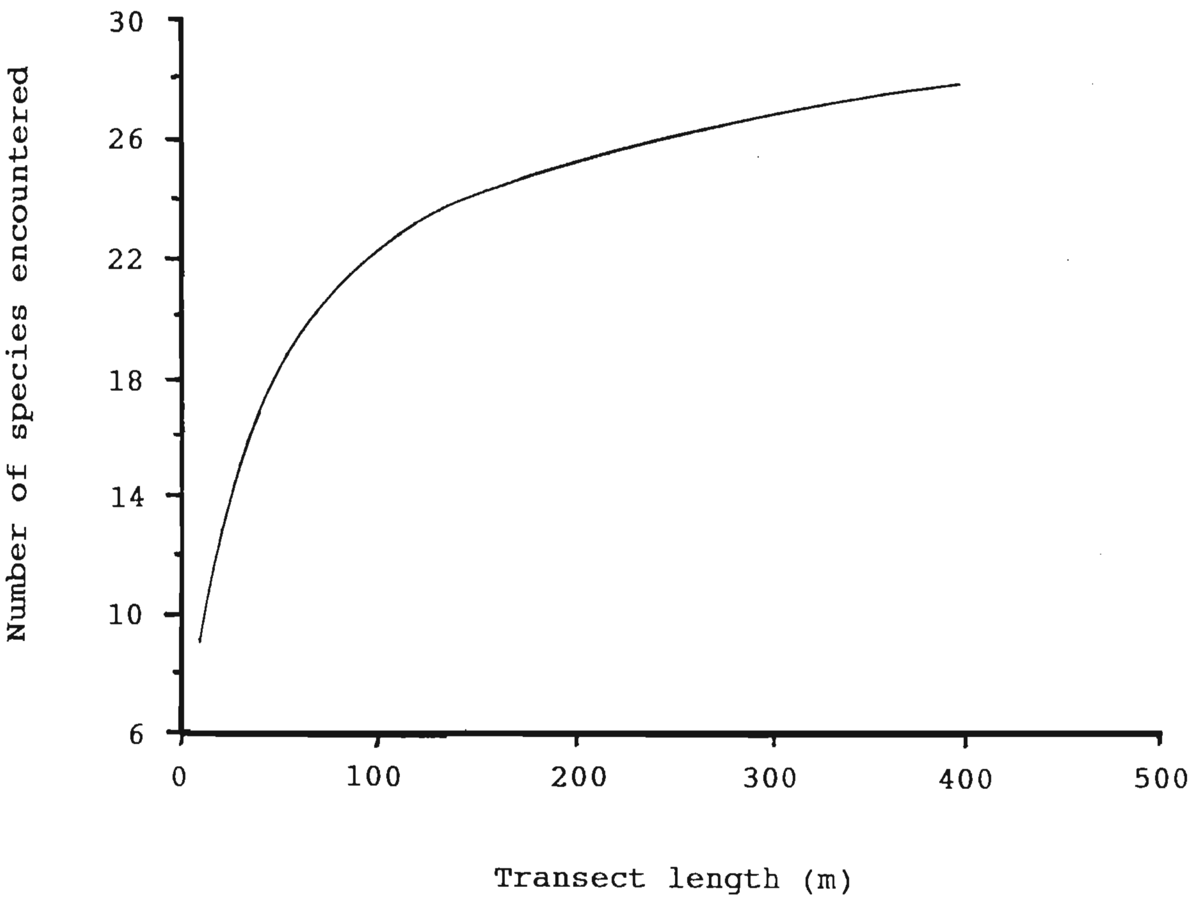

Number of species encountered
30
26
22
18
14
10
6
0
100
200
300
400
500
Transect length (m)

Figure 1

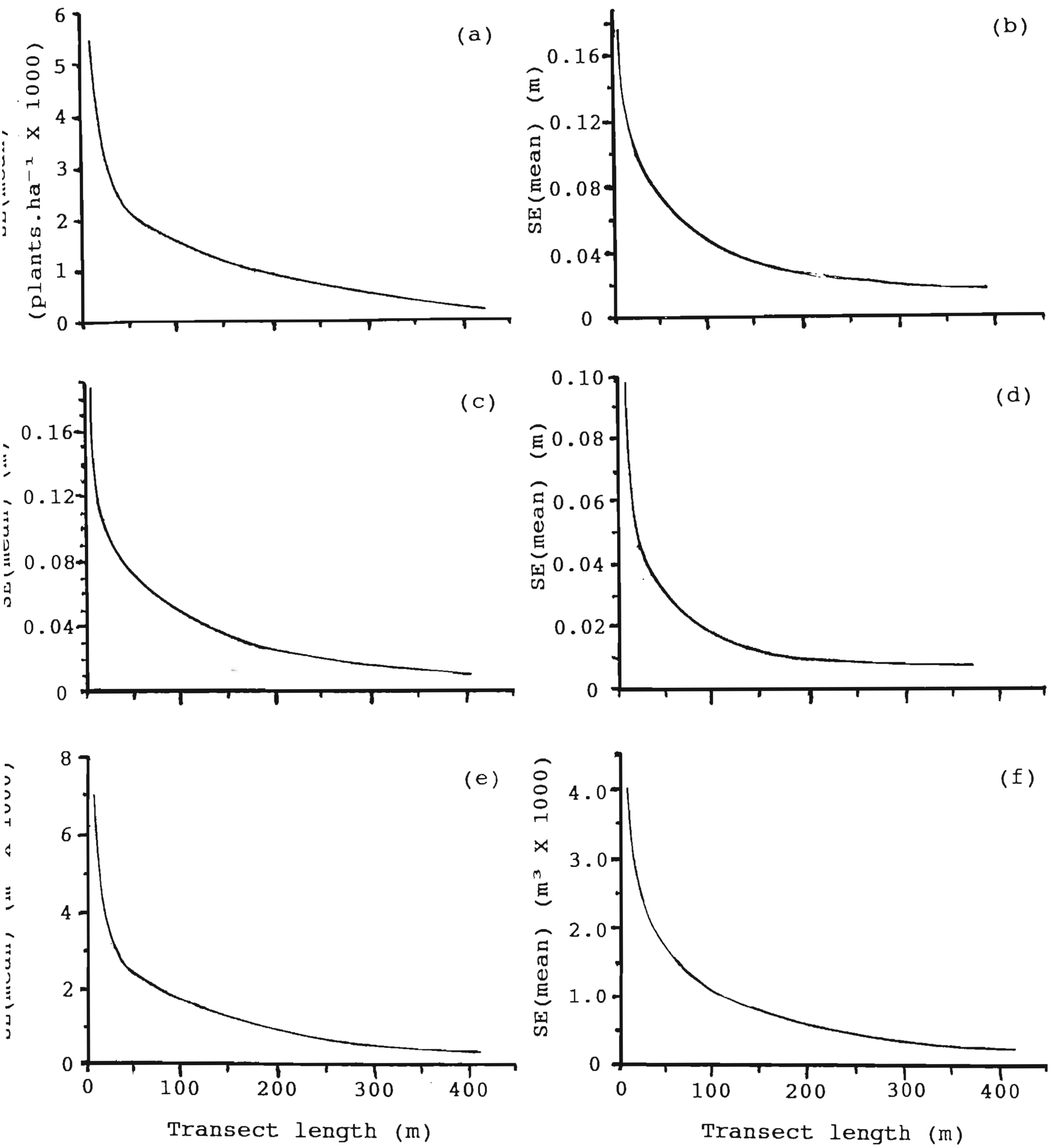
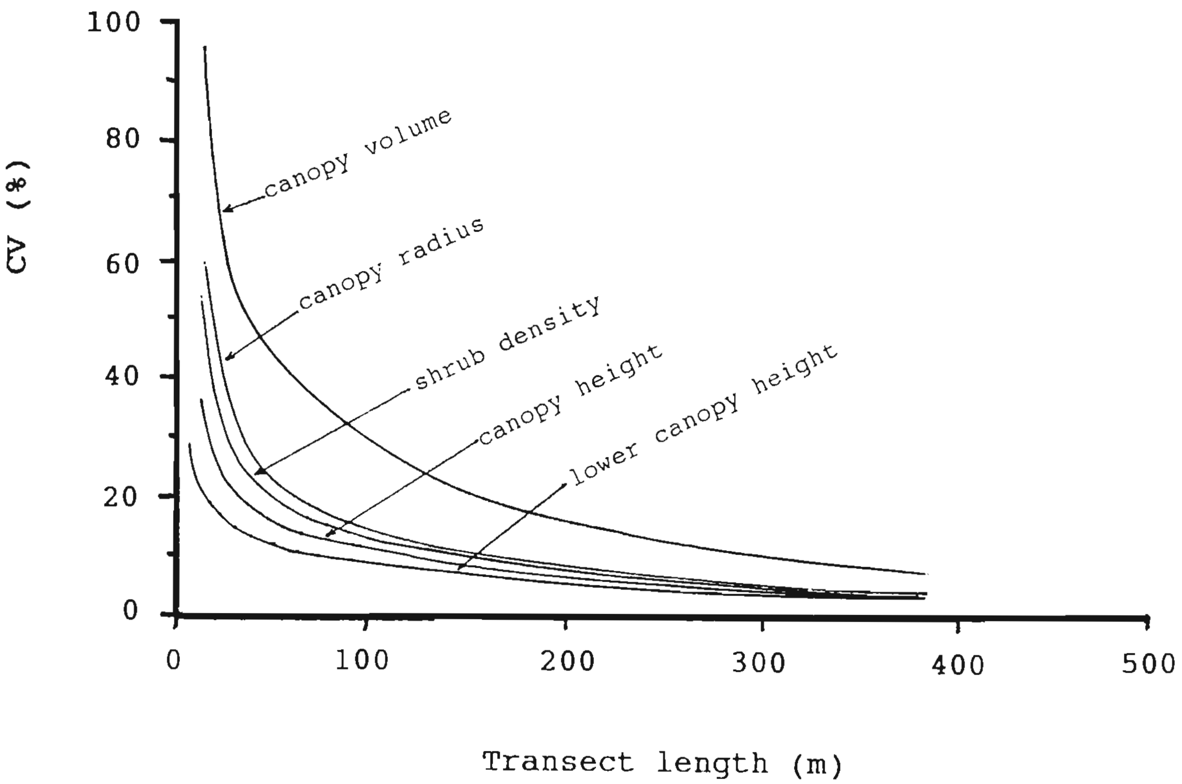
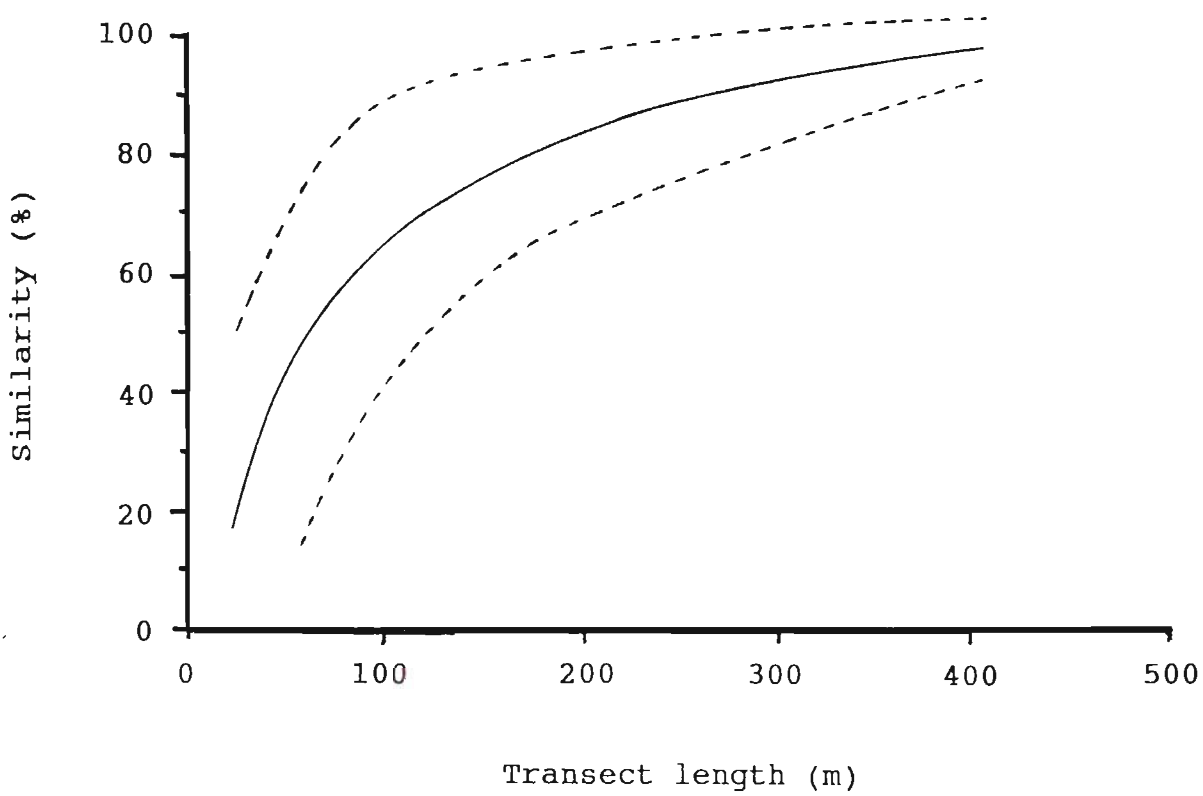

(a)
(plants.ha⁻¹ X 1000)
6
5
4
3
2
1
0
(b)
SE(mean) (m)
0.16
0.12
0.08
0.04
0
(c)
0.16
0.12
0.08
0.04
0
(d)
SE(mean) (m)
0.10
0.08
0.06
0.04
0.02
0
(e)
8
6
4
2
0
0
100
200
300
400
Transect length (m)
(f)
SE(mean) (m³ X 1000)
4.0
3.0
2.0
1.0
0
0
100
200
300
400
Transect length (m)

Figure 2



100
80
60
40
20
0
CV (%)
canopy volume
canopy radius
shrub density
canopy height
lower canopy height
0
100
200
300
400
500
Transect length (m)

Figure 3



100
80
60
40
20
0
Similarity (%)
0
100
200
300
400
500
Transect length (m)

Figure 4

REPEATABILITY OF THE DOMIN-KRAJINA COVER-ABUNDANCE SCALE IN KAFFRARIAN SUCCULENT THICKET

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ABSTRACT

The objective was to evaluate this survey technique in an attempt to find a method for monitoring change in this dense and tangled vegetation.

A single operator was not able to reliably survey the vegetation but this was largely overcome by using multiple operators where the mean, derived from a number of operators' independent estimates, is used as the variate value for a site.

The modified technique (with multiple operators) is more efficient than either the point-centred-quarter or belt transect methods. It has the disadvantage, however, of relying on a degree of operator subjectivity, the value of which depends on training and experience. While the modified technique (with multiple operators) can probably be used to rapidly survey sites for inventory and research purposes, it is unlikely to be sensitive enough to support pro-active adaptive management.

INTRODUCTION

The Kaffrarian Succulent Thicket (Cowling 1984) or Valley Bushveld of the eastern Cape (Veld type 23 b,c & d; Acocks 1975) is, in its 'pristine' state, so dense that it is difficult to move through it. Shrubs grow in tangled multistoried canopies and objective survey methods have proved to be extremely tedious, even for research purposes (Stuart-Hill a & b in prep). Phytosociological methods such as Braun-Blanquet (Mueller-Dombois & Ellenberg 1974) had been advocated for these vegetation types (Vorster 1982) and their effectiveness needed to be tested. Le Roux (1986 pers comm) suggested, however, that the Domin-krajina (D-K) scale should rather be used as it has more appropriate scale intervals for this vegetation type than the Braun Blanquet scale. The D-K cover-abundance scale is a popular method of estimating overall cover and species cover of shrub communities (Westfall & Panagos 1984; Anon 1988).

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The objective of this investigation was to rapidly evaluate the method for repeatability. The test was made on the estimates of total shrub cover as well as on species composition (determined from the species cover abundance).

PROCEDURE.

The approach was to tackle the test in two phases. Firstly, the repeatability of individual operators was evaluated to see whether they were precise enough to consistently distinguish at least those differences observable in the field. If single operators were not able to consistently distinguish obvious difference in sites then the second phase was implemented. Here, the estimates from two or more operators were averaged and these means were then tested for repeatability. This approach allowed repeatability to be quantified for cases when total shrub cover and species composition were determined from the mean of various numbers of assessors independently derived estimates (see the approach taken by Stuart-Hill 1991).

Total shrub canopy cover

After initial training, eight observers independently estimated the overall percentage shrub cover of five sites representing various positions along the ecological status gradient (see Stuart-Hill 1989).

The mean canopy cover and standard errors of a single estimate (SE(x)) were determined for each site. From these SE(x)'s, relationships between increasing numbers of operators (contributing to the mean estimate cover) and the standard error of the mean estimates (SE(mean)) were developed. The SE(mean)'s were converted to least significant differences (LSD) so that the relationships developed are practically applicable.

Species composition (cover-abundance)

The species composition (derived on the basis of cover-abundance data) were determined for the data of each operator. These were compared with all other operators' estimates by calculating the percentage similarity (PS) for each comparison. The mean PS of all the comparisons was then determined for the off-diagonal terms in a 8 x 8 similarity matrix (similar to the approach used by Hardy & Walker 1991). This was then plotted against n=1 to represent the repeatability of determining species composition with a single operator.

Where species composition is to be determined using two operators, a similar approach to that described above was followed except that firstly, the mean composition from two operators was determined. These were compared with the compositions determined from other pairs of operators and the mean PS determined from the similarity matrix as explained previously. This mean PS was then plotted against n=2 to represent the repeatability of determining species composition obtained by averaging two operators estimates.

The above procedure was repeated for n=3 and n=4. A relationship between number of operators (n) and repeatability (mean PS) was thereby developed and this describes the repeatability of determining species composition with multiple operators.

RESULTS

Total shrub canopy cover

The SE(x)'s, along with the average canopy cover estimates for each site are illustrated in Table 1. The relationships between LSD ($P \leq 0,05$) of estimating canopy cover and the number of observers for each of the five sites is illustrated in Figure 1.

INSERT TABLE 1

INSERT FIGURE 1

It should be emphasised that these data were obtained with operators who (apart from one) had never before used the technique. This, I believe, makes the relationships illustrated in Figure 1 conservative. To be even more conservative, I assumed that the 'average' precision (i.e. the repeatability one would normally expect) is represented by the curve with the third highest LSD (Figure 1).

The reliability of using the mean from four or fewer observers will be inadequate for most surveyor objectives. On 'average', the mean from at least five observers will be required to distinguish ($P \leq 0,05$) 20% differences in canopy cover and approximately double that will be necessary to distinguish 10% differences.

Species composition (cover-abundance)

The replicate similarity was relatively low when a single operator estimated species composition (Figure 2). This rapidly improved, however, when species composition was determined from the mean cover-abundance values derived from two or more operators. It is highly recommended, therefore, that at least two operators should be used because in addition to the improvement in replicate similarity, field workers usually work in pairs and if both were to independently estimate cover-abundance, little extra time would be taken at each site. To obtain a reasonable level of repeatability (i.e. 85%), however, at least four operators would be required taking a total of c. 50 man minutes. This is a vast improvement over the point centred quarter and belt transect methods (Stuart-Hill a & b in prep.).

INSERT FIGURE 2

CONCLUSION

It is apparent that a single operator cannot be relied upon to estimate either total shrub cover or species composition. However, using the mean of more than one operator rapidly improves repeatability. Given that four people can be transported in the average sedan and time spent at each site is relatively short (approximately 10 to 15 minutes), no fewer than four operators should ever be used. Even this does not, however, yield a really useful result for total shrub cover, where it would be safer to double this number of operators. The problem with this technique is that all the operators need to be well trained and using large numbers of such operators is expensive despite the time saving. In addition the technique is also prone to criticism in that it relies on a degree of subjectivity.

Despite this method being a considerable improvement over the Point centred quarter and Belt transect methods tested earlier (Stuart-Hill a & b in prep.), I believe that it is still not sufficiently sensitive to support pro-active adaptive management.

ACKNOWLEDGEMENTS

I am extremely grateful to the Department of Agriculture for financial support, C.J.G. le Roux for suggesting the D-K cover-abundance scale and for training the operators and in particular, the following people who were the operators: H.J. Barnard, L.P. Du Toit, C.J.G le Roux, H. Lourens, L.O. Nel, K. Stander and M.L. Swart.

REFERENCES

Acocks J.P.H. 1975. Veld types of South Africa (2nd edition). Mem. Bot. Surv. S. Afr. No. 40.

Anon 1988. The plant number scale - an improved method of cover estimation using variable-sized belt transects. Misc. notes, Bothalia 18(2): 289-291.

Cowling R.M. 1984. Asyntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome. Bothalia. 15(1&2): 175-227.

Hardy M.B. & Walker R.S. 1991. Determining sample size for assessing species composition in grassland. J. Grassl. Soc. South. Afr. 8(2): 70-73.

Mueller-Dombois D. & Ellenberg H. 1974. Aims and methods of vegetation ecology. John Wiley, New York.

Stuart-Hill G.C. in prep. (a). Evaluation of the point centred quarter method of sampling Kaffrarian Succulent Thicket.

Stuart-Hill G.C. in prep. (b). Evaluation of a belt transect method of sampling Kaffrarian Succulent Thicket.

Vorster M. 1982. The development of the ecological index method for assessing veld condition in the karoo. Proc. Grassld.

Soc. South. Afr. 17: 84-89.
Westfall R.H. & Panagos M.D. 1984. A cover meter for canopy and basal cover estimations. Bothalia 15(1&2): 241-244.

Table 1 The error in determining total shrub cover with the D-K cover abundance scale at five sites in Kaffrarian Succulent Thicket. These sites represent the range in ecological status and their average cover (determined from eight operators) is also shown.

	Ecological status	SE(x) (%)	Average Canopy Cover(%)
Site 1	100	10	60
Site 2	90	9	71
Site 3	45	15	43
Site 4	20	14	30
Site 5	-10	7	26

FIGURE CAPTIONS

Figure 1 The repeatability of estimating total shrub cover with the Domin-Krajina cover-abundance scale by using the mean value derived from an increasing number of operators' independently estimated cover values. Broken lines indicate actual error curves measured for the five experimental sites. The solid line represents the mean error over all five sites.

Figure 2 Replicate similarity of determining species composition (cover-abundance) with the Domin-Krajina cover-abundance scale, when using the mean composition derived from multiple operators. The vertical bars represent the range in similarity as measured at each of the five experimental sites

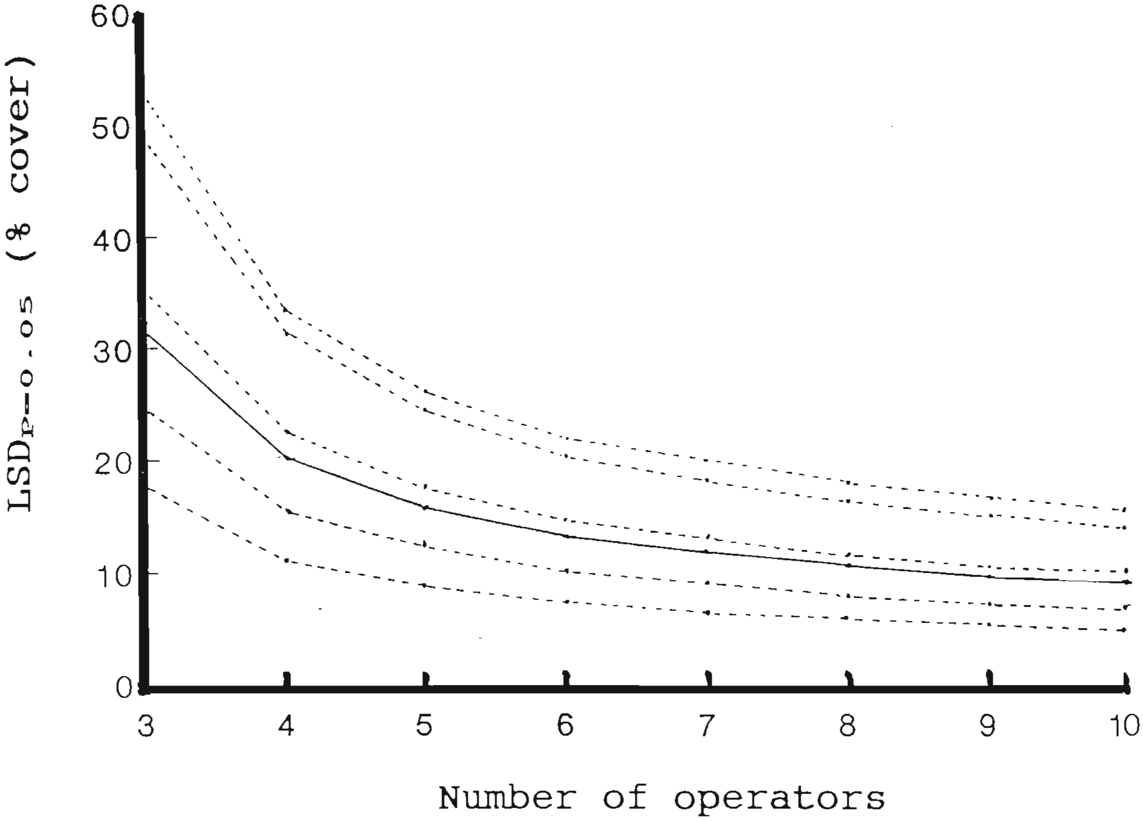
LSD$_{P=0.05}$ (% cover)
60
50
40
30
20
10
0
3
4
5
6
7
8
9
10
Number of operators

Figure 1

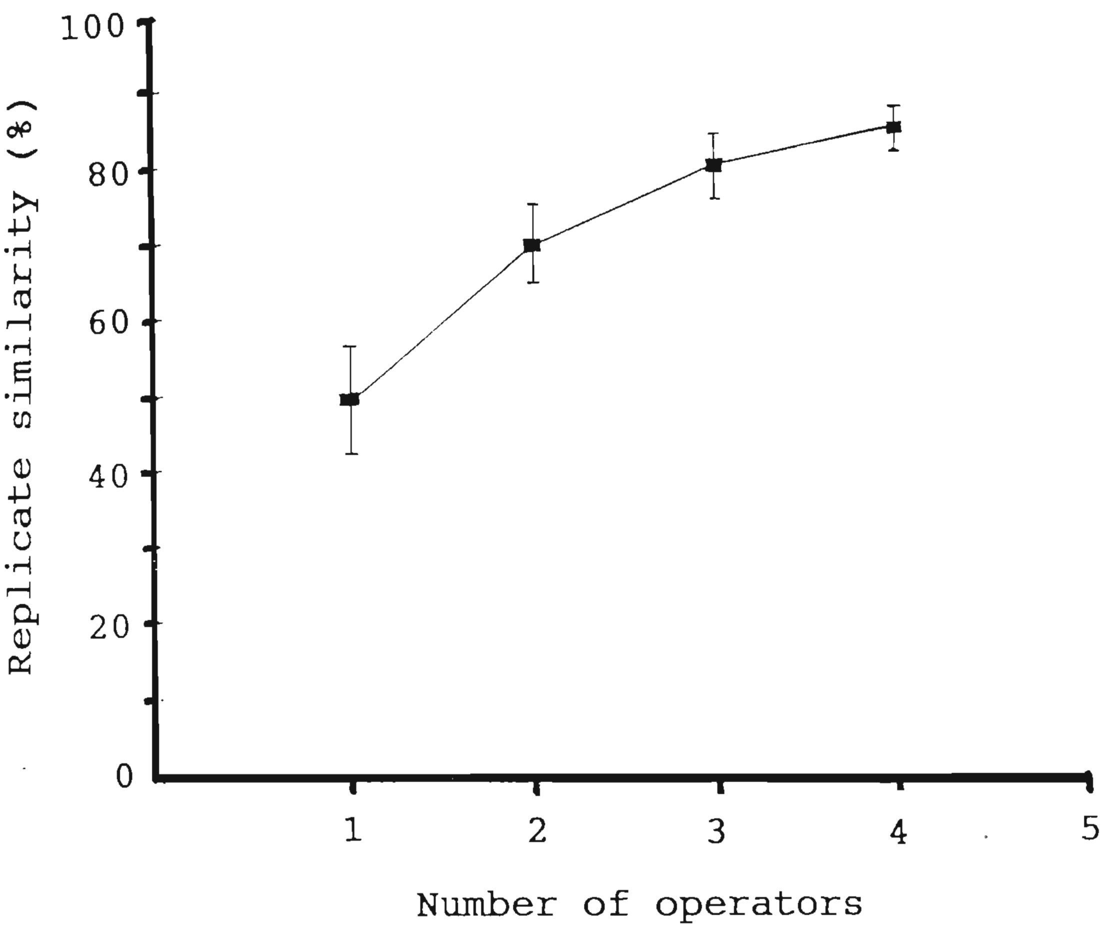
100
80
60
40
20
0
Replicate similarity (%)
1
2
3
4
5
Number of operators

Figure 2

[P 3.5.1]

THE 'BUBBLE' TECHNIQUE FOR SAMPLING KAFFRARIAN SUCCULENT THICKET: 1. TECHNIQUE DEVELOPMENT

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ABSTRACT

Surveying this vegetation is frustrated by the lack of an efficient technique. Research has discarded conventional botanical methods based on plant density and canopy volume but it was still necessary to test frequency and cover based methods. For various reasons, convention quadrats were not practicable in this vegetation and it was necessary to develop and test a new survey method.

This paper, the first of a three part series, reports on the development of a three dimensional quadrat method known, because of its shape, as a 'Bubble'. It uses a simple apparatus which consists of two staffs, hinged together. One is held vertically, while the second is rotated in all directions without moving the first staff. Any species which can be touched by the rotating stick is recorded. Ultimately, two types of species composition (relative frequency and relative cover) as well as various univariate descriptive parameters can be obtained with this method.

INTRODUCTION

The Kaffrarian Succulent Thicket (Cowling 1984) or Valley Bushveld of the eastern Cape (Veld type 23 b, c & d; Acocks 1975) is, in its 'pristine' state, so dense that the multistemmed shrubs grow in tangled multistoried canopies. The failure of the conventional botanical survey methods, such as the belt transect and point centred quarter methods (Stuart-Hill a & b in prep.), is probably a result of them being based on plant density - a poorly repeatable parameter when it is difficult to distinguish between individual plants. Even if density could be repeatedly measured, any technique based on this parameter would be insensitive (and not suitable for pro-active adaptive management) because it would depend on the death and replacement of individual plants. As a result of this, and the difficulty of identifying individuals, density and density based techniques were discarded.

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In this early work there had, however, been an unarticulated but intuitive understanding of this problem. As a consequence, various volumetric measures were tested; the idea being that plants will diminish in size (due to 'over-browsing') before they die. These methods were however, also discarded because their repeatability is extremely poor (as a result of multiplicative errors which accumulate when these parameters are calculated).

Cover does not appear to have the problems of density or volumetric measures and the visual Domin-krajina (DK) cover-abundance scale (Westfall & Panagos 1984; Anon 1988), based on the Braun Blanquet technique (Meuller-Dombois & Ellenberg 1974) was tested (Stuart-Hill c, in prep.). This method seems to hold some promise, but only if multiple operators are used. The requirement of a large number of skilled persons (c. eight) is a (surmountable) limitation, but the technique is also criticized in that it is prone to operator bias because of the subjective decisions which must be made. Also it appears to be inadequate, even with multiple operators, for pro-active vegetation management. Because of this I again turned to objective survey methods, but this time concentrated on cover and frequency. To sample these, however, necessitated the development of a new technique. This first paper of the series, reports on its development.

NECESSITY FOR A NEW SAMPLING TECHNIQUE

Physically moving through this vegetation is a limitation and as a consequence, point based techniques to measure frequency were discarded because of the large numbers of points necessary with such techniques.

Frequency can often be measured with quadrats wherein presence or absence of a species is recorded. Establishing conventional two dimensional quadrats (squares, rectangles or circles) of appropriate size in this vegetation is problematical because these require either:

i) rigid or rigidly collapsible quadrats;
ii) ropes to demarcate square or rectangular quadrat boundaries; or
iii) a staff to act as a radius for a circular quadrat.

The first was a non-starter because the quadrat apparatus was too unwieldy to move around and place in the dense vegetation.
The second is poorly repeatable because operators require: a high degree of land-survey skill to site the quadrats in the dense vegetation; they have to lay the rope around the quadrat perimeter and this is susceptible to bias; and most importantly, such quadrats are extremely time consuming to establish.

A circular quadrat (using a single staff as the radius) solves many of the above problems. However, it suffers in that with random placement, the centre of the circular quadrat will often lie in an inaccessible place. In addition, with the many multistemmed shrubs in this vegetation, rotating such a staff at ground level is impossible. It was felt that if the rotation problem could be solved then this technique could have potential. The obvious way was to lift the rotating staff above the shrubs but this was not entirely satisfactory as deciding whether a plant was in or out was particularly prone to errors of parallax.

Eventually a three-dimensional quadrat, called a 'Bubble' was devised which avoided the problems discussed above and enabled a frequency based technique to be applied to this vegetation.

DESCRIPTION OF THE BUBBLE TECHNIQUE

The 'Bubble' quadrat technique is a derivative of a conventional frequency based quadrat method; the difference being that the Bubble quadrat is three dimensional and presence is recorded when any aerial portion of the plant is within this volume.

The volume of this three-dimensional quadrat is demarcated with a simple apparatus which consists of two staffs, hinged together (Figure 1). One of the staff's (1.5m) is placed on the ground at the sampling point and held vertically. The second, 2.3m long and hinged on top of this 'upright leg', is rotated in all directions without moving the first staff. The second staff acts as the radius of a three-dimensional quadrat and any species which is within this volume or can be touched by the rotating stick is recorded as being present. This three-dimensional quadrat is called a 'Bubble' because of its shape which arises as a result of the rotating stick being longer than the upright-leg (Figure 1). Because the 'hinge' is elevated well above ground level (and above the multiple shrub stems) the rotating leg has much greater freedom of movement than if it were at ground level (as with the two dimensional circular quadrat).

INSERT FIGURE 1

The origin of the dimensions of the two legs of the apparatus were those that described the same sized 'Bubble' that I would demarcate when standing in a single upright position and tried to touch all species (in all directions) with a standard staff of 1.5m held in my hand. This approach was informally developed whilst trying to conduct a rapid survey to compare vegetation across a fence-line. As this 'human' method is not repeatable between operators (people differ in height and arm length) and operators are unable to stand at every position determined by random point placement, it was necessary to develop the 'Bubble' apparatus. The dimensions of the two legs are therefore, simply due to an historical accident. As with all quadrat techniques, quadrat size is important and should strictly be varied for each species. This was not evaluated although I acknowledge that this may need to be done. Notwithstanding this, the Bubble size appears to be adequate for most species.

PARAMETERS WHICH CAN BE RECORDED

At each bubble, the total cover of all woody plants can be visually estimated as a percentage of the circle described by the maximum radius of the 'bubble' (radius = 2.3 m). Cover is defined as the vertical projection of the shrubs' canopies onto the soil surface.

After estimating overall cover, the three species which contributed most to cover within the quadrat are ranked in descending order (i.e. the species which contributes most to cover is ranked 1, and so on). This ranking need not always be performed[2], but it enables cover at a species level to be determined using the principles of the dry-weight-ranked method (t' Mannetje & Haydock 1963).

After ranking the three most important species (in terms of cover), the presence of all other species is recorded. Presence is recorded when the rotating leg of the 'bubble' apparatus can <u>touch</u> any part of the plant. The plant need not be rooted within the 'bubble' to be recorded. The repeatability of recording species presence is greatly enhanced if the operator starts at the top of a finite list and checks off each species in turn rather than recording each species as it is encountered[3].

From these field measurements the following vegetation parameters can be determined:

i) total woody plant cover;
ii) frequency per species;
iii) species composition calculated on the basis of frequency (relative frequency);
iv) cover per species; and
v) species composition calculated on the basis of cover (relative cover).

It is important to note that the measurement for each species is essentially independent of the measure of all others. Consequently, it is possible to use this technique for a single species alone.

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2 It does slow down measurement considerably, especially if the operators agonize over the decision which at times can be very difficult.

3 This is because it is very easy for operators to forget to call out a species strike when scanning the bubble for all plants.

MODIFIED CLIPBOARD AND DATA SHEET

To ensure that the data are transcribed accurately in the field, either an electronic datalogger or a modified clipboard is required. The latter consists of a slide which moves from left to right across a compatible data sheet. The data sheet is a matrix where rows are for species and columns are for sample points (Figure 2).

INSERT FIGURE 2

The slide exposes only the column of the sampling point being measured and the common problem of recording data into the wrong columns is thus avoided. To facilitate rapid location of the appropriate species row, species codes are embossed on the slide itself (Figure 3).

/INSERT FIGURE 3/

CONVERSION FACTORS FOR ESTIMATING SPECIES COVER

Procedure

Thirty five bubble quadrats were taken to represent a range in total cover and species compositions. At each bubble, total cover was estimated and the three most dominant species ranked in order of decreasing contribution to cover (as would normally be done when using the technique). In addition, separate estimates of cover were then made for each of these three species. Relationships between total cover and cover for each ranking were developed irrespective of species; e.g. all plants, regardless species, were used to develop the relationship between total cover and cover per species ranked 1, 2 and so on. Total cover was the independent variable and the intercept was forced through zero as it is logical to expect that when total cover is zero, cover per species would also be zero. Linear relationships were fitted and the slopes of the curves (one for each ranking) estimated. The latter become the multipliers to estimate, from total cover, cover per ranked species.

Results

There were relatively good relationships between total cover and cover per ranked species (Table 1).

INSERT TABLE 1

The slope of each relationship represents a conversion factor where, for example, a species ranked 1 would have a cover value of c. 59% of the total cover estimate. Approximate conversion factors could be 60%, 30% and 15% of total cover for species ranked 1, 2 and 3 respectively. It will be noted that an apparent abnormality is that the sum of the cover values from the three ranked species exceeds total cover by c. 5%. This is to be expected however, as in most circumstances the canopies of the various species overlap.

DISCUSSION & CONCLUSION

The Bubble method differs from conventional quadrat methods because the sampling units are three dimensional in shape and plants are recorded even if only aerial portions fall within the 'bubble'.

It appears to be an extremely rapid technique which theoretically can be applied to either fixed-point or random point monitoring. It has proved to be immensely popular with those operators who have used it. However, its repeatability and efficiency need to be evaluated before the technique can be recommended. This is addressed in the following two papers of this series.

REFERENCES

Acocks J.P.H. 1975. Veld types of South Africa (2nd edition). Mem. Bot. Surv. S. Afr. No. 40.

Anon 1988. The plant number scale - an improved method of cover estimation using variable-sized belt transects. Misc. notes, Bothalia 18(2): 289-291.

Cowling R.M. 1984. Asyntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome. Bothalia. 15(1&2): 175-227.

Mueller-Dombois D. & Ellenberg H. 1974. Aims and methods of vegetation ecology. John Wiley, New York.

Stuart-Hill G.C. in prep. (a). Evaluation of the point centred quarter method of sampling Kaffrarian Succulent Thicket.

Stuart-Hill G.C. in prep. (b). Evaluation of a belt transect method of sampling Kaffrarian Succulent Thicket.

Stuart-Hill G.C. in prep. (b). Repeatability of the domin-krajina cover-abundance scale in Kaffrarian Succulent Thicket.

t'Mannetje L. & Haydock K.P. 1963. The dry-weight-rank method for the botanical analysis of pasture. J. British Grassl. Soc. 18: 268-275.

Westfall R.H. & Panagos M.D. 1984. A cover meter for canopy and basal cover estimations. Bothalia 15(1&2): 241-244.

Table 1 Linear regression relationships between estimates of total cover (TC) and cover per species (C1, C2, C3) ranked according to decreasing contribution to total cover.

Ranking	Equation	r^2
1	C_1 = TC * 0.59	0.80^{**}
2	C_2 = TC * 0.31	0.68^{*}
3	C_3 = TC * 0.15	0.56^{*}

* $P \geq 0.05$
** $P \geq 0.01$

FIGURE CAPTIONS

Figure 1. The bubble apparatus and the resulting three-dimensional sampling area.

Figure 2. An example of a data sheet for use with the bubble apparatus.

Figure 3. A modified clipboard for use with the bubble apparatus. The slide with species codes embossed, moves across the data sheet with each 'bubble' and is specifically designed to reduce the chance of data being entered into the incorrect column.

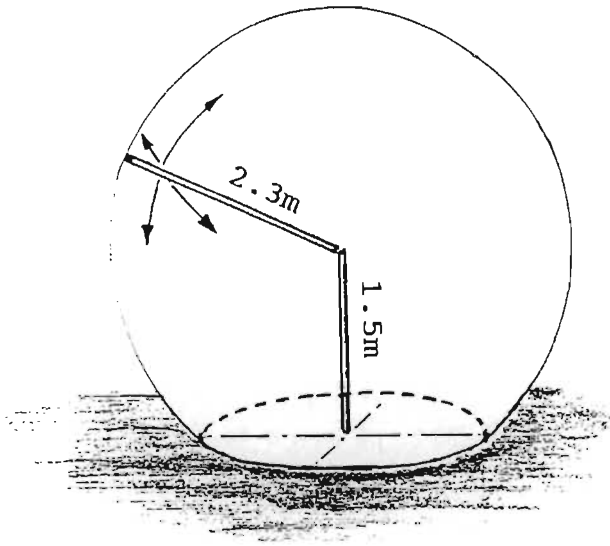
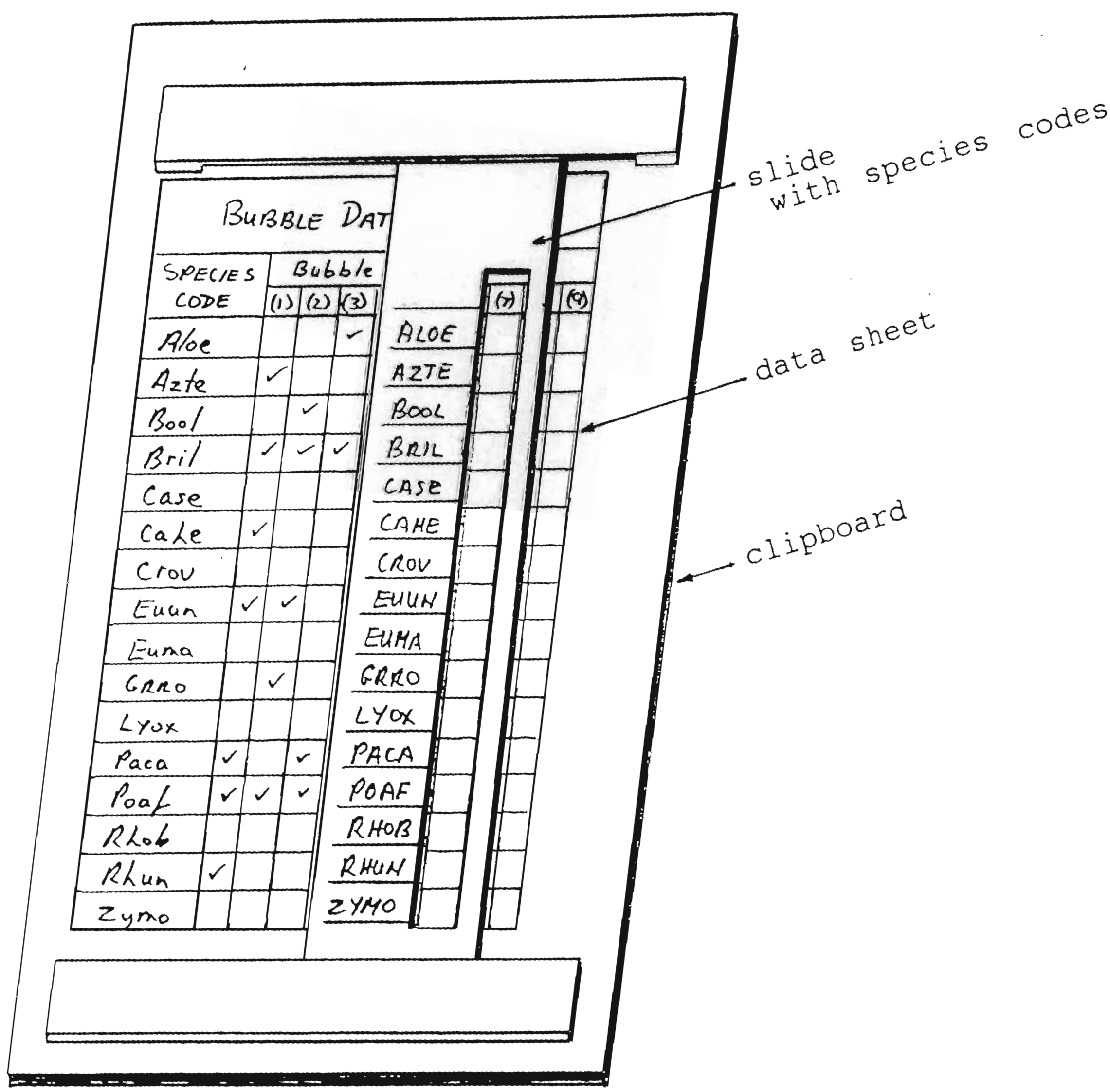


Figure 1

BUBBLE DATA SHEET

SPECIES CODE	Bubble Number								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Aloe									
Azte									
Bool									
Bril									
Case									
Cake									
Crov									
Euun									
Euma									
Grro									
Lyox									
Paca									
Poaf									
Rhob									
Rhun									
Zymo									

Figure 2



slide with species codes
data sheet
clipboard
BUBBLE DAT
SPECIES CODE
Bubble
(1) (2) (3)
Aloe
Azte
Bool
Bril
Case
CaLe
Crov
Euun
Euma
GRRO
Lyox
Paca
Poaf
RLob
RLun
Zymo
ALOE
AZTE
BOOL
BRIL
CASE
CAHE
CROV
EUUN
EUMA
GRRO
LYOX
PACA
POAF
RHOB
RHUN
ZYMO
(7)
(8)

Figure 3

THE 'BUBBLE' TECHNIQUE FOR SAMPLING KAFFRARIAN SUCCULENT THICKET: 2. EVALUATION OF FREQUENCY MEASUREMENTS

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ABSTRACT

This paper, second of a three part series, is aimed at evaluating the repeatability of the Bubble method's frequency derived measures of the vegetation. The method was evaluated with 'bubbles' placed at fixed (permanently marked) and random points.

At 72% of the fixed bubble points, all six operator pairs agreed on the presence or absence of a species. For fixed point monitoring, more than one operator should determine the presence of a species.

Species composition had high repeatability, especially if measured at fixed points. The improvement in repeatability with increasing sample size was initially extremely rapid and sampling more than five and 10 bubbles (for fixed and random bubble placements respectively) may not be worthy of the improved result. Using fixed sampling points is not generally recommended because of the problem of correlated variance, and the extra time and costs associated with marking and later finding the points. I suggest that for rapidly quantifying vegetation composition (relative frequency) for most vegetation community research efforts, 15 randomly placed bubble quadrats would probably be sufficient. This would provide a replicate similarity of c. 85% and take c. 75 man minutes. For pro-active adaptive management, however, this method is likely to be too tedious. For example, it will take well in excess of 4 hours to obtain a replicate similarity of 95%, even with fixed monitoring points.

INTRODUCTION

After devising a technique to survey this dense and tangled vegetation (see Part 1 of this series), it was necessary to test the repeatability of this new method. The objective was to evaluate the Bubble quadrat method and in particular, this paper aimed to test the repeatability of those parameters which are derived from <u>frequency</u> measures; i.e. the error about determining the frequency of occurrence of a species, or for example, determining species composition from relative frequency as

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opposed to relative density or cover. The analysis was conducted from two viewpoints:

i. the repeatability of various vegetation parameters measured at fixed Bubble quadrats (a technique for vegetation monitoring); and

ii. the repeatability of various vegetation parameters measured at randomly placed Bubble quadrats within a 2ha sample site (a technique for vegetation inventory and monitoring).

FIELD PROCEDURE

Fixed points repeatability

Ninety six fixed points in three different paddocks were randomly identified and marked with steel fencing standards driven into the ground. At each of these points, six operator pairs measured the vegetation parameters described in Part 1 of this series. The base of the iron standard was used as the fixed point and the basal leg of the 'bubble' apparatus was held vertically above this point (i.e. operators were told not to lie the 'upright-leg' of the apparatus against the pole).

This analysis was intended to shed light on the repeatability of using fixed monitoring points. The reason for this approach was that managers were anxious to monitor vegetation change and assumed that the most sensitive manner would be to have fixed points which are periodically returned to.

Random point repeatability

A 2 ha site was selected to represent vegetation in the central range of ecological status (see Stuart-Hill & Hobson 1991 for a definition of ecological status). Each operator 'placed' 50 randomly selected Bubble quadrats throughout the 2 ha area in a systematic random fashion.

The operators were encouraged to position each sampling point in an objective fashion, not to keep to paths. If the point was in the middle of a bush, then the base of the 'bubble' apparatus was lowered into the bush and the operator then walked around the bush, bringing the rotating leg along with him and recording all 'strikes'.

ANALYTICAL PROCEDURE AND RESULTS

REPEATABILITY OF RECORDING A SPECIES IN ONE FIXED BUBBLE

Analysis

Fourteen of the most common species were selected for this analysis (see Table 1). At each of the 96 fixed points, the degree of agreement between operators' estimates of presence or absence of a species was evaluated. Three categories of agreement were used: 100% agreement where all six operator teams had the same answer; 83% agreement where five of the six operator teams had the same answer; and ≤ 67% where four or fewer operator teams agreed. In this last category, only in very few cases were there less than four operators in agreement and for practical purposes this category can be assumed to represent 67% agreement.

Results

The degree of agreement between the six operators, per species, is presented in Table 1.

INSERT TABLE 1

Averaged over all species: there was 100% agreement at 69 of the 96 points (i.e. 72%); one operator was contrary to the rest at 18 of the 96 points (i.e. 19%); and 2 or more, at 9% of the sites.

REPEATABILITY OF SPECIES COMPOSITION (RELATIVE FREQUENCY)

Fixed bubble points

Analysis

The species lists obtained by each of the six operator teams at each of 24 randomly selected fixed points were compared by determining percentage similarity (PS) for each comparison (i.e. 15 operator comparisons by 24 points). The mean PS of the 15 operator comparisons was determined for the off-diagonal terms in a 6 x 6 similarity matrix for each of the 24 randomly selected fixed points (similar to the approach used by Hardy & Walker 1991). These were plotted against N = 1 to represent the repeatability of determining the species list at a single fixed point.

Where species composition (relative frequency) is to be obtained from more than one fixed point, a similar procedure to that described above was followed, except that the percentage composition from 6, 12, 24 and 48 fixed points (N) was determined for each of the six operator teams. Sixteen, eight, four and two randomly selected (without replacement) samples of 6, 12, 24 and 48 fixed points respectively, were drawn and the mean PS of the 15 operator comparisons was determined for the off-diagonal terms in a 6 x 6 similarity matrix for each sample. It follows that there were unequal numbers of samples to determine mean PS for each N but this was unavoidable as the random samples were drawn without replacement (which is a more rigorous routine than that used by Hardy and Walker 1991).

The mean PS's were plotted against increasing N, and a curve was fitted to reflect the average repeatability that could be expected.

Results

The relationships between repeatability of measuring species composition from increasing numbers of fixed points illustrated that, even at a single point, the repeatability was relatively good with a PS of 85.5% (± 6.6) and this improved to 92.5% (± 0.7) when species composition was determined from 48 fixed points (Figure 1). A replicate similarity of 90% was achieved with only c. 13 fixed points.

INSERT FIGURE 1

The poorest repeatability (replicate similarity) was 67% and the best 100%. The extremes were obtained when species composition was determined from a single fixed point. It is noteworthy, however, that repeatability of less than 70% occurred at only 6.7% of the replicate comparisons, and at c. 18% of these comparisons, repeatability of determining species composition was 100%.

Random bubble points

Analysis

Five sub-samples were drawn randomly from the 50 bubble quadrats that each team measured. These five (5, 10, 20, 30 and 40 bubble quadrats) together with all the bubble quadrats measured by the operator team (N = 50) represent increasing numbers of randomly placed bubble quadrats.

For each of these six samples, species composition (relative frequency) was determined so that six estimates of species composition were obtained per operator team, each reflecting an increasing number of bubble quadrats. The repeatability (PS) between the operators for each sample size was calculated, yielding a similarity matrix from which mean PS was determined. These were plotted against increasing sample size (numbers of bubble quadrats) to represent the repeatability of determining species composition from increasing numbers of bubble quadrats.

Results

There was a rapid initial improvement in replicate similarity so that after c. 10 bubble quadrats little improvement was obtained (Figure 2). It seems therefore, that at least 10 bubble quadrats should be placed for maximum efficiency but 15 would probably be safer. There was only a 5% improvement in replicate similarity with an increase from 15 to 50 bubble quadrats. The results are similar to those for fixed points (Figure 1) except that:

i) replicate similarity was c. 6% higher with fixed bubble quadrats (once the curves had 'stabilized'); and
ii) replicate similarity with fixed bubble quadrats was high even with very low numbers.

The latter is to be expected given that the operators resurvey the same bubble quadrats. However, the small improvement in replicate similarity with fixed bubble quadrats was rather surprising.

INSERT FIGURE 2

DISCUSSION AND CONCLUSIONS

The effectiveness of recording the presence of a species in a fixed bubble quadrat was rather disappointing, but should be tempered with the realisation that a disagreement by one of the six operators represents a 17% chance of being incorrect. Further, the operators were inexperienced, had a fairly extensive list of species and were allowed to record them in the order in which they saw them. I believe that these results reflect the worst case. With experienced operators, working with a limited species list in a fixed sequence, the repeatability should be greatly enhanced. However, for baseline surveys (the first survey in a monitoring programme) it would be safest to use more than one operator (recommend at least 3) and use consensus to determine the presence or absence of a species at a fixed point. Whether this effort is justifiable with respect to monitoring for proactive adaptive management, remains in question.

Determining species composition (i.e. relative frequency) was efficient with respect to simply quantifying change (i.e. for research purposes). While fixed bubble sampling points are necessary if very few sample points are taken, ultimately there was little difference between fixed or randomly placed bubble quadrats (c. 6% improvement in PS with fixed points). Establishing and later finding the fixed points may not be worth this improvement and rather than use fixed sampling points, it may be preferable (to avoid correlated variance and for reasons of efficiency) to simply increase the sampling frequency of random bubble points. However, having said that, it must be pointed out that 50 random bubbles (c. 250 man minutes) will yield a similar repeatability (i.e. PS=89%) as nine fixed bubbles (c. 45 man minutes plus initial establishment and searching time). It follows that users will ultimately have to decide, for themselves, which option is appropriate.

With efficiency in mind, 15 random bubble quadrats is probably adequate for most survey applications where the objective is to quantify the impact of some perturbation on the vegetation. This would provide a replicate similarity of c. 85% and take c. 75 man minutes. For pro-active adaptive management, however, this method is likely to be too tedious. For example it will take well in excess of 4 hours to obtain a PS of 95%, even with fixed monitoring points.

ACKNOWLEDGEMENTS

I am extremely grateful to the Department of Agriculture for financial support, F.O. Hobson for his considerable logistic support and in particular, my former colleagues who so cheerfully acted as operators.

REFERENCES

Stuart-Hill G.C. & Hobson F.O. 1991. An alternative approach to veld condition assessment in the non-grassveld regions of South Africa. J. Grassl. Soc. South. Afr. 8(4): 179-185.

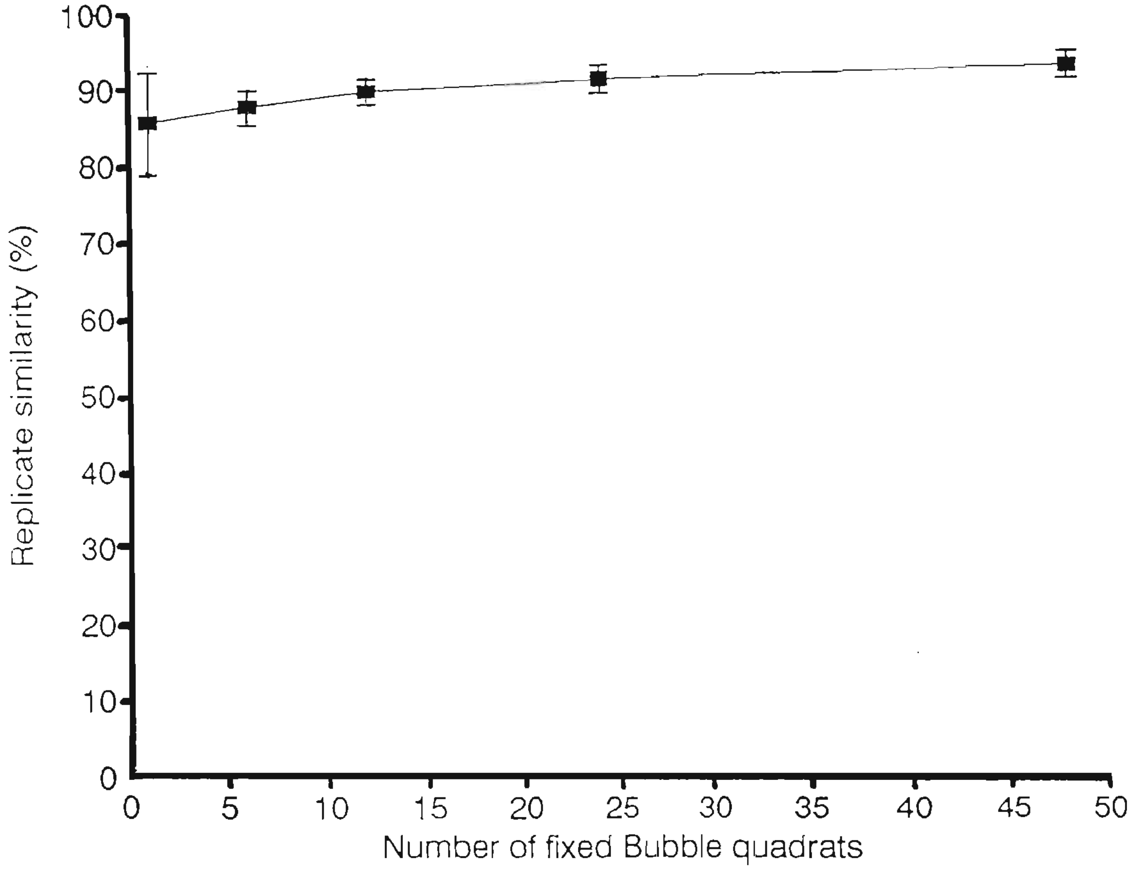
Table 1 The number of fixed points (out of 96) where all six operators agreed (100%); where five of the six operators agreed (83%); and where four or fewer of the six operators agreed (≥ 67%) on the presence or absence of a species.

Species	100%	83%	≥67%
Portulacaria afra	84	12	0
Euclea undulata	74	8	14
Maytenus spp.	56	24	16
Azima tetracantha	77	14	5
Schotia afra	67	11	18
Pappea capensis	70	20	6
Capparis sepiaria	54	31	10
Rhus undulata	57	27	13
Lycium oxycarpum	81	10	5
Crassula ovata	74	14	7
Euphorbia bothea	61	26	9
Grewia robusta	56	23	17
Eheritia rigidia	89	7	0
Protosparagus spp.	60	26	10
Mean	69	18	9
SE(X)	11.6	8.1	5.8

FIGURE CAPTIONS

Figure 1 Replicate similarity (percentage similarity) for determination of species composition (relative frequency) with increasing numbers of fixed bubble quadrats. Error was determined from repeated estimates made by six operator teams.

Figure 2 Replicate similarity (percentage similarity) for determining species composition (relative frequency) with increasing numbers of randomly placed bubble quadrats. Error was determined from repeated measurements made by six operator teams.



100
90
80
70
60
50
40
30
20
10
0
Replicate similarity (%)
0
5
10
15
20
25
30
35
40
45
50
Number of fixed Bubble quadrats

Figure 1

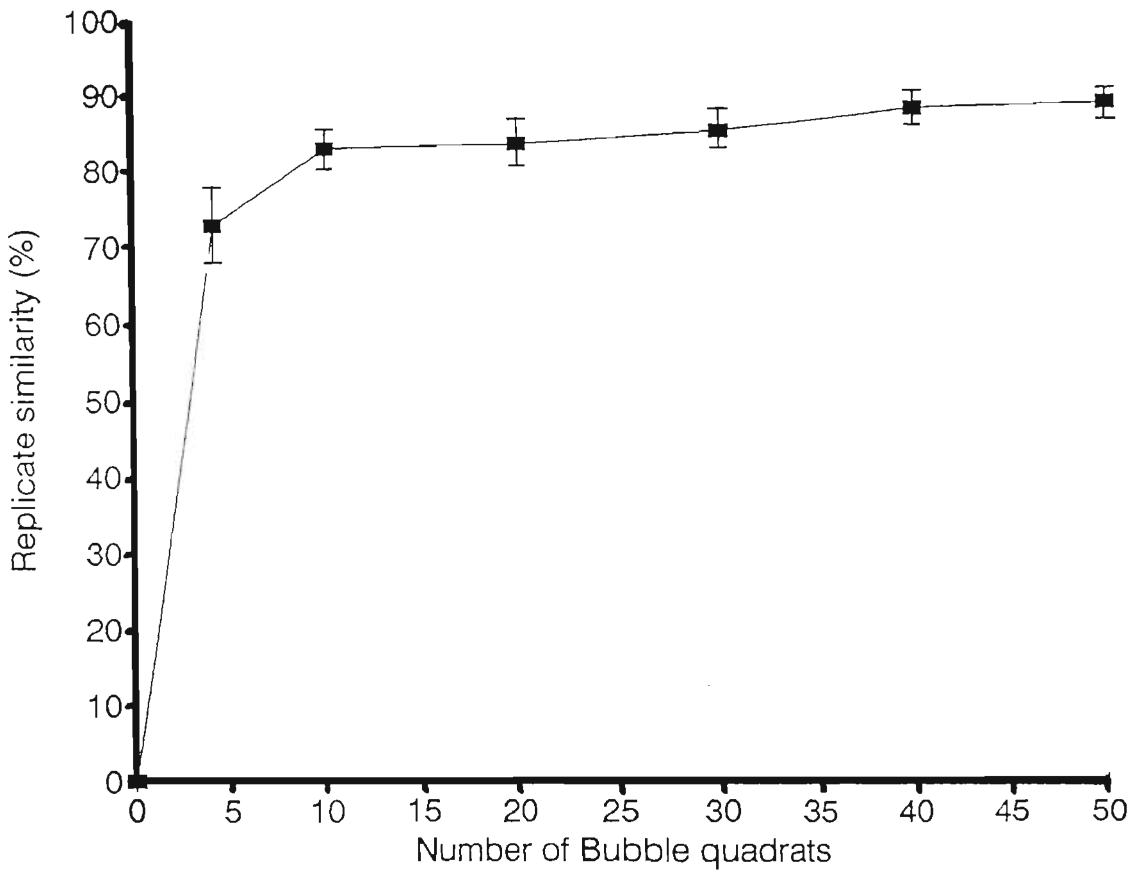

100
90
80
70
60
50
40
30
20
10
0
Replicate similarity (%)
0
5
10
15
20
25
30
35
40
45
50
Number of Bubble quadrats

Figure 2

THE 'BUBBLE' TECHNIQUE FOR SAMPLING KAFFRARIAN SUCCULENT THICKET: 3 EVALUATION OF COVER BASED MEASUREMENTS

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ABSTRACT

This paper, last of a three part series, aimed to evaluate the repeatability of the Bubble method's <u>cover</u> based measures of the vegetation. The method was evaluated with 'bubbles' placed at fixed and random points.

While it took on average c. seven man minutes per bubble sampled, the extra effort of obtaining the cover data (over and above the standard frequency data - Paper 2) took c. two of these minutes (i.e. translating into roughly a 40% increase in sampling effort).

Monitoring species cover at a single permanent bubble point was ineffective unless the mean estimate from multiple operators was used. Estimating cover of a species at a site generally, while moderately more repeatable, was not even sufficient to <u>detect</u> changes of c. 50%

Species composition (relative cover) had poor repeatability for random point placement but relatively good repeatability for fixed point repeatability.

Overall canopy cover could be estimated with equal precision with either fixed or random points and differences of c. 10% could be detected (P=0.05) from c. 25 bubble quadrats (an extra 50 man minutes).

While total canopy cover may be a useful attribute for monitoring depending on sampling resources, the cover derived measures for species were poorly repeatable and as a consequence, unsuitable for proactive adaptive management - or for that matter, even monitoring for research purposes. It follows that the extra sampling effort to rank species according to cover contribution is probably not worth the extra information yield.

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INTRODUCTION

After devising the bubble technique (see Part 1 of this series) and testing the frequency derived measures (Part 2), it remained to evaluate the repeatability of those parameters which are derived from <u>cover</u> measures; e.g. the error about determining overall shrub cover, the cover of a single species or determining species composition from relative cover as opposed to relative density or frequency.

As with Part 2, the analysis was conducted from two viewpoints:

i. the repeatability at fixed bubble quadrats (for vegetation monitoring); and
ii. the repeatability at randomly placed bubble quadrats (for vegetation inventory and monitoring).

FIELD PROCEDURE

The cover measurements (described in Part 1 of this series) were obtained from the same fixed and randomly selected bubble quadrats as described in Part 2 of the series.

The procedure is explained fully in Part 1 but essentially the species cover data are obtained in a manner similar to the approach of the dry weight rank method of (t'Mannetjie & Haydock 1963). The overall cover per bubble was estimated and the three most dominant species are ranked in terms of their contribution to cover. The conversion factors for the rankings respectively were 60% , 30% and 15% of total cover. All other species were assumed to be at 1% of total cover.

ANALYTICAL PROCEDURE AND RESULTS

REPEATABILITY OF ESTIMATING COVER OF A SPECIES AT ONE FIXED BUBBLE QUADRAT

Introduction

It may on occasion be necessary to monitor change in cover of a particular species at a single permanent sampling point. The intention of this section was, therefore, to determine the repeatability of estimating such a parameter. This evaluation was only performed on fixed bubble quadrats because random bubble sampling is not appropriate to in this instance.

Analysis

The cover per species, at each fixed bubble was determined from the rankings and correction factors developed previously (see Part 1).

The mean cover and SE(x) of each species, at each fixed point was determined from the six operator estimates. These were plotted against each other in a scatter plot to see if error of estimation changed with the actual cover of the species. If no change occurred with plants of different size (cover) then the mean SE(x) was to be determined (i.e. the data could be pooled) and the relationship between the repeatability of cover estimates per species and increasing numbers of quadrats was determined. If error of measurement changed with plant size (cover) then different relationships between repeatability and number of operators would have to be determined for each size (cover) category of plant.

Results

Apart from those plants which were un-ranked but present (i.e. contributing an assumed 1% of total cover) there was no consistent change in error of measurement with increasing plant size (measured by cover) (Figure 1).

INSERT FIGURE 1

This allowed for the data to be pooled and a single relationship to be determined describing repeatability of estimating cover of a species as a function of increasing numbers of operators (Figure 2).

INSERT FIGURE 2

The error in determining cover of a single ranked species in a fixed bubble quadrat with one operator is c. ± 4.5%. This is not very large for these plants which have large values for cover, but when looking at real cover values of approximately 5 to 20%, this error is excessively high in relative terms. Given that error decreases rapidly when using the mean from a number of operators' estimates (Figure 2) and that operators usually work in pairs, it is recommended that the mean estimate of at least two but preferably three or four operators be used when monitoring cover of a species at a single fixed bubble quadrat.

REPEATABILITY OF COVER OF A SINGLE SPECIES FROM MANY BUBBLES

Fixed Bubble Quadrats

Analysis

The mean cover (and SE(x)) of every species was determined for each operator over all 96 fixed bubble quadrats. For each species the highest of the six SE(x)'s was selected as representing the operator with the worst precision. These values were related to mean cover per species to see whether error in determining cover changed depending on actual cover. If a relationship existed, then it would be necessary to develop different relationships reflecting repeatability with increasing number of bubble quadrats, dependent on actual cover. If not, then a single relationship should be developed to represent repeatability for all species and plant sizes.

Results

There was a strong linear relationship between the error in measuring a species's cover and the actual cover of that species (Figure 3). Consequently, different relationships describing repeatability with increasing plant canopy size were developed (Figure 4). After c. 10 fixed bubble quadrats, the further decrease in error (of measuring cover per species) was so small as to not warrant the extra sampling effort. Although the error in measurement at this point was small (6 to 2% for real cover values of 25 and 5% respectively), these were large relative to actual cover (e.g. from approximately 24 to 40% respectively).

INSERT FIGURE 3

INSERT FIGURE 4

Random bubble quadrats

Analysis

Similarly as for fixed bubble quadrats.

Results

As with the fixed bubble quadrats there was a strong linear relationship between estimation error and the actual cover of that species (Figure 5). Similarly, different relationships describing repeatability with increasing plant size were developed (Figure 6).

INSERT FIGURE 5

INSERT FIGURE 6

In contrast to the fixed bubble quadrats where little improvement in error was obtained with more that 10 bubbles, error was still decreasing noticeably at 25 randomly placed bubbles, except for species with low cover (c. 5%) where improvement in error beyond 15 points was probably not worth the extra survey effort. Again the errors were rather small in absolute terms (at n = 25) ranging between 2 and 9% for real cover value of 5 and 25% respectively but represented relative errors of 40 and 36% respectively; i.e. cover would have to change well in excess of 50% for the technique to detect significant change.

REPEATABILITY OF DETERMINING SPECIES COMPOSITION (RELATIVE COVER)

Analysis: Fixed bubble quadrats

The repeatability of estimating species composition (relative cover) was evaluated by drawing random samples of increasing sizes, determining composition (relative cover) and calculating the average replicate similarity between operators.

Analysis: Random bubble quadrats

The repeatability of estimating species composition (relative cover) was determined by drawing random samples of size 50, 25 and 12 bubbles and after determining species composition (relative cover), the average replicate similarity for these three sample sizes was calculated and plotted against sampling intensity.

Results

The similarity of species composition (relative cover) using fixed quadrats was as expected, significantly better than that derived from randomly placed bubble quadrats (Figure 7). Sampling more than 12 fixed bubble quadrats is not worth the resulting increase in replicate similarity and even with 50 randomly placed bubbles, replicate similarity only just reached 80%.

It follows that if species composition (by relative cover) is to be monitored then fixed points would be preferable to using random points despite the statistical shortcomings of monitoring at fixed sampling locations.

INSERT FIGURE 7

REPEATABILITY OF DETERMINING TOTAL SHRUB COVER

Using fixed bubble quadrats

Analysis

The mean and SE (x) of the six operator estimates of total cover for each of the 96 fixed points was determined. These were plotted against each other to see whether there was a relationship between total cover and the error of measuring the parameter; i.e. was the repeatability of operators influenced by the amount of cover? If not, then it is legitimate to determine an estimate of error from all of the data combined; if there is a relationship, then separate estimates of error need to be made for each cover category.

The greatest, smallest and average SE's were selected from the 96 possibilities to represent respectively, the worst, best and average repeatability of estimating total cover at a single fixed point. From these values, three curves were developed to reflect SE(mean) with increasing numbers of operators at a single fixed point; to represent the worst, best and average error in estimating cover if the mean estimates from more than one operator were to be used.

In addition a relationship between error and increasing numbers of points was developed for determining the repeatability of estimating total cover with fixed points (using a single operator).

Results

There was no relationship between cover and the error in estimating total cover; i.e. operator precision did not change with cover (Figure 8). As such there was no reason to determine repeatability for various cover values and the data were pooled to determine the error of a single observation (± 18.09%). This was used to develop a relationship between increasing sampling intensity and sampling error (Figure 9).

Even in the worst instance (the fixed points where the difference in the operators estimates was greatest) repeatability of estimating total cover at a single point with a single operator was below 10% (Figure 10). On average, it was below 6% and in the best case below 2%. Using the mean from multiple operators did not greatly increase precision other than in the worst site where using two operators would reduce error by c. 30%.

It would seem that estimating total cover at fixed points is highly repeatable and that a single operator on approximately 25 fixed bubble points (Figure 9) would be adequate for monitoring a 10% change in cover (P=0.05).

INSERT FIGURE 8

INSERT FIGURE 9

INSERT FIGURE 10

The mean total cover estimate for each of the three camps as determined by each operator team are presented in Table 1.

INSERT TABLE 1

The SE (x) of determining % cover in each of the three camps was exceedingly small and on average an error of only 3.3% may be expected given the number of points sampled. This verifies Figure 9 which predicts c. 3.6% and 2.6% for n=24 and 48 respectively.

Using random bubble quadrats

Analysis

The total cover estimates at all 300 bubble quadrats (six operators x 50 bubble quadrats each were pooled and the mean and SE (x) determined. The SE (x) was then used to derive a relationship between error of estimating mean cover with increasing numbers of bubble quadrats (placed in a systematic random manner).

Results

As with the fixed bubble quadrats, there is little point in determining total cover from more than 25 bubbles (Figure 11) and at that sampling intensity, random placement of bubbles increases SE (mean) by less than 0.5% (compare Figure 9 and 11). It follows that there is little point in going to the expense and trouble of using fixed positions for monitoring total shrub cover.

A means of checking the above is to compare the estimates of cover made by the six operators. This was done by randomly selecting 25 (half of the) bubble quadrats from each operator's data and determining total shrub cover. These results are presented in Table 2.

INSERT TABLE 2

The SE (x) of determining total shrub cover with the different operators was 4.5 and this compares favourably with the predictions of Figure 11.

INSERT FIGURE 11

DISCUSSION AND CONCLUSIONS

While it took on average c. seven man minutes to sample each bubble fully, only c. two of these minutes were due to the extra effort of obtaining the cover data. This translates into roughly a 40% increase in sampling effort to obtain the cover data.

The error in monitoring species cover at a single permanent bubble point was c. ± 4.5% and this is judged to be excessively large relative to the actual cover values. It is recommended that, if this attribute is required (e.g. monitoring species cover at permanent points), then multiple operators should be used and their mean estimate used.

Estimating cover of a species generally with either fixed or random bubble points, was moderately more repeatable than measuring a species at a single monitoring point (error relative to actual cover ranged between 24 and 40%). However, even this improvement was not sufficient to detect changes of less than c. 50%, regardless of sampling intensity.

Species composition (relative cover) had poor repeatability for random point placement but relatively good repeatability for fixed point repeatability. Approximately 12 fixed bubble points (i.e. 84 man minutes) could be used to monitor species composition change with a replicate similarity of c. 85%. This would take a total (excluding initial marking of the sampling point), of c. 84 man minutes but if the frequency data were also required then this translates to an extra 24 man minutes of sampling effort.

Overall canopy cover could be estimated with equal precision with either fixed or random points. Differences of c. 10% could be detected (P=0.05) from 25 bubble quadrats meaning that relative changes in total shrub cover of less than 20% can be detected with this degree of sampling. This would require c. 175 man minutes but as mentioned previously it would add an extra 50 man minutes to any frequency based sampling at this intensity level.

It appears that the extra sampling effort required to obtain cover data with the bubble method is probably not worth the extra information it will yield. This effort would be better spent in increasing sampling for the basic frequency derived measures of the vegetation (Part 2).

ACKNOWLEDGEMENTS

I am extremely grateful to the Department of Agriculture for financial support, F.O. Hobson for his considerable logistic support and in particular, my former colleagues who so cheerfully acted as operators.

REFERENCES

t'Mannetje L. & Haydock K.P. 1963. The dry-weight-rank method for the botanical analysis of pasture. J. British Grassl. Soc. 18: 268-275.

Table 1 Mean % canopy cover at fixed points in three camps as estimated by six operator teams (n is number of points).

		Team number							
Camp name	n	1	2	3	4	5	6	Mean	SE(x)
Brakkefontein	24	66	67	74	69	68	61	68	4.0
Piekniekplek	24	63	66	64	66	66	63	65	1.6
Koedoekamp	48	60	57	64	67	66	57	62	4.4
								Mean	3.3

Table 2 Mean % canopy cover from 25 random bubble quadrats as determined by six operator teams.

	Team number 1	2	3	4	5	6	Mean	SE(x)
Mean cover	50	49	56	52	57	43	51	4.5
SE (mean)	11	15	21	21	21	18	-	-

FIGURE CAPTIONS

Figure 1. A scattergraph illustrating no relationship between the error in determining cover of a single species and 'actual' cover (plant size) of that species using a single fixed bubble quadrat. 'Actual' cover was estimated as the average of the six operator estimates.

Figure 2. The repeatability of determining cover of a single ranked species at one fixed bubble position with different numbers of operators.

Figure 3. The relationship between 'actual' cover and the error in measuring cover of a single species using fixed bubble quadrats. 'Actual' cover was estimated as the average of the six operator estimates.

Figure 4. The repeatability of determining cover of a single species from increasing numbers of <u>fixed</u> bubble quadrats. The four curves represent the repeatability for plants with actual cover values of 25, 20, 15 and 5%.

Figure 5. The relationship between actual cover and the error in measuring cover of a single species using random bubble quadrats.

Figure 6. The repeatability of determining cover of a single species from increasing numbers of <u>randomly</u> placed bubble quadrats. The four curves represent the repeatability for plants with actual cover values of 25, 20, 15 and 5%.

Figure 7. Replicate similarity (percentage similarity) for determining species composition (cover derived) with increasing numbers of randomly placed (- - - -) and fixed(————) bubble quadrats. Error was determined form repeated estimates made by six operator teams.

Figure 8. The lack of a relationship between average total shrub cover and the error in estimating cover from six operator teams at each of 96 fixed bubble points.

Figure 9. The repeatability of determining total shrub cover from increasing numbers of <u>fixed</u> bubble quadrats, where a single operator estimates cover at each sampling point.

Figure 10. The error in determining total shrub cover at a single fixed point by using the mean value derived from increasing numbers of operators. The three curves were selected from a total of 96 to reflect the best, average and worst case scenarios.

Figure 11. The repeatability of determining total shrub cover from increasing numbers of <u>randomly</u> placed bubble quadrats, where a single operator estimates cover at each sampling point.

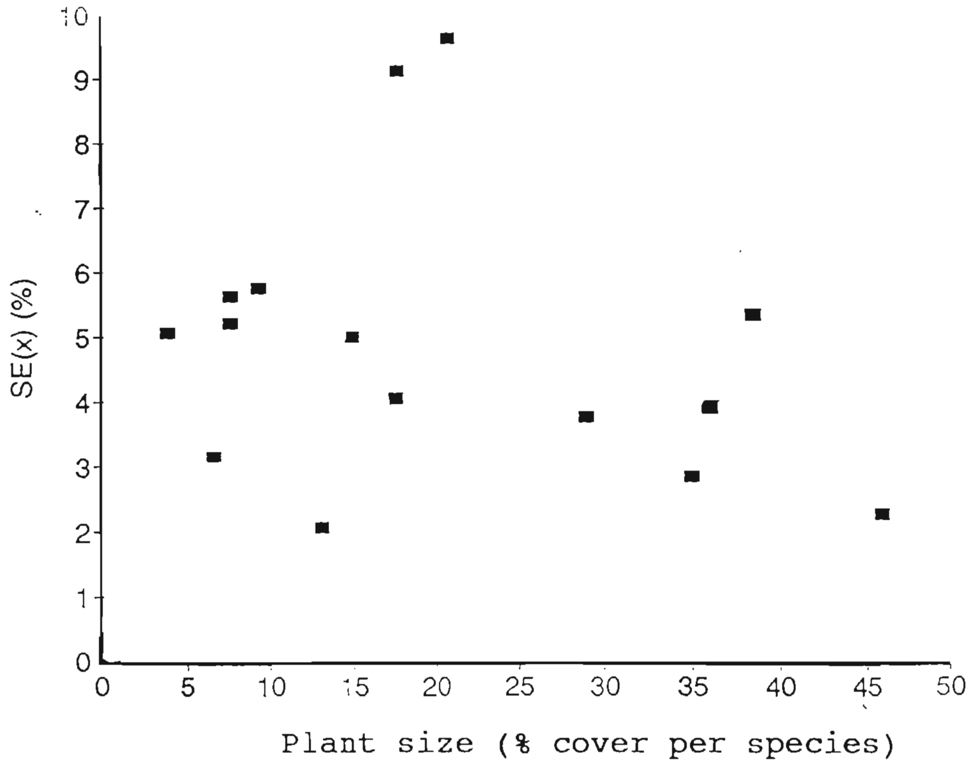
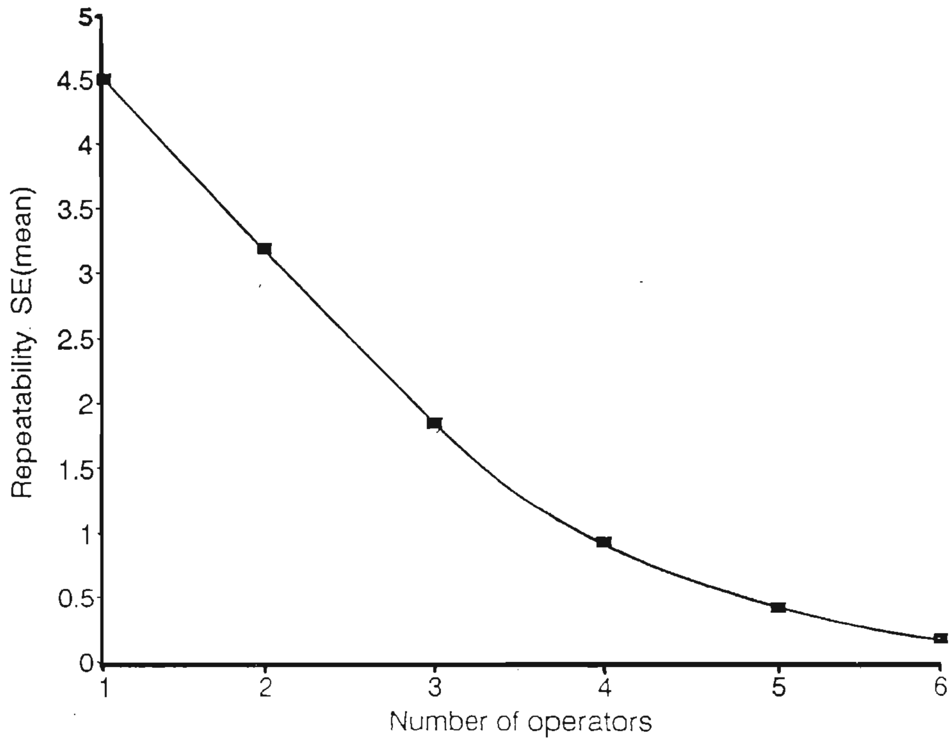

SE(x) (%)
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30
35
40
45
50
Plant size (% cover per species)

Figure 1



5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Repeatability. SE(mean)
1
2
3
4
5
6
Number of operators

Figure 2

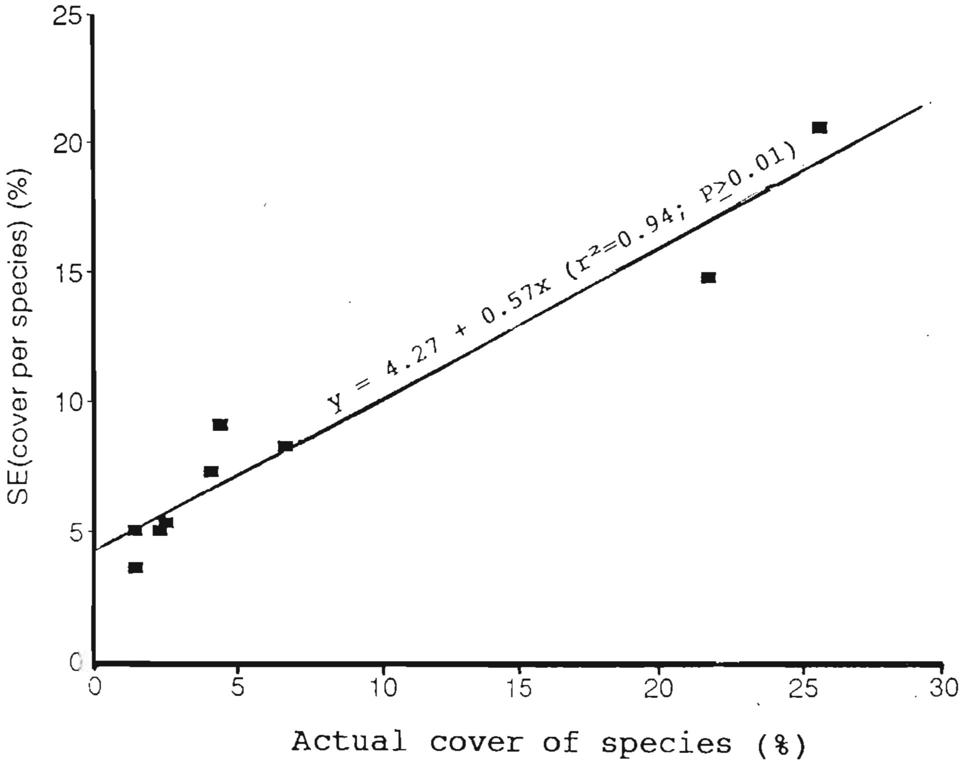

25
20
15
10
5
0
0
5
10
15
20
25
30
SE(cover per species) (%)
Actual cover of species (%)
Y = 4.27 + 0.57x (r²=0.94; P≥0.01)

Figure 3

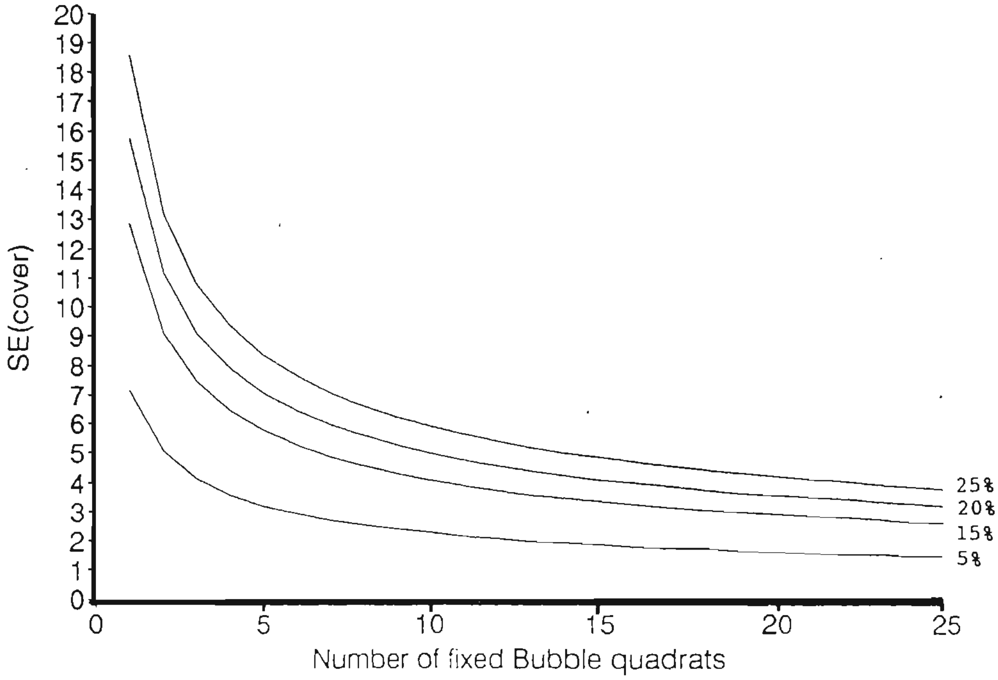
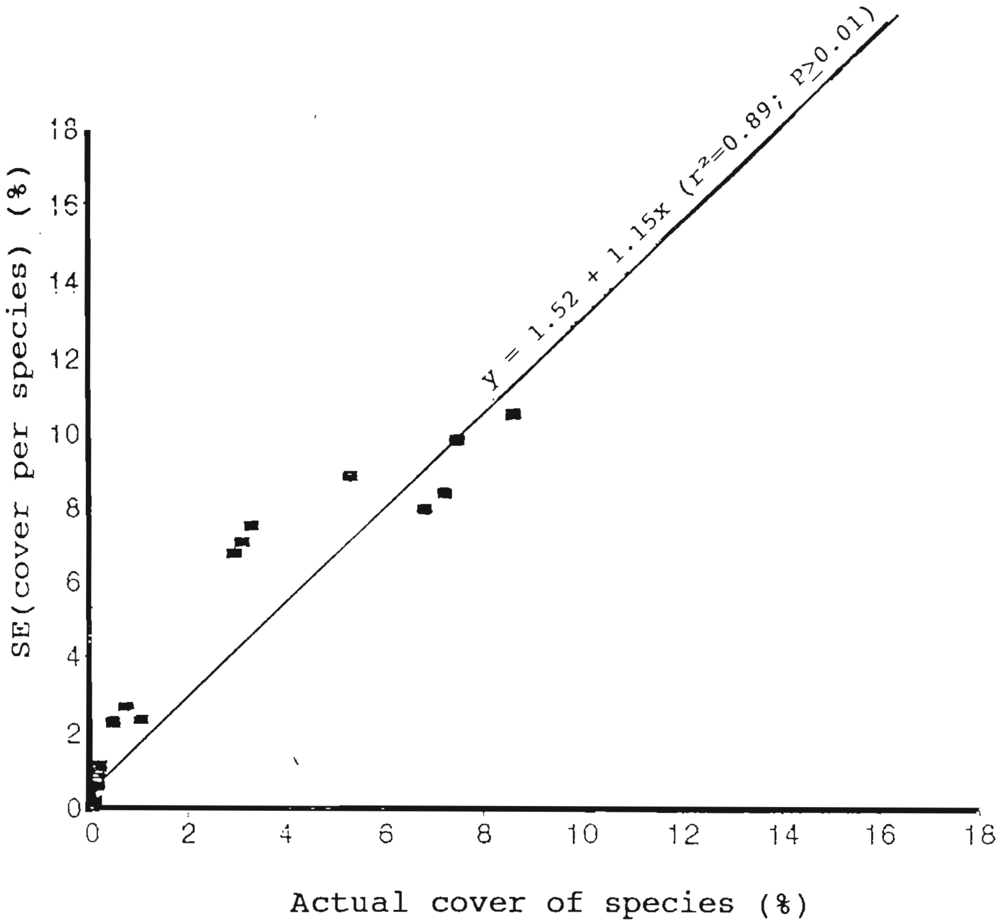

SE(cover)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
5
10
15
20
25
Number of fixed Bubble quadrats
25%
20%
15%
5%

Figure 4



y = 1.52 + 1.15x (r²=0.89; P≥0.01)
SE(cover per species) (%)
Actual cover of species (%)
0
2
4
6
8
10
12
14
16
18

Figure 5

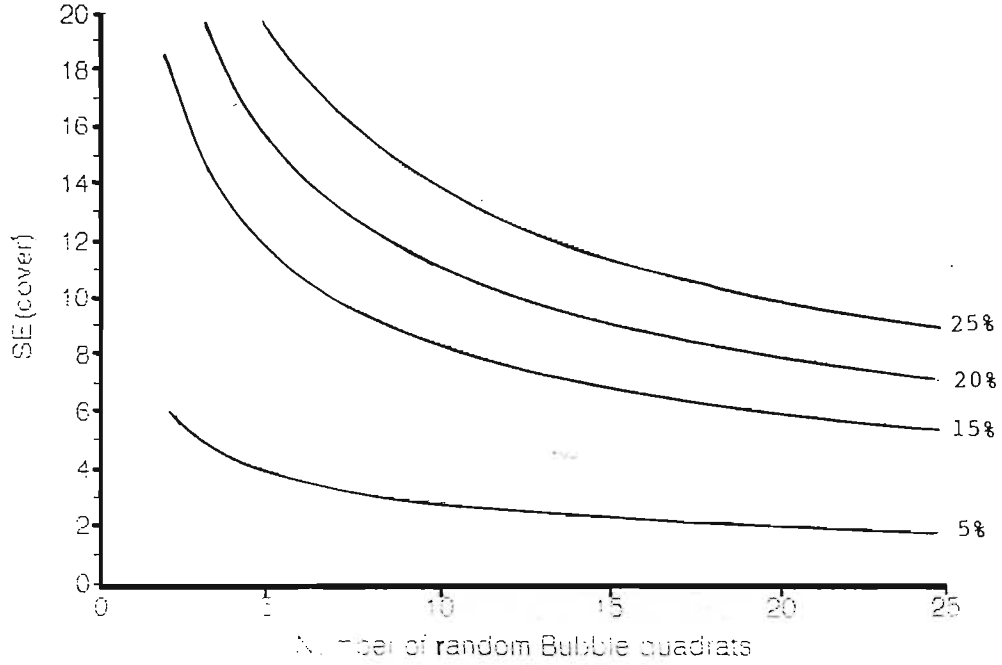


Figure 6

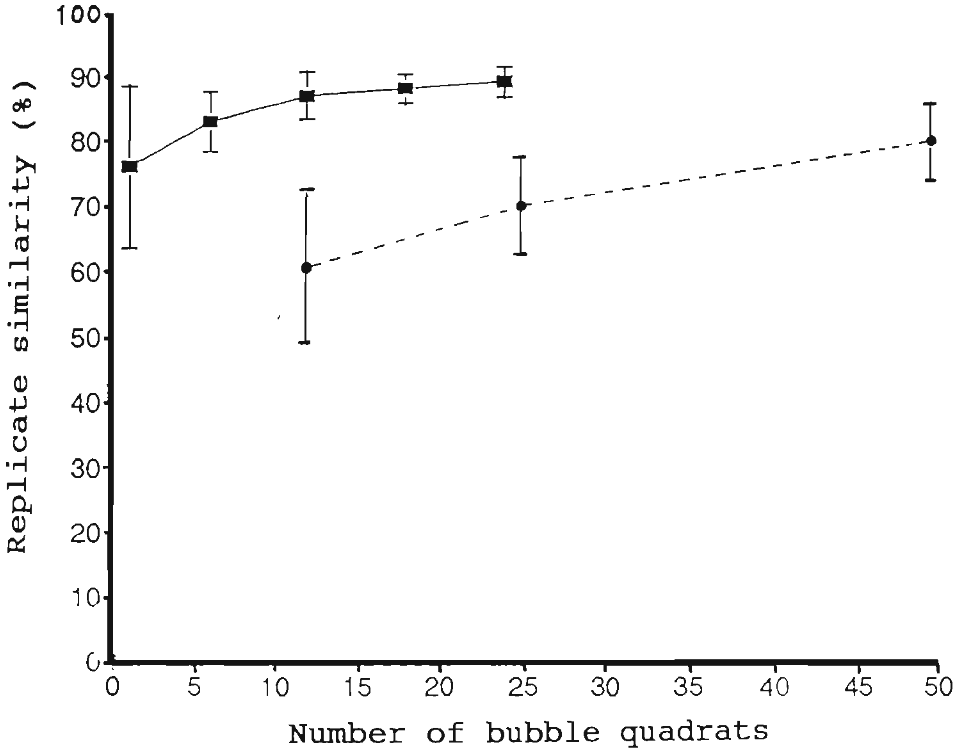

Replicate similarity (%)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50
Number of bubble quadrats

Figure 7

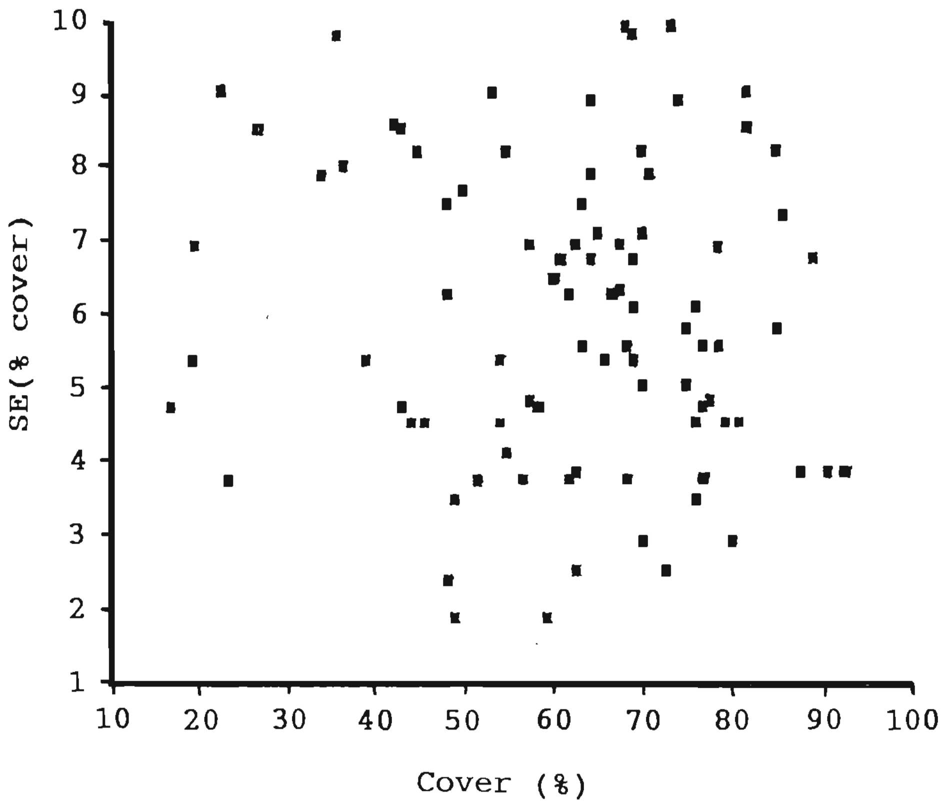


Figure 8

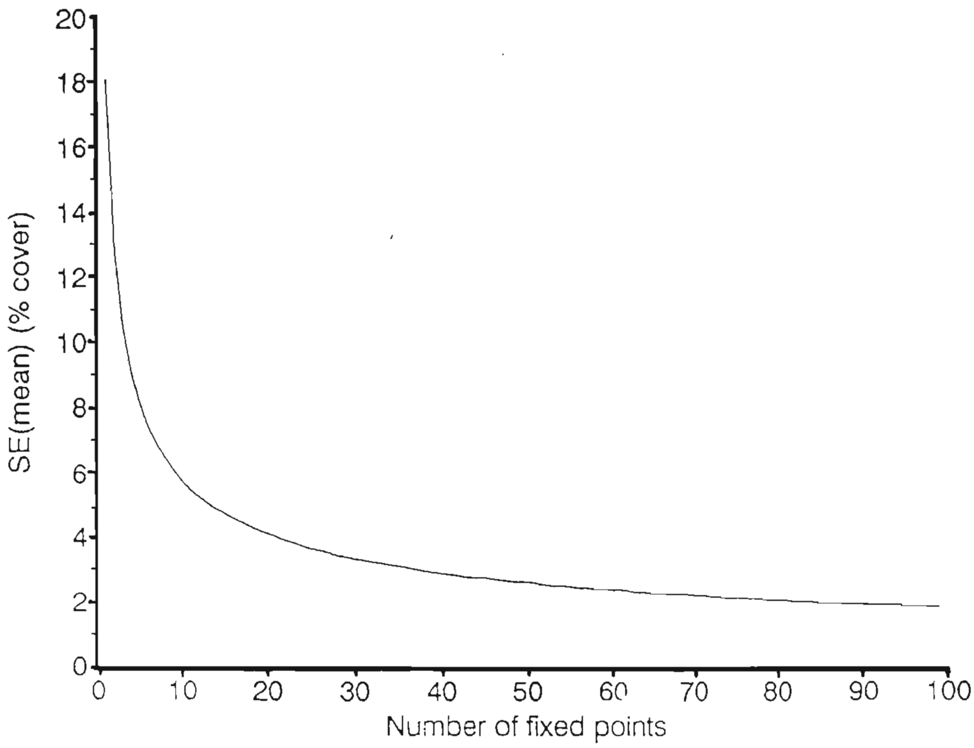

SE(mean) (% cover)
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100
Number of fixed points

Figure 9

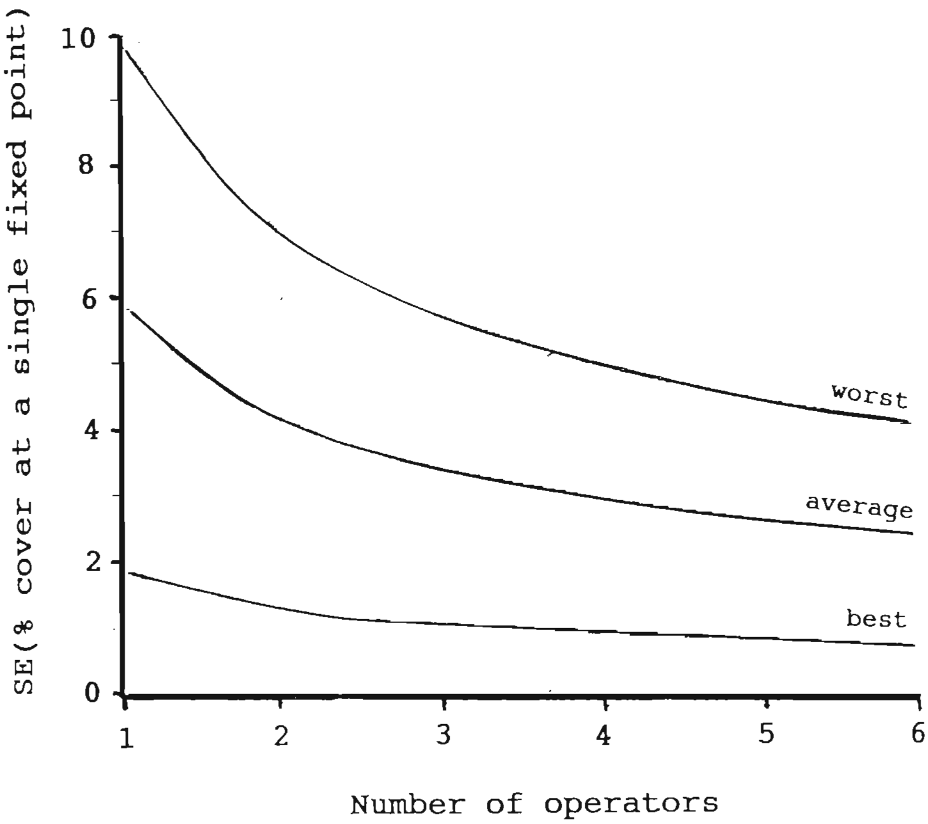
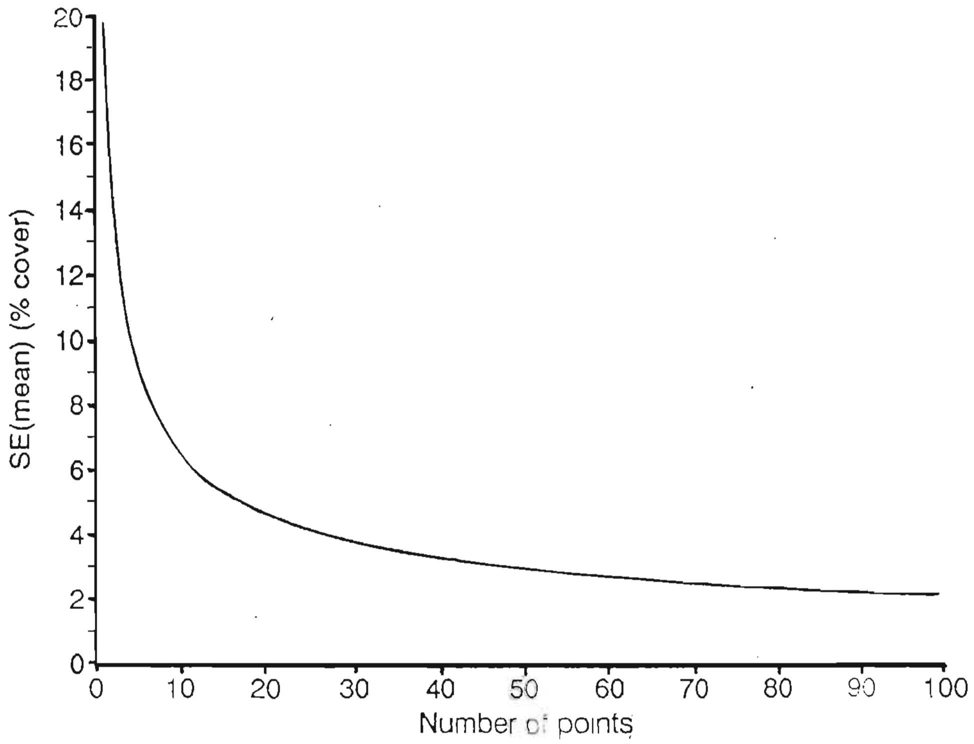

SE(% cover at a single fixed point)
10
8
6
4
2
0
1
2
3
4
5
6
Number of operators
worst
average
best

Figure 10



SE(mean) (% cover)
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
Number of points

Figure 11

VEGETATION MONITORING IN SOUTH AFRICA: IS A PARADIGM SHIFT REQUIRED ?

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ABSTRACT

Vegetation monitoring in South Africa has a poor success record. There is no State monitoring programme despite decades of expenditure (of public funds) on research, extension, subsidies and legislation. Current monitoring techniques for land managers are inappropriate because they are either too complicated, tedious or insensitive for pro-active adaptive management. Only researchers have useful monitoring techniques, but even here, serious scientific 'sins' are regularly committed.

I suggest that this state of affairs is due to incompetent management of environmental agencies, inadequate funding for monitoring programmes, and importantly, because scientists are operating from a single, often inappropriate paradigm. This is one of using objective botanical survey methods, but varying sampling intensity for different users to achieve the appropriate repeatability.

I argue that we need a paradigm shift, for example by employing visual methods for large scale monitoring and using the state of individual plants for farm scale monitoring. Essentially we need to break from the pre-occupation with objective species composition measurements in small research plots.

INTRODUCTION

I have approached this paper by summarising my own perceptions of the state of monitoring in South Africa, especially in relation to user involvement. I emphasis that this is my interpretation and I acknowledge that the critique is done with the benefit of hindsight; an advantage which the various researchers did not have.

Vegetation monitoring and assessment in South Africa have had confused histories and consequently it is not possible to review local monitoring efforts without first understanding the relationship between these two closely related but independent efforts.

Vegetation assessment

Stuart-Hill and Hobson (1991) defined assessment as a once-off evaluation of the vegetation with the express objective of providing information for management and planning (e.g. setting sustainable stocking rates, evaluating erosion hazard, siting fences to separate vegetation with different management requirements, assessing the potential for various enterprises). Range condition assessment is, therefore, a form of vegetation inventory where 'condition' is an index of the current state of the range (in terms of species composition and structure).

Much debate has centred around the concept of range condition which was considered to index the "state of health" of the vegetation; i.e. what the vegetation should be like under normal climate and optimum management (Bailey 1945; Parker 1954; Short & Woolfolk 1956; Tueller & Blackburn 1974; Tainton 1981). Managers were encouraged to strive for this state because this allegedly corresponded to minimal soil loss and maximum carrying capacity (Tainton 1981). Aside from the obvious difficulty of defining 'normal climate', 'optimum management' and 'healthy range', there is a philosophical shortcoming with 'rangecondition' which scientist (especially locally) have neglected. The different states that the vegetation can assume, are not all equal, and land users with different interests have different concepts of 'ideal' vegetation; 'range condition' incorporates a value judgement. It follows that there is no one ideal state for rangeland.

Attempting to alleviate this problem, Stuart-Hill and Hobson (1991) proposed that condition should simply be a descriptive index which conveys multivariate information about the current state of the vegetation at a site; the same principle as using a cows's breed, sex or age (all descriptive indices) to convey multivariate information about that animal to which different people can attach a value judgement. It follows that each land user should use the same descriptive index but interpret it differently depending on their viewpoints/objectives. They proposed that a sample site should be assessed in terms of its similarity (floristically or structurally) to all other sites, and its position in multivariate space should be the index (or 'condition') which inherently describes the state of the vegetation. It is without value judgement.

Vegetation monitoring

Mentis (1984) formally defined monitoring as "the maintenance of regular surveillance to test the null hypothesis of no change". Simply, this means repeated measurements of relevant ecosystem characteristics to detect change and record events. Monitoring, on its own will not provide reasons for change, but merely record it.

The 'confusion' between monitoring and assessment

The first survey efforts were implicitly aimed at monitoring the vegetation as can be seen by the preponderance of permanently marked sites in early monitoring efforts (unpublished data by Roux in the Karoo). However, in attempting to develop a system to index the current state of the vegetation (which I suppose would ultimately have been used to communicate multivariate change in a univariate sense), researchers got involved with concepts such as range condition. A host of techniques evolved which Hurt (1989) broadly classified into two philosophies: viz an ecological approach (based on successional theory) and a forage production approach. As discussed previously, condition is fraught with pitfalls, but for monitoring, the biggest problem was that the researchers concentrated on the concept and development of the index itself, and neglected the repeatability of the survey technique. This was particularly serious where the intended users were not researchers. Agronomic indices, ecological indices and hundreds of species response curves have been developed under the research banner of vegetation monitoring, but even collectively, these have contributed little to monitoring in South Africa.

A Vegetation Monitoring Workteam was formulated in the early 1980's by the CSIR and after considerable academic gymnastics, concentrating on the philosophy and theory of monitoring, an advisory system was produced whereby monitoring procedures tailored to local objectives and conditions could be developed (Mentis 1984). This extremely useful product was encapsulated in an expert system (Mentis et al. 1989) but it concentrated on the monitoring requirements of professionals (i.e. researchers) (Mentis 1989). Despite the 'bigger picture' covered by the expert system, research efforts guided by this workteam essentially operated within the paradigm of objective species composition measurement in small plots (<1ha) (see the papers by Bosch, Holton and Walker in Mentis 1989). Furthermore, the philosophy was to develop relationships between sampling effort and sampling error (or replicate similarity) so that, by defining apriori a level of precision suitable for their requirements, users could then determine what sampling effort would be required. Researchers seem to have 'locked-onto' this, and implicit in recommendations coming from this paradigm is that the same botanical sampling techniques should be used by all users but at different sampling intensities depending on the required precision.

While many important lessons have been learned from this workteam, national and farm scale monitoring has not progressed. The unwritten (and somewhat malicious) allegation of some, is that in debating the theory of monitoring, we have lost a decade of opportunity.

MONITORING IN SOUTH AFRICA

Of great importance with monitoring is the objectives of the users of the data. Hardy and Stuart-Hill (in prep.) suggested various monitoring requirements for South Africa from which I have identified the following users.

i. National and Regional governments
ii. Land Mangers
iii. Researchers

Each of these users has different objectives and these impact on the temporal and spacial scales of the required monitoring programme.

National and Regional governments

Briefly, governments are concerned with the change in vegetation communities at a sub-continental and regional scale. This needs to be considered at a decade-type time scale, except where large episodic events (droughts/floods) massively and suddenly impact on the vegetation. Government responsibility is to the people of the country. They need to monitor to evaluate the success of their costly environmental policies, inform the public of adverse vegetation trends and respond to the changes by policy decisions involving perhaps legislation or incentives. Despite the expenditure of billions of public rands (over the past 70 years) on research, extension, education and subsidies, South Africa still has no scientifically sound national monitoring facility for its rangelands. This is inexcusable especially when seen against the persistent and often dogmatic claims that the vegetation in the country is being degraded through pastoral use.

Recently, the first serious attempts are being made to establish a national vegetation monitoring programme but funding for this is not in proportion to the size of the task, or the expenditure on research and expenditure. I believe further, that a major constraint to this endeavour is that the approach proposed by local scientists is not appropriate to the scale of the monitoring task. All proposals appear to be operating from the botanical research paradigm which revolves around objective survey of species composition within small plots (<1ha).

Environmental agencies (e.g. Dept. Agriculture, Water Affairs and Conservation bodies) are responsible for the land under their control and consequently are directly responsible for the monitoring programmes. Of these, only certain conservation agencies in a few National Parks have any monitoring programme. As yet, none of these have been directly responsible for any change in management policy. The Department of Agriculture has funded many research projects concentrating on vegetation monitoring but, save for a few individual researchers, there has never been any significant and honest attempt (until recently) to address the national and regional monitoring requirement. The failure of sub-continental and regional monitoring in South Africa could perhaps be blamed on the succession of Departmental heads who have not had the necessary insight to realise the significance of monitoring the effectiveness of their Department's efforts.

Land Managers

Land Managers (farmers and wardens of National Parks and dam catchments) need to know how successful their management has been in terms of achieving their objectives. The more advanced officially subscribe to adaptive management (Walters & Hilborn, 1978) where vegetation monitoring is a means of measuring goal attainment (Mentis 1980). Much research in South Africa has concentrated on providing monitoring techniques for managers, but these were never used. Two reasons have been given for the lack of manager adoption:

i. the survey methods were too tedious for busy managers; and
ii a relatively high degree of computational and species identification skill was required.

Various authors tackled these problems (Mentis 1983; Heard et al. 1986; Wills & Trollope 1987; Hurt & Hardy 1989), resulting in the development of various key species methods (i.e. where only a limited number of highly sensitive species are monitored with reduced numbers of sample points).

Despite these modifications, my observation is that few land managers are using any of these techniques, and none are acting on the information received from such programmes. I submit that this is because the implicit assumption has been that managers require a less sensitive monitoring technique than researchers (Hardy & Walker 1991). The proponents of reduced sampling and the key species approaches have been happy to settle for a less sensitive technique in their efforts to address the problems of efficiency and skill limitations.

I argue, however, that land managers need the most sensitive monitoring techniques of all (even researchers). This is because managers need to be pro-active and adapt their management before irreparable damage occurs. People have assumed that because managers seek an 'quick and easy' method, they will be happy with a less sensitive technique.

In a number of studies testing various survey methods, Stuart-Hill (in prep: a,b,c,d) concluded that all of these methods were too tedious or unreliable for pro-active farm scale monitoring in Succulent bushveld (Stuart-Hill in prep: e). The reason for this is that their very nature depends on the death (or severe reduction in size) of individual plants. To a land user, this is not sufficiently sensitive as he needs to take action before losing valuable plants. I suggest that all of the 'conventional botanical' methods used in South Africa will, on critical analysis, suffer the same defect.

Researchers

Researchers, contrary to popular belief, do not generally require the most sensitive monitoring technique. This is because they usually merely seek to quantify the response of some applied treatment; i.e. they are not normally interested in being warned of impending change. What researchers usually require, however, is a full description of change and inevitably the monitoring technique must produce multivariate data.

Research monitoring techniques in South Africa are, in my opinion, usually satisfactory. No doubt due to the individual researchers ensuring that the techniques they use will give them the information they require. However, there are shortcomings and these usually are concerned with researchers who claim change without knowing the technique's inherent repeatability, and importantly, using proportional species composition in areas where vegetation change is density dependent and proportional composition is meaningless, at best (Stuart-Hill 1989).

CONCLUSIONS

I suggest that the lack of successful monitoring programmes in South Africa, especially at the Regional and farm scale, is as a result of incompetent management of environmental agencies and inadequate funding for monitoring programmes. In addition I believe that scientists are operating from an inappropriate research orientated paradigm; that of using objective botanical survey methods, but varying sampling intensity to meet the requirements of the different users.

We need to think laterally and break from the pre-occupation with objective species composition measurements in small research plots, especially for regional and farm scale monitoring. A paradigm shift is required. For example, by perhaps employing visual methods for large scale monitoring, and monitoring attributes of individual plants which give early warning of their imminent demise. Examples of the latter could possibly be monitoring the degree of 'skirting' exhibited by <u>Portulacaria afra</u> (Stuart-Hill 1992) or the aerial tillering phenomenon observed in <u>Themeda triandra</u> (Tainton 1981).

REFERENCES

Bailey R.W. 1945. Determining trend of watershed condition essential to success in management. <u>J. Forestry</u> 43: 733-737.

Hardy M.B. & Walker R.S. 1991. Determining sample size for assessing species composition in grassland. <u>J. Grassl. Soc. South. Afr.</u> 8(2): 70-73.

Heard C.A.H. Tainton N.M. Clayton J. & Hardy M.B. 1986. A comparison of five methods for assessing veld condition in the Natal Midlands. <u>J. Grassl. Soc. South. Afr.</u> 3(3): 70-76.

Hurt C.R. 1989. Relationships between range condition score and long term stocking rates applied to two vegetation types in Natal. M.Sc. Agric. thesis, Univ. Natal.

Hurt C.R. & Hardy M.B. 1989. A weighted key species method for monitoring changes in species composition. J. Grassl. Soc. South. Afr. 6: 109-113.

Mentis M.T. 1980. Towards scientific management of terrestrial ecosystems. S. A. J. Science. 76: 536-540.

Mentis M.T. 1983. Towards objective veld condition assessment. Proc. Grassld Soc. sth. Afr. 18: 77-80.

Mentis M.T. 1984. Monitoring in South African Grasslands. S. Afr. Nat. Sci. Programmes Report. No 19, CSIR, Pretoria.

Mentis M.T. 1989. Vegetation monitoring workshop III. Occasional Report. No 39, CSIR, Pretoria.

Mentis M.T., Starfield A.M., Brockett, B.H. Coombes P.J., Randall L.A., Stalmans M., Walker R.S. & Wills A. 1989. Knowledge-base for expert system on planning vegetation monitoring. In: Monitoring in South African Grasslands. S. Afr. Nat. Sci. Programmes Report. No 19, CSIR, Pretoria.

Parker K.W. 1954. Application of ecology in the determination of condition and trend. J. Manage. 7: 14-23.

Short L.R. & Woolfolk E.J. 1956. Plant vigour as a criterion of condition. J. Manage. 9: 66-69.

Stuart-Hill G.C. 1989. Some problems with using proportional species composition. In: Veld management in the eastern Cape. J.E. Danckwerts & W.R. Teague (Eds). Govt. Printer, Pretoria.

Stuart-Hill G.C. 1992. Effects of elephant and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa. J. Applied Ecol. 29: 699-710.

Stuart-Hill G.C. & Hobson F.O. 1991. An alternative approach to veld condition assessment in the non-grassveld regions of South Africa. J. Grassl. Soc. South Afr. 8(4): 179-185.

Stuart-Hill G.C. in prep.(a). Evaluation of the point centred quarter method of sampling Kaffrarian Succulent Thicket.

Stuart-Hill G.C. in prep.(b). Evaluation of a belt transect method of sampling Kaffrarian Succulent Thicket.

Stuart-Hill G.C. in prep.(c). Repeatability of the Domin-Krajina cover-abundance scale in Kaffrarian Succulent Thicket.

Stuart-Hill G.C. in prep.(d). The 'Bubble' technique for sampling Kaffrarian Succulent Thicket. (Parts 1, 2 & 3)

Stuart-Hill G.C. in prep.(e). Towards a formalized adaptive management framework in succulent bushveld. Ph.D thesis. Univ. Natal, Pietermaritzburg.

Tainton N.M. 1981. (Ed) Veld and pasture management in South Africa. Pietermaritzburg: Shuter & Shuter.

Tueller P.T. & Blackburn W.H. 1974. Condition and trend of the big sagebrush/needlethread habitat type in Nevada. J. Manage. 27: 36-40.

Walters C.J. & Hilborn R. 1978. Ecological optimisation and adaptive management. Annual review of ecological systems. 9: 157-188.

Willis M.J. & Trollope W.S.W. 1987. Use of key grass species for assessing veld condition in the eastern Cape. J. Grassl. Soc. South Afr. 4(3): 113-115.

TOOL 4

A TECHNIQUE FOR MONITORING FORAGE USE AND RECOVERY

[P 4.1] Evaluation of a non-destructive technique to monitor utilization and recovery of two shrub species in succulent bushveld

[TOOL 4]

TECHNIQUE FOR MONITORING FORAGE USE AND RECOVERY

ORIGINAL BRIEF

This is required for management feedback in the short-term and the technique must monitor degree of utilization and forage accumulation so that farmers can decide when an area of veld should be burnt, is ready to be grazed or when animals should be removed from a paddock. I refer to this as forage assessment.

RESULT

This tool was not seriously addressed in this study because:
i) of logistical limitations;
ii) it is only necessary for the implementation of rotational grazing which, in succulent bushveld, is untested;
iii) if the stocking rates are 'correct' then monitoring forage utilization and regrowth is not really necessary; and
i) there is already an informal visual method which monitors the development of a 'browse line' (for utilization) and length of current shoot growth on *P. afra* (for recovery).

Nevertheless, a method of monitoring twig utilization on *P. afra* and *G. robusta* was briefly evaluated and found to be inappropriate, even for research efforts (see the unpublished paper: **Evaluation of a non-destructive technique to monitor utilization and recovery of two shrub species in succulent bushveld [P 4.1]**).

[P 4.1]

EVALUATION OF A NON-DESTRUCTIVE TECHNIQUE TO MONITOR UTILIZATION AND RECOVERY OF TWO SHRUB SPECIES IN SUCCULENT BUSHVELD

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ABSTRACT

A technique, based on repeated leaf counts and twig length measurements, was evaluated for monitoring browse utilization and recovery. The evaluation was not exhaustive, but indicates that while it has the advantage of producing objective data, it cannot be recommended for management or for research purposes as the effort required does not warrant the information quality.

INTRODUCTION

An experiment (reported by Stuart-Hill & Aucamp 1993) was required to determine the relationship between carrying capacity and vegetation state in Succulent Valley Bushveld. Central to this experiment was a requirement for a technique to objectively determine intensity of utilization (by browsing) and degree of recovery (following browsing). After informal screening of various techniques, it was decided to opt for the technique used by Teague (1987) on _Acacia karoo_.

The technique involves repeated measurement of leaf number and twig length on marked twigs. These are related to the previous measurements and if they are less, then utilization is assumed (provided the losses were not obviously drought related) and if greater, growth/recovery has occurred. In the carrying capacity experiment (Stuart-Hill & Aucamp 1993), the measurements were related to the first measurement where the intention was to have final twig measurements equal the original, indicating that the plants had been neither over- nor under-utilized: i.e. utilization equalled recovery, thereby implying sustainable use.

The investigation reported here was originally aimed at determining the reliability (error) of measurement, of the numbers of twigs which had been marked in the carrying capacity

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experiment. With some additional measurements it was possible to evaluate the technique itself.

The objective of this preliminary investigation was therefore, to analyze the precision of this 'leaf number and twig length' method and, using 'effort' and other practical considerations, evaluate the usefulness of the technique.

PROCEDURE

Two 2ha sites were selected; one representing dense and the other open Succulent Valley Bushveld. These two sites had ecological status (ES) scores of 100 and 20 respectively (Stuart-Hill 1989).

In each camp, 18 shrubs each of two species (Portulacaria afra and Grewia robusta) were randomly selected and marked. These species were selected because both are palatable and important forage producers (Aucamp 1979), and P. afra (in particular) is one of the first plants to be eliminated with heavy browsing (Stuart-Hill 1992). On each plant, six twigs were marked, three in the upper canopy and three in the lower (Figure 1). This stratification was made because Teague (pers. comm.) suggested that branches in the upper canopy grow faster than branches in the lower canopy. All twigs were within reach of goats (i.e. $<$ 1.5m).

INSERT FIGURE 1

The 'twig' was defined as all that material distal to the tag and at each sampling event, all leaves were counted and the length of each sub-twig measured. The latter measurements were then summed to give the parameter called 'twig length'.

The twigs were repeatably sampled: before browsing the camp with goats (day=0); during a period where goats were browsing, and during a recovery period where no goats were in the camp. It was not logistically possible to measure twigs of both species in all camps on a single day so measurements are not synchronised (Table 1).

Two operators worked together, one recording and searching for twigs while the other counted leaves and measured twigs. If a tag could not be relocated then all subsequent measurements were treated as missing values.

The differences in twig length and leaf number at each sampling occasion with respect to the initial values (at day 0) were calculated and expressed as a percentage. From these data the mean difference and standard error of a single difference (SE(x)) were determined from all 100 twigs per species per camp. Using the estimates of population variance (SE (x)), relationships between SE(mean difference) and number of twigs were established. A further step, to aid interpretation, was to convert the SE(mean difference) curves into relationships illustrating the least significant difference (LSD, where P=0.05) obtainable by using the mean derived from various numbers of twigs. Different 'error' curves were developed for each sampling occasion, so that for each species (and camp) there is more than one error relationship.

In addition to the foregoing statistical evaluation, operational time and observational notes with respect to the use of the technique (Stuart-Hill & Aucamp 1993) were recorded and drawn upon during the evaluation of the technique.

RESULTS & DISCUSSION

The relationship between LSD (P=0.05) and sampling effort, represented by the number of twigs, is illustrated for:

i) camp 1, P. afra (Figure 2);
ii) camp 1, G. robusta (Figure 3);
iii) camp 2, P. afra (Figure 4); and
iv) camp 2, G. robusta (Figure 5).

INSERT FIGURES 2, 3, 4 & 5
INSERT TABLE 2

Aside from the obvious reduction in error with increased sampling effort, the first general conclusion from these results is that repeatability gets progressively worse with time from initial sampling (Figures 2 to 5 & Table 2). This is despite the average leaf number and twig length at the final sampling occasion being more similar to the initial sampling values than at the intermediate sampling occasions. On the other hand, within the relatively short period of browsing (where little if any growth occurred), it appeared that error also increased in relation to the deviation from the initial values. It seems likely therefore, that both time since initial measurement and degree of deviation from initial measurement play a role. This relationship is summarised in Figure 6.

INSERT FIGURE 6

The consequences of this result is that, to achieve a specified level of precision, more twigs will have to be sampled as the inter-sampling period lengthens and as the values deviate from the initial measurements. This has serious implications for long-term monitoring of twig utilization and recovery.

I suggest also, that all similar monitoring techniques will probably also suffer from the same problem. The reason for this is that, with time, each individual (twig in this case) will become increasingly different as a result of the various and unpredictable array of impacts - the combination and extent of which will be unique to each individual (Figure 7).

INSERT FIGURE 7

The second general conclusion is that G. robusta was monitored with greater precision than P. afra (Figures 2 to 5). The repeatability with P. afra was so poor that, even with exhaustive sampling, LSD's (P=0.05) were still too large to be of much use (Figures 2 to 4). The reason for this result could be that when P. afra twigs are browsed, most of the twig is removed. This leads to a situation where some twigs have zero utilization while others are extremely severely utilized. During regrowth the differentiation between twigs becomes even greater. Because twig material and consequently hormone producing meristems are removed with goat browsing, regrowth from a browsed twig may be zero or very small if most of the meristems had been removed (i.e. a limitation to regrowth is the lack of growth sites). On the other hand, an undefoliated twig with apical dominance could experience extremely rapid growth (a twig length increment of 14 times the initial value within one year was measured on several occasions). To compound this inherent problem, a phenomenon was observed where some P. afra plants were extremely heavily utilized while others were not utilized at all; i.e. the 'sweet' and 'sour' plants of local dogma. It would seem then, that this technique is not really suitable for monitoring small changes (<25%) in the utilization of succulent plants with edible stems. Without defoliation, however, it may be possible to use this technique to monitor growth of these types of plants.

It took approximately 24 minutes to find a marked tree, find each twig and make all the measurements. It follows that even with the relatively good results obtained with G. robusta it would take a recording team (two people) approximately four hours to measure the 60 twigs (beyond which further sampling will not be cost effective). Only a user can determine whether this effort is worth the information received.

CONCLUSIONS

This analysis of the 'leaf number and twig length' technique was not exhaustive. However, some relationships between differences that can be distinguished (P=0.05) and intensity of sampling were produced and may be useful to researchers considering such an approach. Essentially, it is possible to use this technique but I cannot recommend it unreservedly as my value judgement is that the degree of effort does not warrant the quality of information received. It is nevertheless up to each user to make the ultimate decision.

This technique does have the advantage of providing quantitative data which meets the current expectations of scientific rigour but the search for a more efficient method should not be terminated.

Two issues of wider concern also emerged in this investigation. Firstly, and this may be a general principle for any monitoring procedure, the number of samples required to achieve a certain level of precision will increase with the length of time over which monitoring will occur. This needs to be pursued further as it has far reaching implications.

The second is that this technique does not appear to be suitable for monitoring utilization of plants with soft edible stems.

ACKNOWLEDGEMENTS

I gratefully acknowledge the financial support of the Department of Agriculture and the co-operation of the Department of Correctional Services for the use of their land. I am also indebted to L.O. Nel, N. De Riddder, L.P. Du Toit, M.L. Swart, E. Oosthuizen and H. Barnard who on various occasions helped with the backbreaking 'leaf and twig' measurements.

REFERENCES

Aucamp A.J. 1979. Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke. D.Sc. Agric. thesis, Univ. of Pretoria.

Stuart-Hill G.C. 1989. Assessing the condition of valley bushveld. In: Danckwerts J.E. & Teague W.R. (eds). Veld Management in he eastern Cape. Govt. Printer, Pretoria. pp 103-108.

Stuart-Hill G.C. 1992. Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa. J. Applied Ecol. 29: 699-710.

Stuart-Hill G.C. & Aucamp A.J. 1993. Carrying capacity of the succulent valley bushveld of the eastern Cape. Afr. J. Range. For. Sci. 10(1): 1-10.

Teague W.R. 1987. Defoliation and Browse Production of Acacia karroo Hayne in the Eastern Cape, South Africa, Ph.D. Thesis, Univ. of Witwatersrand.

Table 1. Experimental day numbers on which various 'twig measurements' were made for each camp and species. ES refers to vegetation condition index called 'ecological status' (Stuart-Hill 1989).

	ES	Species	Initial measurement	Period of browsing				Period of recovery			
				1	2	3	4	1	2	3	4
Camp 1	100	POAF	0	3	6	9	27	104	200	299	372
		GRRO	0	3	6	9	27	104	202	299	372
Camp 2	20	POAF	0	2	6	28	-	104	202	-	-
		GRRO	0	2	6	28	-	104	202	-	-

GRRO - *Grewia robusta*
POAF - *Portulacaria afra*

Table 2. The SE(x) for each parameter measured on each sampling occasion on the two shrub species in the two camps representing high and low Ecological status.

			Sampling occasion							
	Species & Part		Period of browsing				Period recovery			
			1	2	3	4	1	2	3	4
Camp 1	POAF	leaf	0	10	10	6	6	6	-	-
		twig	0	1	2	2	3	7	-	-
	GRRO	leaf	8	13	14	15	16	18	21	21
		twig	2	4	5	6	6	6	8	6
Camp 2	POAF	leaf	6	7	7	-	8	9	-	-
		twig	2	2	2	-	2	2	-	-
	GRRO	leaf	6	9	10	-	13	15	-	-
		twig	3	5	7	-	8	7	-	-
	Average		3.4	6.4	7.1	-	7.8	8.8	-	-
	SE(x)		3.0	4.1	4.2	-	4.7	5.2	-	-
	n		8	8	8	-	8	8	-	-
		AVERAGE			6.00			8.25		
		SE(X)			3.96			4.85		
		N			24			10		

GRRO - Grewia robusta
POAF - Portulacaria afra

FIGURE CAPTIONS

Figure 1. A diagrammatical representation of the twig sampling strategy on each plant. Insert is the detail of the twig marking procedure. All leaves on the marked twig were counted and the lengths of all the subsidiary twigs were measured and added to give total twig length.

Figure 2. The relationship between sampling intensity (twig number) and sampling error for monitoring utilization and recovery of Portulacaria Afra leaves (a) and twigs (b) in relatively pristine succulent bushveld. Each curve represents different degrees of utilization (%) and regrowth through a period of browsing and subsequent recovery.

Figure 3. The relationship between sampling intensity (twig number) and sampling error for monitoring utilization and recovery of Grewia robusta leaves (a) and twigs (b) in relatively pristine succulent bushveld. Each curve represents different degrees of utilization (%) and regrowth through a period of browsing and subsequent recovery.

Figure 4. The relationship between sampling intensity (twig number) and sampling error for monitoring utilization and recovery of Portulacaria Afra leaves (a) and twigs (b) in degraded succulent bushveld. Each curve represents different degrees of utilization (%) and regrowth through a period of browsing and subsequent recovery.

Figure 5. The relationship between sampling intensity (twig number) and sampling error for monitoring utilization and recovery of Grewia robusta leaves (a) and twigs (b) in degraded succulent bushveld. Each curve represents different degrees of utilization (%) and regrowth through a period of browsing and subsequent recovery.

Figure 6. The suggested influence of time and absolute deviation in measurement from initial sampling, on the repeatability of monitoring permanently marked twigs. Numbers represent sequential sampling events and the solid line represents utilization while the broken line represents subsequent recovery.

Figure 7. A suggested representation of the increasing deviation from the initial measurement with time, as a result of random events not related to treatment.

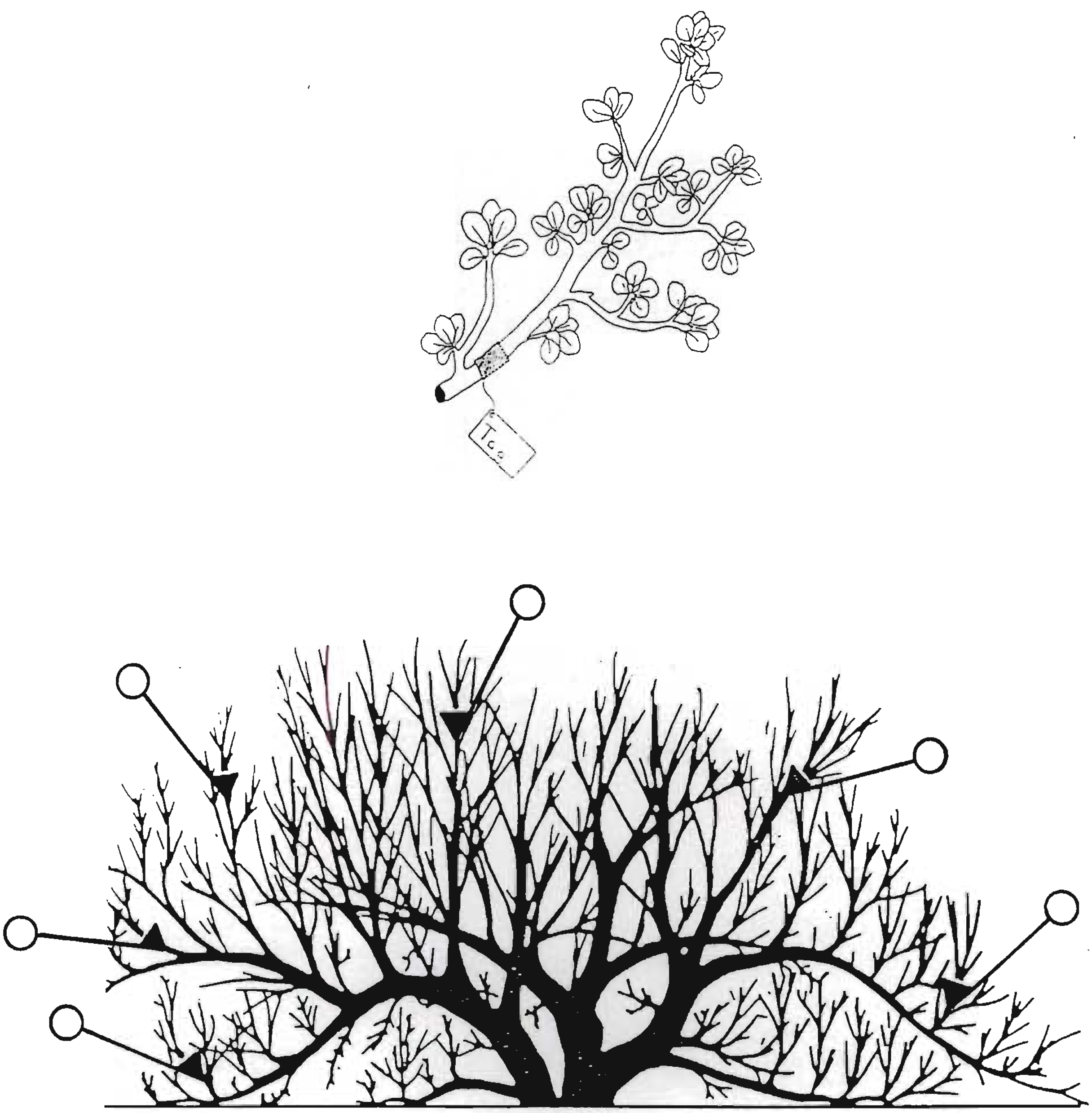


Figure 1

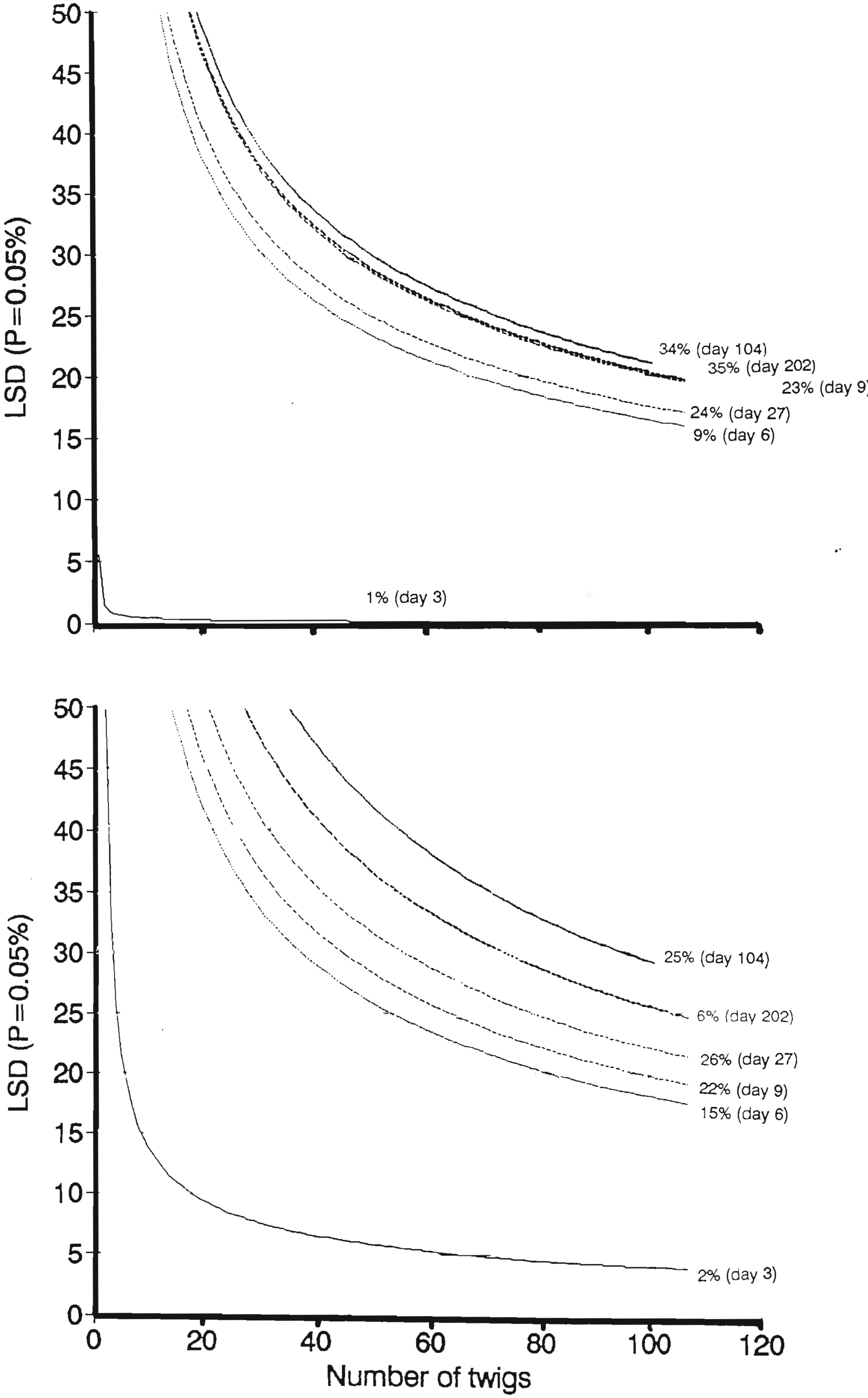
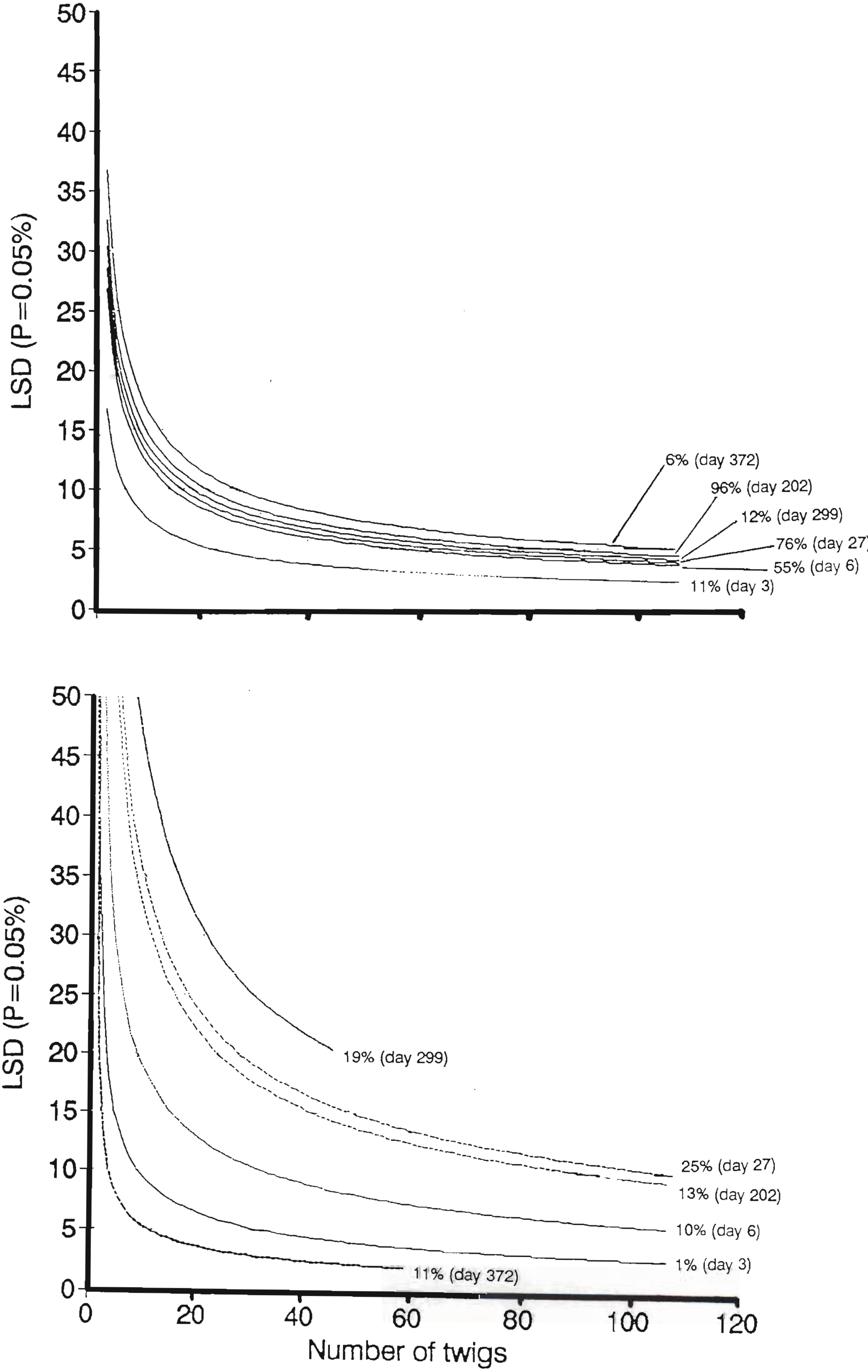
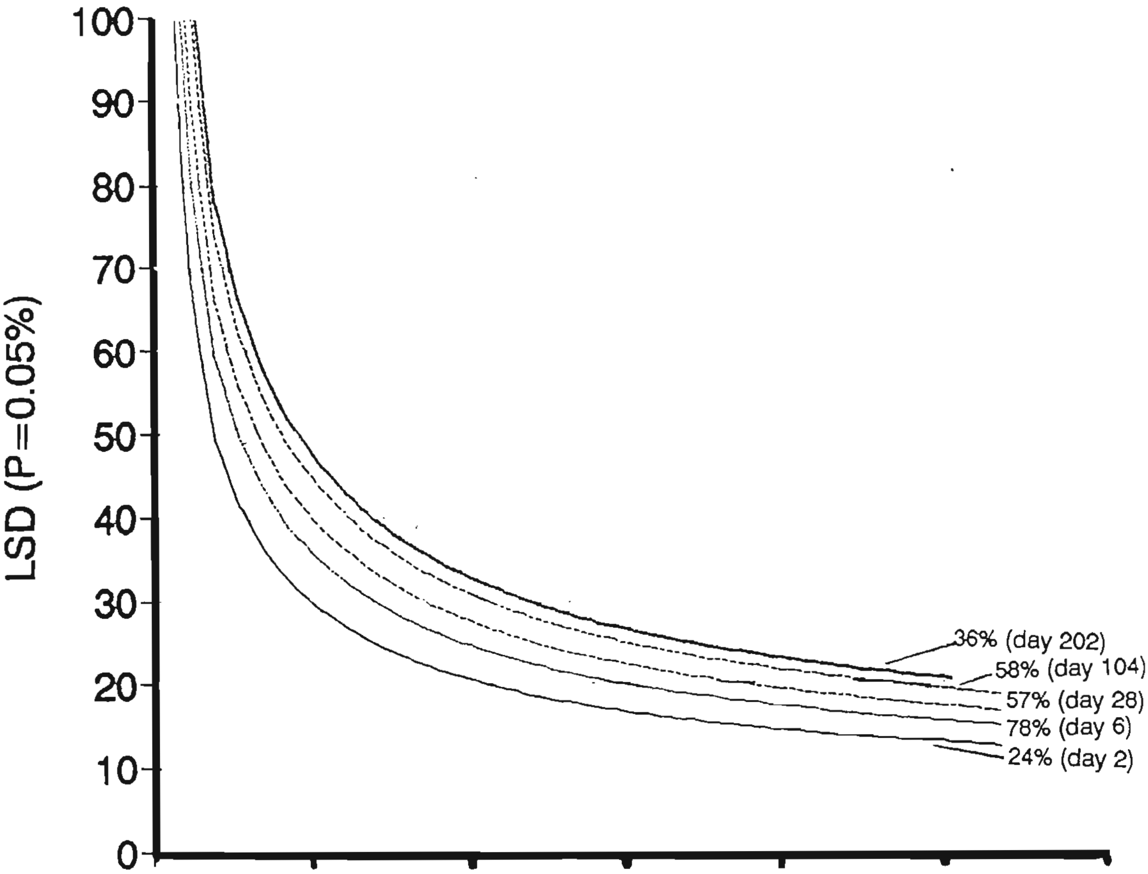

LSD (P=0.05%)
34% (day 104)
35% (day 202)
23% (day 9)
24% (day 27)
9% (day 6)
1% (day 3)
LSD (P=0.05%)
25% (day 104)
6% (day 202)
26% (day 27)
22% (day 9)
15% (day 6)
2% (day 3)
Number of twigs

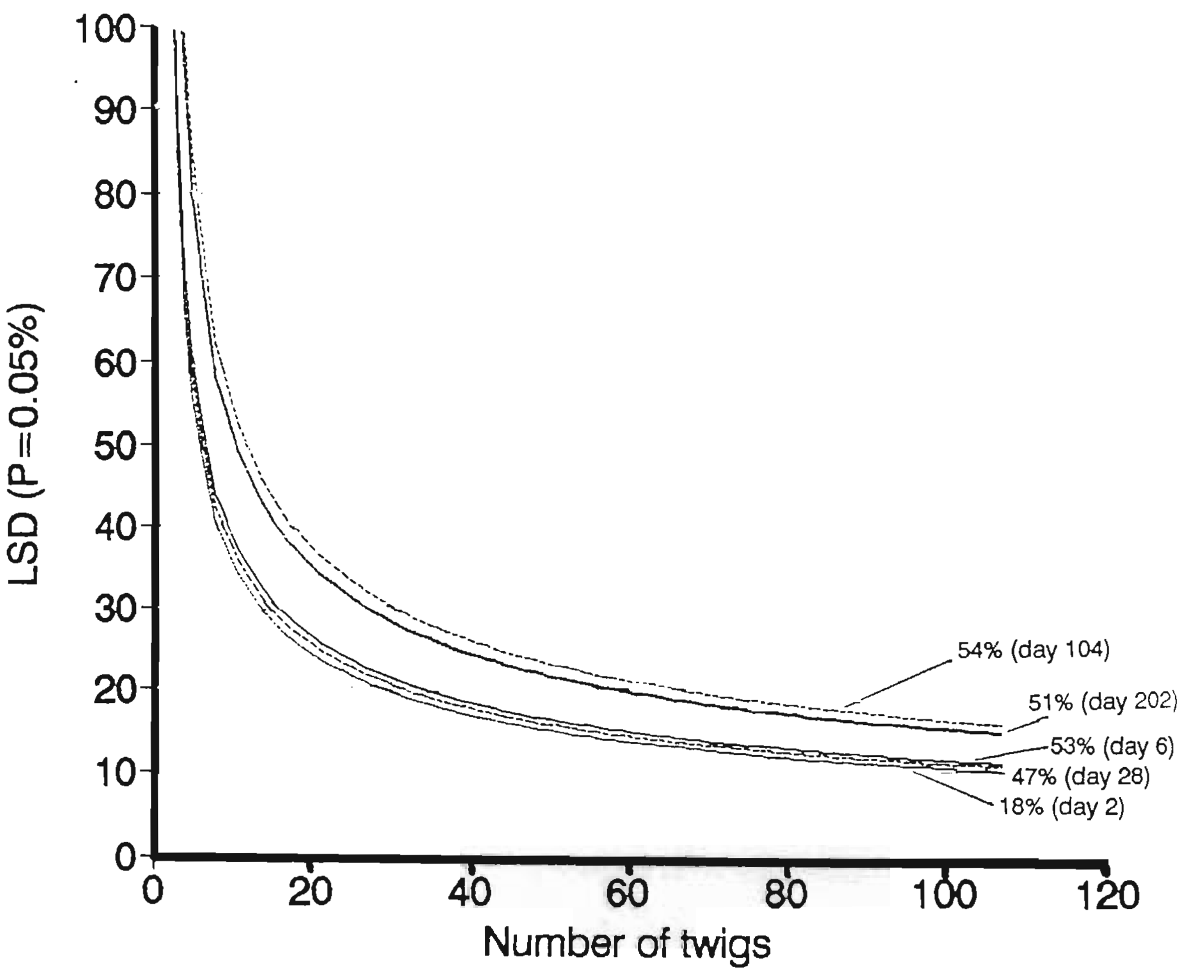
Figure 2



LSD (P=0.05%)
50
45
40
35
30
25
20
15
10
5
0
6% (day 372)
96% (day 202)
12% (day 299)
76% (day 27)
55% (day 6)
11% (day 3)
LSD (P=0.05%)
19% (day 299)
25% (day 27)
13% (day 202)
10% (day 6)
1% (day 3)
11% (day 372)
0
20
40
60
80
100
120
Number of twigs



LSD (P=0.05%)
100
90
80
70
60
50
40
30
20
10
0
36% (day 202)
58% (day 104)
57% (day 28)
78% (day 6)
24% (day 2)



LSD (P=0.05%)
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Number of twigs
54% (day 104)
51% (day 202)
53% (day 6)
47% (day 28)
18% (day 2)

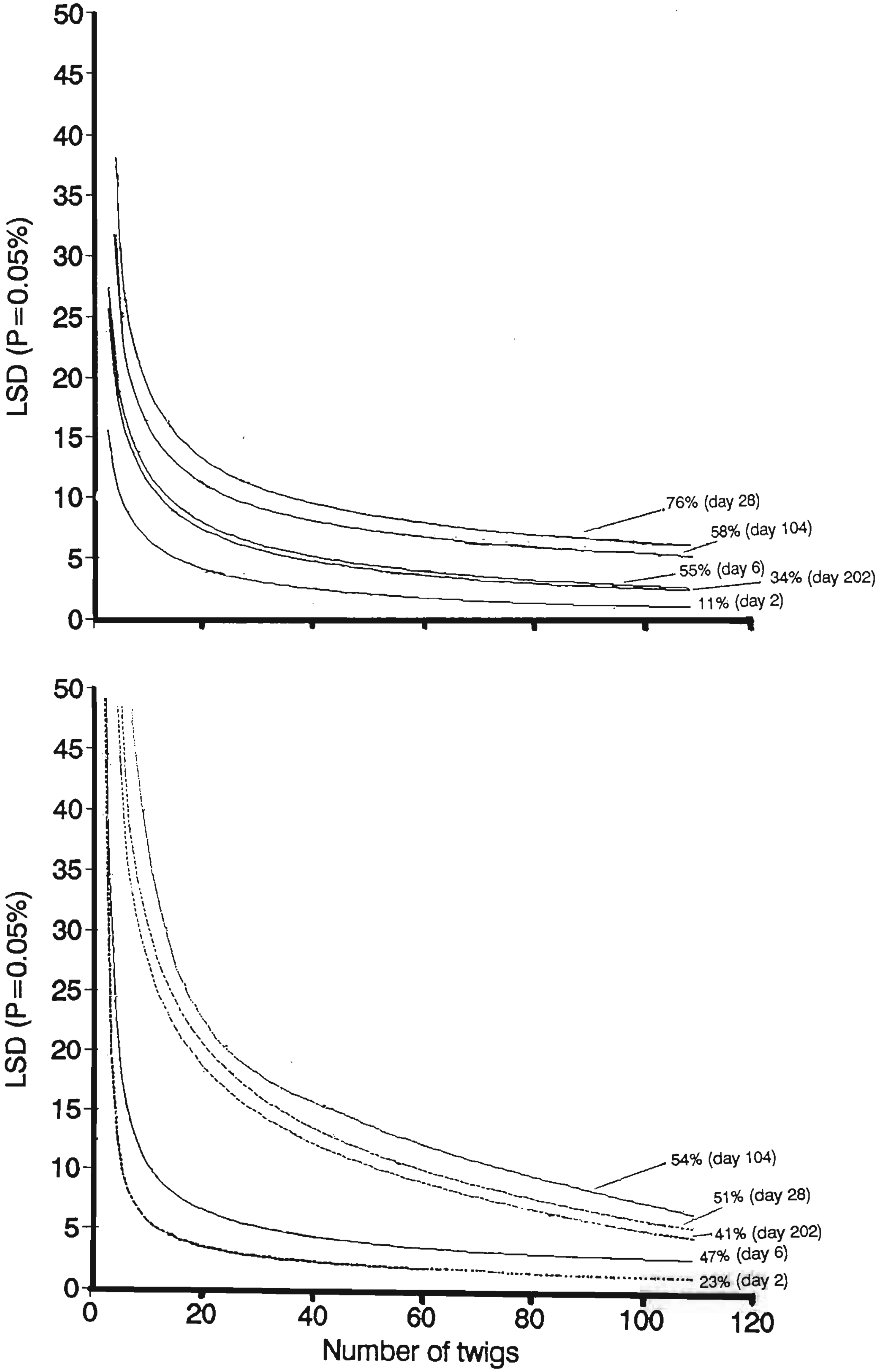

50
45
40
35
30
25
20
15
10
5
0
LSD (P=0.05%)
76% (day 28)
58% (day 104)
55% (day 6)
34% (day 202)
11% (day 2)
50
45
40
35
30
25
20
15
10
5
0
LSD (P=0.05%)
54% (day 104)
51% (day 28)
41% (day 202)
47% (day 6)
23% (day 2)
0
20
40
60
80
100
120
Number of twigs

Figure 5

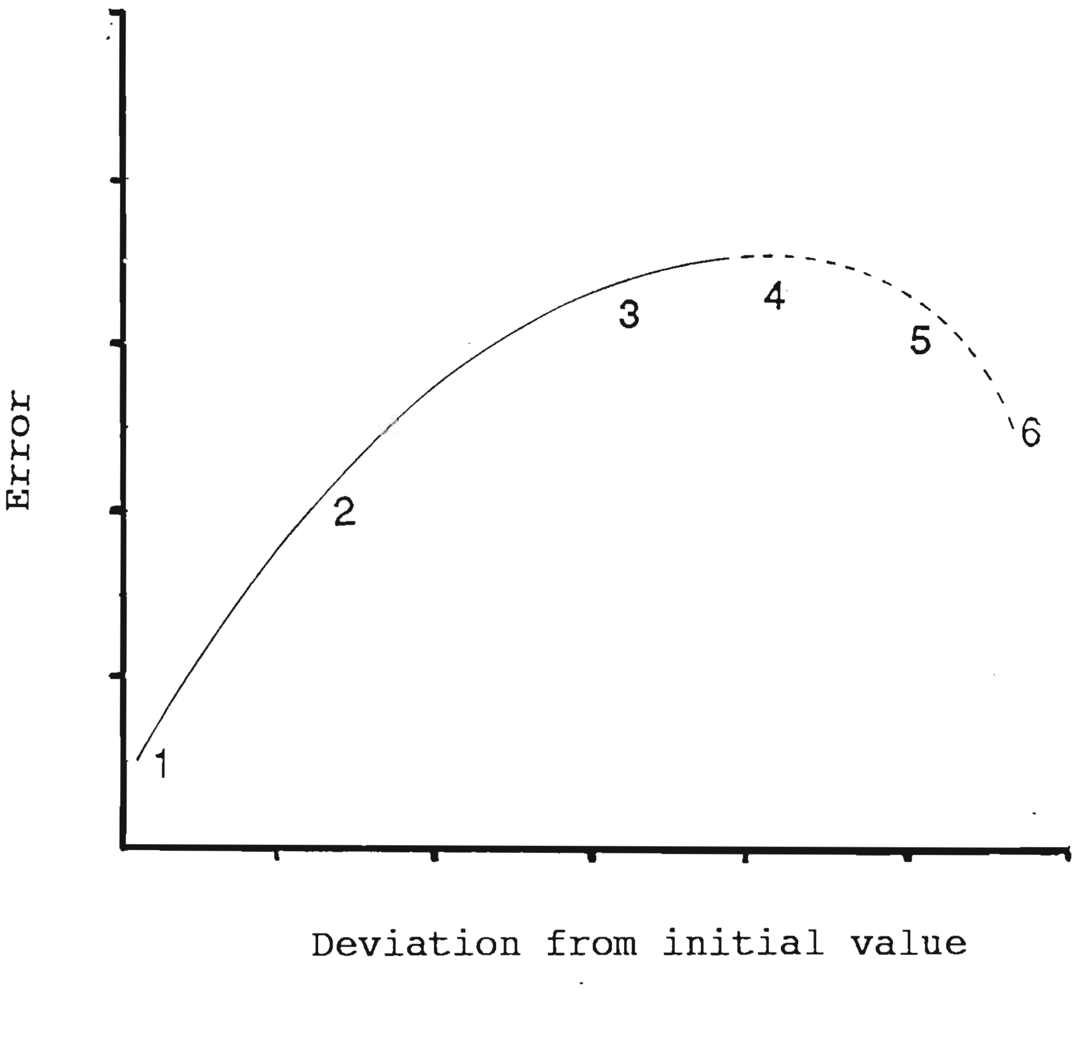


Figure 6

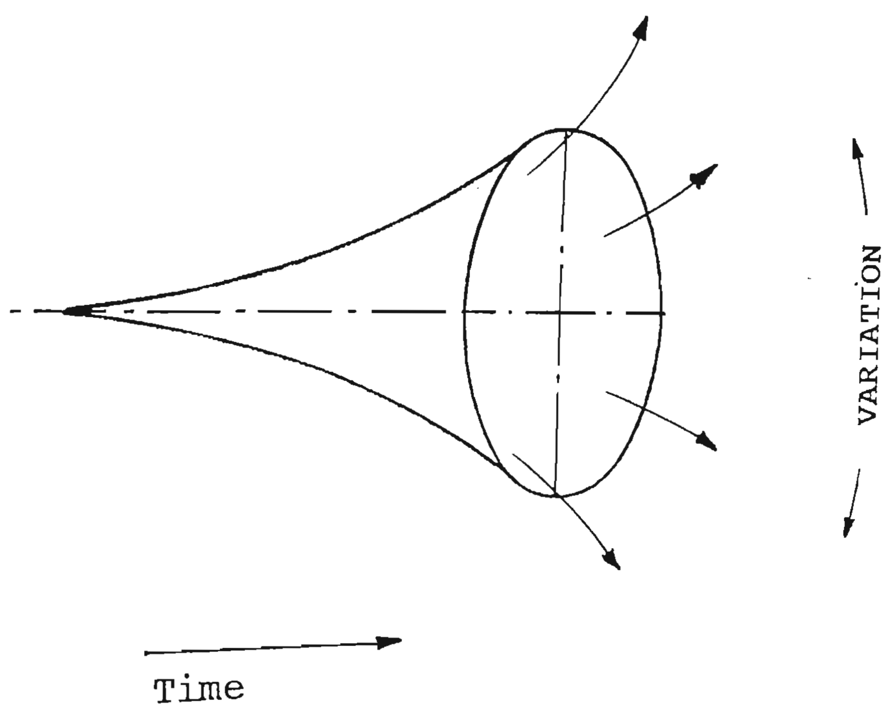


Figure 7

[TOOL 5]

A LIST OF KEY FORAGE SPECIES

ORIGINAL BRIEF

In multi-species communities it is inevitable that utilization levels will differ between species. Consequently the manager should know those plants that are important to his objectives and understand why they are important. I call these plants key species.

RESULT

Tool 5, a list of key forage species, was also not a priority as this had previously been researched by Aucamp (1979). However, while evaluating productivity, Aucamp did not formally consider palatability or acceptability. To address this limitation, a 'first approximation' type investigation was undertaken resulting in the unpublished paper: **The goat preference rating of shrubs in the succulent bushveld of the eastern Cape [P 5.1].** It is important to note that while there exists a differentiation in the palatability of the shrub species in this vegetation type, almost all species will be utilized to extinction if animals are forced to. It follows that when viewed globally, there may be a relatively small variation in absolute palatability between shrubs of the succulent bushveld.

The results of this investigation were then used in a pilot study which aimed to initiate research into understanding goat selectivity. The unpublished research note (**Relationships between some commonly assayed plant chemicals and shrub acceptability (to goats) in the succulent bushveld of the eastern Cape [P 5.2]**) details the results.

PRELIMINARY GOAT PREFERENCE RATING OF SHRUBS IN THE SUCCULENT VALLEY BUSHVELD OF THE EASTERN CAPE

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ABSTRACT

This study attempted to rank the common species according to goat preference. This was done during March of two successive years, only and the study must therefore, be seen as a preliminary investigation.

Indices reflecting the acceptability and dietary importance were determined for a range of species and plant parts (eg. berries). Essentially, these remained unchanged between the wet (1987) and dry (1988) experimental periods.

Portulacaria afra was the most acceptable, and the most important forage species. This, together with it's natural abundance and it's sensitivity to utilization, makes it the obvious choice as the key species for management and monitoring. Other supporting species are Grewia robusta and Capparis sepiaria.

While there exists a differentiation in plant palatability, from a global perspective, almost all species in this vegetation type will be utilized to extinction if animals are forced to.

INTRODUCTION

The succulent valley bushveld is a dense, semi-succulent, thorny vegetation occurring on the eastern seaboard of South Africa in hot, dry (rainfall 225 to 500mm), frost-free areas at low altitudes between the Kei and Gouritz river valleys (data from Acocks, 1975; Cowling, 1984; Everard, 1987). Browse is the production base and this is derived from a number of succulent and evergreen stunted trees and shrubs.

Providing a list of key forage plants is important because in multi-species systems such as this, it is not feasible to consciously manage for all species. Rather, management systems are designed around a few key species with the philosophy that by managing for these, all species will survive. Naturally this is naive. But if these species are carefully selected by knowing which are the most sensitive, preferred and most important forage producers, then chances of achieving this are greatly enhanced.

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Aucamp (1979), while evaluating the productivity of the shrub species in the succulent valley bushveld, did not formally consider palatability or acceptability. There is little known about the relative preferences of shrubs in this vegetation type. Naturally there is speculation (eg. Portulacaria afra is more palatable than the Maytenus group of species), but no objective evaluation has ever been made. This study, a 'first approximation', attempted to address this limitation and its aim was to rank the common species of the succulent valley bushveld according to goat preference. Goats were selected because they are currently the dominant foraging animal in these parts.

PROCEDURE

The investigation was undertaken in a 2ha camp of succulent valley bushveld described by Stuart-Hill (1989) as being in the mid-range of vegetation condition ("ecological status = 46"). It was carried out during 'free-time' whilst goats were browsing the camp for the determination of browsing capacity (see Stuart-Hill & Aucamp 1993). During this experiment, the animals were never under nutritional stress, and while these results should reflect the selective behaviour of goats during sustained vegetation utilization, they will be inadequate for goats under severe nutritional pressure.

The goats were monitored during March 1987 and March 1988 only. These periods represented periods where the plants were (1987) and were not (1988) actively growing (because of dry conditions). Ideally, it would have been preferable to sample throughout the year but the design of the carrying capacity experiment (Stuart-Hill & Aucamp 1993) precluded this. The implication of this is that the experiment was severely flawed. Because sampling was not extended over all seasons of the year, the results are valid for summer only and the study must be regarded as a preliminary investigation. Despite this limitation, the results are of some use because there is no severe browse bottle-neck in winter, in contrast to other browse systems as the vegetation is largely evergreen and driven more by water availability than season.

One goat was followed for approximately two hours on ten different sampling occasions (morning or afternoon on subsequent days) during March 1987 and again during March 1988 (i.e. a total of at least 40 hours of sampling was undertaken and this was approximately equally divided between morning and afternoon observations - depending on available time). Where more than one operator was available, a second (or more) goat was followed and these additional data added to the formal data set.

An acceptability index (AI), similar to that of Owen-Smith & Cooper (1987) was determined for each species. This operated according to their "site-based acceptability" technique, except that the sampling distance for the goats was 1.5m, instead of the 10m for kudu. This modification was made because of the density of shrubs and the short visible distance in this vegetation. At each feeding event (i.e. each time the animal stopped to eat) the plant eaten was recorded, as well as all other plants available to the goat. Plants were considered available if they were within 1.5m of the goat's head. The acceptability index was obtained by determining the ratio between the number of times a species was eaten and the number of times it was available.

Apart from the AI, an index of the relative importance of each species to the goat's diet (DI) was calculated as the number of times a species was eaten, relative to the total number of feeding events observed (as a percentage). Naturally, this does not claim to accurately represent contribution to diet, rather it should be seen in the context of this paper where first approximations with least experimental cost was the underlying philosophy.

The total number of times a species was recorded (irrespective of whether it was eaten or not) gives a relative measure of reliability for the acceptability and dietary importance indices.

The ten sampling occasions for each summer were initially meant to serve as replications to enable statistical confidence to be attached to the acceptability and dietary importance indices for each season. However, using the mean across these sampling occasions distorts these indices. For example, a rare but highly acceptable plant would have a lower mean AI than it should, simply because it was not encountered in many of the sampling occasions. These replications would consequently return zero AI's to the equation determining the mean, whereas in reality, the true AI was a missing plot. The consequence (in this example) is that an AI determined for a rare and palatable plant would be lower than is truly representative. Statistical comparison between the indices for the two summers was, therefore, abandoned.

Naturally, as sampling intensity is increased, so is confidence in the ultimate result. Some of the 1987 data were used to evaluate this. A palatable and an unpalatable species was selected and their AI's repeatedly determined with ever increasing numbers of observations. Here, an observations is defined as when a species is encountered within the 'feeding area' - the area described by a circle (1,5m radius) around a feeding goat. Ultimately a relationship was established illustrating variation in AI as a consequence of sampling effort.

RESULTS AND DISCUSSION

Repeatability of technique

The most important point to establish is that sampling intensity can be measured as either the number of feeding events or the number of times the target species is encountered within the 'feeding area'. Repeatability is dependent on the latter, not the total number of feeding events. This is especially true with rare species which are seldom encountered and even with exhaustive sampling, there may simply be too few observations where the plant is present for a reasonable estimate of AI to be obtained. It follows that, each species will require a different number of feeding events for the same level of precision, and this can practically be determined only once the data have been obtained. However, once obtained, the degree of reliability can be qualitatively evaluated by simply referring to the number of times the target species was encountered.

The results of the repeatability study are illustrated in Figure 1 and the most important conclusion is that there is little point in sampling beyond 100 observations for each species. However, because each species requires a different number of feeding events to attain these many observations, there is not much one can do to reduce sampling effort. What these results show, however, is that AI's and DI's determined with more than 100 observations are reliable to within at least 8%, greater than 25 observations may reveal useful trends and <25 observations, whilst differentiating between species with very high of very low AI's, should be treated with healthy suspicion.

INSERT FIGURE 1.

Acceptability

Over both summers P. afra, Grewia robusta and Capparis sepiaria were highly acceptable. During the wet 1987 season, the Panicum group of species joined this category (Figure 2).

INSERT FIGURE 2.

Lycium oxycarpum, Zygophyllum morgsana, Euclea undulata, Sansveria leaves, Azima tetracantha, Rhus undulata, and the Maytenus and Protosparagus groups of species, were consistently unacceptable with Schotia afra and 'Other grasses' leaving the moderately acceptable category and becoming unacceptable during the dry (1988) and wet (1987) summers respectively.

The rest of the species fell into the moderately acceptable category.

It is noteworthy that the species which changed category, were those which were not particularly well sampled and perhaps little significance should be attached to these changes (Figure 2). If this last statement can be accepted, then it may be concluded that, for practical purposes, acceptability did not change between the two summers.

Whilst Figure 2 contains only some of the plants surveyed (the ones with a reasonable degree of sampling), the information with respect to the other species (in Table 1) should not be ignored entirely as they may reveal some trends.

i. Maerua caffra and the berries of Sansveria ("mother in law's tongue") were extremely acceptable and it was obvious in the field that the goats went to great efforts to consume these.

ii. Crassula ovata was obviously not highly acceptable despite its lack of woodyness and absence of spines.

iii. Pappea capensis, Eherita rigida and Brachylaena ilicifolia are probably moderately acceptable but this needs to be confirmed with increased sampling.

INSERT TABLE 1.

Dietary importance

Over both summers P. afra was found to be, by far, the dominant component of the diet (Figure 3). Grewia robusta and 'Other grasses', whilst not nearly as important as P. afra, also contributed significantly overall, but the grasses dropped out of this second category during the 1988 dry period. This was probably a result of there being little leaf left on these predominantly stoloniferous grasses.

A relatively large number of plants made up the 'relevant forage' category over both seasons (C. sepiaria, Euphorbia bothea, the Panicum group, Lycium oxycarpum, Azima tetracantha, Schotia afra and the Maytenus and Protosparagus groups of species) but there was a high degrêe of change into and out-of the 'nibbled or avoided' category between seasons (Figure 3).

INSERT FIGURE 3.

Table 1 shows that the goats ate more species during the dry (March 1988) than the wet (March 1987) period, despite a limitation in sampling intensity -it being only 72% of that during the wet period (March 1987). This result is intuitive as animals are likely to feed on more plants during times of stress. In addition, P. afra assumed even greater dietary significance (DI increased by 8%) during the dry period which is again intuitive given the succulent nature of this shrub (Table 1).

Matching acceptability with dietary importance

While goats used a relatively wide variety of plants, they concentrated on the highly acceptable P. afra for the bulk of their dietary requirements. This was despite other species (G. robusta, C. sepiaria and during wet periods, Panicum species) being almost as acceptable to goats as P. afra (Table 1). This may have been a result of either the inherent efficiency of harvesting browse from a succulent plant, and/or the relative abundance of this plant. The latter should not, however, be over-emphasised because the experimental camp had less than half the amount of P. afra as the potential for this vegetation type (see Stuart-Hill 1989).

The main point which emerged is that there was no relationship between acceptability and dietary importance (Figure 4), even though P. afra was both the most acceptable and most important dietary component in succulent valley bushveld.

INSERT FIGURE 4.

CONCLUSIONS

While this study has shown that there exists a differentiation in the palatability of shrub species in succulent valley bushveld, it must be remembered that almost all species will be utilized to extinction if animals are forced to so so (Stuart-Hill et al. 1986; Stuart-Hill 1992). The animals were never under nutritional stress during this experiment (see Stuart-Hill & Aucamp 1993) and it follows, that, when viewed globally, there may actually be a relatively small variation in absolute palatabilities between shrubs of the succulent valley bushveld.

Portulacaria afra is undoubtably the most acceptable and important forage species to goats in the succulent valley bushveld. This, together with its abundance (Stuart-Hill 1989), its sensitivity to heavy utilization (Stuart-Hill et al. 1986; Stuart-Hill 1992) and its capacity to produce forage (Aucamp 1979), makes P. afra the obvious choice as the key species for management and monitoring. Other supporting candidates are G. robusta and C. sepiaria (particularly the former), whilst grasses should not be discarded.

ACKNOWLEDGEMENTS

I gratefully acknowledge the financial support of the Department of Agriculture and the co-operation of the Department of Correctional Services for the use of their land. I am also indebted to N. De Ridder, E. Oosthuizen and M.L. Swart who on various occasions helped with monitoring the goats feeding behaviour.

REFERENCES

Acocks J.P.H. 1975. Veld types of South Africa, 2nd edition. Mem. Bot. Sur. of South Africa., No 40. Government Printer, Pretoria.

Aucamp A.J. 1979. Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke. D.Sc. Agric. thesis, Univ. of Pretoria.

Cowling R.M. 1984. A syntaxonomic and synecological study in the Humansdorp region of the fynbos biome. Bothalia. 15: 175-227.

Everard D.A. 1987. A classification of the subtropical transitional thicket in the eastern Cape, based on syntaxonomic and structural attributes. S. A. J. Botany. 53: 329-340.

Owen-Smith R.N & Cooper S.M. 1987. Assessing food preferences of ungulates by acceptability indices. J. Wildl. Manage. 51: 372-378.
Stuart-Hill G.C., Aucamp A.J., Le Roux C.J.G. & Teague W.R. 1986. Towards a method of assessing the veld condition of the Valley Bushveld in the Eastern Cape. J. Grassl. Soc. South. Afr. 3(1): 19-24.
Stuart-Hill G.C. 1989. Assessing the condition of valley bushveld. In: Danckwerts J.E. & Teague W.R. (eds). Veld Management in he eastern Cape. Govt. Printer, Pretoria. pp 103-108.
Stuart-Hill G.C. 1992. Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa. J. Applied Ecol. 29: 699-710.
Stuart-Hill G.C. & Aucamp A.J. 1993. Carrying capacity of the succulent valley bushveld of the eastern Cape. Afr. J. Range. For. Sci. 10(1): 1-10.

TABLE CAPTION

Table 1. The acceptability indices (AI), importance to diet (DI) and number of individuals (N) for plant species (and attributes) encountered by goats during the late summers of 1987 and 1988. In addition, the overall indices for both summers are provided. A relative measure of confidence for each value is given by N, where greater than approx. 100 represents exhaustive sampling and less than approx. 50 inadequate sampling.

Code	Species	March 1987 N=520 Feeding events A.I. (%)	D.I. (%)	Sampled (N)	March 1988 N=372 Feeding events A.I. (%)	D.I. (%)	Sampled (N)	Overall N=892 Feeding events A.I. (%)	D.I. (%)	Sampled (N)
POAF	*Portulacaria afra*	55	31	285	63	37	211	58	34	496
GRRO	*Grewia robusta*	46	14	154	47	17	129	47	15	283
CASE	*Capparis sepiaria*	41	7	80	52	4	29	44	6	109
LYOX	*Lycium oxycarpum*	11	4	196	6	3	175	9	4	371
EUPH	*Euphorbia bothea*	20	7	168	23	7	108	21	7	276
MAsp	*Maytenus spp.*	1	0	134	19	5	100	9	2	234
PRsp	*Protasparagus spp.*	2	1	183	12	3	102	6	2	285
AZTE	*Azima tetracantha*	8	3	206	16	7	165	12	5	371
EUUN	*Euclea undulata*	1	0	145	3	1	60	2	0	205
SAbe	*Sansveria* (berries)	91	2	11	-	0	-	91	1	11
SAle	*Sansveria* (leaves)	5	2	236	0	0	116	3	1	352
FORB	Small herbs	0	0	13	50	0	2	7	0	15
RHOB	*Rhigozum obovatum*	13	0	8	-	0	-	13	0	8
SCAF	*Schotia afra*	31	3	45	17	1	30	25	2	75
CROV	*Crassula ovata*	0	0	7	13	0	8	7	0	15
PACA	*Pappea capensis*	14	0	7	46	2	13	35	1	20
MACA	*Maerua caffra*	100	0	2	-	0	-	100	0	2
RHOY	*Rhoicissus spp.*	35	2	23	25	1	16	31	1	39
ZYMO	*Zygophyllum morgsana*	17	1	18	3	0	39	7	0	57
RHUN	*Rhus undulata*	6	0	35	19	2	32	12	1	67
EUMA	*Euphorbia mauritanica*	100	0	1	0	0	2	33	0	3
VYGI	*Mesem. spp.*	10	0	10	0	0	10	5	0	20
TAsp	*Tapinanthus spp.*	0	0	1	100	0	1	50	0	2
ALOE	*Aloe spp.*	0	0	3	-	0	-	0	0	3
CAHE	*Carissa haematocarpa*	0	0	2	-	0	-	0	0	2
EHRI	*Eherita rigida*	40	0	5	0	0	1	33	0	6
BRIL	*Brachylaena ilicifolia*	29	0	7	-	0	-	29	0	7
PANI	*Panicum spp.*	40	4	45	27	1	15	37	3	60
GRAS	Other grasses	17	17	508	31	8	95	19	13	603

FIGURE CAPTIONS

Figure 1. The relationship between increasing sampling effort (number of occurrences of a target species within a feeding area - radius 1,5m) and the range of possible estimates of acceptability (AI) for a highly preferred and unpreferred species. Notice how the range in AI's decreases as sampling effort is increased.

Figure 2. Frequency distribution of acceptability AI) of various plants in the succulent valley bushveld during: a wet period (March 1987), a dry period (March 1988), and combined for both seasons. See Table 1 for species codes.

Figure 3. Frequency distribution of dietary importance (DI) of various plants in the succulent valley bushveld during: a wet period (March 1987), a dry period (March 1988), and combined for both seasons. See Table 1 for species codes.

Figure 4. The relationship between the acceptability of a number of edible species and their contribution to the diet of goats in succulent valley bushveld.

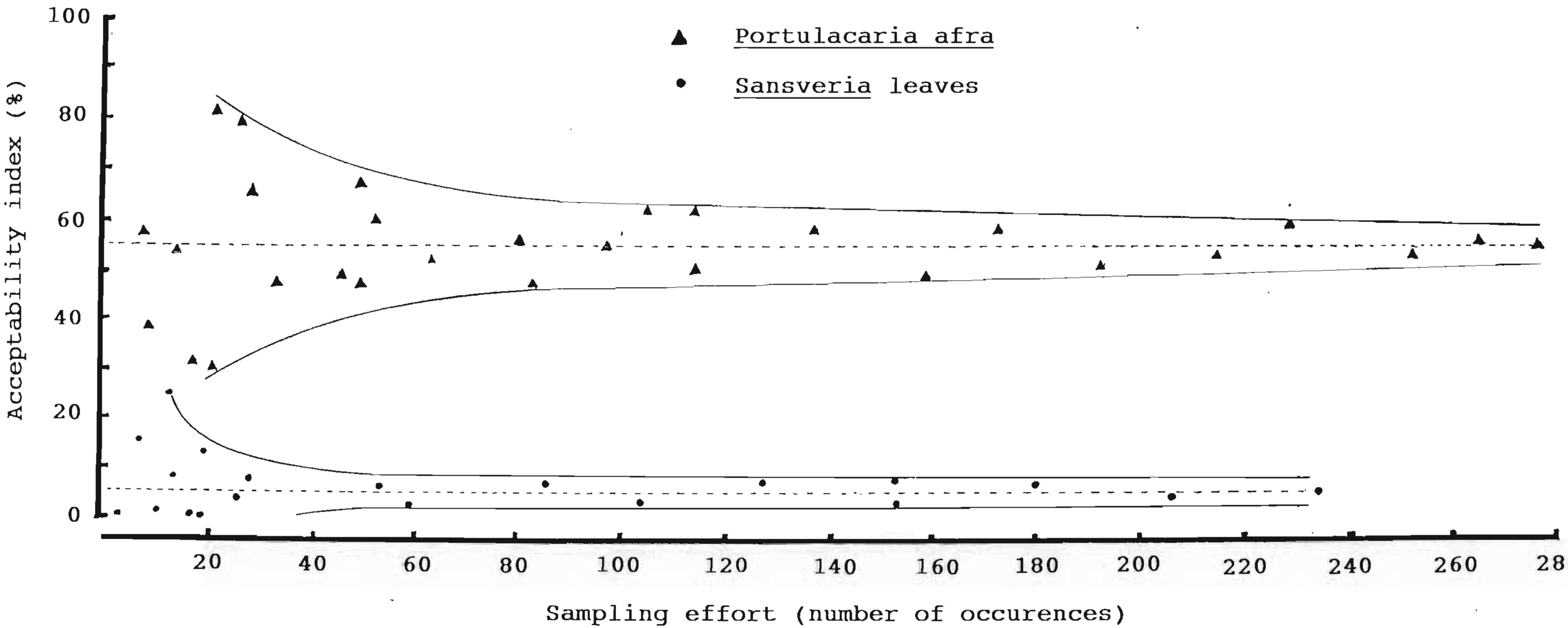
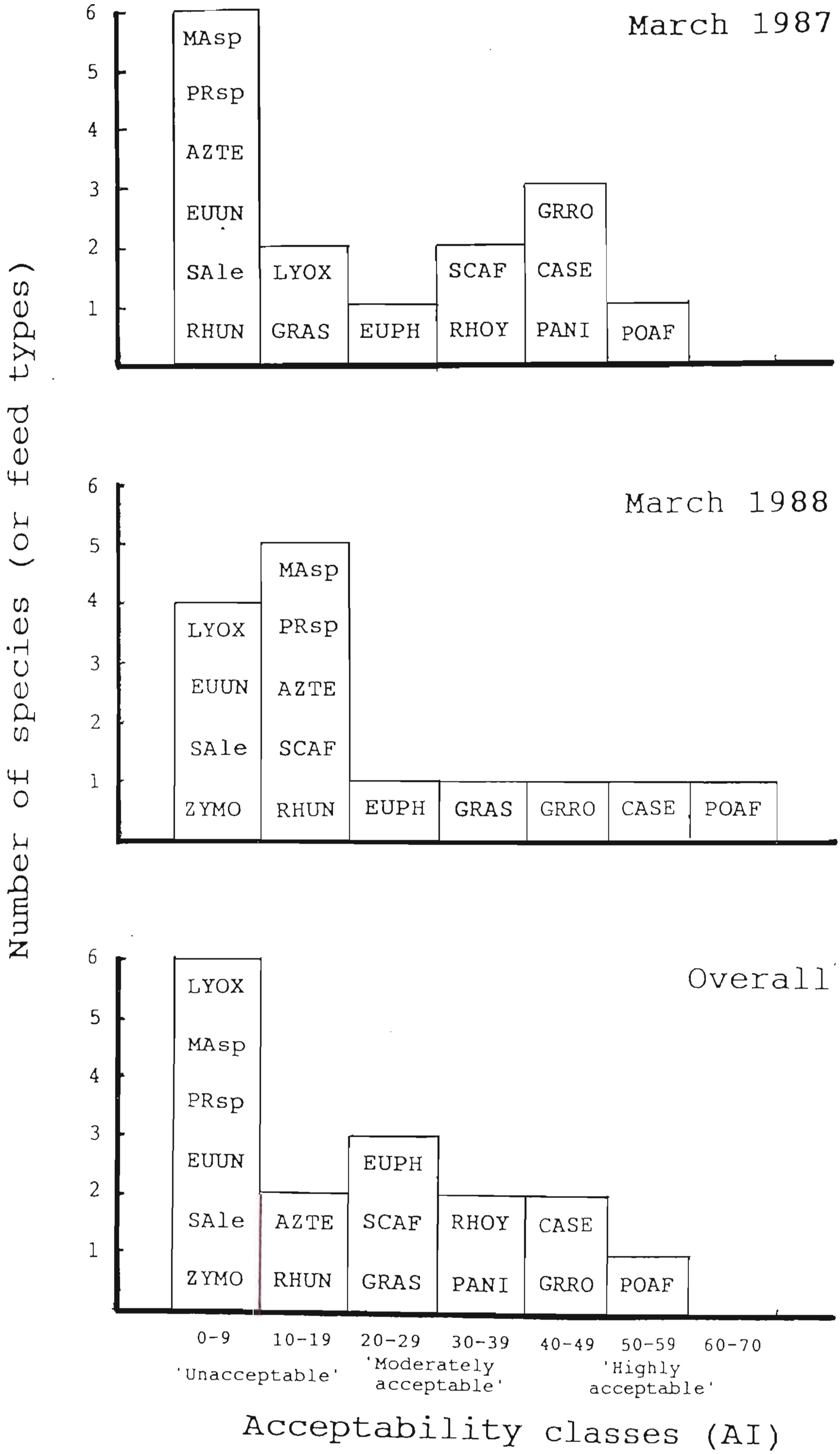

Portulacaria afra
Sansveria leaves
Acceptability index (%)
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Sampling effort (number of occurences)

Figure 1



Number of species (or feed types)
March 1987
6
5
4
3
2
1
MAsp
PRsp
AZTE
EUUN
SAle
RHUN
LYOX
GRAS
EUPH
SCAF
RHOY
GRRO
CASE
PANI
POAF
March 1988
MAsp
PRsp
AZTE
SCAF
RHUN
LYOX
EUUN
SAle
ZYMO
EUPH
GRAS
GRRO
CASE
POAF
Overall
LYOX
MAsp
PRsp
EUUN
SAle
ZYMO
AZTE
RHUN
EUPH
SCAF
GRAS
RHOY
PANI
CASE
GRRO
POAF
0-9
10-19
20-29
30-39
40-49
50-59
60-70
'Unacceptable'
'Moderately acceptable'
'Highly acceptable'
Acceptability classes (AI)

Figure 2

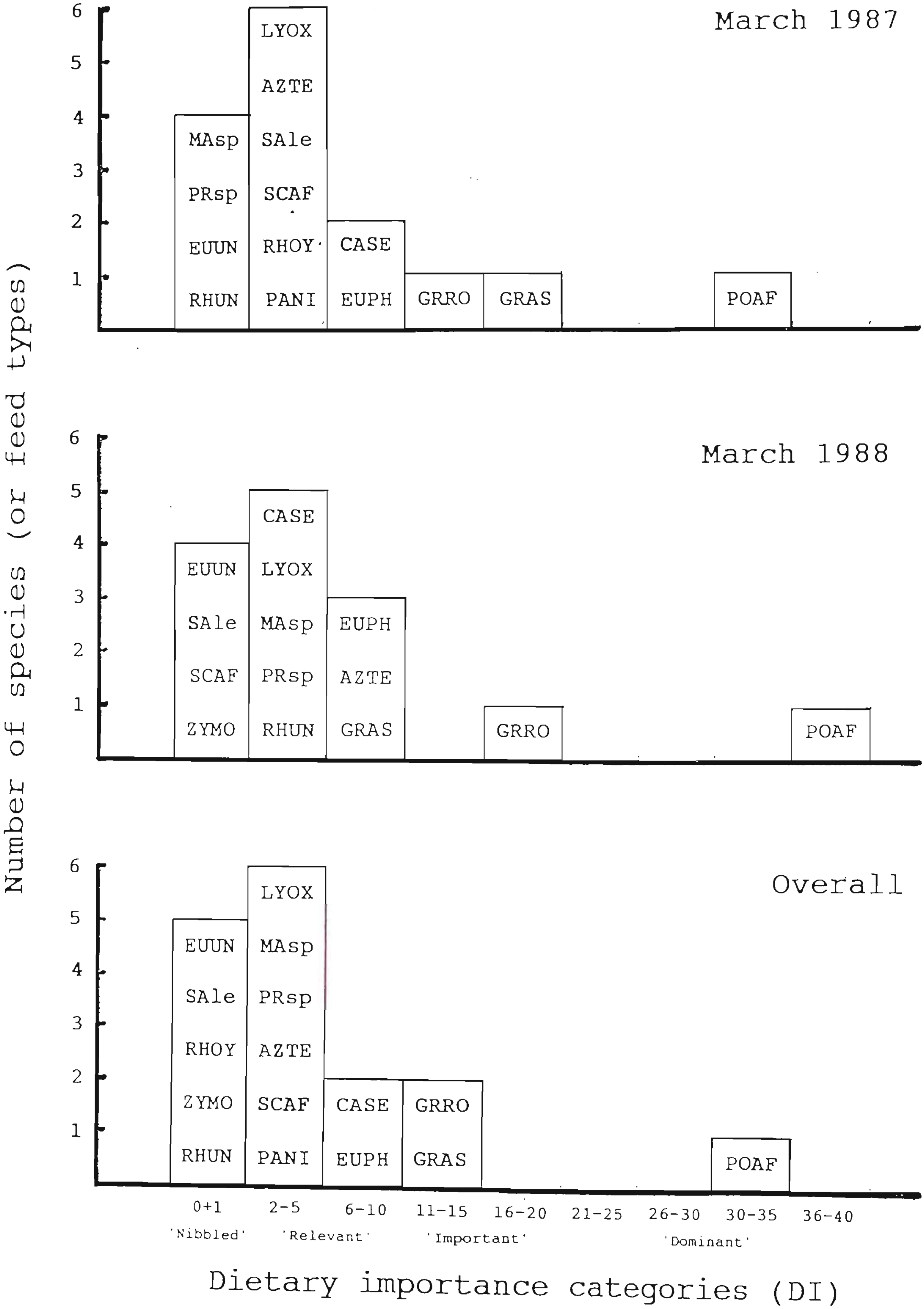
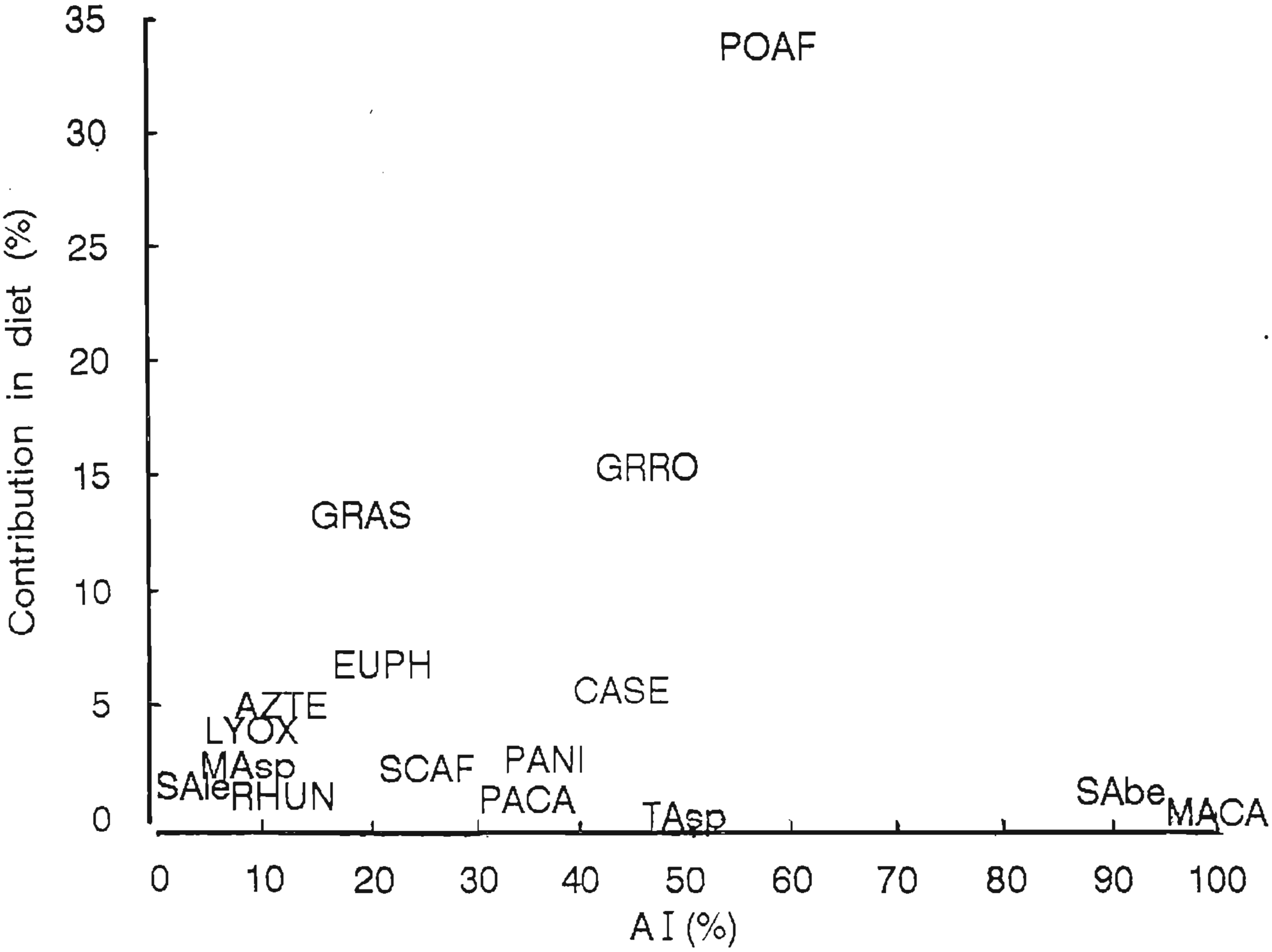

March 1987
March 1988
Overall
Number of species (or feed types)
LYOX
AZTE
MAsp
SAle
PRsp
SCAF
EUUN
RHOY
CASE
RHUN
PANI
EUPH
GRRO
GRAS
POAF
ZYMO
0+1
2-5
6-10
11-15
16-20
21-25
26-30
30-35
36-40
'Nibbled'
'Relevant'
'Important'
'Dominant'
Dietary importance categories (DI)

Figure 3



POAF
GRRO
GRAS
EUPH
CASE
AZTE
LYOX
MAsp
PANI
SCAF
SAle
RHUN
PACA
TAsp
SAbe
MACA
Contribution in diet (%)
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
AI (%)

Figure 4

RESEARCH NOTE

RELATIONSHIP BETWEEN SOME COMMONLY ASSAYED PLANT CHEMICALS AND SHRUB ACCEPTABILITY (TO GOATS) IN THE SUCCULENT BUSHVELD OF THE EASTERN CAPE

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ABSTRACT

The chemical properties of thirteen common succulent bushveld shrubs (as assayed in standard Department of Agriculture analyses) were subjected to principal component analysis and discriminant function analysis in an attempt to explain shrub preference.

No relationship between the chemical composition and acceptability could be found. It appears that the chemicals commonly assayed for plant chemical composition are poor predictors of these plant's acceptability.

INTRODUCTION

The succulent bushveld is a dense thicket vegetation occurring on the eastern seaboard of South Africa in hot, dry, frost-free areas at low altitudes between the Kei and Gouritz river valleys (Stuart-Hill a in prep.). Browse is the production base and this is derived from a number of succulent trees and shrubs.

The objective of this study was to initiate discussion and research on shrub selection by goats in the succulent bushveld of the eastern Cape. The intention was not to challenge global hypothesis on feeding ecology, but rather take the first step towards this by screening various commonly assayed plant chemicals for their usefulness as predictors of acceptability.

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PROCEDURE

This study was concerned with the following hypothesis for 13 common shrubs of the succulent bushveld:

> the chemical composition of a shrub (as determined by standard Department of Agriculture analysis - Steenkamp & Hayward 1979) determines its acceptability to goats.

The plant chemical composition for each shrub was obtained from existing Tables compiled by Steenkamp and Hayward (1979). These contained values for a dry and a wet (growing) period. Separate Principal Component Analysis (PCA) were performed at each of the two periods, based on the following chemical variables: crude protein (CP), crude fibre (CF), ether extract (EE), ash, N-free extract (NFE), Na, K, Ca, P, Mg, Fe, Cu, Mo, Mn, Co, Ca/P and Ca/Mo.

In a separate study the shrubs were classified into three palatability classes according to a modified version of Owen-Smith and Cooper's (1987) "site-based acceptability" technique (Stuart-Hill b in prep.). This assessment was repeated on two different occasions (one during a dry phase and the other during a wet or growing period). Three broad acceptability categories emerged (i.e. highly acceptable, moderately acceptable and unacceptable), none of which changed between surveys. During the dry period in question, all species had leaf material and so this is compatible with the chemical analysis data because Steenkamp & Hayward (1979) analyzed only leaf material.

The approach in interpreting results, was to examine the scatter of species in ordination (chemical composition) space and these compared with the shrubs' acceptability categories. The idea being that, if species were separated out by any of the chemical composition axes, and these coincided with the acceptability groupings, then it would be possible to identitify which, if any, of the plant chemicals under consideration are correlated with goat preference. These chemicals could then be subjected to critical analysis for prediction of acceptability. In addition to this, Discriminant Function Analysis (DFA) was also performed on these data to specifically test the hypothesis above.

RESULTS AND DISCUSSION

The scatter of species along the first three axes in ordination space for the wet and dry periods are presented in Figure 1.

INSERT FIGURE 1

It was evident that the acceptable and unacceptable species were not separated out by either ordination (Figure 1). Indeed, there are some highly acceptable plants which are chemically more similar to some unacceptable plants than the rest of the palatable species. The DFA also failed to produce any singificant relationships and it appears, therefore, that shrub acceptability to goats is not determined by the chemicals assayed by Steenkamp and Hayward (1979). The hypothesis is thus refuted for the plant chemicals under consideration.

This result is not unexpected given that the plant chemicals tested did not include any allelochemicals (except possibly for EE) which generally override the effects of nutrients in determining selection of woody plants by browsers (Bryant & Kuropat 1980). Cooper, Owen-Smith and Bryant (1988) have confirmed this in South African savannas and found that palatable and unpalatable browse species were separated out on the basis of the difference between protein and condensed tannin. In addition to these secondary metabolites, acceptability may also be a function of the physical attributes of the plant (Stuart-Hill & Mentis 1982). Consequently, it is recommended that a similar analysis be conducted, this time using other plant-based attributes (e.g. tannin content, physical variables such as leaf density, colour, spininess, etc.).

ACKNOWLEDGEMENTS

I am extremely grateful to Craig Morris for performing the Discriminant Function Analyses.

REFERENCES

Bryant J.P. & Kuropat P.J. 1980. Selection of winter forage by subartic browsing vertebrates: the role of plant chemistry. Annual review of ecology and systematics. 11: 261-285.

Cooper S.M., Owen-Smith N. & Bryant J.P. 1988. Foliage acceptability to browsing ruminants in relation to seasonal changes in the leaf chemistry of woody plants in a South African savanna. Oecologia 75: 336-342.

Owen-Smith N. & Cooper S.M. 1987. Assessing food preferences of ungulates by acceptability indices. J. Wildl. Manage. 51(2): 372-378.

Steenkamp C.W.P & Hayward F.C. 1979. Chemiese samestelling van die vernaamste plantspesies in die suid-sentrale sektor van die groot eskarpment. Tec. Bull. Dept. Agric. Tec. Services. No. 149.

Stuart-Hill G.C. & Mentis M.T. 1982. Co-evolution of African grasses and large herbivores. Proc. Grassld Soc. Sth. Afr. 17: 122-128.

Stuart-Hill G.C. a in prep. An agriculturists view of the nature and extent of the succulent bushveld.

Stuart-Hill G.C. b in prep. Preliminary goat preference rating of shrubs in the succulent valley bushveld of the eastern Cape.

FIGURE CAPTION

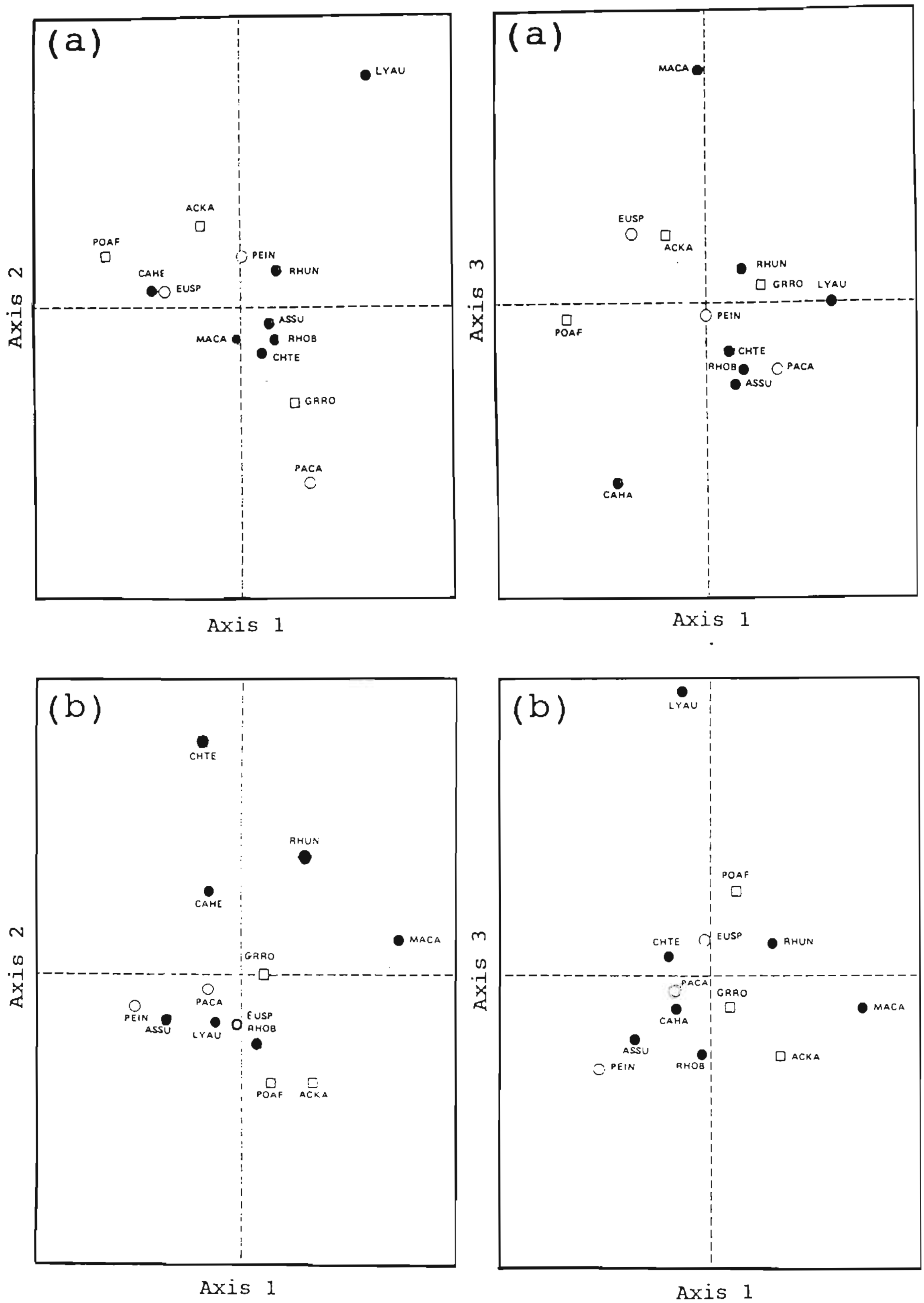
Figure 1. Positions of species on the first, second and third principal components, based on their chemical composition (determined in standard Department of Agriculture analyses) for a growing (wet) period (a) and for a dry period (b).

ACCEPTABILITY CLASSIFICATION:

□ Highly acceptable, ○ moderately acceptable, ● unacceptable

Species codes.

ACKA	*Acacia karroo*	MACA	*Maytenus capitatus*
ASSU	*Asparagus suaveolens*	PACA	*Pappae capensis*
CAHA	*Carrissa haematocarpa*	PEIN	*Pentzia incana*
CHTE	*Chrysocoma tenuifolia*	POAF	*Portulacaria afra*
EUSP	*Euphorbia sp.*	RHOB	*Rhigozum obovatum*
GRRO	*Grewia robusta*	RHUN	*Rhus undulata*
LYAU	*Lycium austrinum*		



[TOOL 6]

A MODEL TO SET INITIAL STOCKING RATES

ORIGINAL BRIEF

This model should integrate, at the very least, rainfall and vegetation condition. Importantly, it should clearly state that it's predictions are not absolute but rather intended to be used as initial values which can be adapted with experience.

RESULT

A model to set initial stocking rates was provided in the published paper: **Carrying capacity of the succulent valley bushveld of the eastern Cape [P 6.1]** (the co-author initiated the field work). This model should be viewed as a first approximation which should be tested and upgraded where necessary. A formal test of the model has been started and is currently the responsibility of F.O. Hobson[2]. The essential preliminary result after three years of treatment, is that while the vegetation at the high stocking rates (i.e. two and three times greater than recommended by the model) is showing visible signs of damage, the goats' productivity (measured with mass gain) continues at control levels (pers comm. F.O. Hobson). Despite this new experimental effort, further on-farm testing is required.

A lesson from the published study was that the research effort was not worth the information obtained, especially in view of the rather nebulous concept of carrying capacity and the temporal and spatial limitations of the predictions. I suggest that future work of this nature should be more holistic, the experimental effort going into increasing the range of sites and variables under test, rather than on the backbreaking and inefficient efforts to objectively monitor plant utilization and recovery.

By way of generalizing the results, and in an attempt to discover a unifying relationship to predict carrying capacity in the woody vegetation communities of the eastern Cape, the model developed for the false thornveld of the eastern Cape (Acocks 1975, veld type number 21) was used to predict the carrying capacity as measured in the above experiment. The result was surprisingly good, given the major differences between the two vegetation types (see the unpublished paper: **Can a common model be used to determine carrying capacity in false thornveld and succulent valley bushveld: a preliminary investigation? [P 6.2]**).

---

[2] Dohne Research Centre, P Bag X15, Stutterheim, 4930.

[P 6.1]

ERRATA & CLARIFICATION NOTES

Specific errors (excluding punctuation and those as a result of changing information or philosophy) are as follows.

Pg. 4	Col. 2	Table 4	The browsing contributed by game were included; i.e. the word "not" in the caption should be deleted!
Pg. 7	Col. 1	Ln. 5	"at high or low ecological.." should read "at low and particularly at high ecological.."
Pg. 8	Col. 2	Fig. 9	The caption should reflect the units $LSU.ha^{-1}$

Afr J Range For Sci 1993 10(1) 1–10

[P 6.1]

Carrying capacity of the succulent valley bushveld of the eastern Cape

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Received 24 January 1992; Accepted 19 January 1993

Abstract

This experiment evaluated the relationship between carrying capacity and veld condition. Goat browsing days were used as a measure of shrub productivity and cattle grazing days as a measure of the sward. Twigs on two shrub species were monitored to quantify utilization and recovery of the woody layer and a pasture disc meter was used to monitor grazing of the grass layer. Dense bushveld (high ecological status) had higher overall carrying capacity than open bushveld (low ecological status). Carrying capacity changed considerably depending on annual rainfall and this was complicated because the more degraded the veld the greater the variation. Maximum long-term grass production occurred at intermediate tree densities. This was, however, extremely unreliable between years and a permanent grazer enterprise cannot be recommended. For total forage production and constant fodder supply, dense bushveld is optimum. Optimum, however, changes from season to season and with operator objectives. In wet seasons it will pay to have veld in the lower range of ecological status (i.e. open bushveld) whereas in other seasons veld with high ecological status (dense bushveld) will be more productive. Farmers with only cattle may aim to have veld in the mid-range of ecological status but this conflicts with farmers who have browsers (e.g. goats and kudu) and with the conservation ideal, because bushveld, once thinned, does not regenerate, thereby limiting future management alternatives.

Introduction

The succulent valley bushveld, also known as Kaffrarian Succulent Thicket (Cowling 1984), occurs on the eastern seaboard of South Africa in hot, dry (rainfall 225 to 500 mm a^{-1}), frost-free areas at low altitudes (usually below 500 m but never above 1 000 m) (Acocks 1975; Cowling 1984; Everard 1987; Agmet. records, Döhne Research Station, Private Bag X15, Stutterheim, 4930 Republic of South Africa). It is a dense, semi-succulent, thorny thicket approximately 2 to 3 m high where succulents contribute in excess of 20 to 30% relative cover (Cowling 1984). Grasses are present, but sparse (10 000–30 000 plants ha^{-1}) and mostly non-perennial (Acocks 1975). In a pristine state this vegetation is dominated by the tree-succulent *Portulacaria afra* (nomenclature follows Gibbs Russell *et al.* 1987), representing over half of the total phytomass (data from Aucamp 1979). It is considered to be the most important plant from a goat forage production viewpoint (Aucamp 1979).

This vegetation is currently farmed with goats and supports a large proportion of the mohair industry of South Africa. It is sensitive to utilization and is rapidly being eliminated under current pastoral systems (Hoffman & Everard 1987; Hoffman 1989; Hoffman & Cowling 1990). This is serious as it represents an irreversible loss of a unique vegetation type, and the community which replaces it is unstable, prone to soil erosion, and alleged to support fewer stock. There has been considerable controversy over the years regarding the carrying capacity of succulent valley bushveld, with some farmers claiming that the vegetation can carry large numbers of animals without becoming degraded. The objective of this study was to evaluate the carrying capacity of succulent valley bushveld in various conditions (states).

Numerous authors have attempted to define carrying capacity (Booysen 1967; Caughley 1979; Collinson & Goodman 1982; Danckwerts 1982; Turner 1988; Trollope & Trollope 1990) but these definitions are not consistent. Carrying capacity is a rather nebulous notion of sustainable productivity and, as a consequence, is an aspect frequently avoided by purist scientists. Despite the academic demerits of determining carrying capacity it is possibly the information most frequently requested by land managers, and applied scientists are, therefore, obliged to provide such guidelines. Invariably, carrying capacity attempts to describe the productivity of the vegetation in terms of the number of animals that can be maintained in a productive state on an area of land without deterioration of vegetation or soil (Danckwerts 1989).

In this study, carrying capacity was determined by using an experimental approach similar to that devised by Danckwerts (1982) for sweet grassveld. The carrying capacity estimates determined in this study are intended to be used as initial guidelines which land managers can immediately implement, and later adapt.

[1] Department of Grassland Science, University of Natal, Pietermaritzburg. Study carried out at Döhne Research Station, Stutterheim

[2] Roodeplaat Grassland Institute, Agricultural Research Council, Pretoria

Procedure

The experimental approach was to use animals to harvest seasonal production with a simulated rotational grazing/browsing system, similar to that devised by Danckwerts (1982). Forage is produced by a host of herbaceous, succulent and woody species, the relative contributions changing from site to site. We viewed this productivity as two sources of forage: herbage for grazers and browse for browsers. The idea was to use goat browsing days to measure shrub productivity and cattle grazing days for the grass. The number of grazing/browsing days obtained per unit area was considered to be an index of the forage productivity and, therefore, carrying capacity.

Five 2-ha camps were visually selected in the Kirkwood district so that (1) they represented a range in possible vegetation conditions or states; (2) the vegetation within a single camp was relatively homogeneous; and (3) they were in close proximity to each other (<1 km) to reduce the influence of differential rainfall events between sites. The sites were surveyed using a modified point-centred-quarter method and the principal components analysis (described in Stuart-Hill *et al.* 1986). Vegetation scores were obtained for each camp and these were later modified by Stuart-Hill (1989) to be independent of value judgement (see also Stuart-Hill & Hobson 1991). Each site received a score which ranged between 100 and −10 (Table 1), although in practice the range in scores is open ended. High scores represent very dense thicket vegetation dominated by *P. afra* (pristine succulent valley bushveld) and low scores represent an ephemeral herbaceous community with a woody layer consisting of a few scattered umbrella-shaped *Pappea capensis* trees interspersed with unpalatable shrubs such as *Lycium oxycarpum* and *Zygophyllum morgsana*.

All wild ungulates (kudu, bushbuck, duiker, and grysbok) were excluded from the experimental camps with a 4 m high game fence and the camps were rested for 10 months before the first grazing in February 1986. Seasons were assumed to start in May and end in April. The experiment continued until the end of April 1988.

Determination of browsing capacity

Portulacaria afra and *Grewia robusta* were selected as the browse indicator plants because both are important forage producers (Aucamp 1979), and *P. afra* in particular is one of the first plants to be eliminated with heavy browsing.

Portulacaria afra and *G. robusta* plants were selected in a stratified random manner and marked. The number of plants per camp varied according to the density of shrubs in each camp (see Table 1 for numbers of plants per camp). Six twigs were permanently marked (Figure 1) on each plant. Twig length and leaf number were monitored before, during, and after each browsing period to ensure that browse utilization was the same between camps.

Goats were placed in each camp and allowed to browse until 50% of leaves of either *P. afra* or *G. robusta* had been removed, or 25% of twig length of either species had been removed, or the animals were losing weight. The weights of 15 goats camp^{-1} were monitored before, during, and at the end of each browsing period. The rest of the animals in each camp (filler animals) were not weighed individually.

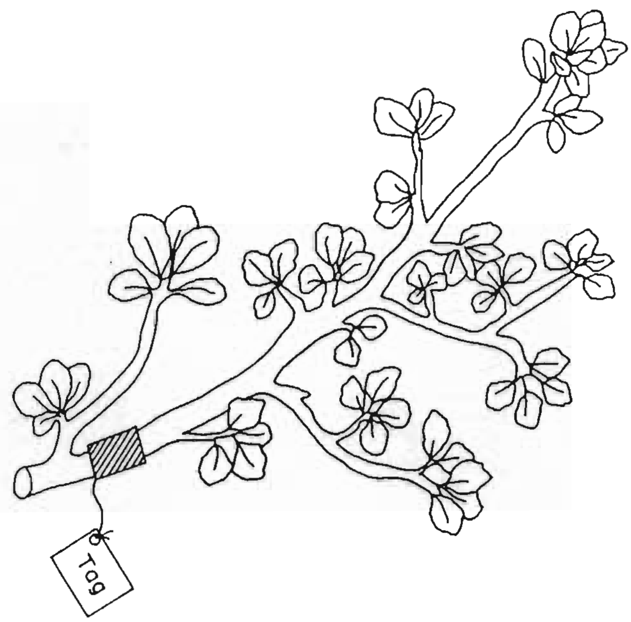

Figure 1 Detail of twig showing marking procedure. All leaves on the marked twig were counted and the lengths of all the subsidiary twigs were measured and added to give total twig length.

During the non-browsing (recovery) periods, the marked twigs were measured at approximately monthly intervals. When twig length and leaf number had recovered to pre-defoliation levels, plants were assumed to have recovered and the next grazing period was started.

Over a period of three years, the total number of kg livemass browsing days for each camp was determined, the idea being that this represented sustainable browse (goat) productivity for that camp. These values were converted to LSU per hectare and hectares per LSU. Throughout the experimental period, it was attempted to keep game out of the camps, but when this was not possible the number and type of animals and the period which they occupied the camps was recorded at weekly intervals. These were all browsers (Smithers 1983) and kilogram livemass browsing days for these animals were added to the browser totals.

Table 1 Number of plants monitored in each of the five experimental camps

Camp number	Vegetation score	*Portulacaria afra* plants	*Grewia robusta* plants
1	100	10	10
2	84	8	8
3	46	6	6
4	20	6	6
5	−9	–	6

There were insufficient *P. afra* plants in camp 5

Determination of grazing capacity

When sufficient grass was present (only following exceptional rainfall events) dry dairy cattle were introduced into each camp. Sward height was monitored with 100 placements of a pasture disc meter (Bransby & Tainton 1977) and the cattle were removed once average disc height was within 5 mm of 30 mm, the height at which animals would be on restricted intake (using the logic argued by Danckwerts 1982). Cattle were weighed before, during, and at the end of each period of occupation, and if they started to consistently lose weight, the experimental rule was to terminate the period of occupation. In addition to monitoring sward height, 50 square quadrats (1 m × 1 m) were cut just prior to and immediately following the period of occupation. Owing to the clumped nature of the woody layer, the sward was discontinuous over the area. Sward sampling was confined to those areas where the sward was dominant and a consequence is that the measurements for the sward do not reflect herbage availability in each camp. Rather, these data were merely used to monitor herbage disappearance to ensure even utilization between camps.

Over a period of three years, the total number of kilogram livemass grazing days for each camp was determined, the idea being that this represented sustainable grazing (cattle) productivity for that camp. These values were converted to LSU per hectare and hectares per LSU. Naturally there was some dietary overlap between the goats and cattle, but as the latter are not a permanent component of farming systems in this vegetation, this problem was overcome by letting the goats be the primary enterprise with the cattle following. It follows that browsing capacity might be slightly inflated at the expense of grazing capacity. This, however, is likely to be insignificant as the goats were never subjected to nutritional stress and were, therefore, primarily browsers (Aucamp 1979).

Productivity of animals

As described, animal mass was monitored during each period of occupation, but as these were inevitably short (less than one month), these data could not be used to reliably quantify animal productivity. They were nevertheless used to ensure that the animals did not lose weight as one of the experimental rules was that the animals were to be removed from the camp as soon as they started to consistently lose weight.

Data analysis

The mean change in twig length and leaf number against that originally present was determined at each sampling date for both shrub species in all five camps. These were relativized (expressed as a percentage change) and plotted against time to give a graphical display of the relative utilization or recovery of the twigs or leaf number (Figures 2 and 3). Confidence limits for each mean are not displayed as they confuse the trends and are not necessary as the repeatability of this technique is being reported in a separate study (Stuart-Hill unpubl.). However, least significant differences ($P = 0.05$) for each parameter on both species in each camp are summarized in Table 2. It will be noted that the technique was more repeatable for *G. robusta* than for *P. afra*.

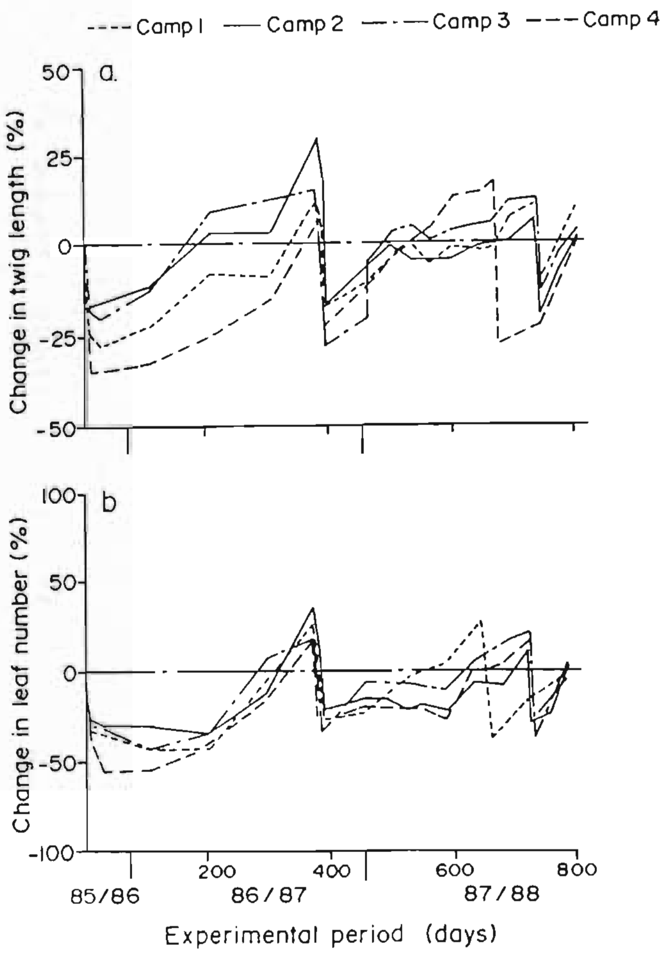

Figure 2 Change over the experimental period of twig length (a) and leaf number (b) of permanently marked *Portulacaria afra* twigs in four 2-ha camps representing differing states of Succulent Valley Bushveld. Camps were rested for 10 months before the first grazing; six twigs were marked on each plant (see Table 1 for number of plants marked per camp); statistics are contained in Table 2.

Results

Browsing capacity

Twig monitoring

The change in twig length and leaf number of *P. afra* and *G. robusta* over the experimental period is shown in Figures 2 and 3, respectively. There was a severe dry spell (1986/87) after the first period of occupation and the plants were slow to recover. In some cases defoliation continued through desiccation (Figures 2b and 3b). During the latter part of the 1987/88 season, growing conditions were more favourable and recovery was rapid.

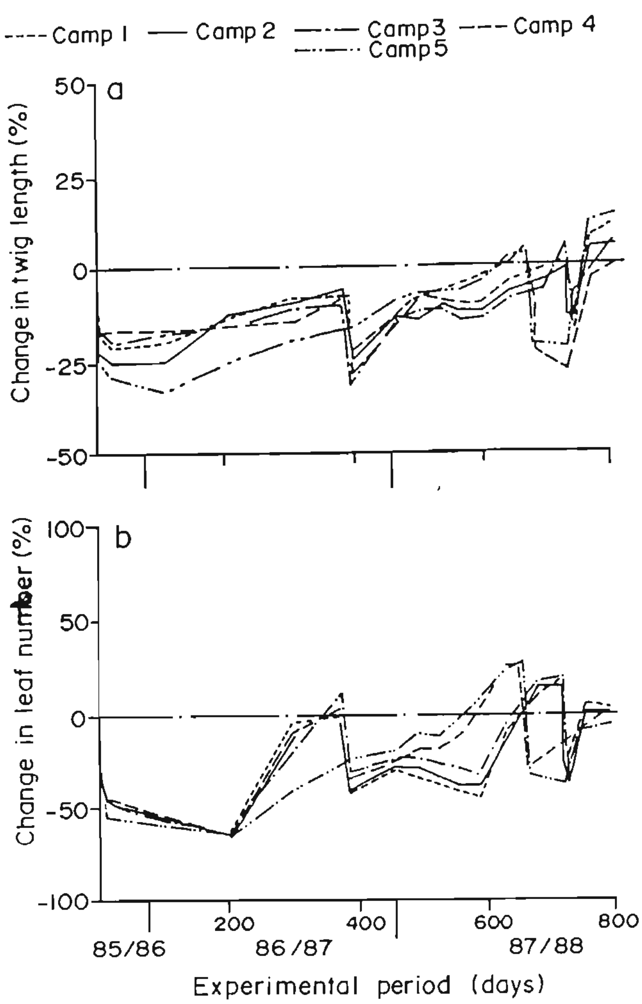

Figure 3 Change over the experimental period of twig length (a) and leaf number (b) of permanently marked *Grewia robusta* twigs in five 2-ha camps representing differing states of Succulent Valley Bushveld. Camps were rested for 10 months before the first grazing; six twigs were marked on each plant (see Table 1 for number of plants marked per camp); statistics are contained in Table 2.

Table 2 Number of samples (N) and least significant differences (P = 0.05) for each parameter measured in this study

	Portulacaria afra			*Grewia robusta*		
		Change in			Change in	
Camp number	N	Twig length (%)	Leaf number (%)	N	Twig length (%)	Leaf number (%)
1	60	20	25	60	12	6
2	48	22	28	48	15	7
3	36	25	35	36	18	8
4	36	25	35	36	18	8
5	0[1]	–	–	36	18	8

[1]There were insufficient *P. afra* plants in this camp

Prior to the second period of occupation, *G. robusta* twig length in all camps had not recovered to pre-defoliation levels, but it was nevertheless decided to browse

Table 3 Mean masses (kg) of goats monitored on each treatment during the various periods of occupation. Standard errors ranged between 6.51 and 7.92 kg

Date	Camp 1	Camp 2	Camp 3	Camp 4	Camp 5
Feb. 1986					
20.2	38	38	40	38	38
25.2	39	39	39	41	39
27.2	42	40	39	39	39
30.2	42	41	40	41	40
2.3	42	42	41	41	39
5.3	42	41	41	41	40
Feb. 1987					
24.2	42	40	42	40	
27.2	42	39	44	39	
3.3	42	40	43	39	
5.3	41	39	42	40	
9.3	41	41	43	39	
11.3	42	40	43	40	
13.3	43	41	43	41	
Dec. 1987					
4.12				50	54
7.12				48	52
9.12				48	53
11.12				50	52
13.12				50	51
16.12				51	54
20.12				52	55
Feb. 1988					
9.2	50	47	51		
10.2	50	50	53		
12.2	52	51	53		
15.2	53	51	53		
17.2	53	51	53		
19.2	52	52	54		

Table 4 Kilogram livemass browsing days obtained from each of five 2-ha camps representing a range in ecological statuses. Browsing contributed by game (kudu, duiker, bushbuck, and grysbok) which had found their way into the camps has not been included

	Camp				
Season	1	2	3	4	5
1985/86	36 833	32 629	13 839	14 205	8 840
1986/87	26 143	26 565	12 200	5 004	0
1987/88	43 063	40 420	16 631	6 961	1 575
Mean	35 346	33 204	14 223	8 723	3 472

camps 1 to 4 as *P. afra* had regrown to well beyond its pre-defoliation levels and *G. robusta* leaves in these four camps had recovered. Camp 5 was not utilized during the second period of occupation (1986/87) as neither the twigs nor leaves of *G. robusta* had recovered to pre-defoliation levels.

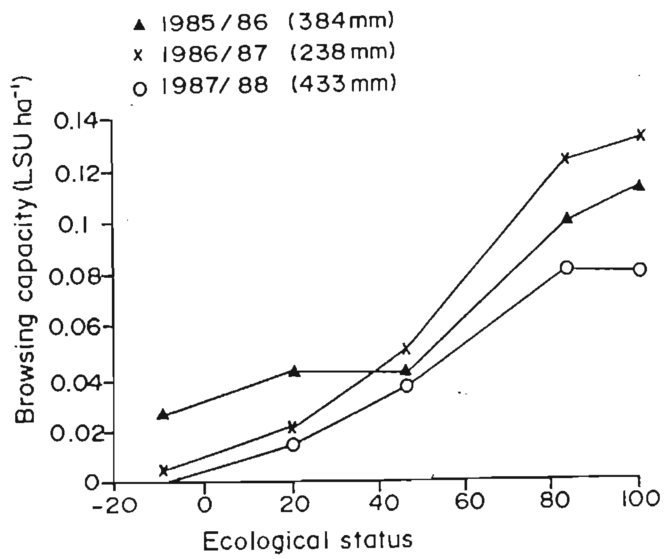

Figure 4 Relation between ecological status of Succulent Valley Bushveld and browsing capacity measured for the three experimental seasons with differing annual rainfall.

Only camps 4 and 5 were browsed during the first period of occupation in 1987/88. In retrospect, camps 1 to 3 were probably also ready to be browsed at this time and camps 4 and 5 should actually have been browsed approximately one to two months earlier. This was partly due to an operational delay of about a month between determining that the plants had recovered and the start of the period of occupation. We believe that this will not greatly influence the results given that the rest of the camps were browsed only two months later and within the same experimental season (1987/88).

The twig length and leaf number of both species had recovered to at least their pre-defoliation levels when the experiment was terminated. Indeed, some twigs had recovered slightly beyond (non-significant) the pre-defoliation levels but this (if meaningful) would emphasize the conclusions drawn in this investigation.

Goat mass

Average goat mass did not consistently decline during any of the periods of occupation (Table 3) and it follows that, from an animal performance viewpoint, none of the camps was over-utilized.

Browsing capacity

The number of browsing days obtained during each season from each camp are displayed in Table 4. Included in these values are the contribution made by game (kudu, duiker, bushbuck, and grysbok) which had found their way into the camps. Their kilogram grazing days were determined as the estimated number of days they occupied the camp multiplied by 0.75 of mean female mass (Smithers 1983).

In all three seasons high ecological status had a higher browsing capacity than low ecological status. Increasing rainfall generally increased browsing capacity but did not markedly affect the shape of the relation (Figure 4). It will

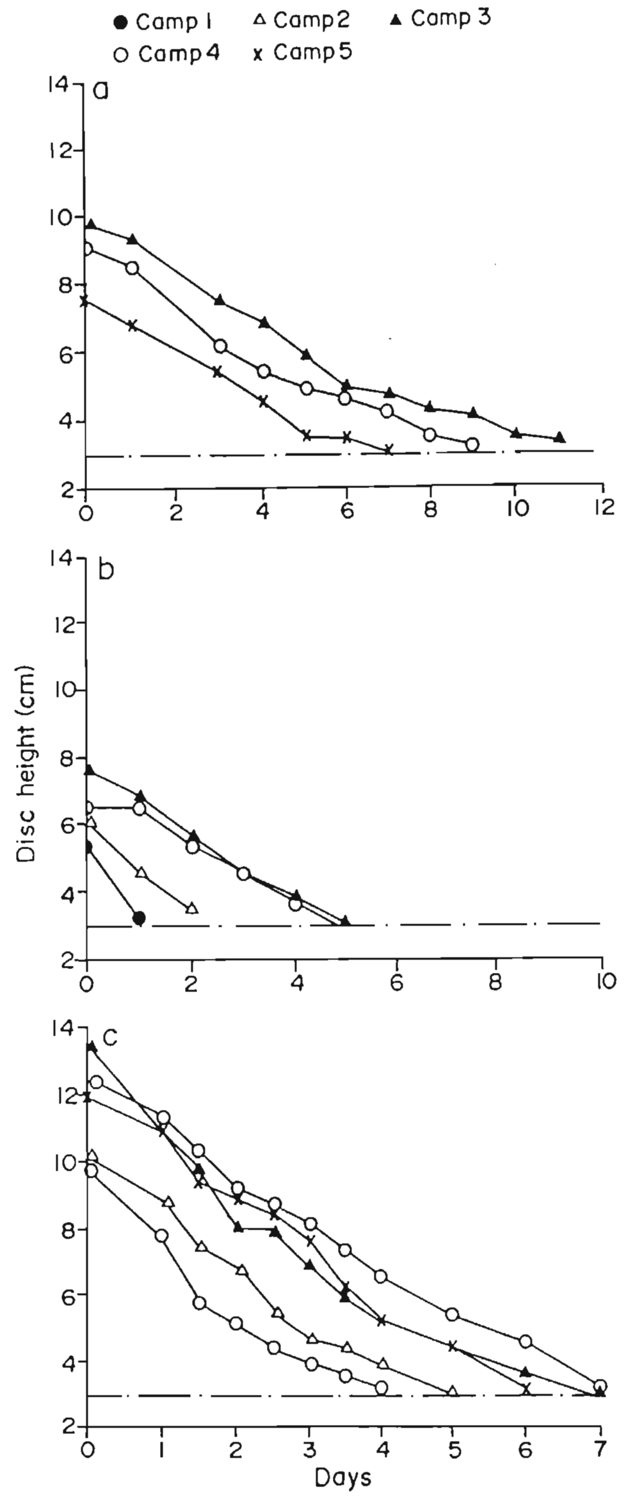

Figure 5 Change in sward height, measured with 100 placements of a pasture disc meter (Bransby & Tainton 1977), during the April 1986 (a), November 1987 (b), and April 1988 (c) periods of occupation. Cattle numbers and average weights are described in Table 6.

be noted, however, that the browsing capacity estimations for the lower two ecological statuses during the 1985/86 season were inconsistent with the rest of the results (higher than expected) and this was possibly due to camps 4 and 5 being more heavily utilized during the first period of occupation. This is evident for camp 4 in the *P. afra* data (Figure 2) and for camp 5 in the *G. robusta* twig length

Table 5 Sward dry matter measurements (kg ha^{-1}) determined by cutting 50 m^{-2} quadrats before and after each period of occupation for each of five 2-ha experimental camps

Date	Camp 1	Camp 2	Camp 3	Camp 4	Camp 5
April 1986					
Before	–	–	1 630	1 505	1 118
After	–	–	554	521	588
Nov. 1987					
Before	897	983	1 169	964	–
After	529	503	572	527	
April 1988					
Before	1 670	1 580	2 450	2 160	2 130
After	544	554	498	550	560

Although the units are kg ha^{-1}, this is not a true reflection of herbage on offer as grass occurred only in patches in the camps. Sampling was concentrated in these areas as the intention was to monitor herbage disappearance, not to determine herbage on offer.

Table 6 Number of days each camp was occupied, number of cattle and average cattle weight (kg) before and after each period of occupation. The before and after masses were compared with paired *t* tests and were not different ($P \leq 0.05$)

Date	Camp 1	Camp 2	Camp 3	Camp 4	Camp 5
April 1986					
No. days	–	–	11	9	7
No. cattle	–	–	5	5	5
Wt. before	–	–	378	415	434
Wt. after	–	–	369	424	439
Nov. 1987					
No. days	1	2	5	5	–
No. cattle	2	2	4	4	–
Wt. before	310	305	336	391	–
Wt. after	295	300	338	398	–
April 1988					
No. days	4	5	7	7	6
No. cattle	2	2	12	12	8
Wt. before	288	328	379	381	451
Wt. after	285	321	388	384	444

Table 7 Kilogram livemass grazing days obtained from each of five 2-ha camps representing a range in ecological statuses

	Camp				
Season	1	2	3	4	5
1985/86	0	0	20 543	18 878	15 278
1986/87	0	0	0	0	0
1987/88	2 897	4 455	38 954	40 020	21 480
Mean	966	1 485	19 832	19 633	12 252

data (Figure 3a), but there was no evidence of excessive utilization of *G. robusta* in camp 4 compared to the other camps (Figure 3). Furthermore, as *P. afra* was absent in camp 5, and therefore not monitored, we cannot be sure of this interpretation.

Grazing capacity

Sward monitoring

The decline in sward height in each camp during the three periods of occupation is illustrated in Figure 5. Measurements of sward mass before and after each period of occupation are contained in Table 5. There was insufficient grass in camps 1 and 2 and in camp 5 during the April 1986 and November 1987 periods of occupation, respectively, to warrant grazing (Table 5, Figure 5).

Cattle mass

Cattle mass did not decline during any of the periods of occupation (Table 6) and it can be assumed, therefore, that the animals were not under nutritional stress.

Grazing capacity

The number of grazing days obtained during each season from each camp are displayed in Table 7. During the 1986/87 season rainfall was low (238 mm) and no grazing days were obtained from any of the camps and grazing capacity, therefore, was zero (Figure 6). In reality, some grass was produced but this was almost entirely utilized by the goats during their period of occupation. Grazing

Table 8 The differences between measured carrying capacity (grazing plus browsing capacity) and predicted carrying capacity derived from a response surface mathematical model using 12 monthly rainfall figures and vegetation condition (ecological status) as input variables

Season	Veld score	Rain (mm)	Measured (LSU ha^{-1})	Predicted (LSU ha^{-1})	Difference (LSU ha^{-1})
1985/86	100	384	0.112	0.106	0.006
	84	384	0.099	0.108	0.009
	46	384	0.105	0.105	0
	20	384	0.101	0.095	0.006
	–9	384	0.073	0.076	0.003
1986/87	100	238	0.080	0.086	0.006
	84	238	0.081	0.071	0.010
	46	238	0.037	0.039	0.002
	20	238	0.015	0.019	0.004
	–9	238	0	–0.002	0.002
1987/88	100	433	0.136	0.124	0.012
	84	433	0.130	0.149	0.019
	46	433	0.169	0.164	0.005
	20	433	0.143	0.138	0.005
	–9	433	0.070	0.074	0.004
Mean difference					0.006

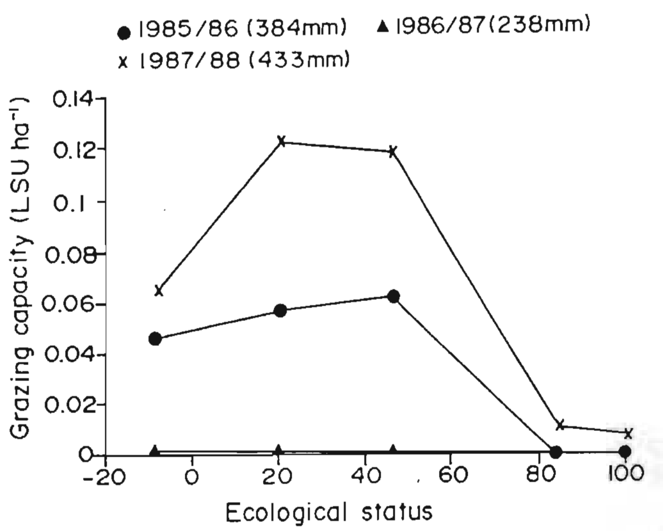

Figure 6 Relation between ecological status of Succulent Valley Bushveld and grazing capacity measured for the three experimental seasons with differing annual rainfall.

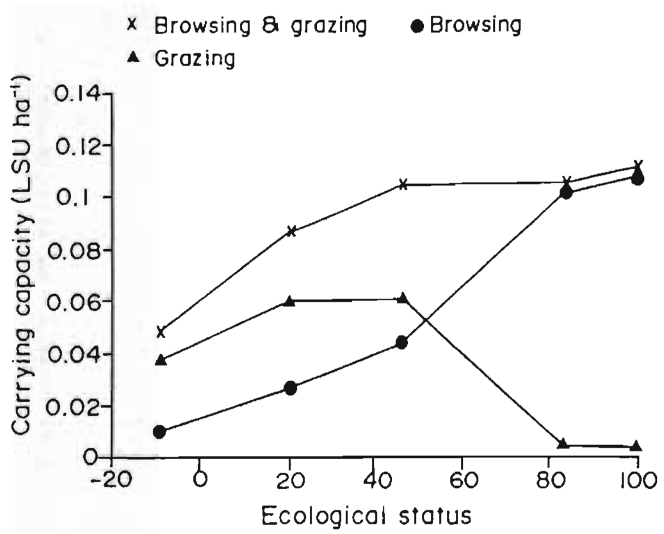

Figure 7 Relation between ecological status of Succulent Valley Bushveld, and average grazing, browsing, and grazing plus browsing capacity measured over the experimental period.

capacity in the other two seasons was highest at intermediate ecological status and decreased considerably at high ecological status. Increasing rainfall had the effect of increasing grazing capacity at intermediate ecological status but had little effect at high or low ecological statuses (Figure 6).

Carrying capacity

Carrying capacity was assumed to be the sum of grazing capacity and browsing capacity. Dense bushveld had a higher overall carrying capacity than open bushveld with a requirement of 9 ha of dense bush LSU^{-1} (i.e. 0.1111 LSU ha^{-1}) down to 21 ha of severely degraded bush LSU^{-1} (i.e. 0.0476 LSU ha^{-1}) (Figure 7). Averaged over all seasons, there was little increase in carrying capacity with ecological status above *c.* 50% (Figure 7). Possibly this represents a measure of the system's potential, which at higher ecological status remains constant, even with rather marked changes in vegetation composition and structure; i.e. the resources (rain, nutrients, etc.) are merely partitioned differently but overall productivity remains the same. However, at lower ecological status, it seems that system breakdown has occurred (e.g. soil erosion) and potential productivity has declined. However, it is evident that between seasons, carrying capacity would vary markedly with ecological statuses of less than *c.* 80% (Figure 8).

Carrying capacity changed considerably depending on rainfall (Figure 8). This was complicated because the more degraded the veld the greater was the variation. Carrying capacity varied by approximately 26% above and below average carrying capacity for pristine bushveld, whereas for degraded bushveld carrying capacity varied by 52% above or 100% below the average.

Discussion

In the long run and with a combination of grazers and browsers it will pay to have dense bushveld (Figure 7). However, it is important to note that optimum veld condition changes from season to season and with management objectives.

In wet seasons, total forage production is highest at intermediate ecological status (i.e. more open bushveld), whereas in other seasons veld with high ecological status (dense bushveld) was more productive (Figure 8). This was due to the sward which, at intermediate tree densities (Figure 6), is extremely productive during wet seasons. Two points, however, must be made regarding this forage source. Firstly, it is extremely unreliable between years (Figure 6) and secondly, in the long term, food from the shrubs at high ecological status will exceed forage from the grass at lower ecological status (Figure 7). For a constant fodder flow, therefore, dense bushveld is preferable to open bushveld (Figure 8). Nevertheless, the considerable amounts of forage produced by degraded bushveld

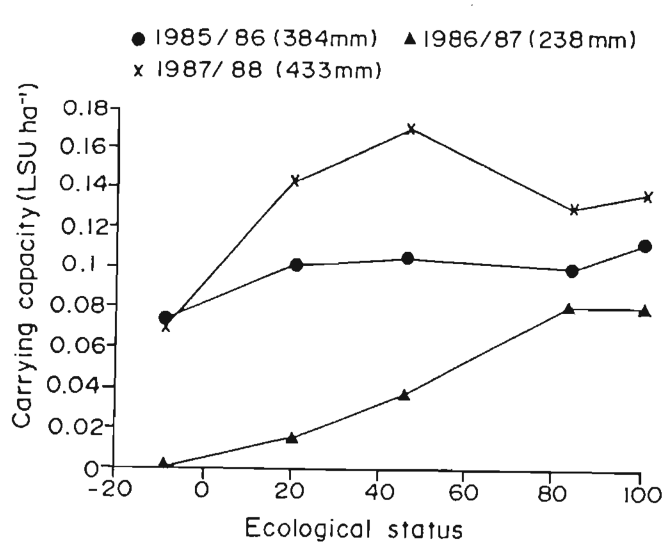

Figure 8 Relation between ecological status of Succulent Valley Bushveld and average grazing plus browsing capacity measured for three seasons with differing annual rainfall.

during exceptional rainfall years is extremely valuable, especially as it remains relatively sweet even when it dries off. Grazers could be bought in on a speculation basis to use this forage but these should never form a permanent enterprise as droughts with zero sward production (Figure 6) are common. Another use of this forage in browser systems is to utilize it during the wet seasons thereby relieving pressure on the areas with dense bush so they get a chance to recover.

Optimum veld condition will also change with operator objectives. For overall productivity, farmers with only cattle (grazers) would aim to have veld in the mid-range of ecological status (Figure 7) but this would conflict with farmers (and conservationists ?) who have browsers (e.g. goats and kudu). Their optimum would be vegetation with high ecological status (Figure 7).

The results appear to comply with the theory of stability and resilience as advocated by Walker (1980). Pristine bushveld (high ecological status) is stable from a forage production point of view (Figure 8) but lacks resilience as once degraded it will not recover (within a human lifespan at least). Veld with lower ecological status is unstable from a forage production viewpoint (Figure 8) but is resilient in that it rapidly reverts to its desert-like character following disturbance.

It is perhaps noteworthy that the carrying capacity result for the wet year (Figure 8) is similar to that found for the more mesic neighbouring False Thornveld of the eastern Cape (Aucamp *et al.* 1983; Stuart-Hill 1987) where total forage productivity was found to be highest at intermediate tree densities. This leads us to question whether there is not a continuum between False Thornveld and succulent valley bushveld.

The results of this investigation enabled a model to be developed, where carrying capacity (C) can be predicted from rainfall and vegetation condition (ecological status). This was done mathematically by developing the following equation which uses 12-monthly rainfall (R) and ecological status (V) as input variables.

$$C = A_1 + A_2V + A_3V^2 + A_4R + A_5R^2 + A_6VR + A_7V^2R + A_8VR^2 + A_9V^2R^2$$

where: C in LSU ha^{-1}; R in mm;
$A_1 = -2.35955432$
$A_2 = 1.73322191$
$A_3 = -1.32997188$
$A_4 = 1.29914587$
$A_5 = -1.22172784$
$A_6 = -1.13147013$
$A_7 = 9.38097966$
$A_8 = 1.81879951$
$A_9 = -1.57320123$

Table 8 shows the difference between the observed and predicted carrying capacities. Other less complex but less accurate equations are available from the senior author. A second model was also developed by employing Kriging (Clark 1982) to interpolate between the measured carrying capacities. This is represented as a three dimensional plot (Figure 9a) for descriptive purposes, and as both a contour plot (Figure 9b) and a read-up table (Table 9) for non-mathematical prediction. The latter, we propose, will be useful for field predictions of carrying capacity. The difference between observed and carrying capacities predicted from the read-up table are presented in Table 10 and it would appear that the table method is more accurate than the mathematical method.

It is important to stress that although the predictions are presented as numeric values, these should be treated with caution, especially when extrapolating beyond the limits of the input variables or, especially, to other areas. In addition, users of these models should be aware that

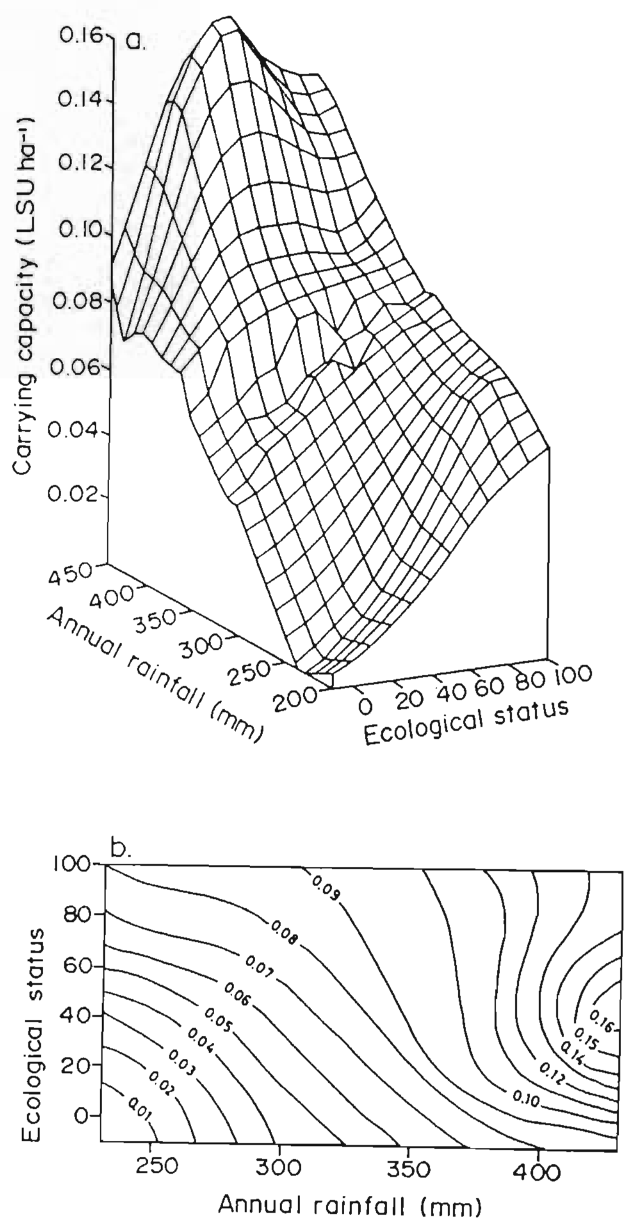

Figure 9 Carrying capacity (browsing capacity plus grazing capacity) of Succulent Valley Bushveld as predicted from Kriging where the independent variables are rainfall and vegetation condition (ecological status). The predicted relation is shown in three-dimensions (a) and as a contour plot (b).

Table 9 Combined predicted carrying capacity (LSU 1000 ha^{-1}) of grazers and browsers in succulent valley bushveld for different ecological statuses and for various rainfall seasons. Predictions were derived from interpolation using linear Kriging (see Clark 1982)

Rain (mm)	Ecological status (%)											
	−10	0	10	20	30	40	50	60	70	80	90	100
240	1	4	9	15	23	31	41	52	63	73	78	79
250	2	6	11	17	25	33	43	54	66	77	81	81
260	8	11	16	22	29	38	47	57	67	76	81	83
270	15	18	22	28	35	43	51	60	68	75	81	84
280	21	25	29	35	41	48	55	63	70	76	81	85
290	28	31	36	41	47	53	60	66	72	78	83	86
300	35	38	42	47	52	58	64	70	75	80	84	87
310	41	44	48	53	58	63	69	74	78	83	87	89
320	42	46	54	59	64	69	73	78	82	86	87	90
330	45	51	56	59	64	74	78	74	83	87	90	93
340	51	55	61	61	65	72	75	81	84	90	89	92
350	56	60	65	71	74	87	89	81	91	92	94	96
360	61	67	81	85	89	91	92	93	94	96	97	99
370	73	78	85	90	93	95	96	96	96	97	100	104
380	73	80	89	96	99	101	101	101	100	99	102	108
390	74	83	93	103	107	108	109	108	106	103	106	113
400	76	87	98	109	116	119	120	118	116	113	114	117
410	78	90	104	117	127	132	133	130	126	122	121	122
420	76	91	110	127	139	146	147	142	134	129	127	128
430	72	92	116	139	150	160	161	151	141	132	131	134
440	77	96	119	140	153	162	163	155	146	138	135	137
450	88	102	120	136	148	156	157	154	148	143	140	139

Table 10 The differences between measured carrying capacity (grazing plus browsing capacity) and predicted carrying capacity derived from Table 9 which uses 12 monthly rainfall figures and vegetation condition (ecological status) as input variables

Season	Veld score	Rain (mm)	Measured (LSU ha^{-1})	Predicted (LSU ha^{-1})	Difference (LSU ha^{-1})
1985/86	100	384	0.112	0.110	0.002
	84	384	0.099	0.101	0.002
	46	384	0.105	0.104	0.001
	20	384	0.101	0.100	0.001
	−9	384	0.073	0.073	0
1986/87	100	238	0.080	0.080	0
	84	238	0.081	0.079	0.002
	46	238	0.037	0.038	0.001
	20	238	0.015	0.012	0.003
	−9	238	0	0.002	0.002
1987/88	100	433	0.136	0.134	0.002
	84	433	0.130	0.133	0.003
	46	433	0.169	0.162	0.007
	20	433	0.143	0.139	0.004
	−9	433	0.070	0.074	0.004
Mean difference					0.002

there are generally high densities of kudu (*c.* 58 per 1 000 ha) and bushbuck (*c.* 13 per 1 000 ha) in this vegetation and these must be taken into account when determining stocking rates. Neglecting to do this could result in over-stocking by between 25 and 45 %.

It should also be stated that this experiment was designed around ensuring that *P. afra* and *G. robusta* were utilized in a sustainable manner. While these species are the most preferred common species there are rarer species which (from observation) are more heavily utilized. It follows that these species may eventually be lost even while *P. afra* and *G. robusta* are maintained. There may be other issues of sustainability which this study was not able to address. If so, then the long-term sustainable carrying capacity could be even lower than these data suggest.

Conclusion

Optimum vegetation condition changes from season to season and with management objectives. However, despite the possibility that for some enterprises veld with intermediate ecological statuses may be preferable to dense bushveld. our recommendation is that existing remnants of pristine bushveld should never be harmed. This is because:

1. It cannot regenerate once destroyed and this limits future management alternatives;
2. it provides a relatively consistent fodder flow between seasons (indeed, farmers in the succulent valley bushveld should never have to rely on drought subsidies);
3. it is more productive than open bush; and
4. most farms already have considerable areas of veld with low ecological status.

Acknowledgements

We gratefully acknowledge the financial support of the Department of Agriculture and the co-operation of the Department of Correctional Services for the use of their land. We are deeply indebted to L.O. Nel, N. de Ridder, L.P. du Toit, M.L. Swart, E. Oosthuizen and H. Barnard who on various occasions helped with the backbreaking leaf-and-twig measurements.

References

Acocks JPH 1975 Veld types of South Africa (2nd edn) Mem. Bot. Surv. S. Afr. 40

Aucamp AJ 1979 Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke DSc(Agric) thesis Univ. Pretoria

Aucamp AJ, Danckwerts JE, Teague WR & Venter JJ 1983 The role of *Acacia karroo* in the False Thornveld of the Eastern Cape Proc. Grassld Soc. sth. Afr. 18:151–154

Booysen PdeV 1967 Grazing and grazing management terminology in southern Africa Proc. Grassld Soc. sth. Afr. 2:45–57

Bransby DI & Tainton NM 1977 The disc pasture meter: possible applications in grazing management Proc. Grassld Soc. sth. Afr. 12:115—118

Caughley G 1979 What is this thing called carrying capacity? In: Boyce MS & Hayden-Wing LD (eds) North American elk: ecology, behaviour and management Univ. Wyoming Laramie USA

Clark I 1982 Practical geostatistics Applied Science Publishers Essex UK

Collinson RFH & Goodman PS 1982 An assessment of range condition and large herbivore carrying capacity of the Pilanesberg Game Reserve with guidelines and recommendations for management Inkwe 1:1—54

Cowling RM 1984 A syntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome Bothalia 15:175—227

Danckwerts JE 1982 The grazing capacity of sweetveld. 1. A technique to record grazing capacity Proc. Grassld Soc. sth. Afr. 17:90—93

Danckwerts JE 1989 Animal performance In: Danckwerts JE & Teague WR (eds) Veld management in the eastern Cape Government Printer Pretoria pp 47

Everard DA 1987 A classification of the subtropical transitional thicket in the eastern Cape, South Africa based on syntaxonomic and structural attributes S.Afr. J. Bot. 53:329—340

Gibbs Russell GE, Welman WG, Retief E, Immelman KL, Germishuizen G, Pienaar BJ, Van Wyk M & Nicholas A 1987 List of species of southern African plants Mem. Bot. Surv. S. Afr. 56

Hoffman MT 1989 Vegetation studies and the impact of grazing in the semi-arid eastern Cape PhD thesis Univ. Cape Town

Hoffman MT & Cowling RM 1990 Desertification in the lower Sundays river valley, South Africa J. Arid Env. 19:105—117

Hoffman MT & Everard DA 1987 Neglected and abused: the eastern Cape subtropical thickets Veld & Flora 73:43—45

Smithers RHN 1983 The mammals of the southern African subregion Univ. Pretoria

Stuart-Hill GC 1987 Refinement of a model describing forage production, animal production and profitability as a function of bush density J. Grassl. Soc. South. Afr. 4:18—24

Stuart-Hill GC 1989 Assessing the condition/ecological status of valley bushveld In: Danckwerts JE & Teague WR (eds) Veld management in the eastern Cape Government Printer Pretoria

Stuart-Hill GC, Aucamp AJ, Le Roux CJG & Teague WR 1986 Towards a method of assessing the veld condition of the Valley Bushveld in the Eastern Cape J. Grassl. Soc. South. Afr. 3:19—24

Stuart-Hill GC & Hobson FO 1991 An alternative approach to veld condition assessment in the non-grassveld regions of South Africa J. Grassl. Soc. South. Afr. 8:179—185

Trollope WSW & Trollope LA 1990 Veld and pasture management terminology in southern Africa J. Grassl. Soc. South. Afr. 7:52—61

Turner JR 1988 Towards the development of a grazing capacity model for the drier grazing areas of Natal MSc thesis Univ. Natal

Walker BH 1980 Stable production versus resilience: a grazing management conflict? Proc. Grassld Soc. sth. Afr. 15:79—83

[P 6.2]

CAN A COMMON MODEL BE USED TO DETERMINE CARRYING CAPACITY IN FALSE THORNVELD AND SUCCULENT VALLEY BUSHVELD: A PRELIMINARY INVESTIGATION ?

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ABSTRACT

The objective was to evaluate commonality in the existing models that predict grazing and browsing capacity for these two contrasting veld types.

In general, there appears to be some potential for a common model. The ("inappropriate") false thornveld model was able to relatively accurately predict the grazing, browsing and total carrying capacity of the succulent valley bushveld for at least two of the three seasons tested. The model failed to predict browsing capacity only during the extremely dry season (rain < 238) but this should not be a concern as the deficiency was entirely explainable, making it possible for a future common model to account for such events.

This investigation also demonstrated the extremely important influence that rainfall has on carrying capacity. While vegetation condition also plays a role, this is trivialized if multiple foraging herbivores are utilized: i.e. both browse and grass are utilized with appropriate animal species.

INTRODUCTION

Contrasting false thornveld and succulent valley bushveld.

On the eastern seaboard of the Cape province exists a variety of vegetation communities within which woody plants are a characteristic and important component (see Acocks 1975). Two of these, the succulent valley bushveld (Stuart-Hill in prep.) and the false thornveld (Acocks 1975) possibly represent the extremes from a land users viewpoint.

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The false thornveld (FT) is a typical savanna and is well represented in the eastern Cape. Essentially, it is a perennial grassland with a scattering of trees, mainly Acacia karoo. The grass layer forms the forage production base while the woody plants are treated as weeds and often great effort is expended in attempting to rid the veld of these plants. In more recent times, and in contrast to other parts of southern Africa, these woody communities now form an important forage source for browser based farming enterprises. Broadly, the utilization philosophy in these eastern Cape savannas' concentrates on conserving (utilizing wisely) the herbaceous layer whilst damaging (controlling) the woody layer because the latter has strong recuperative powers.

In contrast, the vegetation community known locally as succulent valley bushveld (SVB), is functionally different to the savannas because the herbaceous layer is dominated by ephemeral plants and the successional drift towards increased bush is so slow that for all practicable (land use) purposes, it does not exist. It is a dense, semi-succulent, thorny vegetation occurring in hot, dry, frost-free areas between the Kei and Gouritz river valleys (data from Acocks, 1975; Cowling, 1984; Everard, 1987). Browse is the production base and the management philosophy in this vegetation is one of maintaining the shrub component because it is potentially the most productive and if lost, does not regenerate within a human lifespan at least.

Objective

Carrying capacity is a rather nebulous notion of sustainable productivity but despite this, it is possibly the information most frequently required by land managers and applied scientists (Stuart-Hill & Aucamp 1993). Empirical experimental efforts to predict this parameter usually produce parochial results with the predictions being limited in space and time. There was a desire to see whether some underlying model, common to all vegetation types, could be constructed to provide carrying capacity guidelines.

More specifically, the objective of this study was to determine whether there was an underlying commonality in the models which predict grazing and browsing capacity in both the FT and SVB of the eastern Cape.

These veld types were selected because there were existing (independent) carrying capacity models for each, and they represented the extremes in the continuum of the primary forage source: i.e. browse for the SVB and grass for the FT.

PROCEDURE

In principle, the procedure was straight forward, consisting of three phases.

i. The actual carrying capacity of the SVB as measured during three experimental seasons was used (Stuart-Hill & Aucamp 1993) as reference points for comparison.

ii. A basic spreadsheet model was constructed to predict carrying capacity for the FT. This model combined the results by Danckwerts (grazing capacity) with that of Teague (browsing capacity) as suggested by Stuart-Hill 1987.

iii. By taking the input variables of relevance to the SVB, for the three experimental years (Stuart-Hill & Aucamp 1993), and placing them into the FT model, it was possible to predict carrying capacity of the SVB. These predictions were then compared with the measured carrying capacity and the potential for commonality of models thereby addressed.

Both models are essentially driven by 12 monthly rainfall and woody vegetation status. However, the FT model also required some additional input not actually measured in the SVB (e.g. long-term mean annual rainfall, catenal position & grassveld condition score) to run sub-modules within the main model.

Briefly the FT model operates as follows. The grazing capacity is determined from an empirically derived model which used 12 month rainfall and grassveld condition score. It then reduces this to compensate for the competitive effect of the woody layer, following which it further reduces the grazer carrying capacity to account for the amount of grass that the browsers will consume. At the same time, the number of browsers which can be carried by the woody layer is estimated (i.e. dependent on the catenal position of the site and the average annual rainfall) from a two dimensional response surface (or look-up table).

While the operational details of the comprehensive FT model are described in detail by Stuart-Hill (1987), there were some basic assumptions/manipulations which were necessary to make the FT model compatible with the SVB.

Manipulation 1: a common index for evaluating veld condition

The models in the two veld types differed in terms of the manner of establishing the status (or 'condition') of the woody component of the vegetation. The FT model required, as a variable, <u>tree equivalents</u> whilst the SVB model required <u>ecological status</u> (see Teague <u>et al</u> 1981 and Stuart-Hill 1989 for definitions respectively).

To obtain a common means of comparing vegetation status in the two veld types, it was necessary to convert the tree equivalents of the FT into an index of ecological status (called FT ecological status). To do this the following procedure was adopted.

i. Tree equivalents (of the FT) and tree bio-volume (of the SVB) were converted to <u>twig mass</u> (ie dry mass of leaf bearing twigs) with the following formulae (Hobson & De Ridder 1991):

$$\text{Twig mass} = 162.38\ TE^{2.95}$$
where TE = tree equivalents

$$\text{Twig mass} = 145.76\ Vol^{0.98}$$
where Vol = volume of canopy in m^2.

ii. These two formulae combined, enabled TE to be converted to bio-volume or vice versa:

$$TE = Vol/3.7835$$
$$Vol = 3.7835 \times TE\ (m^3).$$

iii. Using the above, the bio-volumes measured in each of the SVB experimental camps (Stuart-Hill & Aucamp 1993) were then converted to TE. As the ecological status of each camp was known, the ratio of TE to ecological status was simply determined for each site and the mean (30,6) used as a conversion factor: i.e. from TE to an index of ecological status (for FT) (Table 1).

INSERT TABLE 1

This was not strictly correct as ecological status (SVB) is determined from not only bio-volume, but also the percentage of <u>Lycium oxycarpum</u>, <u>Portulacaria afra</u>, <u>Schotia afra</u> and <u>Euphorbia bothea</u>, and tree density (Stuart-Hill 1989). It is argued, however, that an approximate index of ecological status (of SVB) can nevertheless be developed from bio-volume alone, because the species composition data contribute little to the ecological status score, and these, together with tree density, are closely correlated ($r^2 > 0,85$) with bio-volume.

Manipulation 2: varying browse production with rain (FT-model)

In the original FT model (Aucamp <u>et al</u> 1983, later refined by Stuart-Hill 1987), browse productivity was not varied in accordance with seasonal rainfall. Obviously this is inadequate, and so an attempt was made to incorporate this into the FT model. This was achieved by using browse production data from Stuart-Hill & Tainton (1988), obtained from three experimental seasons, and plotting these against 12 monthly rainfall (Figure 1).

INSERT FIGURE 1

These initial results indicated a dramatic collapse in production when yearly rainfall is less than approximately 350mm. In retrospect, this is predictable because plants require a minimum amount of water in order to survive and furthermore <u>A. karoo</u> does not occur in veld types with less than this amount of rainfall (unless it has access to supplies of sub-soil water). Where there are acceptable levels of rainfall for A. karoo growth (i.e. > 350mm), the decline in browse productivity with decreasing rainfall is described by the linear relationship illustrated in Figure 1.

The upshot of this manipulation is that with rainfall above 350mm, the FT model will vary browse productivity according to the amount of rain which fell. Rain less than this amount will result in a prediction of no browse.

Assumption 1: for comparable browse productivity (FT-model)

The FT model required an estimate of the long-term mean annual rainfall and catenal position because a module in this model uses this information to allocate number of 'browse units' necessary to sustain one goat for a year (Teague et al 1981; Stuart-Hill 1987).

An average annual rainfall of 400mm was assumed, as this was similar to the relatively more arid conditions of the SVB and it was approximately the lowest level at which the 'browse unit per goat' module operated (Teague et al 1981).

The productive bottomland catenal position in the 'browse unit per goat' module was assumed, because the shrubs of the SVB are mostly evergreen and also better adapted to arid conditions than A. karoo. Consequently, one may expect that under the same conditions of aridity, fewer browse units are necessary to support one goat in SVB, than in the FT.

Ultimately these assumptions produced a requirement of 14446 'browse units' to sustain one 'large stock unit' of goats for a year.

Assumption 2: for comparable grass productivity (FT-model)

The grazer stocking rate module in the FT model requires an estimate of the grassveld condition score from which grazing capacity is predicted (Danckwerts 1984).

A grassveld condition score of 35% was assumed to reflect a comparable sward composition in SVB, as this would be dominated by Cynodon species but interspersed with very few plants of Panicum maximum, P. deustum, Sporobolus fimbriatus, Eragrostis obtusa and E. chloromelas. This score may have been a little high, as during dry periods, many plants may die and the sward becomes extremely sparse.

RESULTS

Predicting grazing capacity

The measured and predicted grazing capacities for the three experimental years are displayed as a function of ecological status (Figure 2).

INSERT FIGURE 2

The FT model predicted grazing capacity with relative accuracy for all three seasons. It was, however, weak at low ecological status and this is to be expected given that the difference between the FT and SVB becomes most apparent at these vegetation states. This is because where there are few trees in FT, the herbaceous layer is a dense perennial grass sward, whereas in the SVB, it is a sparse ephemeral community.

Predicting browsing capacity

The measured and predicted browsing capacities for the three experimental years are displayed as a function of ecological status (Figure 3).

INSERT FIGURE 3

The FT model predicted browsing capacity with a reasonable degree of accuracy for the two wet seasons, but was hopelessly inadequate for the dry, 1986/87 season. Here, it predicted no browsing whereas a reasonable amount was actually measured. This failure is expected, given that the FT model is based on A. karroo, a deciduous species not able to survive with rainfall of less than 350mm per year. In addition, the SVB is dominated by evergreen and succulent trees and shrubs, and it follows that the woody layer is better able to cope with dry conditions than A. karroo.

At low ecological status, measured browsing capacity for the 1985/86 and 1987/88 seasons was probably higher and lower respectively, than it should have been. This was possibly a result of the paddocks having been browsed beyond sustainability, in the first season, this followed by a drought in the second, with the consequence that the vegetation was in a recovery period during the last season. In the broad sense, given the errors in measurement and the inherently unreliable nature of predicting carrying capacity, the predictions for the 1985/86 and 1987/88 seasons are probably reasonable.

Predicting total carrying capacity

The measured and predicted total carrying capacities (i.e. grazing plus browsing capacity) for each of the three experimental years are displayed as a function of ecological status (Figure 4).

INSERT FIGURE 4

Total carrying capacity was reasonably accurately predicted for the two wet seasons, but was hopelessly inadequate for the dry, 1986/87 season. As carrying capacity is the sum of grazing and browsing capacity, this failure is expected given the failure of the FT model to predict any browsing capacity during the 1986/87 season.

DISCUSSION AND CONCLUSIONS

In general, there appears to be some potential for a common carrying capacity model to be constructed for both the FT and SVB.

The predictions for grazing, browsing and total carrying capacity for the seasons with more than 350mm of rain (i.e. 1985/86 & 1987/88) were reasonable when seen against the background of uncertainty inherent with a variable such as carrying capacity. In contrast, the FT model failed to predict browsing capacity for the dry 1986/87 season and this resulted, in turn, in the failure of the model to predict total carrying capacity for that year. It did, on the other hand, correctly predict grazing capacity for that year.

Fortunately the failures (to accurately predict carrying capacity) were explainable. This, together with the encouraging predictions of the ('inappropriate') FT model, illustrate that we should strive to construct a robust common carrying capacity model for (at least) the woody communities of the eastern Cape.

A spin-off conclusion from this investigation is the clear demonstration of the extremely important influence that rainfall has on carrying capacity. In addition, while the vegetation state plays a secondary (and nevertheless important) role, this is trivialized if multiple foraging species are utilized: i.e. the overall productivity of the system remains relatively constant across vegetation states if both browse and grass are utilized with appropriate animals. That is not to say that vegetation condition is irrelevant. Indeed, the SVB during very dry seasons, still plays a significant role in supporting herbivores (see Figure 4).

REFERENCES

Acocks J.P.H. 1975. Veld types of South Africa. 2nd edition. Mem. Bot. Surv. S. Afr. No. 40.

Aucamp A.J., Danckwerts J.E., Teague W.R. & Venter J.J. 1983. The role of *Acacia karroo* in the false thornveld of the Eastern Cape. Proc. Grassl. Soc. Sth. Afr. 18: 151-154.

Cowling R.M. 1984. A syntaxonomic and synecological study in the Humansdorp region of the fynbos biome. Bothalia, 15, 175-227.

Danckwerts J.E. 1984. Towards improved livestock production off sweet grassveld. Phd. thesis. Univ. of Natal.

Everard D.A. 1987. A classification of the subtropical transitional thicket in the eastern Cape, based on syntaxonomic and structural attributes. S. Afr. J. Botany, 53, 329-340.

Hobson F.O. & De Ridder C.H. 1991 Quantifying indices of potential competitiveness and browse productivity of single-stemmed *Acacia karroo* in south-eastern Africa. J. Grassl. Soc. South. Afr. 8: 1-8.

Stuart-Hill G.C. in prep. An agriculturist's view of the nature and extent of succulent bushveld.

Stuart-Hill G.C. 1987. Refinement of a model describing forage production, animal production and profitability as a function of bush density. J. Grassl. Soc. South. Afr. 4(1): 18-24.

Stuart-Hill G.C. 1989. Assessing the condition of valley bushveld. In: Danckwerts J.E. & Teague W.R. (eds). Veld Management in he eastern Cape. Govt. Printer, Pretoria. pp 103-108.

Stuart-Hill G.C. & Tainton N.M. 1988. Browse and herbage production of the false thornveld of the eastern Cape in response to tree size and defoliation frequency. J. Grassld Soc. South. Afr. 5(1):42-47.

Stuart-Hill G.C. & Aucamp A.J. 1993. Carrying capacity of the succulent valley bushveld of the eastern Cape. Afr. J. Range. For. Sci. 10(1): 1-10.

Teague W.R., Trollope W.S.W. & Aucamp A.J. 1981. Veld management in the semi-arid bush grass communities of the eastern Cape. Proc. Grassl. Soc. Sth. Afr. 16: 23-28.

Table 1. The relationship between derived tree equivalents (TE) and measured ecological status (ES) of five experimental camps in succulent valley bushveld. The TE's were estimated from measured bio-volume, with a formula which is fully described in the text.

Camp Number	Bio-Volume	TE (derived)	ES %	Ratio TE : ES
1	11 933	3154	100	31.5 : 1
2	10 322	2728	90	30.3 : 1
3	5 082	1343	46	29.2 : 1
4	2 369	626	20	31.3 : 1
5	1 213	320	-10	(-32.0 : 1)[1]
			mean	30.6 : 1

[1] This ratio was not included in the mean as it's sign is not comparable with those above.

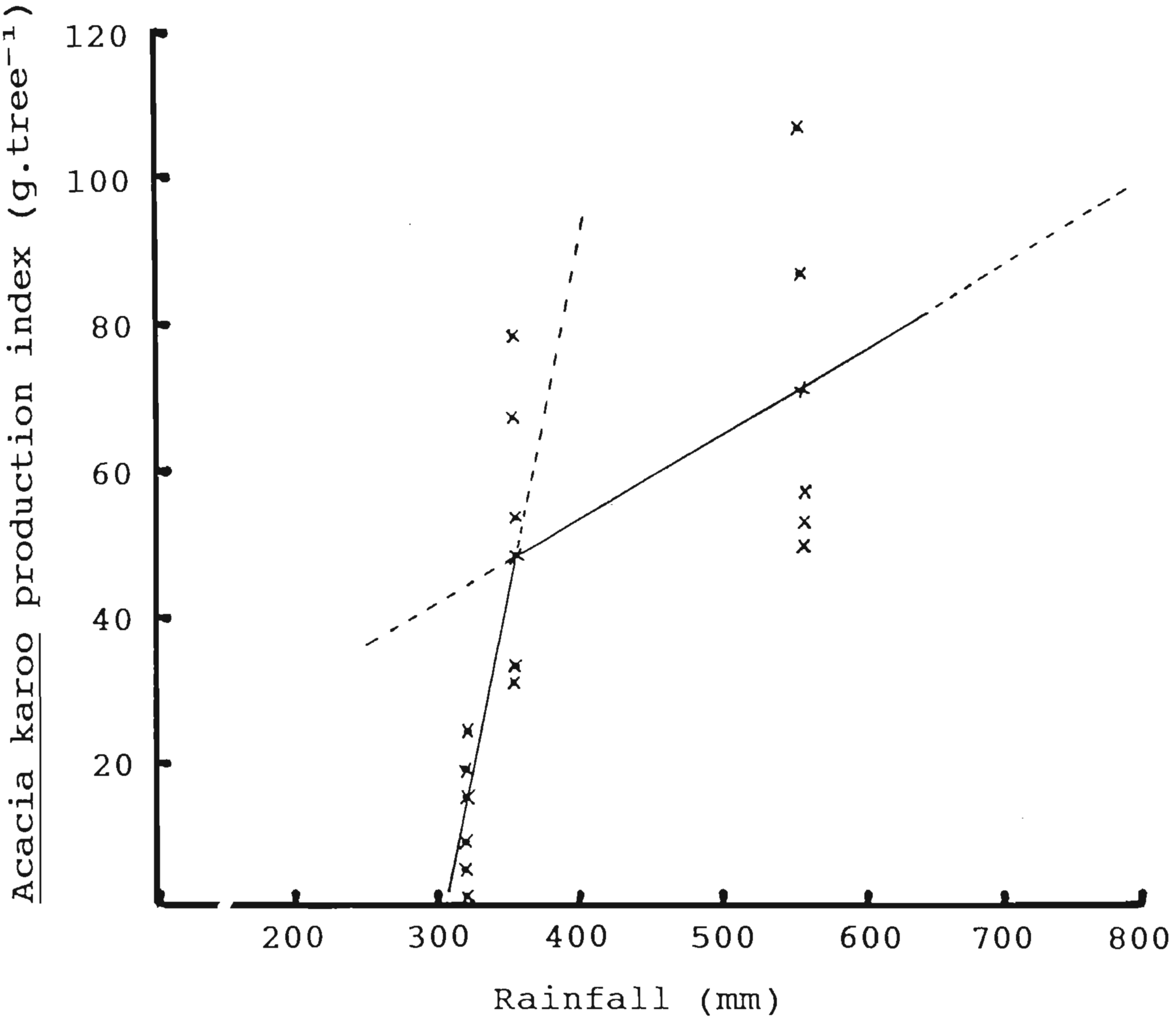
FIGURE CAPTIONS

Figure 1. The response of _Acacia karroo_ browse production to 12 monthly rainfall (data from Stuart-Hill & Tainton 1988).

Figure 2. The predicted (solid lines) and measured (broken lines) grazing capacity response to different vegetation states in succulent valley bushveld. The predicted values were obtained from the false thornveld carrying capacity model. The symbols represent the three different years, with rainfall.

Figure 3. The predicted (solid lines) and measured (broken lines) browsing capacity response to different vegetation states in succulent valley bushveld. The predicted values were obtained from the false thornveld carrying capacity model. The symbols represent the three different years, with rainfall.

Figure 4. The predicted (solid lines) and measured (broken lines) carrying capacity response to different vegetation states in succulent valley bushveld. The predicted values were obtained from the false thornveld carrying capacity model. The symbols represent the three different years, with rainfall.



Acacia karoo production index (g.tree^{-1})
120
100
80
60
40
20
200
300
400
500
600
700
800
Rainfall (mm)

Figure 1

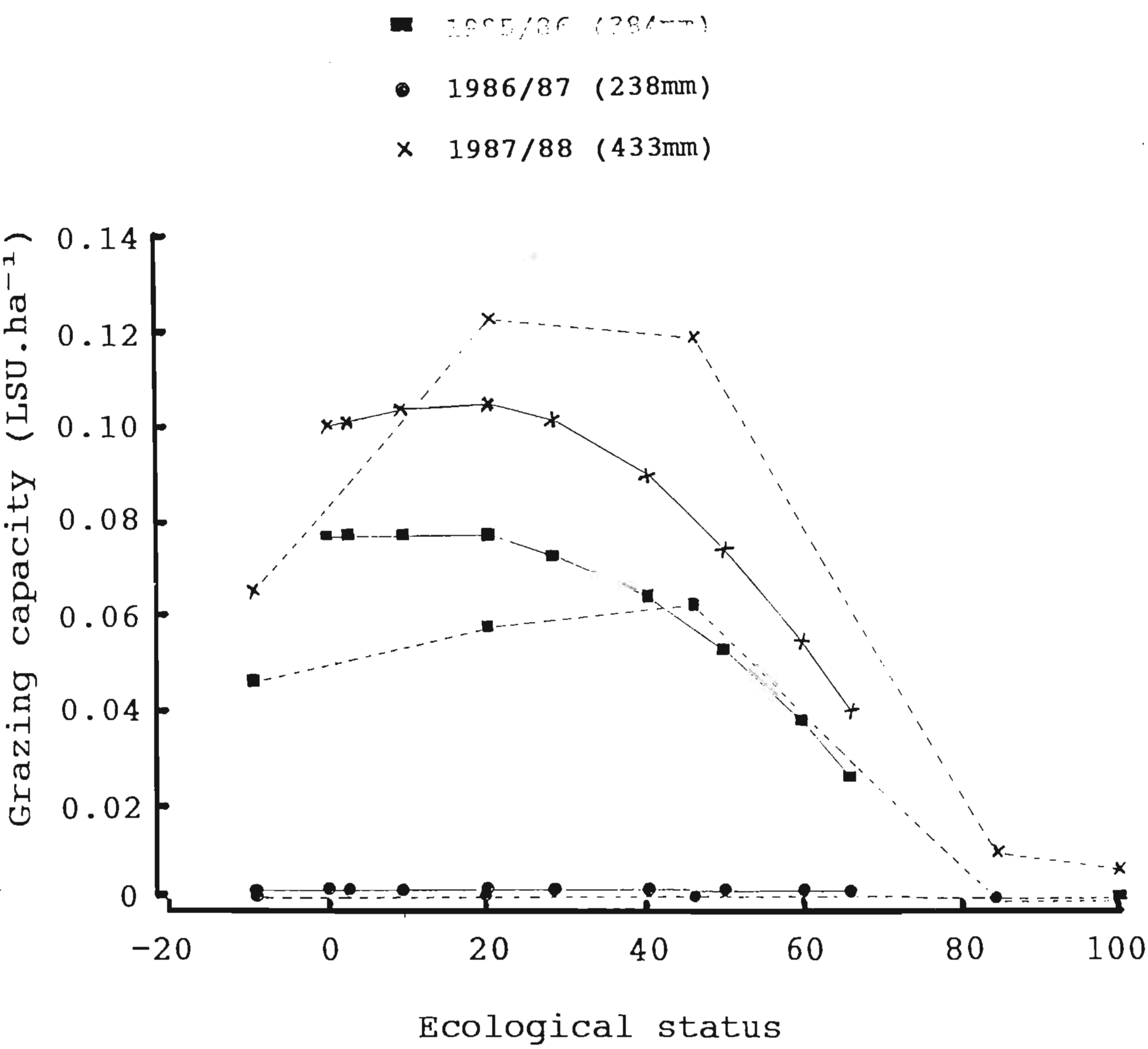
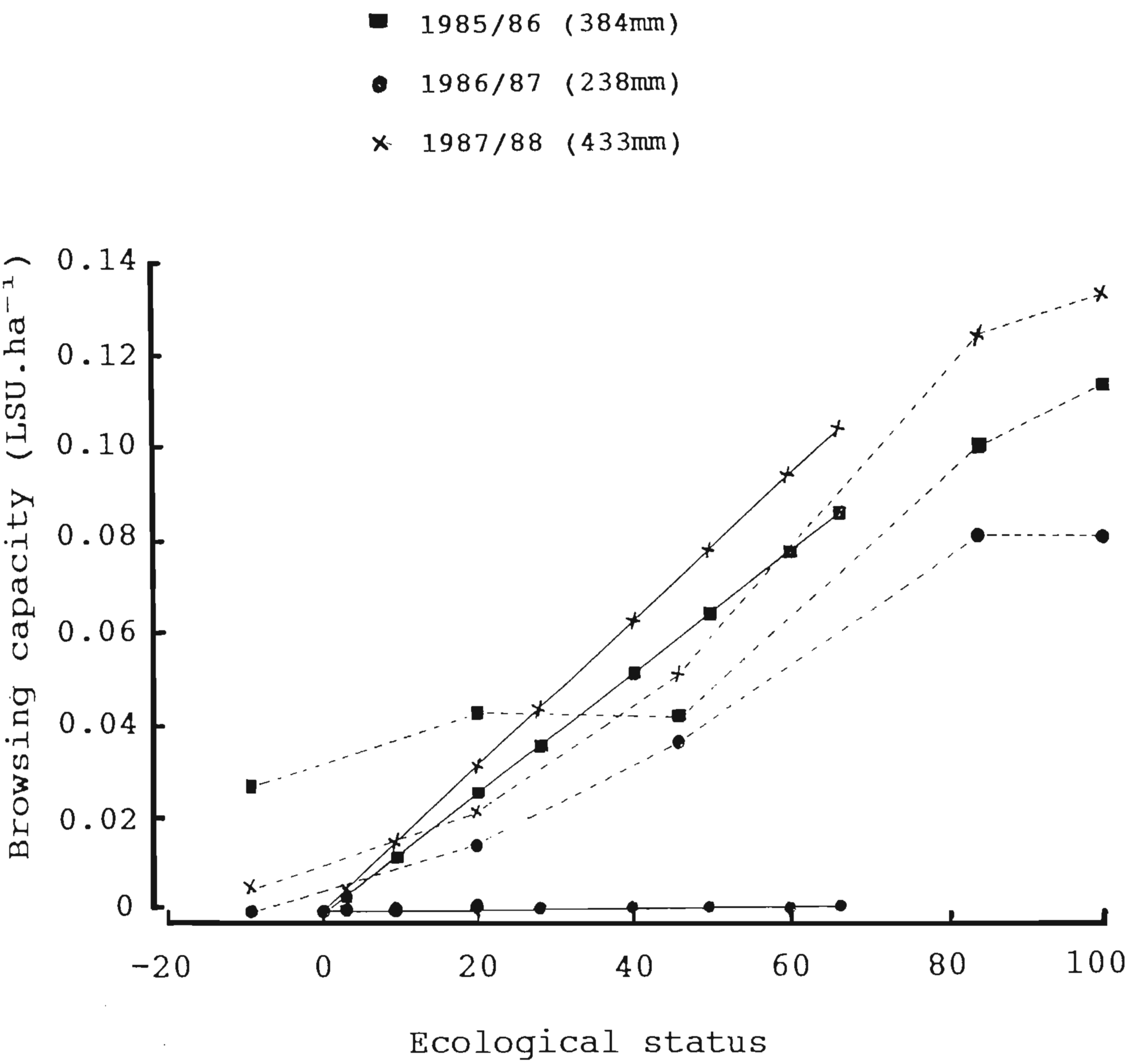
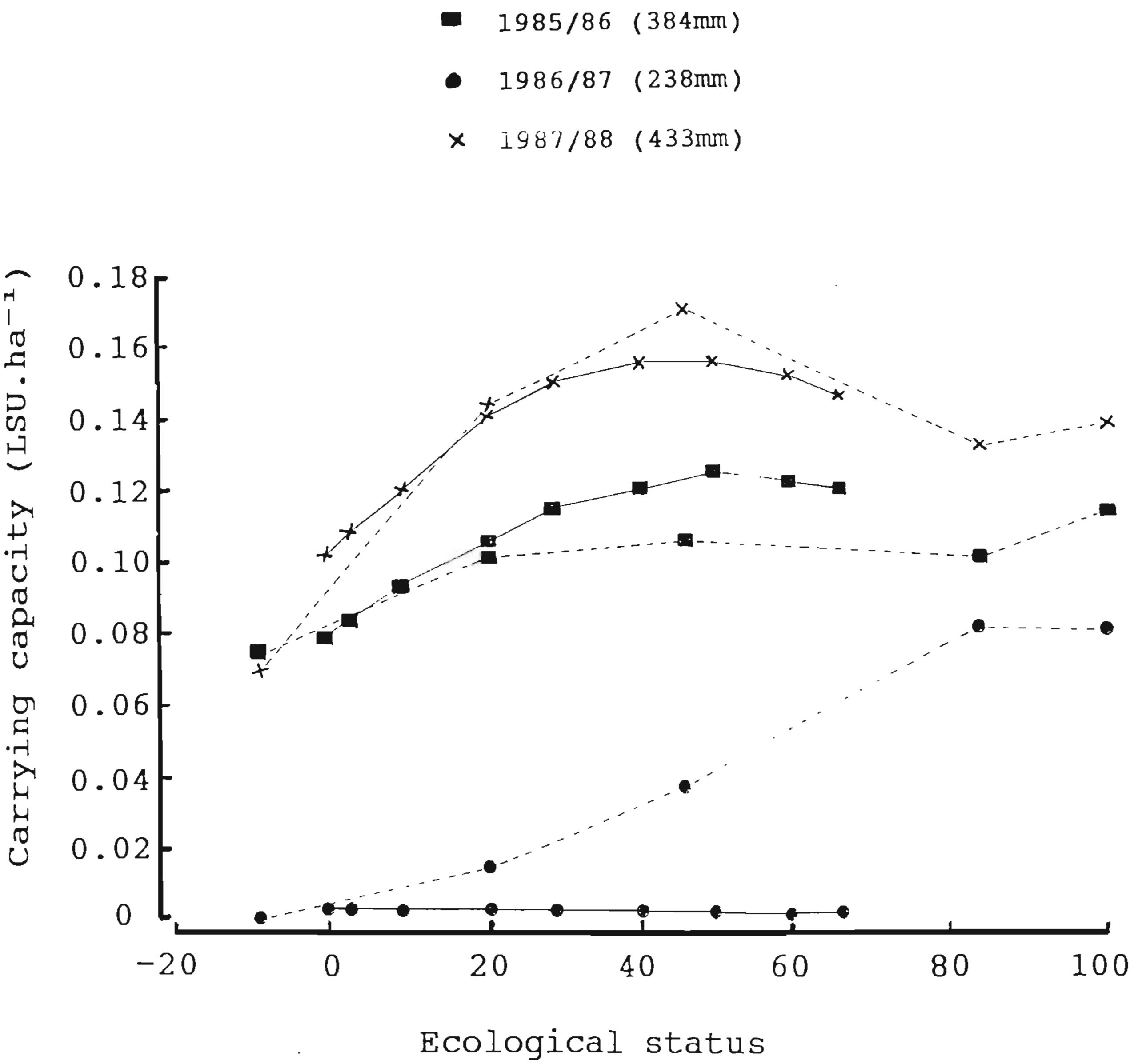

1986/87 (238mm)
1987/88 (433mm)
Grazing capacity (LSU.ha⁻¹)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
-20
0
20
40
60
80
100
Ecological status

Figure 2



1985/86 (384mm)
1986/87 (238mm)
1987/88 (433mm)
Browsing capacity (LSU.ha⁻¹)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
-20
0
20
40
60
80
100
Ecological status

Figure 3



1985/86 (384mm)
1986/87 (238mm)
1987/88 (433mm)
Carrying capacity (LSU.ha^{-1})
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
-20
0
20
40
60
80
100
Ecological status

Figure 4

TOOL 7

A METHOD OF RECORDING ESSENTIAL INFORMATION

[TOOL 7]

A METHOD OF RECORDING ESSENTIAL INFORMATION

ORIGINAL BRIEF

Here the emphasis must be on balanced record keeping and only information which is useful should be collected. It must be clearly stated why each piece of information is being collected; e.g. why collect rainfall data?

RESULT

Tool 7, a model of recording essential environmental and management information, is not specifically provided in this dissertation. It is a complex study which would have received superficial treatment given the resources at my disposal. The complexity comes from the myriad of land-use possibilities, time scales and variables and ideally, each property should have a tailor-made monitoring system. By way of example, however, an elementary information monitoring system is suggested for a national park in the unpublished report: **A vision for ecological monitoring in a National Park [P 7.1].**

A VISION FOR ECOLOGICAL MONITORING IN A NATIONAL PARK

OCTOBER 1993

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PREAMBLE

It is assumed at the outset, that resources for ecological monitoring are limited. As a consequence, the philosophy adopted in compiling this vision, is that only essential information should be collected. The unfortunate consequence is that such a system may, if the system should 'move' in an entirely unpredictable manner, be unable to provide all the information required to explain the change. While this is a weakness, it also confers a strength in that, if followed, it ensures that at least some information will be consistently collected.

PROBLEMS WITH CURRENT INFORMATION SYSTEMS

The consistent problems with monitoring in National Parks are as follows.

1. Insensitive and sensitive monitoring programmes for some biological attributes of the systems while others are poorly or not monitored at all (ie. classic sub-optimization).
2. Too much information is collected in a 'shotgun' fashion (i.e. implicit in current philosophy is "lets record everything because we may need it"). A clear management orientated information analysis needs to be conducted; i.e. what information does the Park manager really need?
5. Poor system of recording essential information. Information becomes lost as master copies are not formally filed and these move around or are lost with staff turn-over (ie. most monitoring programmes are attached to individuals not posts because they happen to correspond to the interests of the individual). Monthly/quarterly reports are a clumsy data collection media, especially when looking for trends over years.

Monitoring in National Parks has usually been the responsibility of scientists who are heavily involved in wildlife research. As such they are under pressure to publish. The consequence of this is that they need to specialize (leading to sub-optimization) and their planning horizons are usually short, leading to a neglect in the long-term aspects of monitoring. It is absolutely essential that a clear distinction should be made between research and the relatively mundane but vital monitoring programmes for adaptive management.

SUGGESTED SOLUTIONS

i) The information system should be simple and focused on absolutely essential information.

ii) The monitoring programmes should be designed around specific requirements (ie. questions that are essential for adaptive Park management). With no relevant formally stated question, no monitoring should be undertaken!

iii) The monitoring programme should be independent of staff turnover and to aid this, clear cut monitoring policies are required detailing responsibilities to posts, not persons. These responsibilities should form part of the induction package given to new occupants of the responsible positions and highlighted when structural adjustments are made in the organisation.

iv) Original master copies of all monitoring data are to be housed at each Park's Head Office in a facility or place which is sacrosanct and not prone to change on the whims of new managers.

v) The monitoring system must specify clearly how and when data are to be collected, recorded and reported and who is responsible for the various aspects.

INFORMATION REQUIREMENT ANALYSIS

The type of information needed for adaptive Park management is best illustrated as questions that managers will ask. Certain questions will be asked at short intervals (eg. daily) whilst others may be asked only every decade or more. It follows, therefore, that it is absolutely essential to account for the time dimension in any monitoring programme. The other dimension is of course, the various attributes of the system itself (eg. soils, fauna and flora).

An example of important questions which will be asked at different times and frequencies with respect to the fauna, flora, abiotic factors and management actions of a typical National Park are illustrated below. Alongside each question is the type of information which needs to be collected, analysed and stored.

Of great importance are the objectives of management e.g. if one should decide on a 'hands-off' approach, then game harvesting and some other questions and monitoring programmes may not be necessary. It follows that each property should have its own monitoring system. This merely attempts to show, by example, how monitoring should be designed around specific questions.

RAINFALL

Annually

1. What was this rainfall year like ?
   Report the past year's rainfall in relation to the long-term average for the equivalent period.

2. Does rainfall explain faunal and forage distribution (large parks) ?
   Map the rainfall distribution for comparison with faunal and forage distribution maps.

Quarterly

1. What was the drought status last quarter ?
   Report the past quarter's rainfall in relation to the long-term average for the equivalent period.

2. What are prospects in the foreseeable future ?
   Predict and compare current stocking rate with recommended stocking rate for the drought status of the past quarter.

Monthly

1. What is the monthly drought status ?
   Record daily rainfall at each station in the park and report the month's total in relation to the long-term average for that month.

2. What are prospects in the foreseeable future ?
   Compare current stocking rate with recommended stocking rate for the respective drought status.

Daily

1. How much rain fell today ?
   Record amount daily each time it rains.

BURNING

Over years/decades

1. What is the fire return frequency at any given location in the Park ?

   Compile a burning map for each year and present them as overlays.

Monthly

1. Have fires burnt ?

   Update map of size and extent of wildfires.

Daily

1. Is a wildfire burning ?

   Report Wildfire immediately.

2. How much did it burn ?

   Map burnt area as soon as possible?

FLORA

Over years/decades

1. How is the vegetation changing ?

   Determine vegetation trend by updating the vegetation community maps and re-visiting and re-photographing fixed monitoring sites.

2. Is the vegetation management programme achieving its objectives ?

   Check that the trend in vegetation composition and structure is in keeping with the vegetation vision for the property

3. What influence are animals having on the changes ?

   Relate stocking history and faunal population performance to vegetation trend, and decide whether stocking rate is driving vegetation trend.

4. What impact has fire had on the changes ?

   Compare burning history with vegetation trend (use map overlays).

Annually

1. What areas should be burnt ?

   Annually, during autumn, inspect the vegetation and draw up a burning plan.

2. Is the Park able to carry the current animal population in the foreseeable future ?

   Annually, during autumn (immediately prior to nutritional bottle necks), inspect the vegetation and decide whether there will be sufficient forage for the coming year.

3. Is it because of drought that the veld looks like it does ?

   Using the drought status reports and the rainfall distribution maps (large parks), decide whether this change is as a result of rainfall.

Quarterly

1. Has veld been burnt, mown, fertilized, any bush control been undertaken ?

   Update the relevant files recording these activities as soon as they occur and report quarterly.

2. What are implications for the forseeable future ?

   Give an assessment of the status of remaining forage in relation to the current stocking rate.

COMMON FAUNA

Over years/decades

1. How is each population performing ?
   Construct measured population trends and compare these with those predicted from modelling (which accounts for sex-age structure, introductions, removals, mortalities, predation and expected growth rates).

2. Is vegetation change affecting the animals ?
   Look for any relationship between vegetation change and faunal population performance ?

3. Where does the population lie with respect to economic and ecological carrying capacity recommendations ?
   Compare intrinsic increment for each year with the theoretical maximum.

4. How many animals could be removed on a mean sustainable yield basis ?
   Check annual removals in relation to the trend in the population's growth.

Annually

1. What is the population estimate now ?
   Conduct census and together with modelling and local knowledge estimate current numbers.

2. How many animals could/should be removed this year ?
   Compare current stocking rate (all species) with carrying capacity of property, and consider sex-age structures and feeding categories

3. Does rainfall explain faunal distribution?
   Map the rainfall distribution (large parks) and compare with faunal distribution maps.

4. What are prospects in the foreseeable future ?
   Predict and compare current stocking rate with recommended stocking rate for the drought status of the past 12 months.

Quarterly

1. What animals have been captured, hunted, culled or introduced recently?

   Summarize the total numbers of animals captured, hunted, culled or introduced over the last quarter.

2. Where have the animals been concentrated during this last quarter ?

   Record monthly and report quarterly on maps.

Monthly

1. Who and how much, should we pay and invoice for animals captured, hunted, culled or introduced this last month ?

   Summarise monthly removals and introductions.

2. What are mortality levels ?

   Record all mortalities encountered and determine cause of death.

VERY IMPORTANT FAUNAL SPECIES (VIS)

Over years/decades

1. Are the VIS performing according to population growth rate expectations?

   Model expected performance and compare with actual population growth from intensive census.

2. If not, why not?

   Consider predation, disease, nutrition, mineral deficiencies, sex/age structure, calf survival and poaching.

3. Can some VIS be sold/hunted without adversely impacting pop. growth?

   Record and report detailed sex/age structure of the population and predict non-impacting removal quotas.

Quarterly

1. Are the calving and mortality levels within acceptable limits for this period ?

   Record all calving and mortalities of VIS and compare with previous years.

2. If not, then why not ?

   Consider predation, disease, nutrition and poaching.

Monthly

1. Are the mortality levels within acceptable limits for this period ?

   Record mortalities of VIS and identify reason for death.

ALIEN PLANTS

Over years/decades

1. Is the Park being invaded by Alien plants?
   Illustrate trend with a sequence of annual 'invaded areas' maps.

2. Are the control efforts worth the cost?
   Estimate the cost and success of the control efforts, evaluate the envisaged impact of the alien plants and determine nett benefit.

Annually

1. Where are the invaded areas and how serious are they ?
   Draw up an 'invaded areas' map, indicating severity of invasion and threat to new areas.

2. How effective have the control efforts been ?
   Determine the percentage kill in treated areas.

3. Is follow up action urgently required and what will it cost?
   Predict, in all treated areas, what the likely alien plant response will be in the following year.

Quarterly

1. What control work has been undertaken, and how much did it cost ?
   Open or update file for each area treated, recording: location, site ID, type of control activity, cost estimate, man-days used; and make a photographic record of before and after treatment.

SOIL EROSION

Over years/decades

1. Is erosion status in the Park improving or worsening?

   With photographic records determine whether soil erosion trend is increasing.

2. Are the control efforts worth the cost?

   Estimate the cost and success of the control efforts, evaluate the 'cost' of the present and probable soil loss and determine nett benefit.

Annually

1. How effective have the erosion structures been and which require further work ?

   Visit each structure and update its file, including new photographs.

Quarterly

1. What control work has been undertaken, and how much did it cost ?

   Open or update file for each area treated, recording: catchment area, site ID, type of control work, cost estimate, man-days used; and make a photographic record.

ROADS AND TRACKS

Annually

1. What is the condition status of all roads and tracks ?

   Visit each road and update its file detailing, km for km, the state of road surface, river crossings and mitre drains.

2. Which roads require repairs now ?

   Prioritize those which roads requiring repairs now. determine which repairs can be budgeted for next year.

3. Which water course crossings require work ?

   From the road inspection, list all water crossings which require repairs.

4. Which mitre drains need work?

   From the road inspection, list all those mitre drains which require repairs.

5. How much should be budgeted for next year ?

   Extract work required for next year from the above.

Quarterly

1. What road maintenance has been undertaken and how much did it cost?

   Update file for each road worked on, recording: road, section, type of repair, cost estimate, man-days used, etc.

MISCELLANEOUS

Notifiable disease

1. Are any notifiable disease outbreaks imminent ?
   Report carcasses with notifiable disease immediately

Water availability

1. Which areas of the property are water limited ?
   Compile and then update quarterly, the surface water availability map.

Interesting observations

1. Have any new species been discovered ?
   Report immediately.

2. What happened that's unusual?
   Report immediately.

TOOL 8

A DATABASE OF ECOLOGICAL PRINCIPLES

[P 8.1] Effects of elephants and goats on the kaffrarian succulent thicket of the eastern Cape, South Africa

[P 8.2] Farmland elephant: a solution to degradation in the woody vegetation communities of southern Africa

[TOOL 8]

DATABASE OF ECOLOGICAL PRINCIPLES

ORIGINAL BRIEF

The ecological principles must be relevant to management by contributing an understanding of the system. Full understanding is unachievable and a library, database or expert systems of ecological principles (which can continually be updated) is probably the best that can be achieved.

RESULT

A database of ecological principles is understandably not fully provided in this dissertation. Nevertheless, a paper was produced which reported on a preliminary community based investigation. The approach was to examine pattern in the community and develop hypotheses describing how the succulent bushveld responds to impact. The study consisted of a three way comparison between the treatments: 'elephant grazing', 'goat grazing' and 'no grazing' (reported in the published paper: **Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa [P 8.1]**). The results implied that the succulent bushveld was changing in sympathy with the change in utilization regime; from that dominated by elephant to that of small domestic stock (mostly goats). The results illustrated that the vegetation is adapted to tolerate elephant impact and not goat farming! This initiated an interest in a basic biological principle, seldom if ever articulated, upon which all of pasture/veld/range/grassland science rests and against which vegetation management efforts inevitably work. IF THE DEFOLIATION REGIME, UNDER WHICH A PARTICULAR VEGETATION TYPE EVOLVED SHOULD BE CHANGED, THEN THE VEGETATION WILL CHANGE IN SYMPATHY WITH THE 'NEW' REGIME. Veld 'degradation' (change away from some agro-ecological 'ideal') is inevitable with modern farming practices and is a symptom of the changing defoliation regime. This principle is simple, but more often than not it is ignored. Bush clearing efforts are a good example and this, together with the results of the above publication, led to the paper (in press): **Farmland elephant: a solution to degradation in the woody vegetation communities of southern Africa [P 8.2]**.

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Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa

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Summary

1. Kaffrarian succulent thicket is a dense, semi-succulent, thorny vegetation which is rapidly being eliminated under current pastoral systems. To understand why this occurs, the effect of defoliation by wild herbivores (mostly elephant) was compared with that of domestic ungulates (mostly goats) from surveys inside and outside the Addo Elephant National Park.

2. Both elephants and goats reduced canopy cover and increased shrub density in relation to control areas. Goats reduced the number of dominant shrub species per quadrat.

3. Replacing elephants with goats resulted in a fundamental change in the shrub community to one dominated by small, unpalatable shrubs with a few scattered umbrella-shaped trees. Removing elephants and not replacing them with goats resulted in the sites becoming more dissimilar, possibly because the vegetation reacted to the unique climatic and edaphic potential of each site.

4. Goats reduced the percentage frequency of the dominant tree-succulent *Portulacaria afra* by 40% and its density by 71% causing a 91% decline in the total area rooted by this plant.

5. It is argued that Kaffrarian succulent thicket (in particular *P. afra*) is adapted to elephant utilization but not to utilization by small domestic ungulates stocked at equivalent biomass. Some implications for land managers are discussed.

Key-words: browse, co-evolution, mega-herbivores, shrubs, species response.

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Introduction

The Kaffrarian succulent thicket (Cowling 1984) occurs on the eastern seaboard of South Africa in hot, dry (rainfall 225–500 mm), frost-free areas at low altitudes, usually below 500 m but never above 1000 m (Acocks 1975; Cowling 1984; Everard 1987; Palmer 1990; Agmet. records 1991). It is a dense, semi-succulent, thorny thicket *c.* 2–3 m high in which succulents contribute in excess of 20–30% relative cover (Cowling 1984). Grasses are present, but sparse (10 000–30 000 plants ha^{-1}) and mostly non-perennial (Acocks 1975). In a 'pristine state' this vegetation is dominated by the tree-succulent *Portulacaria afra*[†], representing over half of the total phytomass (data from Penzhorn *et al.* 1974; Aucamp 1979). It is considered to be the most important plant for production of goat forage (Aucamp 1979).

This vegetation is currently farmed with goats and supports a large proportion of the mohair industry of South Africa. It is sensitive to utilization and is rapidly being eliminated under current pastoral systems (Hoffman & Everard 1987; Hoffman 1989; Hoffman & Cowling 1990). This is serious because it represents an irreversible loss of a unique vegetation type; and the community which replaces it is unstable, allowing soil erosion and supporting fewer stock (Stuart-Hill & Danckwerts 1988). Clues to understanding the lack of persistence of this vegetation could be found by examining recent (past 200 years) developments, notably the replacement of indigenous herbivores (in particular elephants) by small domestic ungulates.

Accounts from early travellers and hunters in the region reported large numbers of elephants (Barrow 1801; Lichtenstein 1811; Pringle 1966; Skead 1989). As the plants in this vegetation are largely evergreen and highly nutritious (Aucamp 1979), and perennial rivers are always in close proximity, elephants would

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† Nomenclature follows Gibbs Russel *et al.* (1987) for plants, and Smithers (1983) for animals.

have been neither nutrient- nor water-limited and the early reports of large numbers were probably accurate. It follows that elephants would have had a major impact on the evolution of this vegetation and especially the dominant plant *P. afra* which, in 1835, was noted as the '. . . .favourite food of the elephant. . . .' (Pringle 1966), an observation since confirmed by research (Archibald 1955; Penzhorn, Robbertse & Olivier 1974).

The objective of this investigation was to contrast the effect of elephants and goats on the shrub component, in order to understand why this vegetation was able to tolerate the impact of many elephants, but not the current utilization by goats. Comparisons were made at three levels. At the first two of these, hypotheses were generated from the responses of the community of individual plants. The third was a test of the specific hypothesis that elephants and goats differentially affect the physiognomy of the dominant shrub, *P. afra*.

Adaptation of P. afra *to defoliation: a conceptual model*

Sexual reproduction of *P. afra* is of limited importance because seeds are small and short-lived (B. Whiting, personal communication); and because germination and seedling establishment are extremely rare (personal observation). This plant is, however, able to reproduce vegetatively from side branches which, as they grow, bend downwards, eventually rooting at regions where the nodes touch the ground (Fig. 1a). Undisturbed plants are characterized by having a 'skirt' or 'apron' of rooted side branches. With time, the plants become multi-stemmed and spread horizontally, eventually forming new individuals as the connecting branches become detached.

On farmland, *P. afra* is being eliminated (Stuart-Hill *et al.* 1986; Hoffman 1989). It is here suggested that this is because goats defoliate the lower portions of the canopy and effectively prevent the development of the 'skirt' of rooted branches (shown in Fig. 1a and b). If goat browsing is severe, the shrubs take on an umbrella shape (Fig. 1c), eventually collapsing as the weight of the succulent canopy becomes too great for the relatively weak stem to support. The plant then dies.

Elephants, by contrast, browse from the 'top downwards' and consequently severely damage the upper portions of the canopy. The lower rooted branches, however, escape defoliation; and vegetative reproduction is allowed to continue regardless of the damage to the upper canopy (Fig. 1b).

In summary then, the conceptual model proposes that *P. afra* is chiefly dependent on asexual reproduction which continues under utilization by elephants, but not under heavy browsing by small animals such as goats.

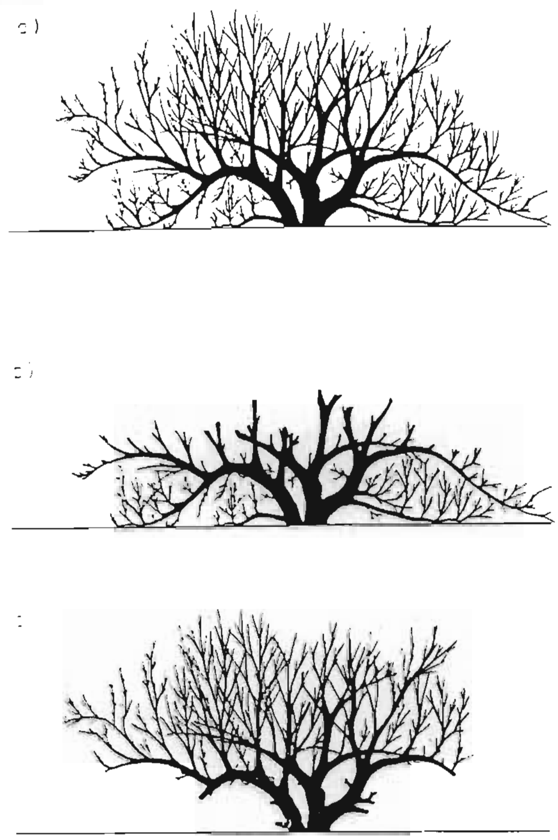

Fig. 1. Effect of (a) no browsing, (b) elephant browsing and (c) goat browsing on the growth habit and vegetative propagation of *Portulacaria afra*.

Study area

The study was undertaken in and around the Addo Elephant National Park (33°31′S, 25°45′E): the reserve for the last remaining elephants in the Cape province of South Africa (Fig. 2). Elephants were at their lowest densities (approximately 10 animals left) just prior to 1931 when the park was finally proclaimed and the eradication programme which culminated in 120 elephants being shot in a 'few months', was halted (Penzhorn *et al.* 1974). Before 1954 the elephants wandered throughout the region; but they have since been confined. Initially the fenced area was 2270 ha and the elephant population rapidly increased to 60, so that by 1971, Penzhorn *et al.* (1974) reported that they had begun to over-utilize the vegetation. Subsequently, the fenced area was progressively enlarged, while the population had grown to 166 by September 1990. The park is currently some 8600 ha in extent, but the elephants only have access to 8200 ha, the rest being set aside as botanical reserves (Fig. 2).

Topographically the park environs form a series of low undulating hills (altitude between 76 and 341 m). The soil is a light-red clay-loam (Archibald 1955) derived from sandstone and mudstone of the Sundays River Stage, Uitenhague Series, Cretaceous System (Toerien 1972).

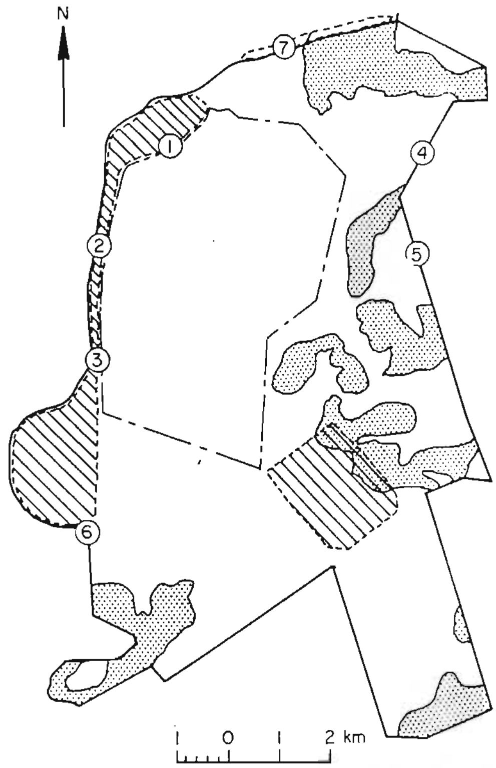

Fig. 2. Addo Elephant National Park showing: Kaffrarian succulent thicket (□), other plant communities (□) (after Archibald 1955), botanical reserves (▨), original elephant-proof fence (— · —), and seven sampling areas (numbered).

Mean annual rainfall (27 years) is 436 mm and falls throughout the year with small peaks in late summer (February–March) and spring (October–November). Mean daily temperature is 32·4 °C in January and 13·5 °C in July, but temperatures greater than 40 °C are frequently recorded in summer. Mean minimum temperature is 16·4 °C in January and 5·0 °C in July with frosts being extremely rare (Agmet records).

Archibald (1955) described five plant communities, the most extensive being Kaffrarian succulent thicket (Fig. 2) which covered more than 90% of the park (Penzhorn *et al.* 1974).

Methods

TREATMENTS

Three treatment areas were identified: (i) those in the park to which elephants have access ('elephants'); (ii) those outside the park where goats are the dominant browser ('goats'); and (iii) botanical reserves from which both elephants and goats have been excluded (control). In all three of these treatment areas, kudu, bushbuck, grysbok and duiker were present, although probably at different stocking rates. The park areas were stocked with various herbivores at a rate of approximately 50 kg livemass ha^{-1} (Table 1). Of this, elephants contributed 78% and it is realistic to attribute most of the defoliation effect in the park to them. It is important to note that, at two animals km^{-2}, the elephants were heavily stocked in comparison to that recommended in other areas of Africa with similar rainfall (Glover 1963; Van Wyk & Fairall 1969; Penzhorn *et al.*

Table 1. Approximate stocking of herbivores on 8200 ha in the Addo Elephant National Park (Park records)

Species	Feeding class*	Assumed mean mass† (kg)	Numbers	Total biomass (kg)	Relative contribution (%)
Elephant (*Loxodanta africana*)	G/B	1931	166	320 546	78·4
Kudu (*Tragelaphus strepsiceros*)	B	128	>180‡	23 040	5·6
Bushbuck (*Tragelaphus scriptus*)	B	26	>150‡	3 900	1·0
Grey duiker (*Sylvicapra grimmia*)	B	18	>250‡	4 500	1·1
Black rhinoceros (*Diceros bicornis*)	B	1350	21	28 350	7·0
Eland (*Taurotragus oryx*)	G/B	300	25	7 500	1·8
Grysbok (*Raphicerus melanotis*)	G/B	10	>50‡	500	0·1
Buffalo (*Syncerus caffer*)	G	390	46	17 940	4·4
Hartebeest (*Alcelaphus buselaphus*)	G/B	90	21	1 890	0·5
Total				408 166	100·0

* Browser (B) or grazer (G).
† 0·75 of mean female mass (Smithers 1983).
‡ Estimated from counts.

1974). The stocking rate of the farmland (goat) treatments could not be assessed accurately because farmers tend to avoid divulging this information, fearing that it could be used to prosecute them for overstocking. Whereas some of the farms were stocked relatively conservatively, others appeared to exceed the recommended 36–50 kg livemass ha^{-1} (Stuart-Hill 1990).

SAMPLING

From 1:10 000 aerial photographs, seven sampling areas were identified (Fig. 2) ensuring that, as far as possible: (i) they were spread along the perimeter of the park but confined to Kaffarian succulent thicket; (ii) they included a portion of a botanical reserve or were in positions where the three treatments were in close proximity; (iii) they were not in areas which had been previously cultivated; (iv) they represented different farms and, in the park, various histories of elephant usage.

Field location of the three treatment sites within each of the sample areas was achieved by driving along the elephant fence until the fifth iron fence post was encountered within the designated sampling area. This post was then used as the reference point from which the treatment sites were located. The first point in the elephant treatment site was always positioned perpendicular to the fence and 10 m from the reference point. The site on the opposite side of the fence (either farmland or botanical reserve) was located in a similar manner except that it was 15 m from the fence to accommodate the service road. The third treatment site in a sampling area was, on occasion, some distance from the reference point, in which case sites were located on the same altitude and aspect as the other two sites. At two of the sampling areas there was no botanical reserve and the control was unavoidably omitted, contravening condition (ii) above. It follows that there was an unequal number of replications for each treatment (elephants = 7, goats = 7, control = 5).

MEASUREMENTS

To determine the response of the vegetation to elephant and goat defoliation, the occurrence of 23 of the common shrub species (see Appendix) was recorded in seven circular quadrats (radius = 2·3 m) at each treatment site. Presence was recorded even if only part of a plant's canopy fell within the quadrat since this proved to be more efficient and repeatable than recording only rooted individuals. Percentage frequency, per treatment site, was determined for each species from these data. The percentage canopy cover in each quarter of the circular quadrat was estimated and the mean used as the cover estimate for the quadrat as a whole.

To test the conceptual model (Fig. 1), the profile of each plant was visually assigned to one of three categories: triangular with base on the ground, inverted triangle (umbrella-shaped), or box-shaped (or undecided). The degree of development of the 'skirt' of rooted branches was also recorded in one of three categories: well developed, absent, or poorly developed. To limit bias, these variables were recorded by operators who were unaware of the hypothesis being addressed. In addition, the following variables were measured on the first 10 *P. afra* plants encountered from the starting point: canopy height, maximum canopy radius, height of maximum canopy radius, radius of the rooted area, and height of the lowest leaf-bearing twigs. The last two measures were incorporated as an objective test of the visual classification made by the operators when assessing canopy shape and degree of 'skirt' development.

To obtain an index of density of *P. afra*, the distance from the centre of the plant being measured to the centre of the nearest neighbouring *P. afra* was recorded. An index of density of all trees and shrubs was obtained in a similar manner, except that the distance to the centre of the nearest neighbour, regardless of species, was recorded.

ANALYSIS

Because the park had been opened up in stages, different parts of the reserve had different histories of elephant usage. Similarly, the surrounding farms, having been farmed by different land owners, represented different intensities of goat utilization. Since this investigation involved comparing usage by goat with that by elephant, the approach was to sample throughout the area, with the variation due to different intensities of usage being allocated to error. This permitted more stringent testing of hypotheses because, if they held over all these situations, they could be accepted with greater confidence.

The measurements (on each plant or in each quadrat) within each treatment site were considered to be subsamples and their means were used as the variate values for that site. In consequence, degrees of freedom were drastically reduced (e.g. from 69 to 6 for the elephant and goat treatments), but this was preferred since it avoided pseudo-replication and allowed rigorous tests of significance.

Confidence limits (95%) were calculated (and are displayed in Figs 3, 4, 6 & 9–11) for each mean. In addition, the significance of treatment differences was evaluated using Student's *t*-test. Significance was set at the 95% level ($P<0{\cdot}05$).

The floristic data were initially subjected to principal component analysis (PCA). The responses of the individual species to the treatments were evaluated using *t*-tests in the manner described above. In addition, the responses of the species common to both sides of each fence were evaluated for consistency, using the Fisher's exact probability test in an approach similar to that adopted by Noy-Meir *et al.* (1989). In this study, a consistent response was assumed if at least three of the fence line comparisons had significant ($P < 0.05$) responses in the same direction and had no significant response across the fence in the opposite direction.

Results

GROSS COMMUNITY CHANGE

Both elephants and goats had a marked effect on density and cover of trees and shrubs in the community. Each increased the density of the shrub community, i.e. the distance between woody plants was significantly ($P < 0.05$) less under goats and elephants than in the control (Fig. 3a). On the other hand, each reduced ($P < 0.05$) the canopy cover of the woody community (Fig. 4a); but only goats reduced ($P < 0.05$) the number of woody species per quadrat (Fig. 4b).

The first two axes of the PCA accounted for 66% of the floristic variation. The first axis appeared to represent a goat degradation gradient similar to that quantified by Stuart-Hill *et al.* (1986), and had *Porticulacaria afra*, *Euclea undulata*, *Capparis sepiaria* and *Schotia afra* located on one end and *Lycium oxycarpum* and *Zygophyllum morgsana* on the other (Fig. 5a). The second axis had *Azima tetracantha* and *Protasparagus* spp. on one end and *Maytenus* spp., *Rhigozum obovatum* and *Grewia robusta* on the other, and separated sampling areas 6 and 7 from the rest (Fig. 5a,c,d). *Grewia robusta* was abundant in areas 6 and 7; but this species was absent or rare at the other sampling areas although generally common in the vegetation as a whole. Given this, and results from a previous gradient

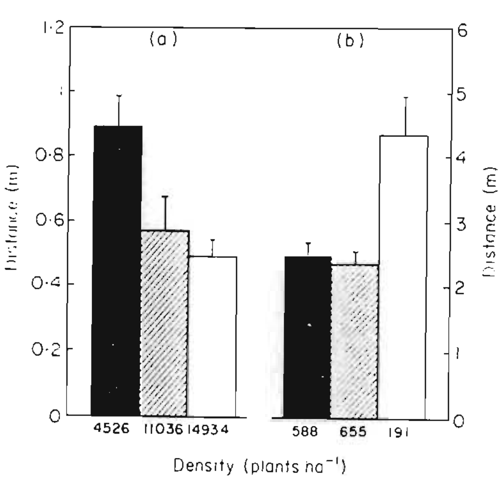

Fig. 3. Effect of neither elephants nor goats (■), elephants (▨) and goats (□) on the nearest neighbour distance between (a) woody plants of any species, and (b) *Portulacaria afra* plants. The values at the base of each column are approximate densities from a formula in Bonham (1989) (upper 95% confidence limit of the mean).

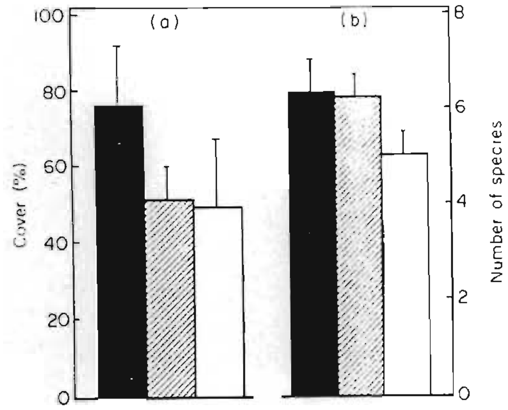

Fig. 4. Effect of neither elephants nor goats (■), elephants (▨) and goats (□) on (a) the canopy cover of woody plants, and (b) on the number of woody species per quadrat (upper 95% confidence limits of the mean).

analysis (Stuart-Hill *et al.* 1986) where *A. tetracantha*, *R. obovatum* and *G. robusta* were indicators of differences between sites, the second axis appeared to represent inherent site-dependent differences.

All the elephant and control sites were situated towards the right on axis 1 while most of the goat sites were situated towards the left (Fig. 5b), indicating that *P. afra*, *C. sepiaria*, *E. undulata* and *S. afra* were associated with elephants and the control, and *L. oxycarpum* and *Z. morgsana* with goats (Fig. 5a, b). Although the botanical reserves are referred to as the control, one could also argue that this is a treatment (i.e. elimination of elephant as the natural dominant browser without goat replacement) and the sites within the park are the 'control'. This means that the reults can be interpreted from different viewpoints, which becomes especially relevant when considering treatment trajectories (Fig. 5c,d) in ordination space. I present both interpretations and from these it appears that elephant browsing drew the community (Fig. 5c) into a relatively small domain situated towards the right on axis 1 and in the centre on axis 2 (Fig. 5b). Removal of elephants without replacement by goats (i.e. the botanical reserves) caused the vegetation to drift away from the centre of this domain (Fig. 5d), the sites becoming increasingly different.

RESPONSE OF INDIVIDUAL SPECIES

The effect of elephants and goats on frequency of 23 trees and shrubs is presented in Fig. 6. From the low frequencies, it is evident that the quadrat was too small for reasonable assessment of the less common species and these were eliminated from further analysis. The following species were retained because they were either: adequately sampled (*Protasparagus* spp., *A. tetracantha*, *Capparis sepiaria*, *Euclea undulata*, *G. robusta*, *Maytenus* spp., *P. afra*, *S. afra* and *Euphorbia mauritanica*); not well sampled but nevertheless showing significant

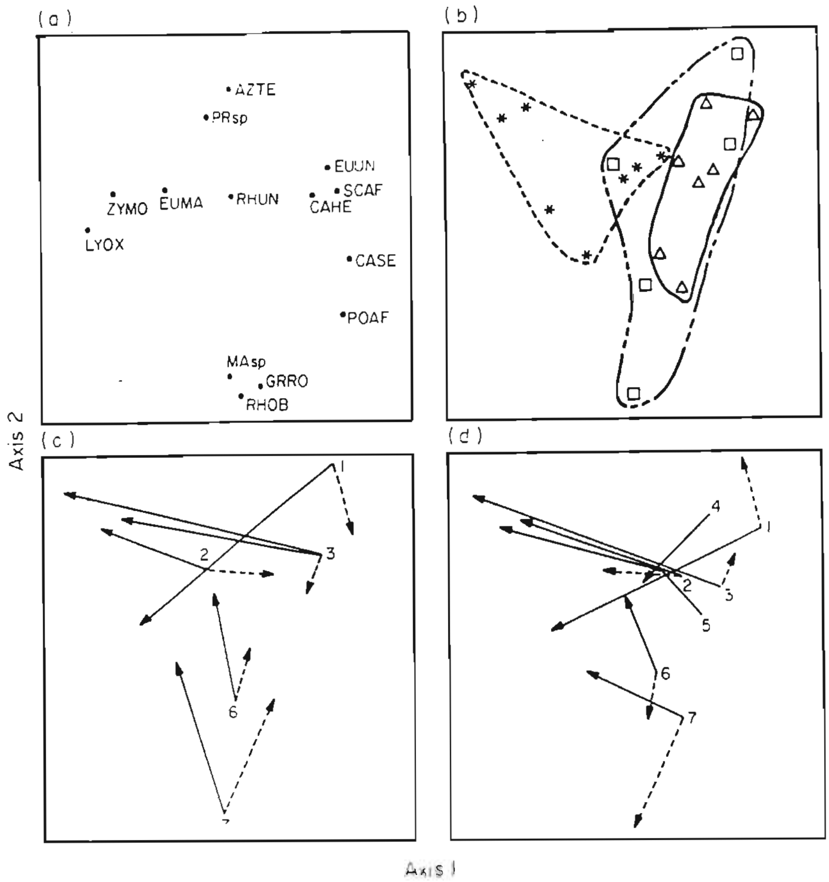

Fig. 5. Principal component analysis of floristic data from sites in and around the Addo Elephant National Park showing: (a) plot of diagnostic species; (b) domains of the control (□), elephant (▽) and goat (*) sites; (c) the treatment trajectories where the control acts as the anchor; (d) trajectories where 'elephant' acts as the anchor. Solid arrows indicate change by goats; broken arrows indicate change by elephants (c) or by removal of elephants without replacement with goats (d). Numbers in (c) and (d) indicate sites; absence of trajectories for sites 4 and 5 is due to lack of controls for these sites. See Appendix for species codes.

($P < 0{\cdot}05$) responses (*Z. morgsana* and *R. obovatum*); or marginally sampled and showing consistent trends (*Carissa haematocarpa* and *L. oxycarpum*). For each of these species, absolute changes in frequency are presented in Figs 7 and 8, and the changes relative to the control are summarized in Table 2.

Effect of goats

Relative to the control, goat browsing resulted in a decrease ($P < 0{\cdot}05$) in the percentage frequency of *G. robusta*, *P. afra* and *R. obovatum*. Goats also resulted in relatively large (>50%) decrease in *C. sepiaria*, *C. haematocarpa*, *E. undulata* and *S. afra* (Table 2) and, although these were not significant given the efficiency of sampling, they were consistent across fences (Fig. 7a).

Z. morgsana was the only species which increased significantly ($P < 0{\cdot}05$) in response to goats but the large relative increase (88%) in frequency of *L. oxycarpum* (Table 2) is a trend worth noting, as is the response of *E. mauritanica*, because both these species consistently increased across fences (Fig. 7a).

Effect of elephants

Relative to the control, elephant browsing resulted in a significant ($P < 0{\cdot}05$) decrease of only a single species, the succulent climber, *E. mauritanica*

Table 2. Increase (%) in frequency of 14 common trees and shrubs in circular quadrats ($r = 2{\cdot}3$ m) due to goat and elephant utilization, relative to the frequency measured in areas where goats and elephants had been excluded. Statistical analysis and symbols described in Fig. 7

Species	Goat	Elephant
Azima tetracantha	11	4
Capparis sepiaria	−50	17
Carissa haematocarpa	−55	33
Euclea undulata	−50	38
Euphorbia mauritanica	25	−82*
Grewia robusta	−70*	−21
Lycium oxycarpum	88	−41
Maytenus spp.	−5	1
Portulacaria afra	−39*	−1
Protasparagus spp.	7	5
Rhigozum obovatum	−90*	−80
Rhus undulata	4	19
Schotia afra	−56	25
Zygophyllum morgsana	100*	0

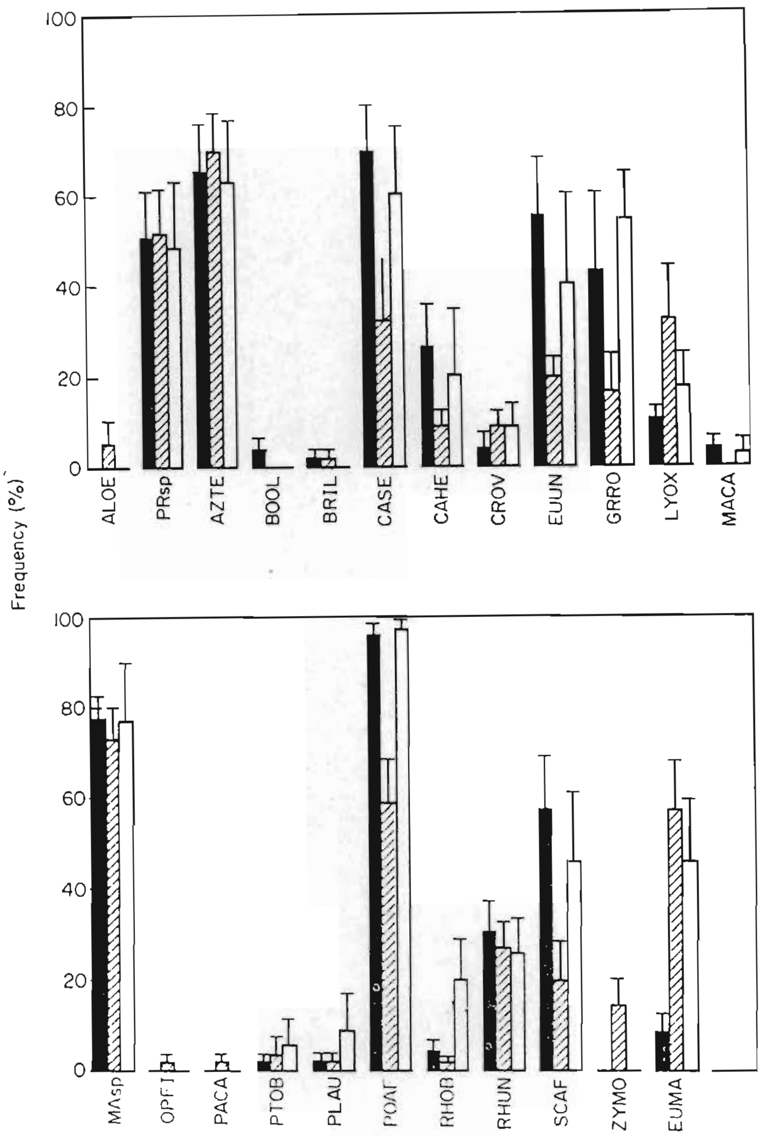

Fig. 6. Effect of elephants (▨), goats (□), and neither elephants nor goats (■) on the frequency of 23 trees and shrubs (upper 95% confidence limit of the mean). See Appendix for species codes.

(Table 2, Fig. 7b). *R. obovatum* was the only other species which showed a relative decrease greater than 50% (Table 2) in response to the influence of elephant, but this was neither significant nor consistent (Fig. 7b).

Elephants did not cause large, significant or consistent increases in any species (Table 2, Fig. 7b).

Relative effect of elephants and goats

Relative to elephant, goat browsing resulted in higher frequencies of *Z. morgsana* and *Euphorbia mauritanica* ($P < 0{\cdot}05$) and a large and nearly significant ($P < 0{\cdot}05$) increase in frequency of *L. oxycarpum* (Fig. 8).

Elephant browsing, on the other hand, resulted in more *P. afra*, *Euclea undulata*, *Capparis sepiaria* and *S. afra* in comparison with goats ($P < 0{\cdot}05$). *Carissa haematocarpa* and *G. robusta* were also higher under elephant than goat browsing and while not significant these trends were consistent across fences (Fig. 8). It should be realized that elephants did not actually increase the frequency of these species; rather these species were able to maintain themselves under elephant but not under goat browsing (see previous sections).

PORTULACARIA AFRA

The distance between *P. afra* plants was greater ($P < 0{\cdot}05$) on farmland than in the control or the elephant browsing areas (Fig. 3b), i.e. *P. afra* density was lowered by goat browsing. Because of the non-linear relationship between distance and density (Bonham 1989) it was not possible to evaluate significance on the basis of plant density.

All *P. afra* plants growing without goat or elephant defoliation were either box-shaped or triangular in profile (Fig. 9). Elephants reduced the fraction of box-shaped plants, thereby increasing the fraction of

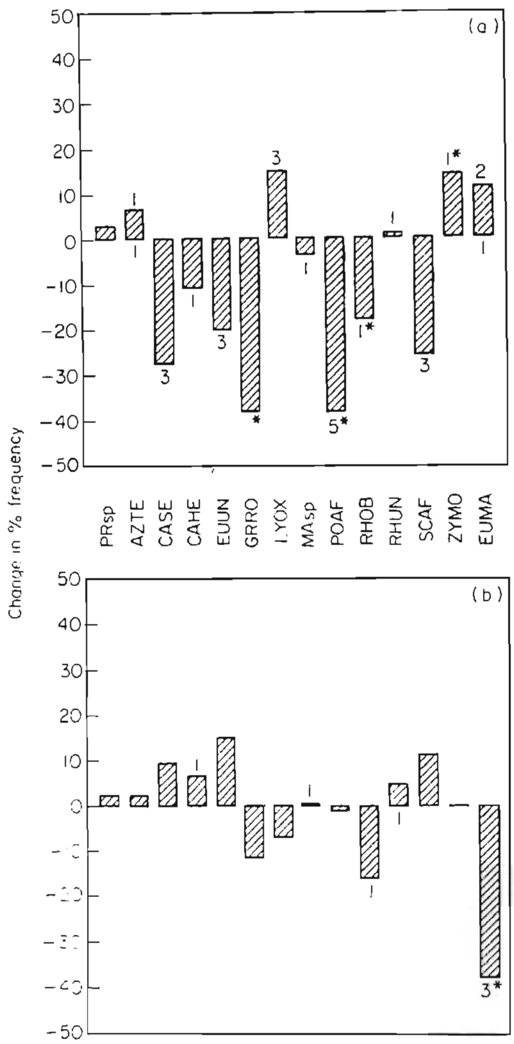

Fig. 7. Change in percentage frequency, compared with control, of 14 common trees and shrubs as a result of browsing by (a) goats and (b) elephants. Asterisks indicate significant ($P < 0{\cdot}05$; df = 6) differences between treatments, using t-tests where fence-lines were used as replications. Numerals indicate the number of individual fence-line comparisons (out of 7) where significant ($P < 0{\cdot}05$) changes were recorded using Fisher's exact probability tests. Tests were performed on actual frequencies recorded. See Appendix for species codes.

plants with triangular and umbrella-shaped canopies. Goats eliminated almost all of the triangular canopies ($P < 0{\cdot}05$) and drastically increased ($P < 0{\cdot}05$) umbrella-shaped plants so that 70% of all *P. afra* plants had umbrella canopies.

Most of the control plants had well developed 'skirts' of rooted branches, only 8% having none (Fig. 10). Elephants increased the fraction of 'full-skirts' in relation to the control but this was not significant. Goats on the other hand, reversed the frequency distribution ($P < 0{\cdot}05$) by eliminating almost all of the 'full-skirts'.

P. afra plants growing under the influence of elephants were shorter than both the control plants and the plants growing on the farmland ($P < 0{\cdot}05$) (Fig. 11a). Plants browsed by goats were the tallest

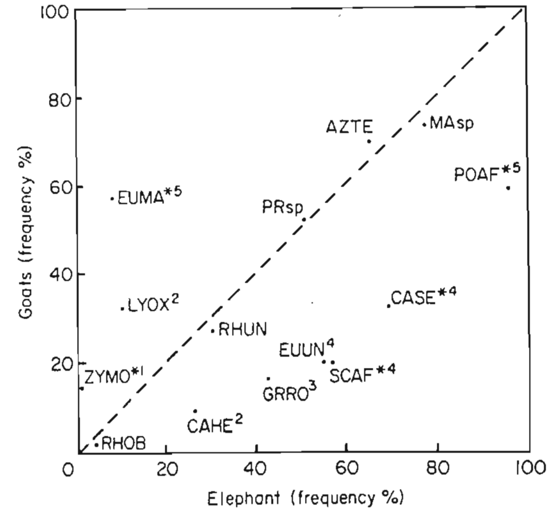

Fig. 8. Comparison of the effect of browsing by goats and elephants on the percentage frequency of 14 common trees and shrubs. Statistical analysis and symbols described in Fig. 7; see Appendix for species codes.

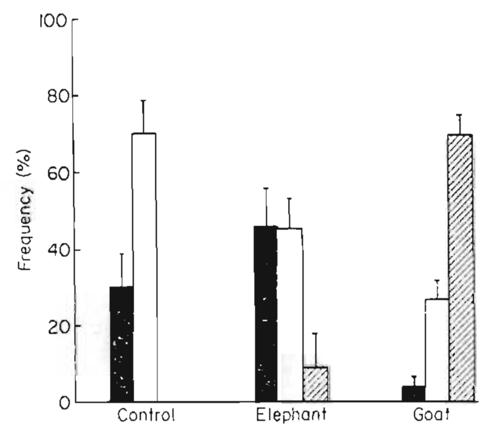

Fig. 9. Population frequency distributions of canopy profiles for *P. afra* plants growing under the impact of elephants, goats and neither elephants nor goats (control). Triangular canopies with bases on the ground (■), box-shaped canopies (□) and umbrella-shaped canopies (▨) (upper 95% confidence limit of the mean).

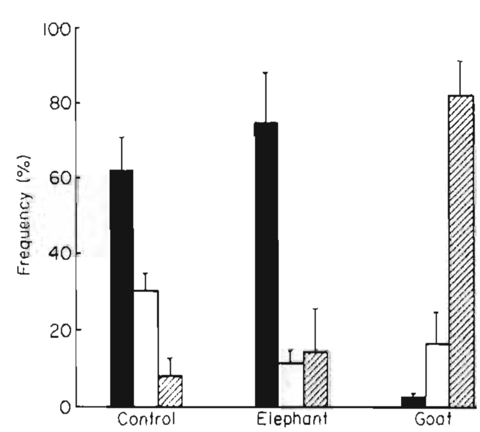

Fig. 10. Population frequency distributions characterizing the development of 'skirts' of rooted side branches for *Portulacaria afra* plants growing under the impact of elephants, goats and neither elephants nor goats (control). Fully developed (■), poorly developed (□) and absent (▨) (upper 95% confidence limit of the mean).

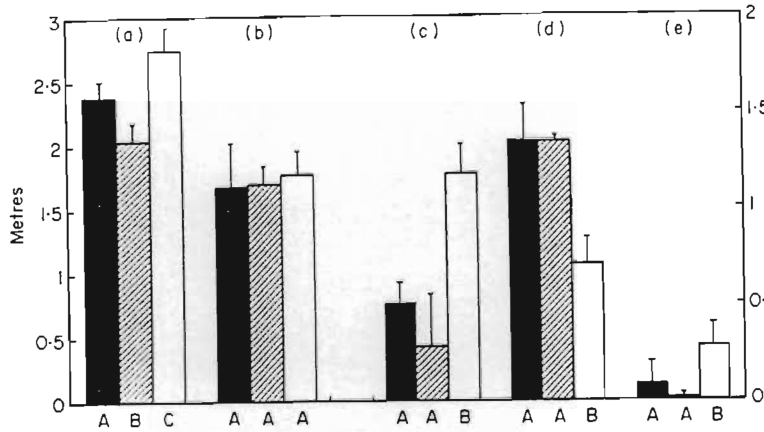

Fig. 11. Effect of elephants (▨), goats (□), and neither elephants nor goats (■) on: (a) height, (b) maximum canopy radius, (c) height of maximum canopy radius, (d) radius of the rooted area, and (e) height of the lowest leaf-bearing twigs of *Portulacaria afra* (upper 95% confidence limit of the mean); items with the same letters below the column do not differ significantly ($P<0{\cdot}05$).

of all plants ($P<0{\cdot}05$). In addition to the lack of top-defoliation, this result reflects elimination of many smaller individuals by goats (Fig. 3b).

The maximum canopy radius did not differ between treatments (Fig. 11b) but *P. afra* plants growing on farmland had their maximum canopy radius at a greater height ($P<0{\cdot}05$) than undefoliated plants or plants defoliated by elephants (Fig. 11c).

Goats reduced ($P<0{\cdot}05$) the radius of the rooted area of *P. afra* in comparison to that of plants not browsed by goats (Fig. 11d). Although this reduction is only 48%, it represents a 73% reduction in rooted area per plant.

The lowest leaf-bearing twigs of *P. afra* on farmland were higher ($P<0{\cdot}05$) than those of plants growing under the influence of elephants (Fig. 11e).

Discussion

THE COMMUNITY

Elephants, in contrast to goats, did not reduce the number of shrub species (Fig. 4b) but limited the variation in floristic composition to a relatively small domain characterized by high amounts of *P. afra*, *C. sepiaria*, *E. undulata* and *S. afra* (Fig. 5). The removal of elephant without goat replacement (i.e. the control), increased floristic variation between sites causing the 'envelope' in ordination space to increase in size in all directions away from the centre of the domain of the elephant sites (Fig. 5b, d). Perhaps this is because, once elephants are no longer present, the shrub community is able to respond to the unique combination of edaphic and microclimatic conditions prevailing at each site, leading to increased spatial variation. This result implies that elephants maintain succulent thicket in a relatively uniform state, and it is important to note that this state corresponds to that which has been found to have highest forage potential for goat farming (Aucamp 1979; Stuart-Hill & Danckwerts 1988; Stuart-Hill 1990).

Goats, on the other hand, caused a significant decline in *P. afra*, *C. sepiaria*, *E. undulata* and *S. afra* (Fig. 7a), reduced the number of species per unit area (Fig. 4b), increased *L. oxycarpum*, *Z. morgsana* and *E. mauritanica* (Figs 7a & 8), and moved the sites in ordination space towards a new domain (Fig. 5) corresponding to a state of low goat-forage productivity (Aucamp 1979; Stuart-Hill & Danckwerts 1988; Stuart-Hill 1990). Some of the goat-sites (sites 4 and 5), however, were within the domains of the elephant and the control sites (Fig. 5b) and this may be because these sites experienced relatively low goat utilization. By contrast, the sites which moved furthest in the ordination space (goat-sites 1, 2 and 3) were situated close to homesteads, and had consequently been subjected to heavy goat usage (Fig. 5). It is possible therefore, that goats do not inevitably cause a change in floristics but the community response depends on the intensity of goat browsing. Equally, however, it could be argued that the goat sites within the elephant and control domains are in the process of moving towards the goat domain (Fig. 5c & d), and that consequently all farmland will eventually end up in the area towards the left on axis 1.

The decrease in number of species per quadrat (Fig. 4b), the increase in apparent density (Fig. 3a), and the increase in *Z. morgsana*, *E. mauritanica* and *L. oxycarpum* (Fig. 7a), means that the farmland areas are becoming invaded by these unpalatable shrubs (Stuart-Hill & Danckwerts 1988) and this is corroborated by data from Stuart-Hill *et al.* (1986). On the other hand, the increase in the density with elephant defoliation (Fig. 3a) is due to an increase in the density of all species (see Figs 3a & 4b). This probably results from the elephants breaking down trees (the decline in cover, Fig. 4a), thereby promoting coppicing. However, elephants may also promote seedling establishment because they churn the soil, which together with large amounts of rotting litter (elephant dung, leaves, twigs, and broken branches), makes an excellent seedbed. A further possibility is that the flightless dung beetle (*Circellium bacchus*), which depends on coarse dung and locally has become almost confined to the Addo Elephant Park (Grobler & Hall-Martin 1982), could also promote seedling establishment. These insects bury balls of elephant dung which could also contain viable shrub seed.

SPECIES RESPONSE

All the species which were adequately sampled (Table 2) were able to tolerate fairly heavy levels of elephant utilization, except for the succulent scrambler *E. mauritanica* (Figs 6 & 7). Other workers have noted that there are other species which may also be harmed by elephants. Penzhorn *et al.* (1974) measured no *Aloe africana* in the park but recorded it as relatively abundant outside. J. Midgley (personal communication) noted, in time-sequence photographs, that another tree-succulent (either *Euphorbia tetragona* or *Euphorbia triangularis*) was one of the first plants to be eliminated by elephants. A 50% reduction (non-significant) of *Crassula ovata* was recorded here in response to browsing by elephants (Fig. 6). Interestingly, all these plants are succulents and none appear to coppice if cut at ground level. Conversely, all the non-succulent species have the ability to coppice either from stem bases or from the roots. This attribute enables plants to recover from catastrophic events (e.g. fire or breakage by large herbivores) where the aerial portions of a plant are killed. It could be argued, given that fires do not burn in this vegetation, that the woody plants in this community are adapted to tolerate defoliation by elephants. The succulents, apart from *P. afra*, have probably either 'adopted' an escape strategy (Feeny 1980), growing in inaccessible areas, or else are very rare.

Goats reduced a number of woody shrubs including the succulent *P. afra* (Table 2; Figs 6, 7 & 8). These, with the exception of *E. undulata*, all have leaves which are highly acceptable to goats (Stuart-Hill, unpublished data). *Zygophyllum morgsana* and *L. oxycarpum* increased with goat defoliation, a finding consistent with that of Stuart-Hill *et al.* (1986), probably because these plants are avoided by goats (Stuart-Hill, unpublished data). *Euclea undulata*, however, remains an enigma because it is consistently found to disappear under heavy utilization by goats (this study & Stuart-Hill *et al.* 1986) but does not itself seem to be utilized by goats (Stuart-Hill, unpublished data).

Portulacaria afra

The lower density of *P. afra* under goats (Fig. 3b) confirms that this species is harmed by goats but not elephants, even when the latter are at high densities (Table 1). None of the results (Figs 9–11) refute the conceptual model (Fig. 1). 74% of plants under elephant defoliation had well developed 'skirts' of rooted branches, whereas 82% of plants on farmland had no 'skirts' (Fig. 10). This is corroborated by the larger radius of rooted area and the lower height of the lowest leaf-bearing twigs (Fig. 11). The apparent persistence of some triangular plants under goat grazing (Fig. 9), was due to the collapse of a number of large, formerly umbrella-shaped *P. afra* plants. Multiplying the average rooted area per plant with the densities of *P. afra* (Fig. 3b) for the respective treatments, gives the rooted area of this plant ha^{-1}: i.e. 3694, 3316 and 294 $m^2 ha^{-1}$ for the elephant, control and goat treatments, respectively. Goats, therefore, caused a 91% decline in the area rooted by *P. afra*.

It may be argued that because of its vegetative reproductive strategy, *P. afra* is adapted to utilization by elephant. However, this strategy also renders it vulnerable to utilization by goats: a principle of importance because land managers need to ensure that all *P. afra* plants have a healthy 'skirt' of rooted branches.

It was noticed that a number of *P. afra* plants had been pulled out by elephants, but the lack of any differences in density and rooted area between the elephant and control treatments indicates that this activity has minimal impact.

LIMITATIONS OF THIS INVESTIGATION

The impression could be created that goats *per se* are harmful to the vegetation and in particular *P. afra*. Aucamp (1979) found, however, that *P. afra* was stimulated by light goat defoliation (25% leaf removal), if followed by an extended period of rest (approximately 12 months), a phenomenon recorded in a number of other browse species (Garrison 1953; Lay 1965; Ferguson & Basile 1966; Teague 1987). Stuart-Hill *et al.* (1986) reported that the composition of the shrub community was not adversely affected by goats provided these are lightly stocked. In this study, some of the goat sites were within the plant sociological domains of the control and the elephant sites (notwithstanding the possibility that these sites were moving away from these domains) (Fig. 5b) and, on the basis of the foregoing and of sightings on some goat farms of *P. afra* plants with well developed 'skirts', it would appear that this vegetation is able to tolerate browsing by goats, provided this is lenient. It is probably true, however, that few commercial farms are stocked at such low levels.

A further limitation of this work is that the influence of elephants is not separated from that of the other indigenous browsers such as black rhinoceros, kudu, eland, bushbuck, grysbok and duiker. Bearing always in mind that elephants are the dominant browser, it is nevertheless worth discussing how these other species may have influenced the results, despite their low densities (Table 1). Kudu and eland are taller than goats and would be expected to forage at a higher level. It is suggested, however, that they would have a similar effect on *P. afra* because goats readily stand on their hind legs to browse. Bushbuck, grysbok and duiker browse lower than goats and less intensively and while not preventing the development of the 'skirt', give it a hedge-clipped appearance. Because black rhino feed at a low height and reportedly do not break or tear branches as do elephants (Goddard 1968), one expects them to have a similar effect on the vegetation to goats. However, these animals push over shrubs and young trees to feed on the upper portions of canopies (Smithers 1983), and this would have similar effects to elephant browsing.

CONCLUSION

It appears that a mixture of indigenous herbivores, dominated by elephants and stocked at similar biomass to that of goats on farmland, is not as detrimental to Kaffrarian succulent thicket as goats stocked at current levels. It is doubtful whether this vegetation can be economically farmed with goats at the low stocking rates which would ensure its persistence. As an alternative, the larger land owners (>2000 ha) might consider reducing goats in favour of game and in particular elephant; because tourism, hunting and the products of game can be extremely lucrative.

With the current ban on elephant products (Anon 1989), no production-orientated land-owner is going to bring elephants onto his property if he cannot eventually sell the products of these animals or use his surplus for trophy hunting. Given this, land-owners will probably continue to farm with goats, and elephants will have to stay confined to the limited National Parks. The consequence for farmland will be continuing desertification; and elephants in excess of the carrying capacity of the National Parks will be culled with no financial benefit accruing to those countries and agencies which conserve these animals. This poses obvious problems for a continent populated by poor people, who perceive National Parks as unproductive land set aside as a playground for privileged tourists.

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References

Acocks, J.P.H. (1975) Veld types of South Africa, 2nd edn. *Memoirs of the Botanical Survey of South Africa*, No 40. Government Printer, Pretoria.

Anon (1989) *Convention on International Trade in Endangered Species (CITES): Amendments to Appendices I and II, 1989*. Lausanne, Switzerland.

Agmet records. (1991) Dohne Research Station, South Africa.

Archibald, E.E.A. (1955) An ecological survey of the Addo Elephant National Park. *Journal of South African Botany*, **20**, 137–154.

Aucamp, A.J. (1979) *Die produksiepotensiaal van die Valleibosveld as weiding vir Boer- en Angorabokke*. DSc Agric. thesis, University of Pretoria.

Barrow, J. (1801) *An Account of Travels into the Interior of Southern Africa in the Years 1797 and 1798*. Cadwell & Davies, London.

Bonham, C.D. (1989) *Measurements for Terrestrial Vegetation*. John Wiley & Sons, New York.

Cowling, R.M. (1984) A syntaxonomic and synecological study in the Humansdorp region of the fynbos biome. *Bothalia*, **15**, 175–227.

Everard, D.A. (1987) A classification of the subtropical transitional thicket in the eastern Cape, based on syntaxonomic and structural attributes. *South Africa Journal Botany*, 53, 329–340.

Feeny, P. (1980) Biochemical coevolution between plants and their insect herbivores. *Coevolution of Animals and Plants*. (eds L.E. Gilbert & P.H. Raven). University of Texas Press, London.

Ferguson, R.B. & Basile, J.V. (1966) Topping stimulates twig growth. *Journal of Wildlife Management*, **30**, 339–341.

Garrison, G.A. (1953) Effects of clipping on some range shrubs. *Journal of Range Management*, 6, 309–317.

Gibbs Russell, G.E., Welman, W.G., Retief, E., Immelman, K.L., Germishuizen, G., Pienaar, B.J., Van Wyk, M. & Nicholas, A. (1987) *List of Species of Southern African Plants*, Memoirs of the Botanical Society of South Africa, No. 56. Botanical Research Institute, South Africa.

Glover, J. (1963) The elephant problem at Tsavo. *East Africa Wildlife Journal*, **9**, 30–39.

Goddard, J. (1968) Food preferences of two black rhinoceros populations. *East African Wildlife Journal*, 6, 1–18.

Grobler, J.H. & Hall-Martin, A. (1982) *A guide to the Addo Elephant National Park*. National Parks Board, South Africa.

Hoffman, M.T. (1989) *Vegetation studies and the impact of grazing in the semi-arid eastern Cape*. PhD thesis, University of Cape Town.

Hoffman, M.T. & Cowling, R.M. (1990) Desertification in the lower Sundays river valley, South Africa. *Journal of Arid Environments*, **19**, 105–117.

Hoffman, M.T. & Everard, D.A. (1987) Neglected and abused: the eastern Cape subtropical thickets. *Veld and Flora*, 73(2), 43–45.

Lay, D.W. (1965) Effects of periodic clipping on yield of some common browse species. *Journal of Range Management*, 18, 181–184.

Lichtenstein, H. (1811) *Reisen im Sudlichen Afrika*. C. Salfeld, Berlin.

Noy-Meir, I., Gutman, M. & Kaplan, Y. (1989) Responses of Mediterranean grassland plants to grazing and protection. *Journal of Ecology*, 77, 290–310.

Palmer, A.R. (1990) A qualitative model of vegetation history in the eastern Cape midlands, South Africa. *Journal Biogeography*, 17, 35–46.

Penzhorn, B.L., Robbertse, P.J. & Oliver, M.C. (1974) The influence of the African elephant on the vegetation of the Addo Elephant National Park. *Koedoe*, **17**, 137–158.

Pringle, T. (1966) *Narrative of a residence in South Africa*. Africana Collectanea Series 20. C. Struik, Cape Town.

Skead, C.J. (1989) *Historical Mammal Incidence in the Cape Province*. Cape Department Nature Conservation, Cape Town.

Smithers, R.H.N. (1983) *The Mammals of the Southern African Subregion*. University of Pretoria, Pretoria.

Stuart-Hill, G.C. & Danckwerts, J.E. (1988) Influence of domestic and wild animals on the future of Succulent Valley Bushveld. *Pelea*, 7, 45–56.

Stuart-Hill, G.C., Aucamp, A.J., le Roux, C.J.G. & Teague, W.R. (1986) Towards a method of assessing the veld condition of the valley bushveld in the eastern Cape. *Journal Grassland Society of Southern Africa*, 3(1), 19–24.

Stuart-Hill, G.C. (1990) Carrying capacity of the succulent valley bushveld. *Dohne Agric*. **11**(2), 6–8.

Teague, W.R. (1987) *Defoliation and browse production of* Acacia karroo *in the East Cape South Africa*. PhD thesis, University of Witwatersrand.

Toerien, D.K. (1972) Geologie van die Addo-olifant Nasionale Park. *Koedoe*, 15, 67–75.

Van Wyk, P. & Fairall, N. (1969) The influence of the African elephant on the vegetation of the Kruger National Park. *Koedoe*, **12**, 57–89.

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Appendix

List of woody and succulent plant species recorded in this study with their codes.

Species	Code
Aloe spp.	ALOE
Azima tetracantha	AZTE
Boscia oleoides	BOOL
Brachylaena ilicifolia	BRIL
Capparis sepiaria	CASE
Carissa haematocarpa	CAHE
Crassula ovata	CROV
Euclea undulata	EUUN
Euphorbia mauritanica	EUMA
Grewia robusta	GRRO
Lycium oxycarpum	LYOX
Maerua caffra	MACA
Maytenus spp.	MAsp
Opuntia ficus-indica	OPFI
Pappea capensis	PACA
Plumbago auriculata	PLAU
Portulacaria afra	POAF
Protasparagus spp.	PRsp
Ptaeroxylon obliquum	PTOB
Rhigozum obovatum	RHOB
Rhus undulata	RHUN
Schotia afra	SCAF
Zygophyllum morgsana	ZYMO

[P 8.2]

FARMLAND ELEPHANT: A SOLUTION TO DEGRADATION IN THE WOODY VEGETATION COMMUNITIES OF SOUTHERN AFRICA ?

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ABSTRACT

We highlight the main problems facing land owners in two different vegetation communities dominated by woody plants. In eastern Cape succulent thicket, the most productive vegetation component (the trees and shrubs) is being destroyed by domestic stock, mostly goats. In the savanna regions of southern Africa (c. 40% of the land surface) land owners are plagued with bush encroachment. In both of these vegetation types these problems result in lowered forage production and increased erosion hazard.

We contend that the removal of elephant (Loxodonta africana) has been one of the main contributory causes for the undesirable vegetation changes in these systems. A serious dichotomy exists. While elephant in national parks are being culled to prevent the destruction of woody plants, private landowners in savanna are burning, spraying, chopping and bulldozing bush - at considerable cost. Why destroy rare and endangered animals when they can be the solution to bush encroachment? In succulent thicket vegetation the dominant plants are adapted to defoliation by elephant, not goats. Is it ethical to continue farming with goats when the practise is economically questionable (other than on very large farms) and inevitably results in desert?

Elephant could and should be introduced onto farmland either as working domesticated animals (communal lands and small properties) or as 'wild' animals (on large game farms). We concentrate on the potential for domestication of the African elephant and argue that this will help solve vegetation management problems with the beneficial spin-off of ensuring the survival of elephant in a continent which can ill afford altruistic conservation.

INTRODUCTION

Vegetation degradation in southern Africa is a much discussed topic. Why is this so? In this paper we examine the current status of two differing southern African vegetation types (savanna and succulent thicket), consider why they are degrading and, towards stimulating lateral thinking, pose one of many possible solutions.

Savanna represents in excess of 40% of southern Africa and is, as we all undoubtably know, essentially a perennial grassland with a scattering of trees. The grasslayer forms the forage production base while the woody layer is of secondary importance. With 'mismanagement', bush encroachment occurs and this can be either an invasion of woody plants into an area where none were previously there, or a thickening up of the woody plants already occurring in the area. It is arguably the single biggest problem facing land managers in savanna regions because it:

i) reduces the productivity of the grass layer (ie less food for grazers);
ii) restricts the movement of animals and man;
iii) is aesthetically unattractive (game reserves and game farms);
iv) lowers the water table;
v) promotes soil erosion; and
vi) is exorbitantly expensive to reverse.

Succulent bushveld, on the other hand, is a dense, semi-succulent, thorny vegetation occurring on the eastern seaboard of South Africa in hot, dry (rainfall 225 to 500mm), frost-free areas at low altitudes between the Kei and Gouritz river valleys (data from Acocks, 1975; Cowling, 1984; Everard, 1987. In this vegetation, browse is the production base and this is rapidly being eliminated under current pastoral systems (mostly goats) (Hoffman & Everard 1987; Hoffman 1989, Hoffman & Cowling 1990). This is serious as it represents an irreversible loss of a unique vegetation type, and the community which replaces it, is unstable, prone to soil erosion and is able to support fewer mammalian herbivores (Stuart-Hill & Danckwerts 1988).

Why are these vegetation types degrading (changing)? Let's examine the processes which have led to the current situation.

VEGETATION CHANGE ON FARMLAND

Bush encroachment in savanna regions

Reasons

The competitive advantage enjoyed by the woody components in recent times is probably a result of a number of interrelated processes.

Before modern pastoralism, there was probably a dynamic 'balance' between the woody and herbaceous layers; ie there would have been times where woody plants were increasing and this would have been compensated for times when the grass layer had the upper hand. This would have operated along predator-prey principles where the herbivores are the predators and the vegetation is the prey.

With modern pastoralism the mix of indigenous browsers and grazers was replaced by domestic grazers (cattle and sheep), browsing pressure decreased, and the woody component has been allowed to increase unchecked. The removal of elephant has probably had the greatest negative impact as they are extremely destructive feeders and can be the primary force in changing a woodland or thicket (encroached savanna) into a functional grassland. They are known as "keystone herbivores" (Owen-Smith 1987) and it is proposed that they are essential for the survival of a number of other animals (e.g. roan, sable antelope, tesessebe) in that they create habitats suitable for these species (Owen-Smith 1989).

Once the mix of native herbivores had been eliminated, cattle and sheep were introduced and probably stocked at higher rates than that at which natural grazers had occurred. Further, these numbers remain constantly high because farmers supply water during droughts, inoculation against disease and protection from carnivores. This harms the herbaceous component which diminishes fuel loads, effectively excluding fire. As the bush encroaches, grass production declines with the result that, if the grazer stocking rate is not lowered to account for this, the herb layer becomes increasingly overstocked - exacerbating the situation.

Elephants: the solution to bush encroachment

It is iniquitous that, in the national parks of southern Africa, elephants are culled because they are destroying woody habitat, whereas outside the parks, farmers (and governments) are spending large amounts of money on bush eradication. Surely, part of the solution to the bush encroachment problem on farmland in Africa is there 'across the fence', in the game reserves. Given the expense of having to 'buy-back' the farm when implementing bush eradication programs, and the tenacity of woody plants under current farming systems, it seems that land owners should seriously consider 'farming' elephants - especially since these animals are valuable (meat, skins, ivory, hunting trophies, tourism, etc) yet currently cost relatively little (R10 000 per animal).

Vegetation degradation in succulent bushveld

Reasons

To understand why degredation occurs, Stuart-Hill (1992) compared the effects of defoliation by wild herbivores (mostly elephant) with that of domestic ungulates (mostly goats) stocked at similar biomass. It was found that while both elephant and goats reduced canopy cover in relation to control areas, only goats reduced the number of shrub species per unit area. The replacement of elephant with goats as the dominant browser results in a fundamental change in the shrub community (Figure 1) to one dominated by ephemeral herbaceous plants with a few, small unpalatable shrubs sometimes with a scattering of umbrella-shaped trees.

INSERT FIGURE 1

Goats, in contrast to elephants, reduced the percentage frequency of the dominant tree-succulent Portulacaria afra by 40 %, its density by 71 % and caused a massive 91 % decline in the total area rooted by this plant. Stuart-Hill (1992) proposes that this is because goats defoliate the lower portions of the canopy and effectively prevent the development of a 'skirt' of rooted branches (Figure 2) on which the plant depends for survival. With severe goat browsing, the shrub takes on a umbrella shape, eventually collapsing as the weight of the succulent canopy becomes too great for the relatively weak stem to support. Elephant, by contrast, browse from the 'top downwards' and while they severely damage the upper portions of the plant's canopy, the lower rooted branches escape defoliation and vegetative reproduction continues.

INSERT FIGURE 2

The non-succulent species on the other hand, all have the ability to coppice either from stem bases or from the roots. This attribute enables plants to recover from catastrophic events (e.g. fire or breakage by mega-herbivores) where the aerial portions of a plant are killed. It follows, given that fires do not occur in this vegetation, that the woody plants are adapted to tolerate defoliation by elephant. With these results, Stuart-Hill (1992) argues that succulent bushveld is adapted to elephant utilization, and not to utilization by small domestic ungulates stocked at equivalent biomass.

Elephants: the means of sustainably utilizing succulent bushveld

Given the low stocking rates necessary for sustained goat production (Stuart-Hill & Aucamp 1993) and the fact that expensive fencing and watering schemes are indispensable for goat farming, it is doubtful whether it is economical to farm this vegetation using goats. A case could be presented for all of this land to be turned over to conservation but such altruistic moves seldom meet with approval and are difficult to justify when the majority of the population are impoverished. Alternatively, existing land owners could be enticed to consider reducing goats in favour of game and in particular elephant, because tourism, hunting and the products thereof, can be extremely lucrative.

ELEPHANTS AS FARM ANIMALS

The potential for elephant farming

Advantages

Elephants have the following highly appealing attributes as far as land managers are concerned.

i) They are the only browser, apart from goats, which can be concentrated in high stocking densities and which can, therefore, be used as effective bush control agents.
ii) They allow flexibility in that they can be kept as wild, domesticated or as highly trained working animals.

iii) Elephant have intrinsic value in that their presence, even if they are not utilized, will raise the marketability of a property by making a hunting or tourist package appear to be more attractive.

v) They can be seen as an investment which, against the decline in world elephant populations and the increasing realisation that elephant are the driving force in African savannas (i.e. the solution to bush encroachment), means that their projected value should be enormous. This alone should serve as an incentive to purchase elephant. Recall how a white rhino, a mere 10 years ago, could be bought for c. R 300 whereas today they cost in the region of R 20 000.

Disadvantages

Their main disadvantage is their inherently low intrinsic population growth rate (between 4 and 6%) which ensures that they are not good candidates for farming in the conventional sense (i.e. for their products); the returns on capital invested will approximate the growth rate. It is essential, therefore, that if they are to have any economic value, then 'value must be added'.

There are of course practical problems, but these have been repeatedly addressed by various authors (see Ebedes in Anon 1991 and Stuart-Hill 1991) and are not, therefore, repeated here.

Wild elephant on game farms

Elephant as wild animals on game farms is by now not an unusual concept (Anon 1991) and we waste no more time discussing this other than to point out that inevitably this is only suitable on large properties where neighbours are not averse to wandering elephants. Although we deal with this briefly, the problems of wandering 'wild' elephants should not be underestimated. The long term implication is that there <u>will be</u> breakouts. This is serious, as recovering these animals will probably involve an expensive helicopter chase, failing which, the animal will be destroyed.

For all practicable purposes, most rangeland in southern Africa is in the hands of small private land-owners or tribal communities where wild elephants are not a suitable option. If we are to leave the matter there, then we would neglect a fundamental driving force on the majority of the land surface of the sub-continent (as argued previously). By doing this we must also accept continued vegetation degradation and the associated non-sustainable efforts at vegetation reclamation (eg reversing bush encroachment or planting <u>P. Afra</u>). However, if <u>domesticated</u> elephants could be introduced onto these lands, many of the vegetation problems could be alleviated.

Domesticated elephant

Rather more unusual is the concept of domestication, especially with African elephants. Contrary to popular belief, historians have shown that African elephants have been domesticated and trained as early as the Asian elephant (Elephas maximus): in the fourth century BC Aristotle described the capture and training of African elephants; in 323BC the Ptolemaic dynasty set up training camps for elephants on the banks of the Bakara river (now in Sudan and Ethiopia); in 255BC the Carthaginians used African war elephants to defeat the Romans at Tunis; and of course we recall Hannibal's famous march over the Pyrenees and Alps. The demise of this activity may raise doubts as to the effectiveness of domesticating African elephants and it could be written-off as a failed 'experiment'. However, we propose that it 'failed' because African elephants were used only as war animals, and when the Romans under Scipio Africanus developed techniques of defeating the war elephant, their usefulness disappeared and training stopped. Therefore, because African elephants occurred on a continent where timber was never an important industry, they, unlike their Asian cousins, had little commercial value.

In modern times, African elephants have been successfully captured and trained in large numbers. In the late 1800's the Belgiums started such a project at Kiravunga in the Congo which, in 1930 moved to its present base at Gangla-na-Bodio. At the height of its success, this project housed and trained up to 120 elephant at any one time and these were used for "logging, ploughing, cart pulling and farm clearance" (see King 1992). The project was terminated in the 1960's due to the civil war but four or five working elephants remain. At present there are numerous African elephants being trained by film makers, circuses, safari companies and zoos.

If this activity could be successfully revived, elephant could become part of the African way of life, as have the 14000 domesticated Asian elephants (Elephas maximus) in South East Asia. It is conceivable, for example, that an entrepreneur could contract to clear bush using trained elephants rather than heavy machinery. He could buy a herd of elephant (c. 30 animals) for the price of one bulldozer, 'fuel' would be available free on site, and depreciation would be zero as elephants appreciate with age, especially if domesticated. This sort of enterprise would also stimulate employment, and knock-on enterprises such as firewood collection and charcoal manufacturing. Other possibilities for the use of elephants are: mounted eco-tours (as currently done in Botswana and Thailand), ploughing, work on sugar estates and in the rapidly expanding forestry industry. This idea may be even more appealing if seen against the lack of heavy machinery and maintenance support in many African countries.

Domestication and Training

From the aforegoing, then, we need to distinguish three categories of 'farmland' elephant:

i) wild free-ranging elephants on game farms;
ii) tame elephants, which are amiable and disciplined in the manner of domestic cattle (i.e. you can herd but not ride them); and
iii) trained elephants, in the sense that they can be ridden or used as working animals to perform tasks on command.

The last two categories refer to domesticated elephant.

Unlike Asia, with the demise of the African war elephant in the first century AD, the skills and expertise to capture and train African elephant have largely been lost. What skill there is, presently resides in zoos and circuses. Through the third author, the collective experiences of these experts has been drawn on in this section. A degree of mystique has grown up around the taming of the African elephant with the popular dogma being that this species cannot be trained. Whilst it is true that the difference in temperament between the Asian and African species requires different training techniques, many trainers find the African elephant to be more intelligent and therefore easier to train than the former.

It must be clearly understood at the outset that there is no safe, middle ground between wild and domesticated. Wild means untouched and domesticated means that the animal is obedient and safe for humans to be around. To go half way is to court disaster!

Domestication is split into 2 levels:

i. basic husbandry and discipline; and
ii. specific tasks and duties.

Basic discipline is compulsory and is necessary for the safety of both man and animal during day to day work and care. Included are: restraint, coming when called, stopping on command, lifting trunk and feet for inspection (for medical examination), lying down on command (both sternal recumbent and on its side), good manners, etc.

The key to elephant training is continuity of discipline throughout the animals life. Staff turnover is a problem. It is vital, therefore, that the owner becomes involved in management on a regular basis so that he can supervise the continuous level and standard of discipline. In addition, the American Association of Zoos, Parks & Aquaria (AAZPA), in conjunction with The Species Survival Coordinator and the Professional Elephant Managers Association, has produced a <u>Protocol</u> for the management and care of elephants in captivity. This document provides a guideline for acceptable behaviour for both keepers/trainers and the animals. It could form the basis for ethical training in this country and if all trainers follow it, will ensure that animals and handlers can be interchanged. It will not be possible to train without any discipline at all but this should be guided by the Protocol. With this it is possible to train elephants (to the level of the Gangla-na-Bodio animals) without resorting to the rigorous techniques applied in Asia.

Restraint at night is an important part of maintaining discipline and should be strictly adhered to for at least the first three years of captivity, depending on the degree of initial training. During this period it will be necessary to feed during the night and this needs to be of high quality, especially if the animals are very young.

To instil basic discipline (as described above) in wild caught elephants measuring between 120-150cm at the shoulder should not take more than 12 to 14 weeks per animal. One trainer should be able to oversee the preparation of batches of 10 animals at a time provided that he has an experienced team of four assistants. Once good basic discipline has been established and the elephant is comfortable and secure with his handlers, then specific tasks may be incorporated into the training if desired. These may include riding, logging, pulling, pushing down trees, etc.

The logistics of training will not be difficult as trainers could be brought in (from Asia and Western circuses and zoos) to handle more elephants than currently available. The biggest problem foreseen will be the training of handlers and owners.

Domestication to aid elephant conservation

Capturing and transporting surplus elephants presents a major constraint to elephant conservation. Currently, all adult animals in selected herds are culled and only the youngsters are captured. This is extremely inefficient because of the removals, only c. 6% (Whyte 1990) becomming available for restocking new reserves. If adults can also be captured and transported, more animals will become available, less care will be necessary (infants require special care), the complex social structure will be less adversely affected, and importantly it would not be necessary to wait years before they breed.

The reason for taking only youngsters is that, with current methods, the strength and weight of adults excludes their capture. By contrast, the capture and taming of c. 100 000 <u>adult</u> Asian elephants has occurred over the past century in South East Asia (Sukumar 1991). One of the most efficient methods is to drive the herd into a stockade ("keddah") where the captives are then controlled and calmed with "monitor" (tamed adult) elephants. The captives are then roped in a 'chain gang' interspersed with the monitors, and walked to the training area. Each animal is then secured to a tree with ropes and tamed with frequent handling. With modern drugs, ingenious corrals and monitor elephants, the capture and taming of wild adult elephants has become much more humane and efficient. Dogma had it that young African elephants were too aggressive to tame but this was disproved in modern times during the early 1900's and again in the 1960's (Moore & Munnion 1989). Current dogma has it that adult African elephants can never be tamed. This dogma should at least be tested. If adults could be captured and tamed, whole herds could be moved rather than culled as they have the ability to cover large distances on foot. Even if this 'taming' is merely to aid translocation (via 'chain gangs') this would considerably speed up the restocking on new game reserves and avoid the adversely publicity that elephant culls could have on our potential for international eco-tourism. Central to the success of such a project is the availability of tamed adult elephants; an incentive to tame elephants now!

Further incentives for domestication are: that it would make considerable tracts of land (of highly suitable habitat) available for the conservation of the species (eg. 40% of South Africa); and it will remove the fate of the elephant from the hands of governments who, in an overpopulated continent, will have to address the demands of the majority of (impoverished) people.

CONCLUSION

'Farmland elephant', and especially if domesticated, can have the potential to solve important vegetation management problems plus contribute to local entrepreneurship. If successful, the spin-off can be to ensure the elephants' future in a continent that cannot afford altruistic conservation. Probably one of the biggest stumbling block's, however, is the conservative attitude of conservationists who, whilst informed about wild elephants, are ignorant of those domesticated.

REFERENCES

Acocks J.P.H. 1975. Veld types of South Africa, 2nd edition. Mem. Bot. Sur. of South Africa., No 40. Government Printer, Pretoria.

Anon 1991. Proceedings of a symposium on the African elephant as a game ranch animal. Wild. gp. S.A. Vet. Assoc., Onderstepoort.

Cowling R.M. 1984. A syntaxonomic and synecological study in the Humansdorp region of the fynbos biome. Bothalia. 15: 175-227.

Everard D.A. 1987. A classification of the subtropical transitional thicket in the eastern Cape, based on syntaxonomic and structural attributes. S. A. J. Botany. 53: 329-340.

Hoffman M.T. 1989. Vegetation studies and the impact of grazing in the semi-arid eastern Cape. Ph.D. thesis, University of Cape Town.

Hoffman M.T. & Cowling R.M. 1990. Desertification in the lower Sundays river valley, South Africa. J. Arid Envir. 19: 105-117.

Hoffman M.T. & Everard D.A. 1987. Neglected and abused: the eastern Cape subtropical thickets. Veld and Flora.

King J.M.P. 1992. The history of the domestication of the African elephant. Proc. of the 1st Natal bushveld symposium. Special publ., Grassland Soc. Southern Africa.

Moore R.J. & Munnion C. 1989. Back to Africa. Southern Book Publishers, Johannesburg.

Owen-Smith N. 1987. Pleistocene extinctions: the pivotal role of megaherbivores. Paleobiology. 13 : 351-362.

Owen-Smith N. 1989. Megafaunal extinctions: the conservation message from 11,000 years B.P. Conser. Biol. 3(4): 405-412.

Stuart-Hill G.C. 1992. Effects of elephants and goats on the kaffrarian succulent thicket of the eastern Cape, South Africa. J. Appl. Ecol. 29: 699-710.

Stuart-Hill & Aucamp 1993. Carrying capacity of the succulent valley bushveld of the eastern Cape. Afr. J. Range. For. Sci. 10(1): 1-10.

Stuart-Hill G.C. & Danckwerts J.E. 1988. Influence of domestic and wild animals on the future of succulent valley bushveld. Pelea. 7: 45-56.

Stuart-Hill G.C. & Davies R.J. 1991. Bush utilization: the solution to bush encroachment. Proc. of the Hlabisa beef & game symposium. (Pp: 69-84), Dept. of Agric, Pietermaritzburg.

Sukumar R. 1991. Conservation. In Illustrated encyclopedia of elephants from their origins and evolution to their ceremonial and working relationship with man. S.K. Eltringham. Salamander books, London.

Whyte I.J. 1990. Census results for elephant and buffalo in the Kruger National Park in 1990 and culling quotas for the 1990/91 culling year. Unpubl. report. National Parks Board, Skukuza.

FIGURE CAPTIONS

Figure 1 Principal component analysis of floristic data from sites in and around the Addo Elephant National Park showing: the domains of the control (■), elephant (Δ) and goat (*) sites (after Stuart-Hill 1992).

Figure 2 The effect that no browsing (a), elephant browsing (b) and goat browsing (c) has on the growth habit and vegetative propagation of Portulacaria afra (Stuart-Hill 1992).

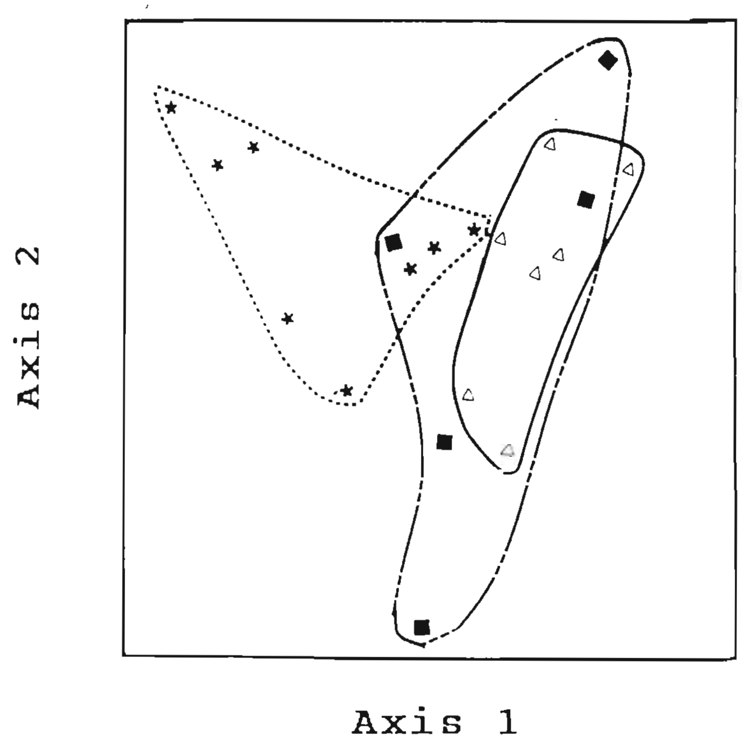

Figure 1

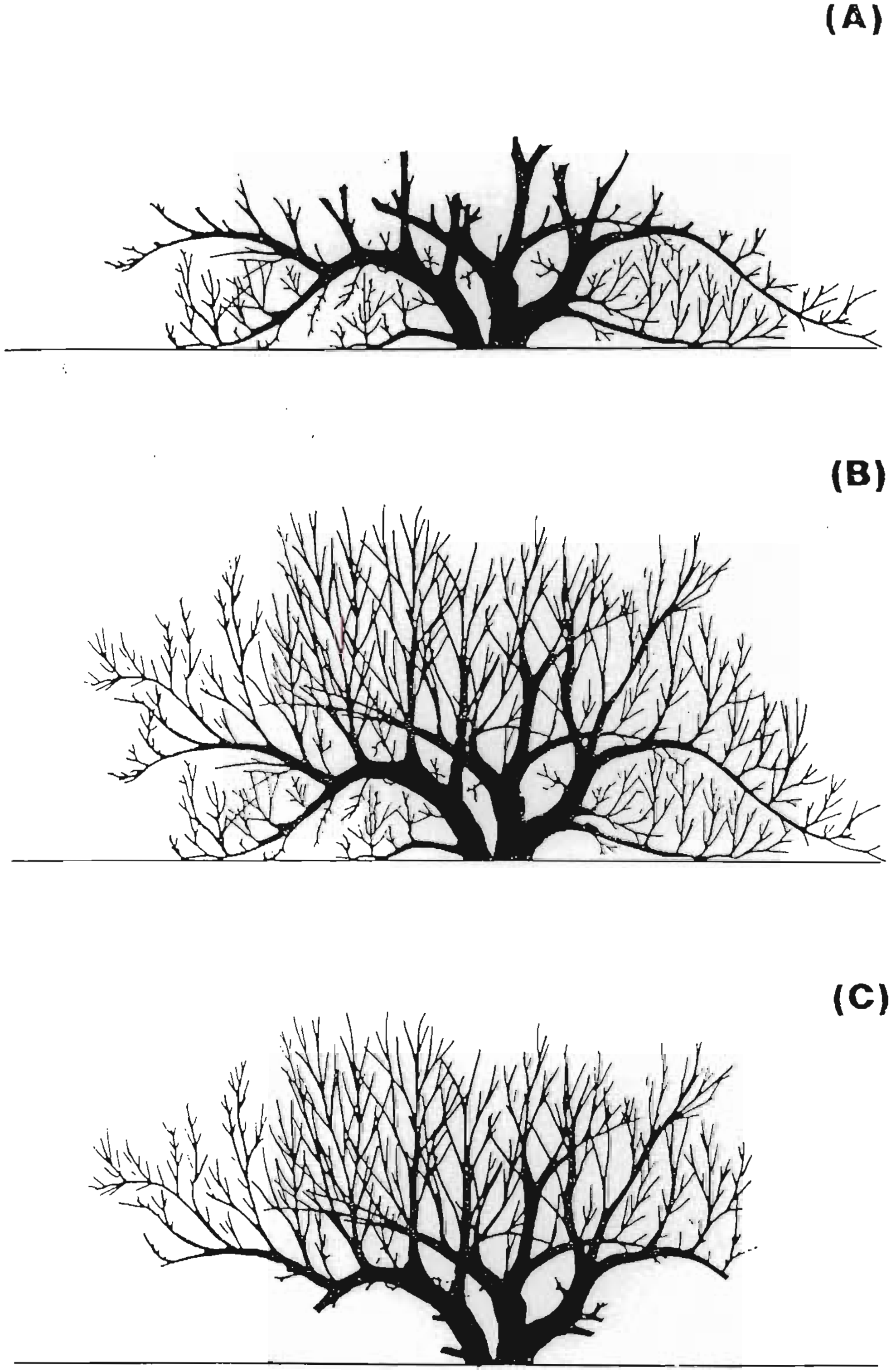

Figure 2

FURTHER WORK

[P 0.2] A framework for the development of a management orientated vegetation model

FURTHER WORK

It is obvious that this study has failed to produce all the tools required for formalized adaptive veld management in succulent bushveld. It is still necessary to develop and test:

i. a vegetation monitoring system for proactive adaptive management (Tool 3); and
ii. a system of recording essential environmental and management information (Tool 7).

Assuming that these are provided, it will then be necessary to formally implement an adaptive management system on various properties and monitor the performance of such systems.

I believe that future work with respect to Tool 8 (ecological principles) should concentrate on the demography of this vegetation type and, in particular, developing an understanding of how individual plants are killed by defoliation. My suggestion for integrating future vegetation work in a manner that is useful to managers is described in the last paper of the thesis: **Framework for the development of a management orientated vegetation model [P 0.2].**

[P 0.2]

A FRAMEWORK FOR THE DEVELOPMENT OF A MANAGEMENT ORIENTATED VEGETATION MODEL

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ABSTRACT

It is alleged that current vegetation research efforts do not meet the information requirements of land managers. This is because the research work is often esoteric, and if potentially useful, then seldom presented in an integrated and practicable applicable manner.

This paper presents a philosophical framework which attempts to address these shortcomings. It centres around the development of a 'vegetation model'. This model, essentially a state and transition model, also incorporates a system of evaluating the vegetation in terms of various land-use options and translating these onto maps. Without this addition, one cannot talk about desirable or undesirable change. If we cannot talk in these 'value loaded' terms then we cannot communicate the consequences of vegetation change to the public or inform the pastoralist of the adverse (or positive) consequences of his actions.

An iterative approach is suggested where a prototype is first developed, evaluated and then upgraded if necessary.

INTRODUCTION

If we are absolutely honest with ourselves, we would acknowledge that most managers are unimpressed with the results of vegetation research and in particular, vegetation monitoring. This attitude is criticised by researchers who implicitly allege that managers are ignorant. I submit, however, that managers are not generally ignorant of the importance of the vegetation and that their attitude towards vegetation research is largely justified. The fault I believe lies with researchers, not managers! Little honest attempt has been made to address managers' problems and information requirements. The research is often esoteric and even if useful, is communicated in an overly detailed clumsy manner, full of jargon and with little attempt to integrate it with practise. In this paper, I propose a vision which will, I believe, address this shortcoming. I present this to researchers to stimulate debate and to provide a framework within which various independent vegetation research efforts can be undertaken, but which nevertheless ensures that all can be integrated into a practicable product.

The overall objective is to develop a 'vegetation model', interpretable by land managers, which integrates vegetation classification, monitoring and dynamics with land-user related interests such as faunal habitat suitability, carrying capacity, ecological sensitivity, tourism appeal, etc. Ultimately, we should be in a position to translate any change in the vegetation into its consequences for society and the pastoralist.

The philosophy is to adopt a 'top-down' systems analysis approach. A prototype model is first developed from existing information which may be either research data and/or experts' opinion. This prototype can be immediately used by land managers on the justification that it is better than nothing. The prototype can also serve as a conceptual framework for research and the various aspects can serve as applied hypotheses for scientific endeavour. It follows that the model will be continuously revised and updated as new information becomes available or it is found to be lacking.

PROCEDURE

This is most efficiently described as a series of steps but these are not necessarily sequential. The detail of description relates to the development of the prototype vegetation model.

1. Demarcation of 'vegetation space'

The intention here is to describe the vegetation community in a manner which is devoid of value judgement. The approach, described by Stuart-Hill & Hobson (1991), should be used as the agricultural concept of veld condition is inappropriate; i.e. a site's position in ordination space is used as the 'score' for the vegetation at that site.

A rapid survey of the vegetation in the study area is conducted ensuring that all major aspects of the vegetation are quantified[1]. All these sites are then subjected to ordination analysis, the goal being to demarcate the bounds of ordination space in the study area. It is not inconceivable that fictitious site's could be generated and added to the data matrix to extend the boundary's of ordination space. It follows that there may be large B-diversity and it could be necessary, for interpretive purposes, to subdivide the data matrix and re-ordinate the various sub-sets. However, the ordination plot (multi dimensional space) for all sites combined represents the initial framework for the 'vegetation model'. The model presented to managers should be a simplified 2-dimensional ordination plot devoid of detail and scientific jargon.

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[1] For Succulent Bushveld I would recommend the 'Bubble method' (Stuart-Hill in prep)

The ordination techniques to be used will undoubtably generate much debate amongst statistical academics. However, for all practical purposes, any range of methods could be used provided that they are not changed over time and are relatively free of distortions in at least the first two axes.

2. Visual vegetation assessment technique

The development of a visual vegetation assessment technique is necessary for the following reasons.

i) To orientate field workers with the vegetation model: i.e. so they will be able to recognise, in the field, the different vegetation communities/states seen in the model.

ii) To extrapolate, in an efficient manner, the model to areas not field sampled. This could also be achieved with satellite imagery, but results with this approach have been disappointing.

iii) As a training exercise for managers and to aid communication between managers and ecologists with regard to the vegetation.

The details of the visual assessment procedure are described by Stuart-Hill (1991), but essentially it involves selecting sites which represent different areas in ordination space (in the vegetation model). The criterion for selection is that they should represent different vegetation communities/states and in addition be easily accessible and relatively close to one another. Each of these sites is then reocated in the field, marked and photographed. These then become the reference sites. Photograph albums are produced which will illustrate the vegetation community/state at the reference sites and these albums could also contain various information (e.g. plant density, cover, species composition, etc.) describing each vegetation community/state. Field training of operators is undertaken by allowing each operator to inspect the site and with the aid of the photograph album, develop empathy with the vegetation model. Looking more broadly, these reference sites could also be presented to visitors to National Parks, who may be introduced to even more simplified versions of the vegetation model.

3. Superimpose user interests onto the vegetation model

The vegetation model described thus far would have little appeal to land managers as it does not evaluate the different vegetation communities/states in terms of any land-use objective. In this step the goal is to superimpose various land-use interests onto the vegetation model (e.g. habitat suitability for various animals, carrying capacity, ecological sensitivity, tourism appeal, fire risk, etc.).

The approach here could be to consult with experienced experts who would be asked to score the value (for each land-use interest) of each reference site. Conceptually, we would then be able to overlay, onto the vegetation model, an evaluation for each land-use interest. Ultimately, it would then be possible to state (for example) that position X in the vegetation model is ideal for impala and goats, has low tourism appeal (because of high bush density), low value for waterbuck and cattle, moderate value for black rhino, high ecological risk (soil erosion), etc.

4. Develop a state & transition model

The 'vegetation space' is essentially a static description of various communities or states and it is necessary, therefore, to develop a full state and transitional (S&T) model (Westoby, Walker & Noy Meir 1989) so that managers will know:

i. how to change the vegetation from one state to another (perhaps more desired) state;
ii. which states are prone to degradation (soil loss and bush encroachment) and consequently require special attention;
iii. how to manipulate the vegetation to help achieve various (and changing) land-use objectives; and
iv. which vegetation states and, consequently, land-use objectives cannot be attained by manipulating the vegetation.

The approach should be to initially develop a hypothetical S&T model by ordinating sites of known differing past impact in an approach similar to that of Stuart-Hill (1992). At a later stage this can be tested with experimentation.

The S & T model should be simplified for managers and could be presented as annotated arrows in the vegetation model and optionally as a decision table or expert system.

5. Transpose vegetation model onto maps

To assist field planning, it is necessary to transpose the vegetation model onto geographic maps, thereby creating a vegetation map. This can be done by using the visual method to determine vegetation community/state at each map location. Aerial survey, aerial photographs, satellite images and geostatistic interpolation (Wills in prep) can be used to aid this activity, as can the techniques developed by Austin and Heyligers (1989). The approach here is to rapidly cover the ground and a conscientious effort needs to be made to avoid getting 'bogged-down' with unnecessary detail.

Once the vegetation data have been transposed onto the maps it will be a relatively simple matter to overlay maps indexing the suitability (or value for the various land-user interests) onto the geographic map. With this information, the study area as a whole can be evaluated in terms of is potential for various land use enterprises and for the possibility (using the S&T model) of changing the vegetation to meet the requirements of a selected land use option. Importantly, the change in these maps over time will provide the information that vegetation monitoring at a regional scale demands; e.g. is the area suitable for cattle farming becoming diminished?.

A possible spin off is that all the data generated by this step will be suitable for currently popular Geographic Information Systems.

6. Prepare user orientated documentation

The central documentation could be the vegetation map, supported by a descriptive guide of each vegetation state showing: a photograph, species and structural composition of the vegetation, its sensitivity, plus perhaps it's suitabilities for various herbivore species. A simplified state and transition model showing clearly the impacts which are required to move from one state to another and those vegetation states which can and cannot be changed. Depending on user objectives, various additional maps detailing habitat suitability (or productivity index) could also be added.

A special effort must be made to present all output products in a manner which is readily interpretable by managers. Consequently, these should be purged of scientific jargon and qualifiers and for the faint hearted, an introductory passage could be written outlining the reasons for this so as to protect the scientific credibility of the developer.

7. Present to users for evaluation

The prototype must then be presented to managers for their evaluation. If their sentiment is that the product is not worthwhile then their opinion should be respected and the project terminated. If not, the products can then be updated as required.

CONSTRAINTS AND CONCLUSIONS

I envisage that the production of a vegetation model will be time rather than cost limited. However, even here the development of a prototype should not take more than a few months of continuous work provided the data have already been collected.

Assuming the users accept, in principle, the prototype, further testing, evaluation and adaptation will be an iterative process. It follows that the vegetation model will, as in the spirit of adaptive management, be dynamic. However, the termination date for such a project should be determined by the users, not the researchers.

A constraint to the iterative approach is the current scientific paradigm. Researchers are encouraged by the 'system' to sub-optimize; i.e. expend an inordinate amount of effort on a small sub-component of the system in order to get work published. This needs to be addressed or else the research and practise dichotomy will continue.

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On reading this proposal one is bound to identify with certain steps as being non-unique. I do not dispute this. This paper is an attempt to integrate the various components of vegetation research and relate these to important land-use objectives. Consequently, I acknowledge all those people who have contributed to the development of this proposal through my interaction with them.

REFERENCES

Austin M.P. & Heyligers P.C. 1989. Vegetation survey design for conservation: gradsect sampling of forests in north-eastern New South Wales. Biological Conservation. 50: 13-32.

Stuart-Hill G.C. 1991. Towards visual veld assessment of succulent valley bushveld. J. Grassl. Soc. South. Afr. 8(2): 63-69.

Stuart-Hill G.C. 1992. Effects of elephants and goats on the Kaffrarian succulent thicket of the eastern Cape, South Africa. J. Applied Ecol. 29: 699-710.

Stuart-Hill G.C. in prep. Evaluation of the 'Bubble' technique of sampling Kaffrarian Succulent Thicket.

Stuart-Hill G.C. & Hobson F.O. 1991. An alternative approach to veld condition assessment in the non-grassveld regions of South Africa. J. Grassl. Soc. South. Afr. 8(4): 179-185.

Westoby M., Walker B. & Noy-Meir I. 1989. Opportunistic management for rangelands not at equilibrium. Journal of Range Management. 42(4): 266-274.