THE FEASIBILITY OF USING REMOTE SENSING AND FIELD-BASED CHECKS TO MONITOR THE IMPACT CAUSED BY COLLECTION OF WOOD IN THE EASTERN CAPE/CISKEI FOREST AND THICKET FORMATIONS

Karl Lane

Submitted in fulfilment of the requirements for the MSc degree
in the Department of Botany, University of Cape Town

Cape Town 1988

ACKNOWLEDGEMENTS

I wish to thank the following persons/organizations most sincerely for their assistance:

- The Foundation for Research Development of the CSIR, for funding the study in 1986 and 1987.

- The University of Cape Town for their facilities, and my supervisor, Prof E J Moll of the Botany Department, for his guidance.

- Dr B McKenzie of the Botany Department of the University of the Western Cape, co-superviser of the project, for his guidance.

- Dr R M Cowling, Prof R I Yeaton and Mr M T Hoffman, for commenting on earlier drafts.

- My wife, Tisha Greyling, for encouragement.

EXECUTIVE SUMMARY

A variety of studies have shown the problems of energy supply faced by low-income communities in southern Africa. Most of these communities are dependent upon indigenous fuelwood supplies. In addition, many of these communities use indigenous wood for construction. This largely uncontrolled utilisation imposes severe threats on woody vegetation communities. The Eastern Cape/Ciskei region is an area where energy supply problems are particularly severe and impacts on woody vegetation correspondingly severe. This study aimed to investigate the feasibility of using remote sensing techniques to monitor the the impact caused by collection of wood in the Eastern Cape/Ciskei forest and thicket communities.

A variety of remote sensing techniques for landcover analysis were investigated. In all cases, visual interpretation was used because it is considerably cheaper and demands less technical expertise than would computer processing. In addition, many studies have shown visual interpretation to be superior.

Maps were drawn from multitemporal aerial photograph sequences and from Landsat and SPOT satellite images. These maps showed that there has been relatively little change in area of woody vegetation in the study area since 1956. However, field studies showed that vegetation community structure had been degraded as a result of intense and sustained human impact. This qualitative decline also reflected a decline in usefulness of the woody vegetation of the area to local communities. This substantial degradation was not visible on any of the remote sensing imageries. This emphasises that field-based checks to monitor human impacts on forest and thicket formations are essential.

Strategies for reducing the dependence of low-income communities on indigenous vegetation for energy supplies and constructional timber have been reviewed from the literature and these are descibed in Appendix 1. Most successful strategies in other parts of the world have been the result of a national commitment to tree planting, recognition of a multiplicity of constraints and the voluntary involvement of the communities the strategies are intended to assist.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 WOOD USE PATTERNS AS MOTIVATION FOR THE STUDY

Like many countries attempting to alleviate the spectre of under-development and its concomitant socio-economic problems, South Africa is increasingly tackling the question of basic human needs (Le Roux 1985). Many authors of publications on the consequences of development have pointed out that the poor are often least likely to benefit from any development programme. Keeton (1984) says that "the primary effect of economic development....is, on the average to decrease both the absolute and the relative income of the poor. Not only is there no automatic trickle down of the benefits of development but on the contrary, the development process leads typically to a trickle up in favour of the middle class and the rich."

Simkins (1984) has shown that in South Africa, as in other less developed countries, the bottom 15% income group have experienced an absolute decline in per capita income since 1960. Le Roux (1985) suggests that 15% may even be a conservative estimate and that the true percentage may lie between 20% and 30%. Le Roux also points out that these figures represent only observations of income growth/decline rates. The actual number of families living below the "bread line" was possibly as high as 80% of South African families even in 1980.

The basic needs approach has been variously defined and the collection of services and facilities which provide for basic needs will obviously be different from country to country. Nevertheless Burki and Ul Haq (in Le Roux 1985) identify "a common core that includes nutrition, education, health, water, sanitation and shelter". It is self-evident that fuel and constructional timber are essential for the fulfillment of at least some of these services. This study was therefore implemented to investigate possible monitoring techniques and the nature of human impacts on the woody vegetation in the eastern Cape/Ciskei.

Where indigenous timber is still plentiful, it is extensively used for construction of houses (Cunningham 1988). In the forested areas of the Transkei, species such as *Buxus macowanii*, *Buxus natalensis*, *Cryptocaria woodii*, *Duvernoia adhatodoides*, *Pavetta lanceolata* are favoured as poles and laths for construction (Johnson 1983). In addition, Cunningham (1988) mentions *Apodytes dimidiata* and *Ptaeroxylon obliquum* as favoured species and points out that these are cut as live wood. These species are favoured because of their durability and resistance to termite attack but this also means they have low annual increments (Cunningham 1988). Indigenous forests are also under pressure to varying degrees from many other forms of utilisation ranging from timber for furniture to foods and traditional medicines (Cunningham 1988).

1.2 FUELWOOD USE

Wood has been utilised for many thousands of years as fuel for household fires. Through studies of charcoals in shelters in Swaziland Prior and Tuohy (1987) have shown that where choice was possible, the plant species used as firewood in Swaziland has remained the same over the last 9 000 years. The most favoured species have been species of Leguminosae and Combretaceae. Variations in Combretaceae and Leguminosae residues in charcoals have been used to indicate changes in abundance of these plants which have been attributed to climatic variation. Today fuelwood still forms the major energy source of black people in Africa (Harrison 1987).

Moller (1985) notes that "Over 4/5ths of rural and white farm blacks (ie black workers on white owned farms) stated that they used wood for cooking or heating in their homes. However, less than 45% of the rural blacks collect their wood nearby. 45% of rural blacks must buy firewood and a further 10% must walk over 30 minutes to collect firewood

Gandar (1983) notes that in KwaZulu, one day per week was given over to wood collection by the woman of the household. In an extreme case, women of a community walked a round trip of over 19km to collect a single headload of 40kg (+/-0,068m^3). This occupied 9,5 hrs per person and contributes to the total of 50 million man-hours per annum spent on wood collection in KwaZulu.

Research by Best (1979), Gandar (1983), Liengme (1983) Furness (1981) indicate similar expenditure of time and effort harvesting similar quantities is other regions of southern Africa. In general it has been found that as the wood supply declines and trees become scarce the volume of wood used declines Gandar (1983). This reflects the logistical and financial problems associated with harvesting timber over large distances. Overall consumption figures vary from 0,2t/capita/yr in Jozanna's Nek in the Transkei to 1,13t/capita/yr in Mozambique (Table 1.1 Eberhard, 1986). Basson (1987) reports that 51% of the energy of low income groups in South Africa is obtained from wood.

It has been estimated that total current fuelwood consumption in South Africa and the National States amounts to 13,6 million t/yr (Eberhard 1986). This amounts to about 6% of the primary energy consumption of the country (Williams 1986).

Traditionally dead wood is collected for fuel and Gandar (1983) estimates that at present dead wood from the KwaZulu forests and woodlands could yield 50% of the total rural fuelwood requirement. Increasing population however increases pressure on woodland until it can no longer supply the community requirements if dead wood alone is harvested. Gandar (1983) observed that in KwaZulu 8% of the fuelwood collected in valley lowveld areas was green, but in areas of greater scarcity such as on the high grassland this figure rose to 42%. Prior and Tuohy (1987) point out that

Table 1. Domestic Rural Energy Consumption/cap/yr in Southern Africa (Eberhard 1986)

Area	WOOD tonne	RESIDUES tonne	DUNG tonne	PARAFFIN litre	OVERALL GJ
Angola	.523	.025	-	3	9.35
Botswana	.797	.059	-	2.3	14.46
Lesotho	.463	.348	-	11.1	13.44
Lesotho	.288	.260	-	5.08	10.33
Malawi	.628	.033	-	0.3	11.16
Malawi	.587	x	-	x	9.98
Mozam.	1.135	.134	-	3.1	21.35
Transkei	.960	x	x	x	16.32
Transkei	.271	x	.08	10.24	7.69
KwaZulu	1.124	x	-	5.68	23.86
KwaZulu	.62	x	.012	2%	10.68
KwaZulu	.74	x	.2%	2%	12.58
Gazankulu	.76	x	x	x	12.92
S Africa	.43	x	.058	x	8.0
Swaziland	.495	.033	-	5.1	9.37
Zambia	.94	.035	-	1.7	17.32
Zimbabwe	1.031	.013	-	3.1	17.89
Zimbabwe	.616	x	-	x	10.47

x : not reported
GJ: gigajoules

some green woods give acceptable fires in spite of the high moisture content. However, removing greenwood from trees slows or halts growth and may eventually kill individual trees.

In the Transkei, tradition has prevented wholesale cutting of live timber

(McKenzie 1986) by prohibiting sharp implements in the Transkei forests. As a result McKenzie showed that the area of forest in Transkei had not decreased over a period of many years. It is, however, evident that cutting of live timber is taking place inside these forests (pers obs 1987) probably due to the increasing pressures from population growth. By contrast in parts of Natal and KwaZulu forests have in historical times contracted (Marshall B 1985 pers comm). Ashton (1952) and Sheddick (1954) state that indigenous trees and forest are traditionally protected in Lesotho although brushwood may be freely collected.

Prior and Tuohy(1987) state that in Swaziland the firewood collectors choose for fuel those species which will coppice readily. This practice has considerable advantage in that it provides numerous regenerated stems of the preferred diameters and lengths for fuel wood. In terms of management it is efficient in that it encourages harvesting whilst productivity is high. A similar situation is reported in Venda in riverine areas (Yeaton R I 1987 pers comm). This kind of practice has been the norm in Europe for centuries and is practiced in South Africa in Acacia and Eucalyptus plantations.

It is clear therefore that there is considerable demand for wood in rural areas and that impacts on wooded areas can be severe. Impacts caused by fuelwood collection are exacerbated by browsing stock (Wyatt-Smith 1982). It may be that in many areas the real constraints on the maintenance of forest systems are imposed by browsing. As a result of browsing pressure, understorey is destroyed (Wyatt-Smith 1982) and the canopy may subsequently be opened. Regeneration patterns are changed due to a changed microclimate and to continuing browsing pressure. In moderation this may be of benefit to forest communities since many species recruit by exploiting the gaps created by tree fall or other clearance. Browsing animals reduce regeneration growth from coppiced stumps and also consume seedlings and suckers. Thus, whilst a forest or woodland may sustain wood collection, it may not sustain both wood collection and browsing.

1.3. ALTERNATIVES TO WOOD

There is a marked reluctance to move away from wood as a fuel for various reasons (Eberhard 1986). For example the cost of alternatives, such as coal and paraffin, is prohibitive, gas is relatively unfamiliar to rural people and household and crop residues are too few. Dung may cause health problems because of smoke generation (Eberhard 1986).

Electrification is seen as an acceptable alternative but the provision of this facility is subject to political and economic constraints. The Institute of Race Relations states that ESCOM has the capacity to supply electricity to every city, town and village in the country but comments that local authorities are unwilling or unable to provide the necessary infrastructures. Many engineers however believe that electrification should not be considered the ultimate goal for all rural areas. They point out that electrification in developed countries expanded at a time when fuel was cheap and abundant. A centralised electrification system also combined well with the existing centralised infrastructures. In developing areas where conditions are very different electrification may not be the optimal solution (El Mahagry and Biswas 1985).

It is therefore clear that dependence on wood as a fuel and as a constructional material, is likely to persist for some considerable time. Against this background it was therefore seen as essential to devise an effective and efficient technique to monitor and describe rural community impacts on woody vegetation. This study was funded by the CSIR's Foundation for Research Development as a step in this direction.

1.4 STUDY AREA: LUJIKO, CISKEI

Eberhard worked in several areas of different environmental qualities in varying parts of South Africa to assess energy use patterns. This study was designed to utilise Eberhard's data for the eastern Cape region, including areas of the Ciskei and Transkei. The criteria for the selection of a study area that it should support woody vegetation, be accessible within the travel budget allocated for the project, support a large fairly traditional rural population, be close to a similar area which was relatively unutilised, and be covered by several years of aerial photography.

Only one of Eberhard's study areas met these criteria. This was Lujiko in the Ciskei which has some 600-700 households Eberhard (1986). It is located in the Peddie district at 33°22'S and 27°22'E on the edge of the Great Fish River Valley and within 20 km of the coast. A 1:50 000 map of this area accompanies this document. Annual rainfall is in the range 1000mm-1200mm pa. Acocks (1953) describes the vegetation types of the area as Valley Bushveld, and Eastern Province Thornveld. More recently, the vegetation of this eastern Cape/Ciskei region has been studied in some depth. Gibbs et al (1981) estimate that the vegetation of the region is comprised of 3 600-4 000 vascular species. Cowling (1982a and 1982b) emphasises the diversity and describes the area as a convergence zone of four major phytochoria resulting in a complex mosaic of communities. This diversity of species has a profound impact on the way the vegetation is represented by remotely sensed images and therefore also on the subsequent interpretation of the images.

Within the limits of the study area the communities were described by Lubke et al (1986) as (codes in brackets are Acocks Veld Types):

a) Subtropical thicket including
    - Dune Thicket (A1(d))
    - Valley Bushveld or Succulent Thicket (A23)
b) Acacia Savanna, including
    - Coastal Acacia Savanna (A7)
    - Upland Acacia Savanna (A21, A22, A68)
c) False Thornveld Grasslands (A21, A22, A68)
d) Mixed Grasslands of several kinds.

Everard (1985) describes the vegetation in more detail and defines the vegetation in which the field sampling was carried out as Kaffrarian

Thicket. Of the two kinds which he identifies, Coastal and Inland Kaffrarian Thicket, all sampling was within the latter.

This vegetation type is characterised by a dense woody shrub and tree thicket community in which woody components comprise 63 per cent of the life forms (Everard 1985). It is found in river valleys and on slopes where the rainfall is in excess of 800 mm per annum. Spinescent, evergreen, sclerophyllous species predominate with some drought deciduous species.

The thicket communities in the study area which are exploited for fuelwood and for constructional timber are considered by Cowling (1984) to be stable but of low resilience. This view is supported by Aucamp and Barnard (1980) who describe these communities as vulnerable to overstocking and slow to recover from disturbance. The vulnerability of the communities to disturbance is demonstrated by the close correlation of low species diversity with high grazing pressure (Everard 1985).

Direct and indirect human impacts on thicket communities represent serious threats. These impacts include clearance for agricultural and urban development, and the collection of timber and grazing of stock within the communities (Everard 1985).

Eberhard noted that indigenous wood was collected from the Fish river valley and that dead wood was becoming scarce. There were however restrictions on the harvesting of green wood. He noted also that considerable quantities of wood were brought into the community from a nearby plantation.

Within this area two valley slopes were selected for the detailed field investigation of plant community structure which is an important component of this study. One of these was within 1 km of Lujiko on the Fish river, and the other was almost directly opposite on the RSA side of the river. This second site was not easily accessible to any community although there was a single household within 1 km. Goats from this household were seen passing through the study site on several occasions and these were assumed to have only a minor impact on the vegetation. The sites were selected to be as alike as possible in terms of morphology, aspect and altitude. Both sites were at approximately 150m altitude faced south-west and had an angle of slope of 23°.

CHAPTER 2

OVERVIEW OF SOME REMOTE SENSING IMAGERIES USED FOR LANDCOVER ANALYSIS

2.1 INTRODUCTION

Remote sensing is, in theory, a quick and accurate method of gathering data to define an area or to monitor change. It suffers however from certain limitations.

The importance of long-term monitoring of land cover change cannot be overemphasised. One-off land cover studies are in themselves of interest and importance, but their usefulness is greatly enhanced if the surveys are made repeatedly. This necessitates a monitoring programme using compatible survey techniques to assess both spatial and temporal change. An outline of various techniques is presented together with some considerations of their effectiveness in terms of constraints and ease of use.

There are numerous definitions of remote sensing and the term and technology has in recent years become increasingly fashionable. It has been increasingly understood by the non specialist to mean space platform, and specifically Landsat imagery. For the sake of simplicity remote sensing can be summed up as any method of data collection from an object at a distance without actual contact with that object. In these terms the human eye becomes a reliable and efficient remote sensing device although unable, as pointed out by Thalen (1979), to produce a permanent record. Any form of photography of distant objects is remote sensing which does produce a permanent record. There should perhaps be a distinction between remote and proximal sensing, although it is not pertinent at this time to attempt to establish at what point remote becomes proximal. For the purposes of this presentation all sensing of this nature will be considered under the umbrella of remote sensing.

Satellite imagery obtained from Landsats 1, 2, 3, Landsat D and from the 1986 launch of the SPOT satellite has revolutionised remote sensing capabilities. Resolution has improved from the 80mx56m of Landsat and 30mx30m of the Landsat thematic mapper to the 20mx20m multispectral and 10mx10m panchromatic imagery of SPOT.

2.2. SOURCES AND KINDS OF PHOTOGRAPHIC IMAGERY

2.2.1. Standard Aerial Photographs

The most accessible are the standard aerial photographic products of the Department of Surveys and Mapping. These include photographs at various scales ranging from 1:10 000 to 1:150 000. The photographs are available in stereo pairs which considerably aid interpretation, improving speed and accuracy. Stereo pairs are necessary if cartographic plotters are to be used when mapping from the photographs. The scale available depends in part on the year in which the photography was taken. Prior to about 1950 photographs were of a large scale, about 1:30 000 and even larger, whilst more recently scales have been reduced to 1:50-60 000. Very small scale photography of the order of 1:150 000 is available for selected areas only. These standard products are panchromatic (black and white). Some colour photography is available for specific areas, but it is very limited.

These standard photo products provide complete coverage of South Africa. Each part of the country is re-flown and photographed approximately every 10 years. Only a portion of the country is photographed in any given year. Pilot skill in maintaining aircraft stability and instability caused by turbulence are factors which influence image quality. The small scale of the standard photo products presents problems with regard to interpretation of fine detail. This imposes limitations on their usefulness in interpretation of vegetation community structure.

Using these photographs it is possible to distinguish between scrub and dense tree cover on a textural and tonal basis, but it is difficult or impossible to distinguish any but gross community differences between different stands of the same vegetation type. It is thus easy and relatively cheap to utilise these products to make gross quantitative statements about vegetation change, but qualitative data is much more difficult to extract. Much depends on the interpreter's experience and on his familiarity with the study area. It is also difficult with small scale photography to make the subjective decisions necessary to delineate vegetation type boundaries. For example, at what point does open canopy woodland become scattered woodland? This problem is exacerbated when multitemporal imagery of different scales is used. At large scales individual canopy diameters can be measured and these diameters used as a yardstick for defining woodland types. Similar indicators of scale can be used with respect to analysis of other vegetation types. At scales of 1:10 000 it is relatively easy to identify, sometimes even at a species level, the more conspicuous trees.

2.2.2. Orthophotos

These are limited and are for those areas which are of some particular importance to central government or local authorities such as urban areas. Orthophotos are produced at a scale of 1:10 000 and are corrected to remove distortion. Direct measurements of area can therefore be made and the large scale makes orthophotos useful for vegetation studies. However, orthophotos suffer from some loss of sharpness since they are printed on ammonia paper and are unfortunately not available as photographic prints.

2.2.3. Unconventional Photography

The photography discussed up to this point has been conventional, near vertical photography using standard aerial photography cameras and formats. Where great accuracy is not required various forms of unconventional photography may be used. In addition, if low precision if low precision is required then relatively cheap and simple methods of mapping may be used (Dowman 1981). The Bausch and Lomb Zoom Transfer Scope can also be used with some of this kind of photography to produce useful maps.

Unconventional photography is defined by Dowman (1981) as "that which is not taken from an aircraft with a metric camera with near vertical axis". This type of photography should therefore be seen also to include hand-held 35mm lateral photography which, if carried out from fixed points at regular intervals can be invaluable. An example of the usefulness of this can be seen in Peterken (1981) who illustrated changes in Scottish woodland using a comparison of the same scene on an early postcard and a recent photograph. Claveran (1966) used polaroid film which produced positive prints which could be annotated in the field. More sophisticated ground photography techniques for monitoring various ground covers are available (Wimbush et al, 1967, Wells, 1971) although these are not relevant at the scales under consideration in this paper.

A hand-held 35mm camera may yield very useful results when used from an aircraft. Over small, familiar areas these photographs may provide a useful mapping data base (Huntley B J, 1987 pers comm). This kind of photography may be used to produce vertical or oblique imagery. But is too imprecise to be used for the production of stereo pairs.

A recent submission to a symposium on long-term data series in southern Africa's natural resources highlighted the value of historical unconventional photographic records. This study showed an increase in woody vegetation in parts of Natal by using archival photographs of farms and hunting trips taken with an ordinary camera.

2.2.4. Photographic Multispectral Method

A recent technique developed at the University of Natal in Durban utilises a twin camera system beneath a light aircraft. One camera is loaded with standard colour film, the other with black and white/infrared. After processing the images from the two cameras are digitally combined resulting in an extremely high resolution, multispectral image (Piper and Scoggins 1987). This method is extremely precise and this may be of prime importance in long term studies when exact location of ground study sites is necessary, particularly when referenced to satellite imagery. It has the capacity to provide a link between satellite imagery such as that available from SPOT and a field study.

2.3. NON-PHOTOGRAPHIC AIRBORNE IMAGERIES

2.3.1. Aircraft Multispectral Scanner Data Acquisition

This is a method of acquiring a wide range of data over a range of spectral bands. A variety of scanners are in use around the world. That which is most accessible to researchers in South Africa is the Daedalus system. Project Daedalus 1268 is a multispectral image airborne acquisition programme flown by the Aircraft Operating Company of Johannesburg and coordinated by the CSIR. Although it is potentially an expensive technique it yields excellent results. The pixel size of 5m-7,5m provides high resolution and consequently high interpretability. The programme is able to simulate the spectral bands of Landsat-3, SPOT and the Landsat-D Thematic Mapper. Image processing is offered by the company flying the mission for those users who do not have access to their own image processing facilities. Coordination by the CSIR of the needs of a number of users considerably reduces costs. The system is subject to the limitations described in the section covering "image degradations."

Planning is extremely important as in all aerial survey work. Resolution is a critical factor and the chosen resolution determines the flying height of the aircraft. This may not be possible in the Daedalus project since the needs of a wide variety of users need to be accommodated. Resolution over an image varies from the chosen resolution beneath the aircraft to 50% at a scan angle of .45°. Spectral contrast is obviously of extreme importance to resolution. The greater the contrast, the less variation in resolution particularly towards the edge of the image (Thomas et al 1987)

Flying height may not be determined by resolution requirements. It may be fixed by the area to be flown and the available funding. Higher altitude flights give broader swathe widths and so greater coverage.

Flying conditions are also important. Calm conditions improve aircraft stability and reduce distortions. The time of day should also be considered. Around midday is best for this kind of scan since sun angle effects are reduced.

2.3.2. <u>Image Degradations in Airborne Remote Sensing</u>

Scanner induced degradations may be routinely removed from the imagery during processing. Degradations introduced by characteristics of the survey flight need to be understood. These are covered in some detail by Thomas et al (1987) but are briefly outlined here:

2.3.2.1. Spatial distortion due to terrain: In areas of undulating or rugged terrain there is a change in pixel size. Since pixel size is a function of the height of the aircraft above ground, a 1% variation in altitude will result in a 1% variation in pixel size. Pixel size variations are also induced by parallax. A 30m change in terrain altitude viewed at a 45° scan angle will result in a 3 pixel displacement in the data (Thomas et al 1987).

2.3.2.2. Spatial distortion due to aircraft instability: Relatively small aircraft movements of yaw, pitch and altitude can result in large data losses as well as spatial distortions. These effects can be reduced by experienced crew, stable air conditions and roll stabilised scanning units.

2.3.2.3 Radiometric degradations: Thomas et al (1987) point out that there is a "radiance fall off" along the scan line from the nadir to the edge. This is due to radiation attenuation and scattering since it must pass through more of the atmosphere on its path from the ground to the airborne scanner. Water bodies can also produce problems, intensely bright reflections from the water surface may saturate the scanner.

2.4. SPACE PLATFORM IMAGERY

Since the early 1970's satellite and other space platform imageries have been used to develop resource monitoring systems. The most well known and widely used of these to date is Landsat. Many authors have discussed the capabilities and limitations of Landsat multispectral imagery. Much of the work relevant to this study has shown relationships between soil exposure and canopy or other vegetation cover (Milton 1978, Tucker and Maxwell 1976, Robinove et al 1981). More recently Allen and Richards (1983) noted that soils in semi-arid areas are highly reflective due to a low moisture content at the surface. Masking of this reflectance by the canopy should be a good indicator of the degree of cover of the canopy. Griffiths and Collins (1983) showed a significant relationship between non-green woody vegetation cover and reflectance levels on rangeland in Kenya. Lane (1983) however was unable to show significant relationships between Landsat MSS data and various vegetation parameters, including woody vegetation cover, in Tanzania. Vujakovic (1986) was successful in using computer processed Landsat MSS data to map woody vegetation bounding the Okavango Swamp area in Botswana. He states that the terrain over which he worked was "level or gently undulating, sand ridges forming shallow rises with intervening swales (wave length between 300 and 450 m, amplitude between 2 and 3m)." He describes vegetation structure as being relatively simple with areas of shrubs dominated by *Grewia* species and a scattering of *Acacia* species. Grainger (1984) proposes satellite imagery as the only practical way in which to monitor global deforestation despite its present limitations. Landsat can be excellent in areas of relatively flat terrain and simple vegetation communities. It is also useful at the small scale appropriate to global monitoring programmes.

Multispectral sensing is based on the concept of the spectral signature. Every object and surface reflects sunlight modified in some way from that which arrived at the surface of that object or surface. The modification is a function of a variety of factors which define that object or surface. Theoretically the infinite minute variations in surface qualities permit all surfaces to be identified in terms of a unique spectral reflectance signature. Signatures described by Mason in Thomas et al (1987) as "fingerprints of life".

Vegetation has a readily recognisable spectral reflectance curve (Curran 1980). This is determined by the structural and photosynthetic characteristics of the vegetation. Gausman (1974) showed that discontinuities in the refractive index within a leaf determine infrared reflection. Whittingham, (1974) showed that the four primary photosynthetic pigments, chlorophyll A, B, beta carotene and xanthophyll absorbed red, blue and green light at specific wavelengths. This gives low reflectance in the visible spectrum associated with energy absorption for photosynthesis. High reflectance portions of the reflectance curve reflect those parts of the spectrum not absorbed and utilised by the plant. Senescence and disease produce a decline in vigour, a corresponding decline in chlorophyll production and energy absorption and therefore an altered spectral reflectance curve. These factors combined lead not only to a characteristic spectral signature for vegetation but to a characteristic spectral signature for plants of particular species, age and vigour.

Vegetation canopy reflectance is also influenced by degree of cover, characteristics of non-leafy components of the vegetation, characteristics of the ground cover, shadow and environmental variables (Colwell 1974, Hoffer 1978). As would be expected, an increase in the leaf area index, (ie the area of leaf in the canopy relative to the ground sensed through the canopy), leads to an increase in the infrared reflectance Orientation of the leaves in the canopy also affects reflectance so that wilting may change the reflectance characteristics. These characteristics are further affected by incident reflectance, soil characteristics and even wind (Suits 1972 in Thomas et al 1987).

It is clear that the relationships between spectral signatures and vegetation are complex. This complexity is increased when it is realised that the spectral signatures produced by the scanners are not of individual plants but are generalised signatures for an area of ground which in the case of Landsat is large. Thus identification of vegetation qualities, especially in complex mosaics may be difficult or impossible. This situation is exacerbated by rugged terrain.

2.4.1 Landsat Imagery

Landsat is one of a series of satellites launched since 1972 to receive and relay to earth based stations spectral data which describe the earth's surface. It is also capable of describing the conditions immediately above and immediately below.

A brief outline of the nature and function of the Landsat system follows but for details about the satellite and its operation the reader is referred to Sabins (1978), Barrett and Curtis (1976).

The Landsat satellites are in a sun synchronous orbit at a nominal height of 800-900 km This means that the satellites pass over a given ground point at the same local time, 09h30, every 18 days. Reflected spectral data are collected by the multispectral scanner (MSS) sensors. The MSS has four spectral bands, 4, 5, 6, and 7 corresponding to visible green, visible red and two near infrared channels. The MSS scans at right angles to the satellite's track and builds up an image by assembling successive scans into a complete scene. A single scene represents a ground area of about 180kmx180km with a nominal resolution of 80m. All data are stored on tape. Each unit of data represents a nominal ground area of 80m x 56m which corresponds to a particular picture element or pixel on the image. Although the satellite passes over the same point every 18 days this is not exact and so it should be remembered that for comparison purposes each picture element or pixel of a given image does not exactly correspond with the pixel of the succeeding image. This in effect means that the useful resolution of Landsat is increased to several hectares.

Each pixel represents an average of the spectral reflectances for the area on the ground which it represents. A displacement of the pixel relative to the ground may mean a different set of data with a different average reflectance. Thus the pixels may appear different where no difference actually exists.

Landsat imagery is available in several formats. Computer compatible tapes (CCT's), paper and transparency false colour composite images (FCC's) and as panchromatic images. False colour images are coloured but not in true colours. Green vegetation for example is represented by shades of red and orange depending upon its species composition, physiognomy and vigour.

CCT's can be translated into a visual image which can be interpreted by standard photographic interpretation techniques. Visual interpretation can represent a considerable saving over the cost of computer processing. At the time of writing, processing costs were in the region of R100/hr at the Satellite Remote Sensing Centre facility at Hartebeeshoek near Pretoria. This includes access to considerable expertise. In addition, computer processing requires considerably more ground truthing than does visual analysis Ultimately in areas where extrapolation can be successfully carried out, (ie uniform vegetation and on flat to undulating terrain) the technique can save a considerable amount of money. However, where vegetation mosaics are complex, and the terrain rugged then computer processing may be more expensive and yield less useful data that would aerial photography and field trips.

The imagery is available at a variety of scales although there is often an unacceptable loss of discrimination at scales greater than 1:500 000. Relatively large scale, say 1:250 000, paper prints can be particularly difficult to interpret.

Transparencies can be projected by means of an overhead projector and thus enlarged to a desired scale or alternatively they can be photographed with slide film and the slide projected onto a glass plate covered with a tracing film. The image can be enlarged to fit a base map of a particular chosen scale and areas of interest can then be outlined with ease. It should be remembered however that this may also cause demarcation of spurious cover types.

In spite of these constraints Landsat has been extremely useful in defining areas of particular characteristics in a large number of studies. In particular are studies which relate to agriculture and to forestry. It should be borne in mind that in both these instances the vegetation types of interest have been uniform or of only a few species. Images can be enhanced or improved in various ways, for example, problems of rugged terrain can be overcome by extensive ground truthing and in part by band ratioing as used by Newby (1985). These enhancement techniques increase the accuracy of point locations and thus of mapping, improve boundary definitions and emphasise differences between selected cover types.

The imagery is best at scales smaller than 1:250 000. It is particularly good at a scale of 1:1000 000. Each project goal must be considered separately when deciding upon the scale of imagery desired.

2.4.2 SPOT Imagery

The SPOT (*Systeme Probatoire d'Observation De La Terre*) satellite was launched in February 1986. The satellite operates as a commercial venture. Imagery is available in South Africa only through the satellite remote sensing centre at Hartebeeshoek.

The SPOT satellite is in a circular orbit at a nominal height of 830km with a cycle of 26 days. Vertical images for a given area can be collected every 26 days. If use is made of the side-looking facility then images for a given area can be collected every +/-3 days. This greatly improves the chances of obtaining a cloud free image. The image is system corrected and may provide some advantage over a vertical image in rugged areas since it allows greater penetration of valleys.

Data are available in various formats ie panchromatic, 3 band multispectral FCC prints and transparencies and as CCTs. At the time of writing there were no processing programmes for SPOT data outside the satellite remote sensing centre, although in the near future, several universities, in particular Natal and Cape Town should have processing suites available.

SPOT imagery has immense promise, particularly for visual interpretation. Resolution has been improved from Landsat's best (30mx30m using the thematic mapper) to 10mx10m in the panchromatic mode. The SPOT multispectral mode imagery has a resolution of 20mx20m and a fusion of the two modes is possible with a resulting resolution of 15mx15m. Nominal ground coverage of an image is 60kmx60km. Simulated SPOT multispectral imagery in visual terms "comes close to taking the place of 1:40 000 and 1:50 000 colour infra-red photography" (Colwell and Poulton 1985). A particular advantage of this imagery is its potential to show slight variations in canopy cover over flat to undulating ground. The infrared component of the imagery is extremely sensitive to plant cover and this sensitivity, coupled with its extreme low sensitivity to soil allows disruptions of cover to be readily recognised.

The images can be obtained as precision-corrected or system-corrected images. This means that the displacement of ground points which is apparent in aerial photography is removed and thus the image allows direct and accurate measurements of area. This represents an enormous saving in time and an improvement in accuracy. It also obviates the need for access to expensive equipment This saving may far outweigh the cost of initial purchase of SPOT imagery. It is too early to say whether or not SPOT will fulfill all its potential but the early results are startlingly good.

A 1:100 000 FCC for example, so clearly shows woody vegetation and agricultural land boundaries that cover types of interest can be digitised directly from the print into a data base. Comparisons and other data interrogations can subsequently be readily carried out.

2.4.3 Computer processing of Landsat and SPOT

Proficiency at photo-interpretation provides a sound basis for a qualitative interpretation of satellite imagery but digital processing allows the possibility of more quantitative analyses. Current digital analyses use four channel digital data from the MSS of the Landsat satellites. The data are collected as spectral reflectance values representative of the earth's surface beneath the sensors. These values are collected for a limited spectral range in each channel. The way in which these data are analysed depends upon the degree of discrimination which can be expected from the sensor and the detail within classes which can be recognised by the sensor. Ground cover can be grouped into classes such as desert, water, forest, croplands, grass lands etc. These would broadly correspond with the hierarchical classification system presented below in Table 2.1 Major divisions may be further subdivided until very fine levels of discrimination are reached.

Table 2.1 Two-level classification scheme for land cover (Anderson et al, 1972)

LEVEL 1	LEVEL 2
01 URBAN LAND	01 Residential
	02 Commercial and services
	03 Industrial
	04 Extractive
	05 Transportation, utilities and
	06 Institutional
	07 Strip and clustered settlement
	08 Mixed
	09 Open and other

02	AGRICULTURAL LAND	01	Cropland and pasture
		02	Orchards, groves, vinyards and horticulture
		03	Feeding operations
		04	Other
03	RANGELAND	01	Grass
		02	Savannas (Palmetto prairies)
		03	Chaparral
		04	Desert shrub
04	FOREST LAND	01	Deciduous
		02	Evergreen (coniferous) and other
		03	Mixed
05	WATER	01	Streams and waterways
		02	Lakes
		03	Reservoirs
		04	Bays and estuaries
		05	Other
06	NON-FORESTED WETLAND	01	Vegetated
		02	Bare
07	BARREN LAND	01	Salt flats
		02	Beaches
		03	Sand other than beaches
		04	Bare, exposed rock
		05	Other
08	TUNDRA	01	Tundra
09	PERMANENT SNOW AND ICEFIELDS	01	Permanent snow and icefields

These levels of discrimination are dependent upon the characteristics of the cover type such as its homogeneity, its variable signature through the growth cycle and the terrain. It is these qualifications which can induce problems and which should be well understood before a computer analysis is begun. In Natal, Brough and Bromley (1984) found that visual interpretation of a Landsat FCC yielded greater accuracy than computer analysis, 79% vs 84%

The fynbos biome map produced by computer processing of a CCT relied heavily on existing photographic imagery and in particular on a comprehensive knowledge of the region by the researchers (Bossi and Moll, 1985). The indications from the literature were that computer processing in this study would not have yielded the information sought, for reasons of vegetation complexity, terrain dissection and scale.

Image enhancement is part of the process of computerised image processing. Visual analysis of a photographic product is improved or enhanced by this process and it improves the accuracy and speed of human visual interpretation.

2.4.4. Space Shuttle Large Format Camera

This imagery is briefly mentioned because of its potential when shuttle missions are re-established. The imagery is obtained using a large format camera of 23cm x 46cm . The processed negatives can be used to produce prints at a desired scale. The imagery would be available in panchromatic as well as colour formats. The scale at which the image is produced is dependent upon the orbital height of the shuttle. Doyle (1985) notes that when enlarged it should be expected to perform at least as well as high quality aerial photography of the scale of 1:40 000. The advantage of this imagery is that it is cheap, readily reproducible and large areas can be covered by a single image Each image represents a ground area of 178km x 356km

2.5. THE SELECTION OF IMAGERY

The selection of imagery depends upon the scale at which cover is to be mapped and the nature of the terrain. This has a profound effect on the visibility of cover pattern, particularly with regard to satellite imagery. It is the responsibility of the researcher to acquaint himself with the strengths and weaknesses of the various imageries and to evaluate his own expertise in the various methods of interpretation. These factors should be weighed against time, funds and the objectives to be fulfilled. Often, after consideration of these points there is little choice available.

Very careful consideration should be given to the standard aerial photographic products before embarking on a programme using space platform imagery. Space platform imagery is expensive and has, in vegetation studies dealing with complex mosaics of species and age structure, severe limitations. Jarman et al (1981) point out that although success was achieved in mapping the marsh vegetation communities at the Langebaan lagoon, "Marsh communities tend to grow in single species stands, giving a greater degree of homogeneity within types. The marsh area is also flat and featureless. There was no confusing spectral information introduced due to topographic features." Complex mosaics and rugged terrain can inhibit delineation of vegetation boundaries and recognition of vegetation types and thus prejudice the accuracy of mapping, particularly at scales greater than 1:500 000. Tupper (1981) also concluded that there were considerable problems associated with Landsat mapping where species mix and soil backgrounds vary. Many authors, for example Jensen (1983) and Brough and Bromley (1984), have emphasised the desirability of specialised training before embarking on a computer processing programme.

SPOT imagery is well suited to visual interpretation and at the smaller scales of about 1:100 000 it provides good results in many instances allowing interpretation of landcover to Anderson's (1972) level 2. It would be cost effective in many surveys especially over large areas since the mapping time is greatly reduced and accuracy greatly increased.

Whatever imagery is chosen, its usefulness depends on the maps subsequently produced. Some general considerations when mapping are presented in the following section:

2.6 MAPPING FROM REMOTELY-SENSED IMAGES

Sophisticated mapping requires considerable investment in specialised equipment and skills. If accurate and detailed maps are required it may be most cost effective to contract out the work to a specialist. This is particularly so at the larger scales. For botanical studies the larger scales, detailed (1:10 000) and ultra-detailed (1:500 and larger) are most appropriate (Aldred and Sayn-Wittgenstein, 1972; Edwards and Jarman 1972). The inadequacy of standard aerial photo's and satellite imagery was also clearly demonstrated in this study. Satisfactory maps of limited detail can, however, be drawn using the techniques which follow.

2.6.1 Mapping of Space Platform Imagery

Mapping from space platform imagery is relatively simple. If maps are to be drawn visually then a geometrically corrected image can be purchased from the satellite remote sensing centre. Vegetation-type boundaries can be simply traced from these images. The precision corrected images available are so accurate that they may be used for the direct production of photogrammetric maps.

If maps are computer-drawn the process is again simple. Reference coordinates are located on the imagery and on the base map used by the computer. A correct map can then be drawn automatically by use of a digitiser or directly from a CCT. As already discussed SPOT FCC images are particularly useful.

2.6.2. Mapping of Aerial Photography

The scale (S) of the aerial photograph is determined by the focal length (f) of the camera lens and the flying height (H) of the aircraft :-

$$S = \frac{f}{H-h}$$

Where:- S = scale
f = focal length
H = flying height
h = height of object or surface above datum

The scale is an important consideration. The conventional range of scales commonly used has been recommended by the Botanical Research Institute (Edwards and Jarman, 1972). These are:-

1) Ultra detailed	1:500 and larger
2) Detailed	1:10 000
3) Semi detailed	1:20 000 and 1:50 000
4) Reconnaissance	1:250 000
5) General reconnaissance	1:1000 000

Satisfactory maps of considerable accuracy can be drawn from the standard aerial photography products of the Department of Survey and Mapping using a variety of techniques. Each technique is subject to its own errors. It should be remembered that vegetation boundaries are rarely easily and accurately defined. Error was frequently introduced in this study during the subjective decision making as to where a vegetation boundary actually lay. Since this is so, it may often be unnecessary to use extremely sophisticated equipment to map to photogrammetric precision.

Unconventional photography can be used to produce reasonably acceptable maps provided care is taken to include locatable reference points from the map base in the photographs. Cover types can then be mapped by inspection or by using a transfer scope such as the Bausch and Lomb Zoom Transfer Scope.

It should be remembered that the scale of aerial photography is a nominal scale only, calculated for a given datum. Over flat ground this factor may be constant but over mountainous terrain the tops of mountains and the bottoms of valleys may fall well outside the datum and thus be at quite different scales. Adjacent photographs and strips may also be at different scales due to changes in altitude of the aircraft resulting from turbulence and varying pilot skills. The scale for each photograph used in a study should therefore be calculated using the formula:-

$$\text{photo scale} = \frac{\text{map distance} \times \text{map scale}}{\text{photo distance}}$$

When using aerial photographic products the researcher should be aware of the effect of the focal length of the camera lens on the relative visibility or frequency of recording canopy cover and the ground. Howard (1970) points out that for the same scale photography and for trees at the same distance apart the base of trees is more frequently recorded using a lens of longer focal length. Smith et al (in Howard 1970) found that when measuring the closure of tree crowns and the height of the trees, photographs taken using a 12" lens were preferable to photographs of a similar scale taken using a 6" lens. Knowledge of the focal length is also of great importance when using a dot template to measure frequency of particular cover types.

Single aerial photographs are useful in the field where actual boundaries can readily be related to boundaries and features on the photograph. Single members of stereo pairs may be assembled into a photo mosaic and the mosaic used as a basis for a working map. In some situations, particularly when the terrain is flat, adequately accurate maps which can be used to monitor relative changes in vegetation can be traced. The area must fall within the central portion of the photograph since point displacement increases towards the edge.

Alternatively, vegetation boundaries can be marked on photographs using coloured wax crayon or felt-tipped marker and then transferred by inspection onto a transparent overlay over a topographical map of an appropriate scale. This method is relatively quick and may be acceptably accurate.

Accuracy can be considerably improved by using stereo pairs of photographs. This is particularly important when working in the laboratory or with an area which is not intimately known. Stereo pairs allow perception of great detail and considerably improve interpretation in vegetation community studies. On rugged terrain it is essential to use stereo pairs if any reasonable accuracy is to be achieved in mapping. Although it is possible to draw maps using stereo pairs and to transfer vegetation boundaries to an overlay on a topographical map, superior accuracy can be achieved using one or other of the planimetric methods which follow.

2.6.2.1. Planimetric Mapping: Details of techniques are described by Howard (1970). Ecological maps can be produced at a range of scales depending upon the application. Few details can be shown at scales of less than 1:10 000 and Howard (1970) suggests scales of 1:10 000 and larger are necessary for detailed vegetation analysis and mapping. Most of the standard aerial photo products available from the Department of Survey and Mapping are at scales of 1:50 000 and smaller.

A Hilger and Watts radial line plotter was found to produce accurate maps when used in conjunction with a topographic map. Similar instruments of other makes are available. A particular advantage of this kind of instrument is that it allows a map to be drawn on an overlay over the standard 1:50 000 topographical map. The scale difference which may be present in adjacent pairs of photographs is readily accommodated by means of the pantograph attached to the plotter and an accurate map of a constant 1:50 000 scale can be drawn from any of the readily available aerial photography. Maps of larger scale can be drawn using the instrument but these do not have available the reliable control provided by the 1:50 000 maps and therefore are less accurate.

Use of a machine of this type is highly recommended particularly since the photographs are viewed in stereo during the mapping process.

The Bausch and Lomb Zoom Transfer Scope (ZTS) is a rather more sophisticated instrument which enormously accelerates mapping. This instrument superimposes a stereoscopic image of the photography onto a blank paper base. Vegetation boundaries can be drawn by outlining the boundaries as they appear on the base sheet. A transparent overlay may also be used over a topographic map. This method is extremely quick and accurate. Photographs can be enlarged by the instrument from 0,6x - 16x and the map to 1x, 2x, and 4x actual size giving a range of useful scales. The stretch facility allows correction of distortion caused by tilt and relief. McGivern et al (1972) state that "....the accuracy obtainable with the ZTS can meet (US) national map accuracy standards"

2.6.2.2. Some problems with mapping: It was found in this study that a major problem associated with the use of aerial photography for mapping vegetation boundaries over a period of time was the variety of scales of imagery which must be used. The early aerial photography is generally at a large scale such as 1:20 000 whilst much of the most recent is at a scale of 1:55 000 and greater. This means that decisions made at one scale are not necessarily the same decisions that would be made at another. A researcher's perceptions of what constitutes a vegetation boundary, or of what identifies a particular vegetation type, change at different scales. When the photographs are from several different years and thus of several different scales it is often not possible to be accurate as to what constitutes a real change and what is a result of a change in perception. In many studies therefore it is not cost effective to attempt to produce accurate maps. Maps to form the basis of a monitoring programme should be of the greatest accuracy possible. Aerial photos and satellite images are in future likely to be available at a variety of scales including the current small scales. Maps could be drawn using photography of more nearly uniform scale thus eliminating perceptual problems.

Ideally, in detailed botanical studies, photography should be specially flown at the required, large scale.

CHAPTER 3

WOODY VEGETATION CHANGE IN THE LUJIKO AREA: MAPPING AND FIELD STUDY

As a result of a review of available remote sensing and mapping techniques two main approaches were adopted to investigate woody vegetation change for the purposes of this study:

a) Satellite images and aerial photographs were visually interpreted and vegetation changes mapped and measured using a dot matrix.

b) A field investigation to describe actual change was carried out. The field study also served to groundtruth (test the validity) of the interpretations of the imagery.

3.1 Mapping

3.1.1. Aerial Photographs: The 1:50 000 topographical map, Prudhoe 3327AC, was obtained for the study area (Figure 1 at the back of this document). Photographs of the study area were obtained for a range of years and at a range of scales as available from the Department of Survey and Mapping. These were as follows:-

Year	Nominal Scale
1938	1: 20 000
1956	1: 30 000
1973	1: 50 000

Stereo pairs of the relevant photographs were purchased. Mapping was carried out for the years 1938, 1956 and 1973 these being the only years for which photography of a useful scale was available.

Mapping of aerial photographs was initially carried out manually using the Arundel method (Howard, 1970). This provided reasonably accurate results when carried out with the aid of the standard 1:50 000 base map but proved to be extremely time consuming and not cost effective. Accuracy and speed were considerably improved by the use of a Hilger and Watts Radial Line Plotter. Planimetric maps were drawn using the standard 1:50 000 sheet as a base map. This was used to correct drift away from reference points. Nominal scale was calculated for each of the photographs. Scale variation was accommodated by adjustment of the pantograph of the plotter so that reference points on each pair of photographs coincided with the same points on the base map. Maps for aerial photo's were produced at a scale of 1:50 000 and are presented as Figures 4.4 to 4.6 in the next chapter (Chapter 4).

3.1.2. Landsat: Computer processing of Landsat computer compatible tapes (CCT's) was considered inappropriate because of the degree of expertise necessary to extract the best results from the processing. Visual interpretation was the alternative and therefore a false colour composite (FCC) transparency of scene ID22169 WRS182-83 for 30 December 1980 was obtained. This was at a scale of 1:1 000 000. A 35mm colour slide of the study area on the FCC was made using a macro lens. This was projected in a darkened room onto a plate glass sheet to which was affixed a tracing film bearing a base map traced from the 1:50 000 topographic map. The size of the image was adjusted using a zoom lens until it matched the base map. This represented a 1:50 000 Landsat image of the study area. Areas of different hue were then outlined on the tracing film. Eighteen apparently different cover types could be recognised. Several maps were drawn with varying degrees of aggregation of apparently different areas. The aggregation decisions were based on the results obtained from aerial photography interpretation which were confirmed during two field trips to the area. Field trips took place during the actively growing season in early May 1986 and 1987 These maps were produced at 1:50 000 and reduced maps are presented as Figures 4.1 and 4.2 in the next chapter (Chapter 4).

3.1.3 SPOT: The SPOT FCC paper image for February 1988 (SPOT 360878T 135-417) at a scale of 1:100 000 was interpreted visually. The image was of sufficiently good quality to allow a direct tracing of the areas of woody vegetation to produce a map at a scale of 1:100 000, (Figure 4.3 in the next chapter). A 2x enlargement gave a map suitable for overlay over a standard topographic map at a scale of 1:50 000. The SPOT map was superior in every way to the Landsat map. In particular it required only a fraction of the time to produce.

3.2. Dot Sampling

The same aerial photographs as used for the mapping were sampled by means of a dot matrix template using the method of Wilson (1949). This method is described below:

The minimum number of samples (dots) required was calculated using the formula (Wilson 1949):-

$$N = \frac{(100-P)38\ 400}{P(AE)^2}$$

N = number of dots

P = assumed percentage of the study area occupied by the cover class of interest

AE = acceptable error in percent (0,05)

Note: 38 400 is derived from the statistical standard $1,96^2 \times 100^2$ to fix probability

It was assumed that the cover classes of interest occupied more than 10% of the total study area. This was greater for the woody vegetation categories but assumption of a lower area than actually present corrected the possibility of under sampling. Acceptable error was taken to be 10%.

Thus, the number of dots required to sample the study area is calculated as follows:

$$N = \frac{(100-10)38\ 400}{10(10)^2}$$

$$N = 3\ 456$$

$$\text{Number of dots required per photo} = \frac{3\ 456}{\text{no. of photos}}$$

Therefore, for each year:

Year	No. of Photos	Dots per Photo
1938	144	24
1956	23	150
1973	10	320

It was important that the same areas were not sampled twice in adjacent photographs. It was therefore necessary to ensure that the dot template sampled only the central area of each photograph. Assuming the use of standard 230mm x 230mm photographs with a 60% overlap along the strip and 30% overlap between strips, this effective sampling area will measure approximately 160mm x 90mm. As pointed out by Wilson, (1949) however, the overlap on rugged terrain may vary very substantially and therefore the template dimensions should be further reduced to approximately 115mm x 65mm. These dimensions were proportionately reduced to accommodate variations from the standard photograph size in the case of the 1938 photography.

The dot template was drawn on an acetate sheet and dots spaced evenly over the template. The template was overlaid on the centre of each photo in turn, orientated so that the long axis of the template was perpendicular to the flight line. The cover type on which the dots fell was then recorded. The ratio of the dots falling on any particular cover type to the total number of dots within the boundaries of the study area, represented the percentage of that cover type.

3.3 Field Methods

3.3.1 Ground Truthing: Field verification or ground truthing is an essential component of any remote sensing study (Hoffer, 1971). In this case it was of particular importance since the images showed only slight changes in area of woody vegetation. Common sense suggested that a large community utilising a woody vegetation resource would have had a greater impact on that resource. In fact field observations showed that whilst there were not substantial changes in area there were considerable differences in physiognomy and community structure between high impact and low impact areas. These were not visible on the images.

Ten sites were selected in the Fish River valley . These were selected by means of a grid overlay on the woody vegetation maps. All sites had been correctly interpreted. Ten additional sites across the map were selected in a similar manner. In four of these sites, green grass and *Phragmites* beds in narrow river valleys had been incorrectly classified as woody vegetation.

3.3.2. Fuelwood size: Timber in two fuel wood piles at different and separated households was measured. The lengths and average diameters of 30 poles pulled at random out of each of the piles were measured. This was done to obtain some broad guidelines as to the fuelwood size and species preferences. Since this wood had been purchased it was assumed that people would only buy preferred species. The size guidelines were used to select the sizes of stems to be quantified on the transects. These data would give an indication of the present capability of the nearby woody thicket to provide fuelwood.

3.3.3. Vegetation Transects: Slope of the study sites was measured using an Abney level. Two transects of 100m x 2m were surveyed on each slope. All woody stems greater than 5cm circumference at 30cm above ground were identified. Basal area and height were also measured. Two additional transects were surveyed measuring only those stems greater than 5cm diameter and longer than 200cm as these stem sizes reflected the composition of stems found in local wood piles. The following data were collected from all transects:-

Species
Basal area
Height

3.3.4. Profile Diagrams: One 26m x 1m profile was drawn for each slope. These were drawn to scale and are presented in Figures 4.8 and 4.9. Profile diagrams were chosen as a quick and effective way of displaying the great differences between the high impact and low impact sites.

Results obtained from the above-descibed mapping and field study are presented and discussed in the following chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This study was not intended to define or to describe the detailed vegetation community structure of the study area. Logistical problems associated with budgetary constraints and distance to the study site mitigated against extensive field work. The aim of the study was two fold. Firstly, to ground truth the maps drawn from the various imageries and secondly, to obtain an indication of the severity of human impacts on woody vegetation which were not apparent on the remotely sensed images. Consequently a transect sampling method was used. This was limited to three 2x100metre transects at each site. The total sampling area at each site was therefore $600m^2$. This is considerably less than required for a meaningful statistical analysis and classification. Cowling (1984), determined an optimum plot size of 10m x 10m in his study area which included Kaffrarian Thicket. This size gave a compromise between effort expended and information gained and yielded 50% of the species present in one hectare. The same plot size was also used by Palmer (1981) and by Everard (1985). Even at this intensity of sampling, Everard stated that his study was not intended to accurately classify the vegetation at the level of the association but rather with the characterisation of the floristic variation.

4.2 WOODY VEGETATION MAPS

1:50 000 maps were drawn from the satellite images and from the aerial photographs as described in the previous chapter. These maps have been reduced to A3 size and are presented as follows:

- Maps drawn from Landsat images:
  Figure 4.1
  Figure 4.2

- Map drawn from SPOT image:
  Figure 4.3

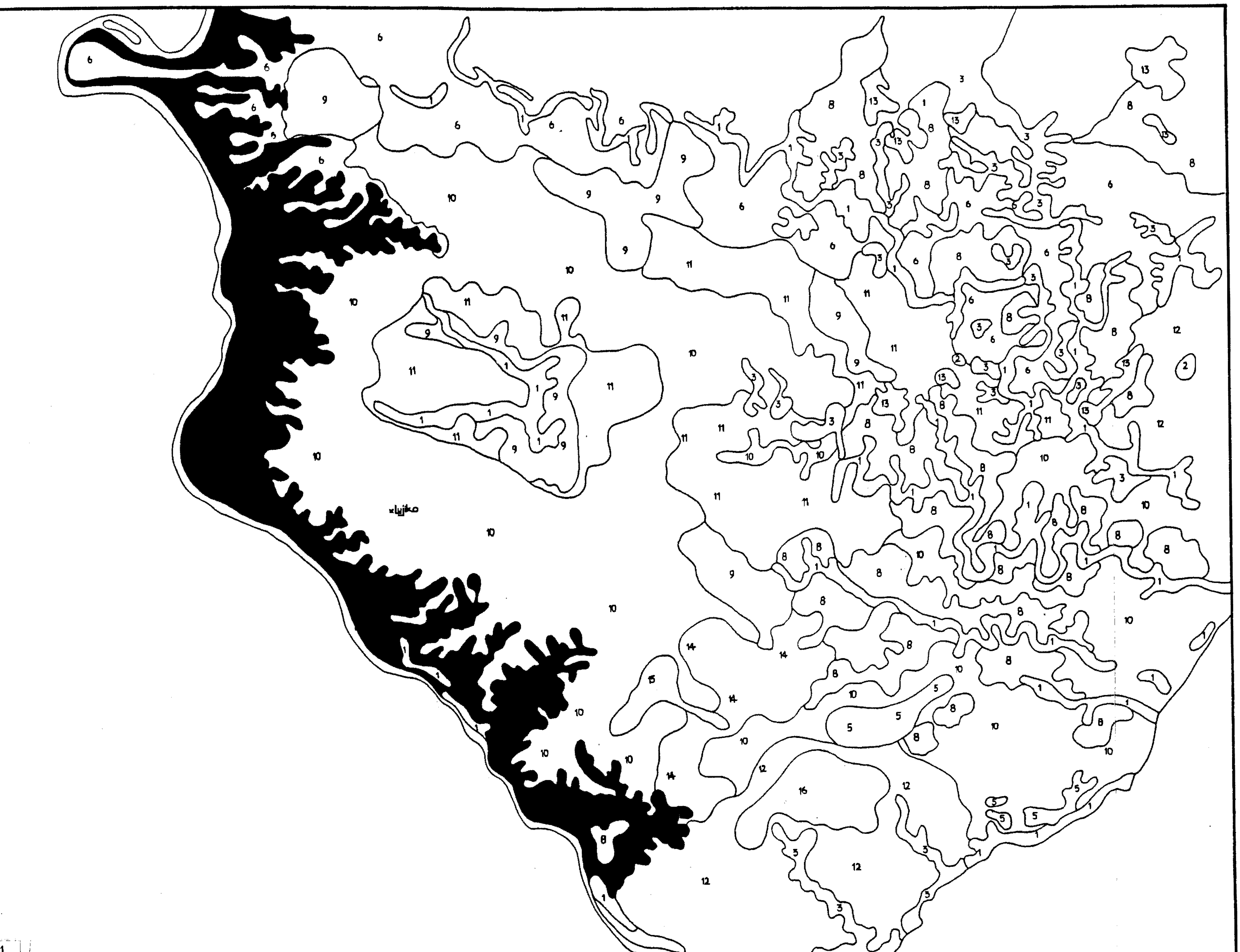
- Maps drawn from aerial photographs:
  Figure 4.4
  Figure 4.5
  Figure 4.6

The land cover type of significance to this study is principally that of the closed canopy (CC) woody vegetation. Riverine vegetation was not drawn on the maps made from the 1956 and 1973 aerial photography because at the scale of the photography this appeared of little significance forming little more than a thin dark line on the photograph. Dune thicket communities along the coast were mapped from the satellite images but not from the aerial photographs since this region fell outside the study area and photographs were not purchased to cover it.

4.2.1. Satellite maps

4.2.1.1. Landsat: Two visually interpreted and manually drawn maps taken from the image discussed in the text are presented. The first is Figure 4.1 showing all 18 recognisable areas of different hue. This map clearly shows the subtropical thicket, Everard's Inland Kaffrarian Thicket, of the Fish River. The boundary of this vegetation zone correlates well with that shown on the 1:50 000 topographic map and corresponds to the upper contour boundary between the valley slopes and the undulating, grass-covered upland. Ground truthing showed that many areas identified on this map as cover types 1 and 3 were also woody vegetation. In Figure 4.2 therefore, these areas have been combined and it is this second map which most clearly represents the woody vegetation distribution. These additional areas of vegetation differed in density, height and species composition from the Fish River valley thicket but the

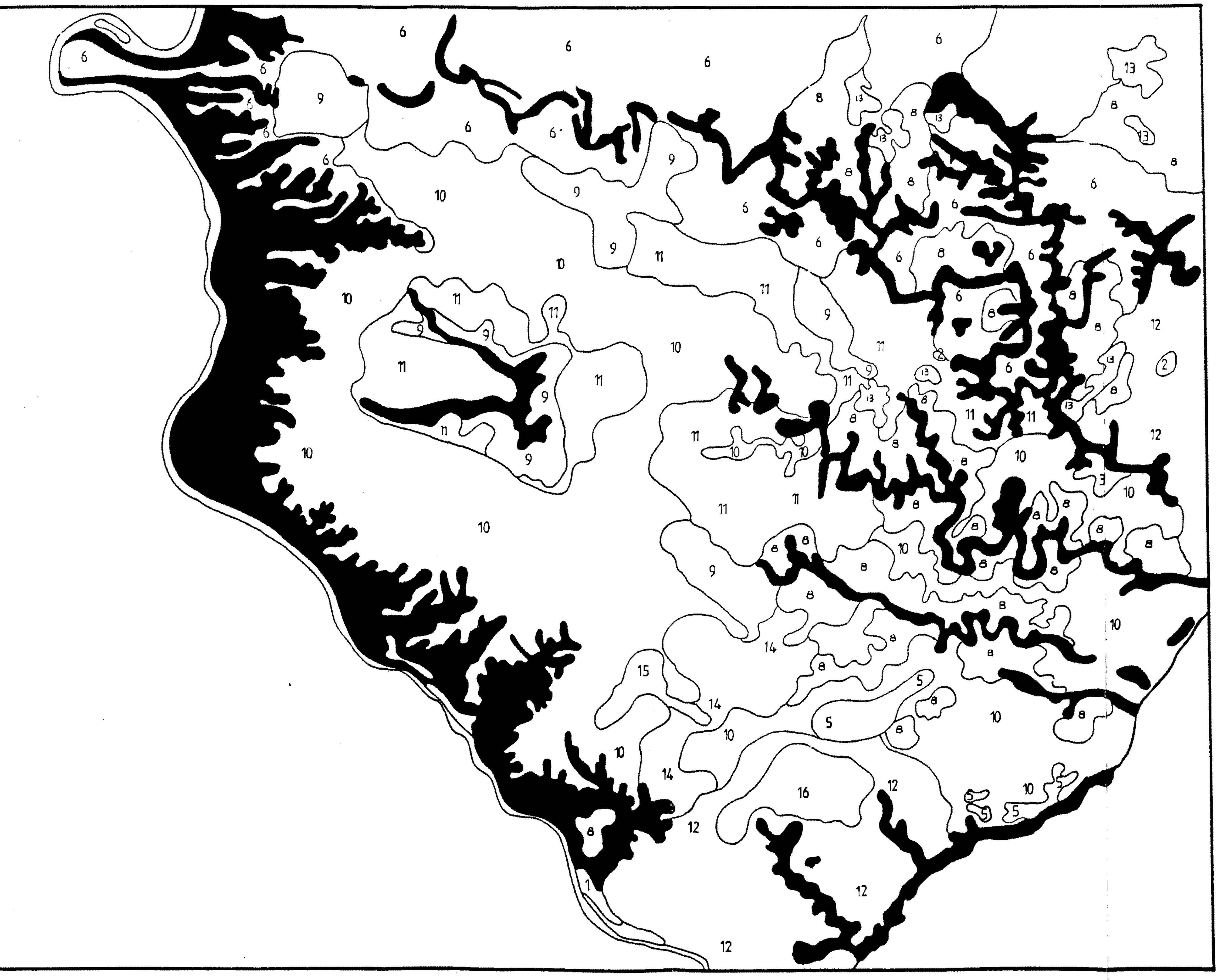
LANDCOVER TYPES



Lujiko December 1980

SCALE 1:100000

LANDCOVER TYPES



LUJIKO DECEMBER 1980

SCALE 1:100000

extent of this difference was not measured as it is outside the scope of this study. Ground truthing showed that some of these areas were incorrectly identified as woody vegetation. Notably in narrow river valleys, green *Phragmites* beds and agricultural land had been classified as woody vegetation. This kind of misclassification of bright green vigorously growing grass and crops was also experienced by van der Zel (1988) in his work on the preparation of a forest map for southern Africa. All 10 sites in the Fish River valley thicket which were used for ground truth were correctly classified but four of the other 10 sites in narrow river valleys in other parts of the map were incorrectly identified as woody vegetation.

Areas of *Acacia karoo* invasion were not identified on the Landsat map although they were known to have been present for some years. It is possible that heavy browsing pressure by goats reduced the green growth sufficiently to mask its presence. Much of this scrub is covered with long white thorns which are highly reflective. This factor could be expected to affect the reflectance characteristics of this vegetation type.

Small thickets which are found widely scattered over the grassland could not be identified on this image. The potential contribution of these thickets to the total fuel resource of the area may be considerable but most of the thickets are of less than 30m in diameter and therefore fall well inside a Landsat pixel and cannot be resolved. The variations which these thickets would introduce into the spectral signature of the grassland in which they are found could not be recognised visually.

4.2.1.2. SPOT: A map drawn from a 1:100 000 print as described in the text is presented in Figure 4.3. This map was considerably more useful in the field than was the Landsat map. Cover types were more readily recognised and accuracy for a variety of cover types was greater. In ground truthing no errors in terms of the cover classes of interest were made except in river valleys. As with the Landsat map, vigorously growing grasses in narrow river valleys were sometimes classified as woody vegetation.

LANDCOVER TYPES

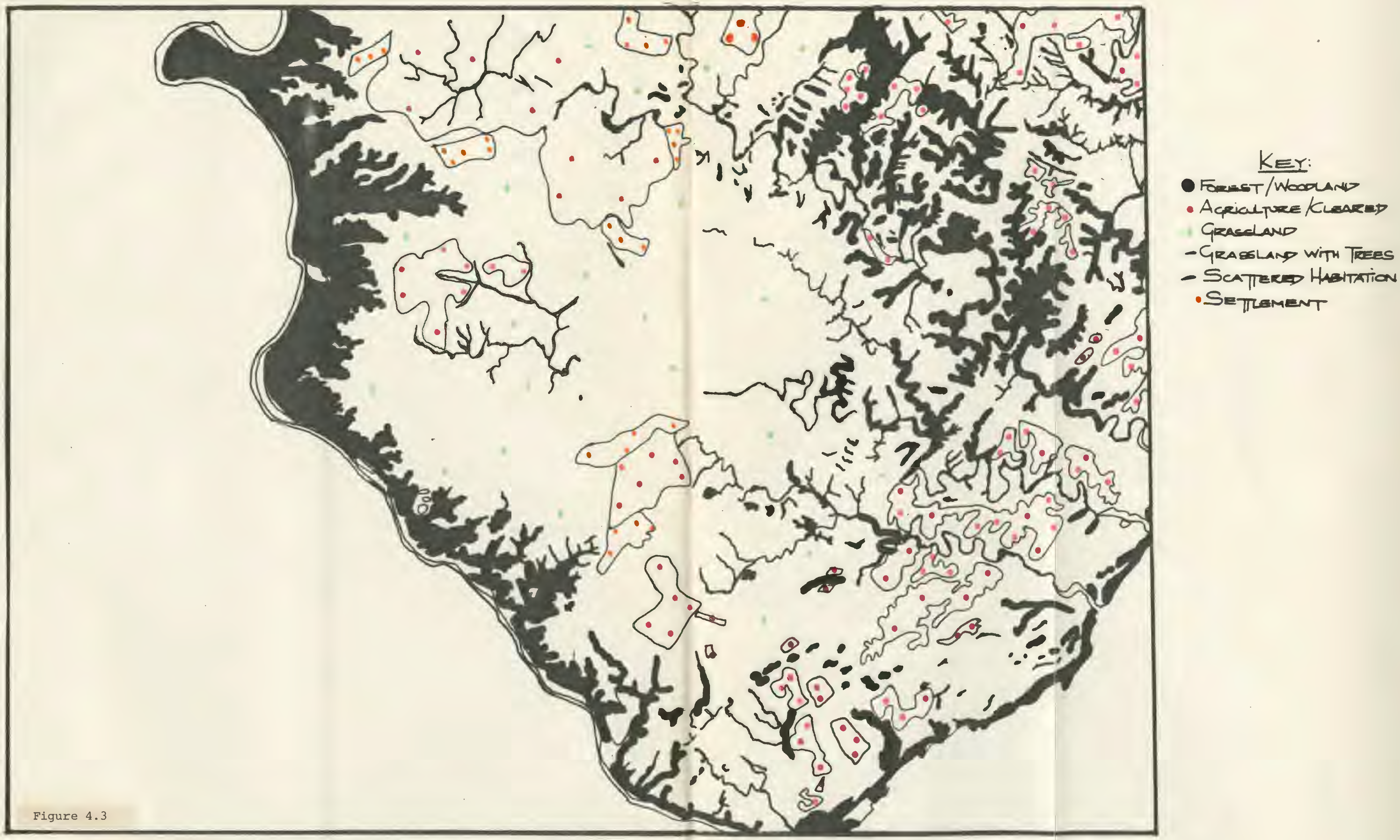


Figure 4.3

Lujiko February 1988

Scale 1:100000

Small dams, roads, sports fields and areas of bare ground were readily identified. A small *Eucalyptus* plantation was clearly visible but the thickets scattered over the grassland were not. *Acacia karoo* invasion in the south of the region which could not be seen on the Landsat map was clearly visible as red-orange blotches scattered over the grassland. However no difference in the quality of the vegetation on the transect sites could be seen.

4.2.2. Aerial photograph maps

The three maps drawn from stereo pairs of photographs for the years 1938, 1956 and 1973 are presented in Figures 4.4, 4.5 and 4.6.

Riverine vegetation was drawn on the 1938 map but not on the later maps. Most apparent change in woody vegetation took place in the years between 1938 and 1956. By 1956 most consolidation of agriculture in this area had taken place. In the years between 1956 and 1973 a small amount of further consolidation took place and some areas which had been farmed in the south of the Fish River valley had been abandoned and subsequently invaded by scrub. These have in fact been classified as "thinned canopy" on the 1973 map when in fact they are areas of recolonisation. This was verified in the field. In the extreme north-west of the region a substantial area of vegetation was cleared. This has been caused by human impacts following the establishment of a large settlement adjacent to this area. The thicket vegetation in the Fish River valley otherwise shows little change in area between 1938 and 1973.

In the east of the region there has been substantial apparent clearance but this should be treated with a degree of circumspection since it must be remembered that the photography for this year was of a very much larger scale than that of 1973.

LUJIKO 1938

LAND USE PATTERNS

KEY:

- Forest/Woodland
- Agriculture/Cleared
- Grassland
- Grassland with Trees
- Scattered Habitation
- Settlement

SCALE 1:100000

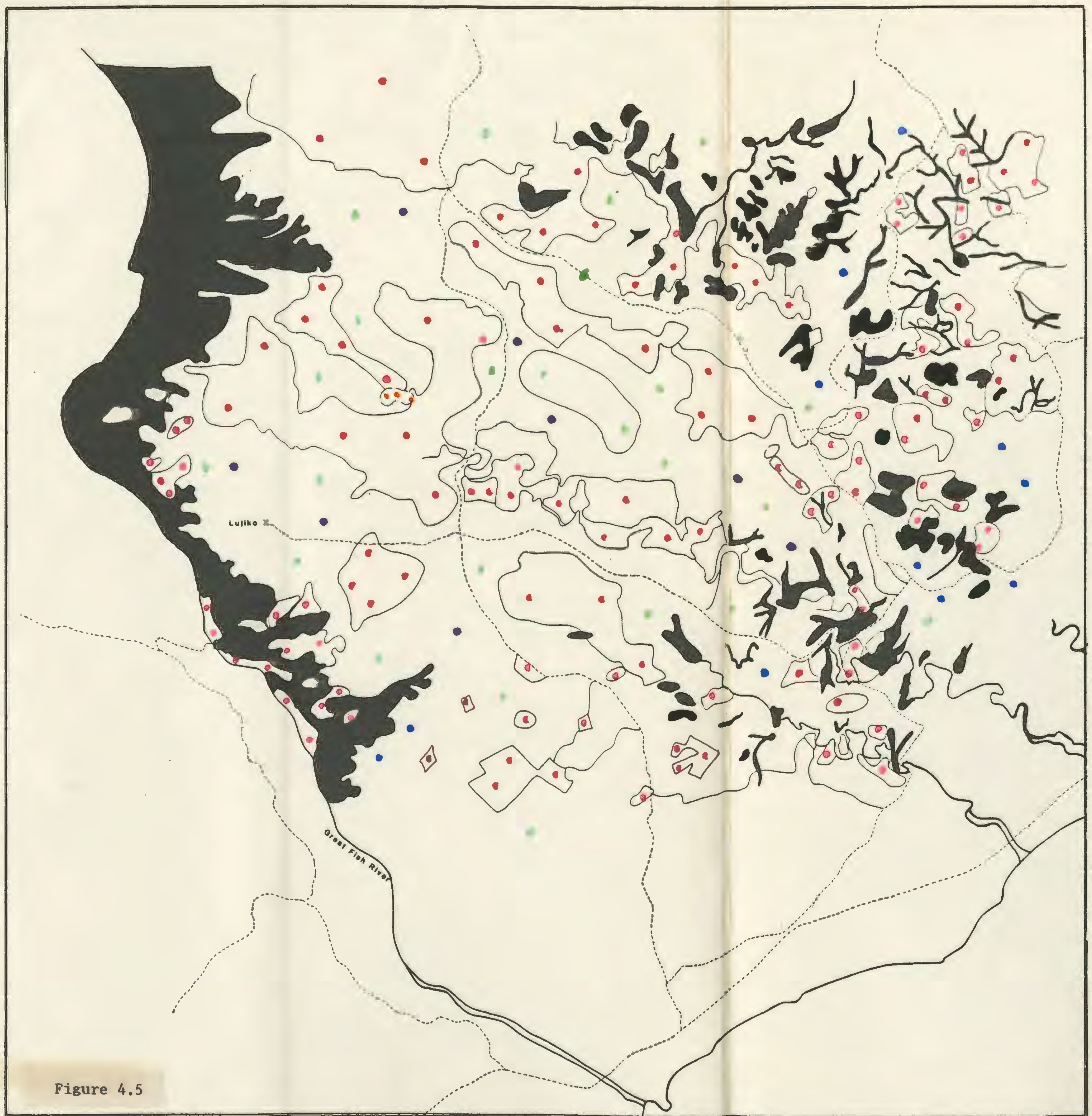


Figure 4.5

Lujiko 1956

Land Use Patterns

Key:

- ● Forest/Woodland
- • Agriculture/Cleared
- • Grassland
- • Grassland with Trees
- • Scattered Habitation
- • Settlement

Scale 1:100000

Figure 4.6

LUJIKO 1973

LAND USE PATTERNS

KEY:
- FOREST/WOODLAND
- AGRICULTURE/CLEARED
- GRASSLAND
- GRASSLAND WITH TREES
- SCATTERED HABITATION
- SETTLEMENT
- THINNED CANOPY

SCALE 1:100 000

4.3 DOT SAMPLING

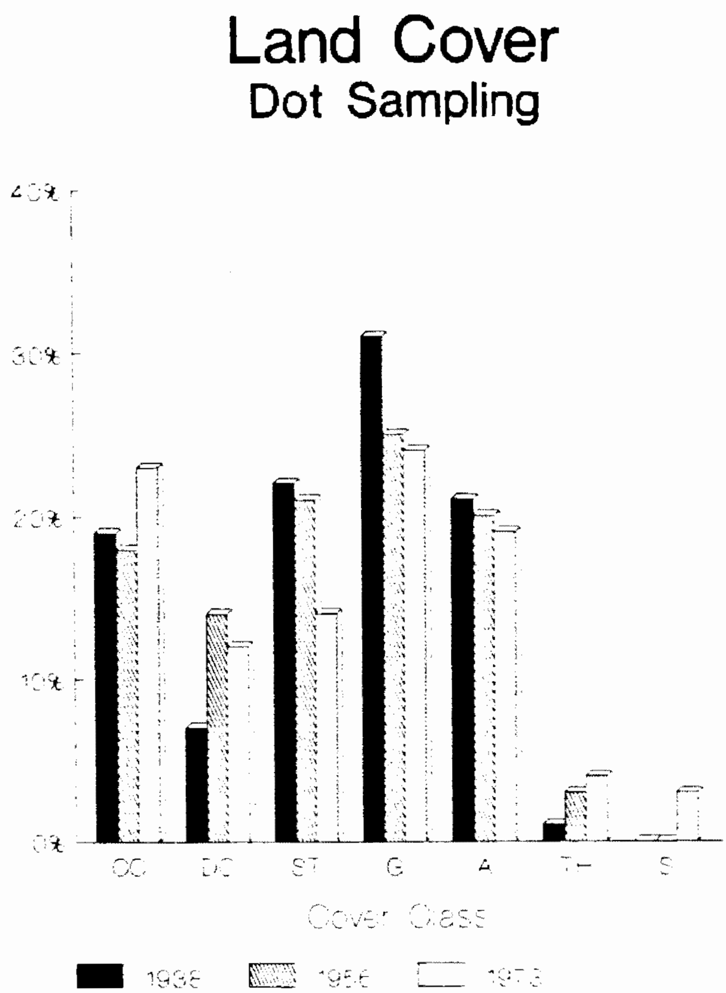
Figure 4.7 shows a land cover frequency histogram for various land cover types in 1938, 1956 and 1973.

The closed canopy thicket (CC) showed unexpected stability with only a small decline of 2% between 1938 and 1956 and a small overall increase of 5% by 1973. This falls well within the acceptable error of the sampling method. This stability is interesting in the light of the fuelwood collection pressure, and the almost universally accepted view that widespread clearance is being caused by this collection (Everard 1985, Aucamp and Barnard 1980). Some areas which have been invaded by *Acacia karoo* have been included in the closed canopy cover class and this would have contributed to some of the increase.

The discontinuous canopy class (DC) has shown a striking increase of 10% whilst the area of scattered trees in grassland (ST) and grassland (G) have declined. This is probably due to an increase in settlement and to increased *Acacia* invasion. The thicket which was cleared in the north of the region fell outside the dot sampling area.

The slight decrease in frequency of agricultural land was caused by government consolidation through the "betterment schemes" and this would have allowed recolonisation and invasion of abandoned lands thus contributing to the increased woody vegetation classes.

Habitation shows a marked increase, almost doubling since 1956. This reflects the rapid population growth and emphasises the need to develop fuelwood production strategies.



CC Closed canopy
DC Discontinuous canopy
ST Scattered trees and grassland
G Grassland
A Agriculture
TH Traditional habitation
S Recent concentrated settlement

Figure 4.7 Land-cover histogram from dot sampling

4.4. FIELD STUDY

4.4.1 Fuelwood size

Two fuelwood piles were examined in order to obtain some indication of the preferred fuelwood size. Where possible species were also identified. A total of 60 lengths of wood from two piles at two separate households in different areas were measured with the following results:-

Mean length 175cm

Mean diameter 5,6cm

Families were informally interviewed. It was revealed that very little wood was collected in the nearby Fish River valley. The reasons given were that the available sticks were too small except for kindling. Most fuelwood was purchased from sellers who harvest indigenous timber on the South African (low impact) side of the Fish River or inland in the Ciskei. Several truck and trailer loads of green indigenous wood were seen in the study area during the field trip. Much of this was timber greater than 10cm in diameter and suitable for construction purposes. It included popular constructional species such as *Olea europaea ssp africana* and *Ptaeroxylon obliquum.*

During the same period only two headloads of wood were seen and these were small and comprised of slender sticks of around 2-5cm diameter.

4.4.2 Stem density

The low impact site has approximately 30% more stems greater than 5cm diameter per hectare than does the high impact site as shown in tables 4.1 and 4.2. Whilst the low impact area has a much greater volume of timber the high impact site could nevertheless be more productive in terms of useful fuelwood since smaller sticks are more easily cut. Williams (1986) comments that "Rural inhabitants in developing countries are more

Table 4.1 Stem density: Low impact site. Combined data from 3 transects 100m x 2m for all stems equal to or greater than 5cm diameter.

SPECIES	STEMS PER HECTARE
Allophylus decipiens	233
Apodytes dimidiata	16
Azima tetracantha	117
Brachylaena elliptica	133
Carissa haematocarpa	0
Cassine aethiopica	150
Chaetacme aristata	100
Clerodendrum glabrum	16
Cussonia spicata	50
Ehretia rigida	183
Euclea undulata	283
Euphorbia grandidens *	583
Euphorbia triangularis *	450
Grewia occidentalis	67
Harpephyllum caffrum *	83
Kigellaria africana	16
Maytenus heterophylla	217
Maytenus undata	167
Ochna arborea	100
Pappea capensis	50
Ptaeroxylon obliquum	317
Rhus refracta	117
Schotia afra	467
Schotia latifolia	83
Scolopia sp	33
Scutia myrtina	66
Suregada africana	33
TOTAL	4 130
TOTAL, MINUS NON-UTILIZED SPECIES(*)	3 014

Table 4.2 Stem density: High impact site. Combined data from 3 transects 100m x 2m for all stems equal to or greater than 5cm diameter.

SPECIES	STEMS PER HECTARE
Acokanthera oblongifolia	33
Allophylus decipiens	200
Brachylaena elliptica	0
Canthium inerme	100
Carissa haematocarpa	33
Chaetacme aristata	50
Clerodendrum glabrum	100
Coddia rudis	67
Cussonia spicata	50
Diospyros lycioides	217
Diospyros scabrida	33
Ehretia rigida	100
Eugenia zeyheri	267
Euphorbia grandidens *	517
Euphorbia triangularis *	117
Ficus sp	17
Grewia occidentalis	17
Harpephyllum caffrum *	100
Maerua racemosa	0
Maytenus heterophylla	33
Ochna arborea	133
Olea europaea-africana	50
Pappea capensis	17
Pavetta capensis	0
Psychotria capensis	0
Rhus refracta	100
Scolopia mundii	33
Scutia myrtina	333
Zanthoxylum capense	50
TOTAL	3 067
TOTAL MINUS NON-UTILIZED SPECIES(*)	2 333

interested in the production of fuelwood sticks than in the production of trees with large trunks. Thus tree and shrub species which respond well to pollarding or coppicing are preferred". The low impact site however has the capacity to provide a great deal of dead timber which does not need cutting and which does not deplete the stock of live wood. It should not be forgotten however that large scale removal of dead wood can be expected to have impacts on nutrient cycles.

4.4.3 Profile diagrams

Profile diagrams for the high and low impact sites are presented in Figures 4.8 and 4.9. These diagrams represent 26m x 1m strips of Kaffrarian Thicket (Everard 1985) and illustrate the enormous physiognomic differences between the two sites. The low impact site is comprised largely of mature trees such as *Ptaeroxylon obliquum*, *Harpephyllum caffrum* and two species of *Euphorbia*. The trees form an almost continuous canopy at 4-5 metres through which the crowns of taller species, in particular *Euphorbia*, protrude. Light intensity beneath the canopy is considerably reduced and consequently the ground here is largely bare of grass and shrubs. There is a deep deposition of litter and seedlings of *Maytenus heterophylla* and *Ptaeroxylon obliquum* are plentiful. Open patches at the sites of tree fall carried more grass, herbs and shrubs. Vines and lianes were abundant.

The canopy of the high impact site by contrast differs markedly. Of the large tree species which contribute to the canopy on the low impact site only *Harpephyllum caffrum* and *Euphorbia spp* grow much over 2m on the high impact site. These species have survived because *Harpephyllum* is a useful fruit bearing species (Cunningham A B 1987 pers comm) and *Euphorbia* is unsuitable for fuel. The remainder of the vegetation on the high impact site is comprised of shrubs and coppice. The ground layer is largely *Panicum maximum* and the area is both browsed and grazed by cattle and goats. Suckers, especially from coppiced plants were numerous but seedlings were found only in the shade of *Harpephyllum*.

PROFILE: HIGH IMPACT S

1,15,19 DIOSPYROS LYCIOIDES
2 SCOLOPIA ZEYHERI
3,9 GREWIA OCCIDENTALIS
4 DOVYALIS ZEYHERI
5 CANTHIUM INERME
6 DIOSPYROS ELLIPTICUS
7 TRICHOCLADUS ELLIPTICUS
8 BRACHYLAENA ELLIPTICA
10 DIOSPYRUS LYCIOIDES
11,17,18 ALLOPHYLLUS DECIPIENS
12,16 MAYTENUS HETEROPHYLLA
13 OCHNA ARBOREA
14 EHRETIA RIGIDA

Figure 4.8

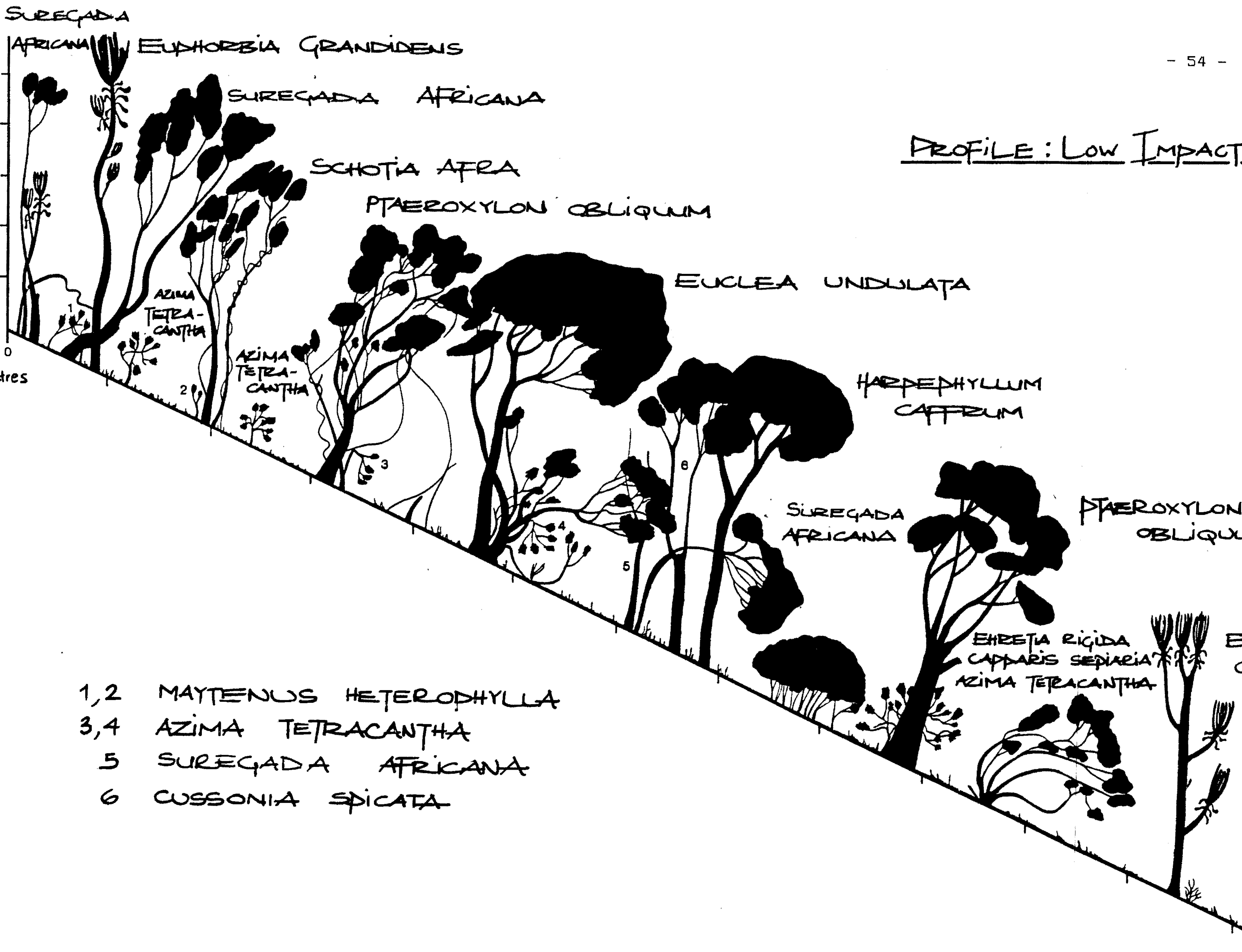

PROFILE : LOW IMPACT
SUREGADA AFRICANA
EUPHORBIA GRANDIDENS
SUREGADA AFRICANA
SCHOTIA AFRA
PTAEROXYLON OBLIQUUM
AZIMA TETRACANTHA
AZIMA TETRACANTHA
EUCLEA UNDULATA
HARPEPHYLLUM CAFFRUM
SUREGADA AFRICANA
PTAEROXYLON OBLIQUUM
EHRETIA RIGIDA
CAPPARIS SEPIARIA
AZIMA TETRACANTHA
0
1
2
3
4
5
6
1,2 MAYTENUS HETEROPHYLLA
3,4 AZIMA TETRACANTHA
5 SUREGADA AFRICANA
6 CUSSONIA SPICATA

Figure 4.9

4.4.4. Species composition

The total number of woody species for the two sites is almost the same, 29 and 27 species, as indicated in Tables 4.3 and 4.4. This approximates the numbers counted by Everard (1985). He found in his study, a mean of 37,3 species per 100m^2 but only 61,7% (23) of these were woody species. The species composition of the two sites however is quite different. Of species comprising more than 5% of the total number of stems only two are common to both sites as shown in the frequency histogram in Figure 4.10. These are *Maytenus heterophylla* and *Euphorbia grandidens*. On the high impact site *Diospyros lycioides* is easily the most numerous comprising 33% of all stems. This proportion is more than twice that of the next most numerous species, *Maytenus heterophylla*. *Diospyros lycioides* was not recorded on the low impact site. This species is characteristic of disturbed areas and is therefore a useful indicator species. By contrast in the low impact area, the forest species *Ptaeroxylon obliquum* is dominant comprising more than 20% of stems.

Brachylaena elliptica is absent from the high impact site in the >5cm stem diameter class as shown in Table 4.4. This is of significance since it is a browse species and its absence or scarcity may prove to be a valuable indicator of browsing pressure.

In the >5cm diameter class the high impact area has seven species as compared to the eight of the low impact site. For species comprising more than 5% of the total and greater than 5cm in diameter only the unutilised *Euphorbia spp* and *Allophylus decipiens* were common to both sites.

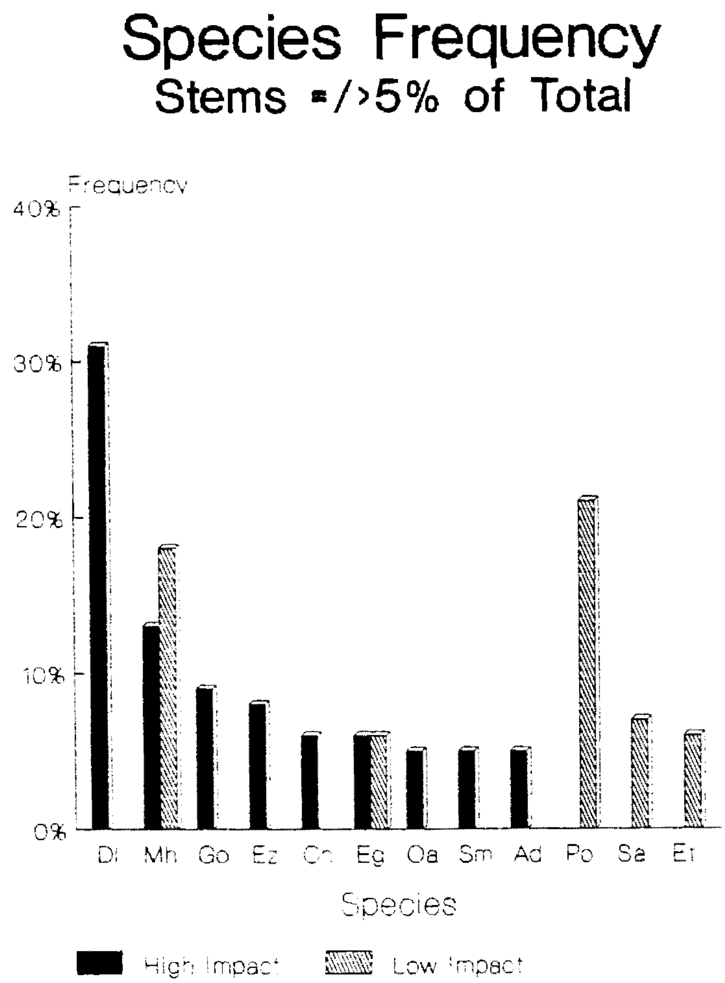
The two sites therefore are clearly very different in terms of their respective woody vegetation communities as shown in Figure 4.11. Both however are classified as Kaffrarian Thicket and both appear the same on aerial photography and satellite images of the area. Desirable construction species include *Ptaeroxylon obliquum* and *Euclea undulata* (Cunningham 1988). Removal of these large canopy species would be expected to substantially change the microclimate in the high impact site and this may therefore mitigate against growth of these canopy species. Light intensity, temperature and competition with grasses are

Table 4.3 Species composition and basal area: Low impact site. Column A shows all stems from 2 transects 100m x 2m. Column B shows all stems equal to or greater than 5cm diameter from 3 transects 100m x 2m.

SPECIES	COLUMN A		COLUMN B			
	NO	%	NO	%	m^2/ha	%
Allophylus decipiens	15	3.18	14	5.62	2.42	1.92
Apodytes dimidiata	1	0.20	1	0.40	0.05	0.04
Azima tetracantha	20	4.25	7	2.81	0.51	0,41
Brachylaena elliptica	8	1.70	8	3.21	1.15	0.92
Carissa haematocarpa	7	1.49	0	0.00	0.00	0.00
Cassine aethiopica	9	1.91	9	3.61	2.05	1.64
Chaetacme aristata	6	1.27	6	2.41	0.53	0.42
Clerodendrum glabrum	1	0.20	1	0.40	0.06	0.05
Cussonia spicata	3	0.64	3	1.20	1.33	1.06
Ehretia rigida	14	2.97	12	4.82	1.14	0.90
Euclea undulata	11	2.34	17	6.83	5.16	4.10
Euphorbia grandidens	30	6.37	35	14.06	29.20	23.19
Euphorbia triangularis	27	5.73	27	10.84	31.47	24.99
Grewia occidentalis	18	3.82	4	1.61	0.26	0.21
Harpephyllum caffrum	5	1.06	5	2.01	8.39	6.66
Kigellaria africana	2	0.42	1	0.40	0.56	0.45
Maytenus heterophylla	85	18.05	13	5.22	1.13	0.90
Maytenus undata	16	3.40	10	4.02	14.32	11.37
Ochna arborea	7	1.49	6	2.41	5.86	4.66
Pappea capensis	4	0.85	3	1.21	0.19	0.15
Ptaeroxylon obliquum	100	21.23	19	7.63	10.79	8.57
Rhus refracta	8	1.70	7	2.81	4.54	3.61
Schotia afra	31	6.58	28	11.24	1.58	1.26
Schotia latifolia	4	0.85	5	2.01	0.69	0.55
Scolopia sp	4	0.85	2	0.80	1.38	1.10
Scutia myrtina	12	2.55	4	1.61	0.88	0.70
Suregada africana	21	4.46	2	0.80	0.25	0.20
TOTAL	471		249		125.92	

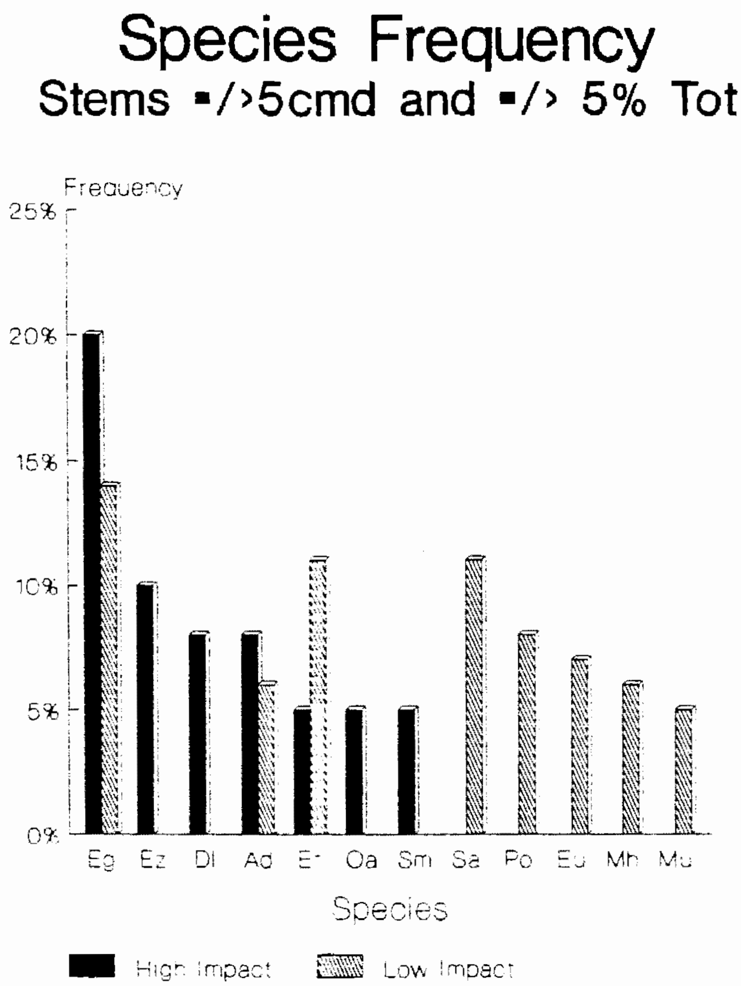
Table 4.4 Species composition and basal area: High impact site. Column A shows all stems from 2 transects 100m x 2m. Column B shows all stems equal to or greater than 5cm diameter from 3 transects of 100m x 2m.

SPECIES	COLUMN A		COLUMN B			
	NO	%	NO	%	m^2/ha	%
Acokanthera oblongifolia	4	0.94	2	1.30	0.72	0.65
Allophylus decipiens	22	5.18	12	7.79	1.14	1.04
Brachylaena elliptica	1	0.24	0	0.00	0.00	0.00
Canthium inerme	10	2.35	6	3.90	1.75	1.60
Carissa haematocarpa	26	6.12	2	1.30	0.17	0.16
Chaetacme aristata	4	0.94	3	1.95	0.26	0.24
Clerodendrum glabrum	6	1.41	6	3.90	1.79	1.64
Coddia rudis	9	2.12	4	2.60	0.37	0.33
Cussonia spicata	5	1.18	3	1.95	2.40	2.19
Diospyros lycioides	132	31.06	13	8.44	2.81	2.57
Diospyros scabrida	18	4.24	2	1.30	0.11	0.10
Ehretia rigida	17	4.00	6	3.90	0.57	0.52
Eugenia zeyheri	34	8.00	16	10.39	3.23	2.95
Euphorbia grandidens	26	6.11	31	20.13	68.43	62.53
Euphorbia triangularis	6	1.41	7	4.55	10.46	9.56
Ficus sp	1	0.24	1	0.65	0.33	0.30
Grewia occidentalis	37	8.70	1	0.65	0.16	0.15
Harpephyllum caffrum	5	1.18	6	3.90	13.50	12.34
Maerua racemosa	6	1.41	0	0.00	0.00	0.00
Maytenus heterophylla	53	12.47	2	1.30	0.63	0.58
Ochna arborea	22	5.18	8	5.19	0.67	0.60
Olea europaea-africana	3	0.71	3	1.95	1.20	1.10
Pappea capensis	10	2.35	1	0.65	0.05	0.05
Pavetta capensis	10	2.35	0	0.00	0.00	0.00
Psychotria capensis	1	0.24	0	0.00	0.00	0.00
Rhus refracta	9	2.12	6	3.90	2.86	2.61
Scolopia mundii	2	0.47	2	1.30	0.09	0.08
Scutia myrtina	20	4.71	8	5.19	2.38	2.18
Zanthoxylum capense	3	0.71	3	1.95	0.38	0.35
TOTAL	425		154		109.42	



Ad	Allophylus decipiens
Dl	Diospyros lycioides
Eg	Euphorbia grandidens
Et	Euphorbia triangularis
Mh	Maytenus heterophylla
Mu	Maytenus undata
Oa	Ochna arborea
Po	Ptaeroxylon obliquum
Sa	Schotia afra
Sm	Scutia myrtina
Go	Grewia occidentalis
Ez	Eugenia zeyheri
Ch	Carissa haematocarpa

Figure 4.10 Frequency histogram for species comprising 5% or more of total stems



Ad	Allophylus decipiens
Dl	Diospyros lycioides
Eg	Euphorbia grandidens
Et	Euphorbia triangularis
Mh	Maytenus heterophylla
Mu	Maytenus undata
Oa	Ochna arborea
Po	Ptaeroxylon obliquum
Sa	Schotia afra
Sm	Scutia myrtina
Ez	Eugenia zeyheri

Figure 4.11 Frequency histogram for stems greater than 5cm diameter and comprising 5% or more of the total.

all much increased. How species respond to disturbance is very variable and up to a point, disturbance may improve diversity (White 1979). However the frequency of disturbance has a profound effect on community structure (Bazzaz 1983). Specialised species with low population variability are considered by White (1979) as most prone to extinction.

Many of the thicket community species do not have seed banks but instead, short lived, bird dispersed propagules (Cowling R M 1987 pers comm). Recruitment should be possible from the South African side of the Fish River but seedlings of these species were not seen on any of the transects in the high impact area. Cowling (1984), considers the thicket community to be of low resilience and Aucamp and Barnard (1980) emphasise the vulnerability of thickets to grazing and browsing pressure. Everard (1985) argues that moist thickets are resilient and will encroach into grassland if disturbance regimes are removed. The prognosis for recovery of the high impact site vegetation therefore seems poor unless disturbance can be controlled by provision of alternative fuels and constructional timber. Most of the thicket species coppice (Cowling R M 1987 pers comm) and this characteristic could form the basis of a management strategy.

4.4.5. Height classes

Everard (1985), found the canopy of Kaffrarian Thicket to be between four and six metres in height. At the high impact site the mean canopy height of 2,27m was much lower than that determined by Everard (1985) and also lower than the low impact site. Most stems in the high impact area are less than 200cm, falling in the class between 100cm and 200cm as shown in Figure 4.12. This indicates coppice regrowth in response to cutting. A large proportion of the individuals in the larger height classes are not used for fuel or construction because they are either unsuitable or useful for fruit. Class 4 (300cm-399cm) with a total of 15 stems is comprised of *Cussonia spicata* and *Euphorbia spp*, neither of which is "useful". Only classes 2 and 3 have any substantial numbers of fuel or constructional timber species and these are either suckers or coppice regrowth.

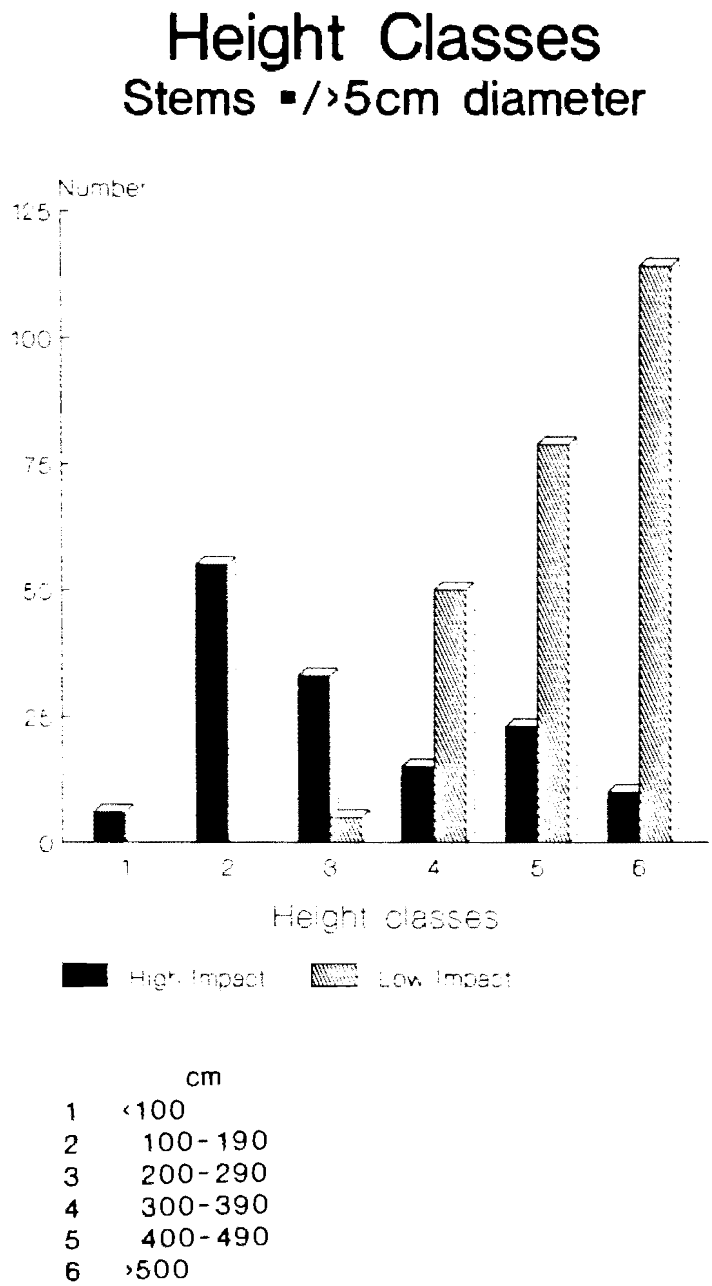


Figure 4.12 Histogram for height classes of stems of 5cm diameter and greater.

At the low impact site the mean canopy height fell within Everard's 4-6 m limits. The shift in the dominant height class as shown by Figures 4.8, 4.9 and 4.12 reflects the high impact of human activity. Many of the species such as *Euclea undulata*, *Ptaeroxylon obliquum* and *Brachylaena elliptica* are useful for fuelwood, construction or tools (Cunningham and Gwala 1986) but inaccesibility has reduced or prevented exploitation.

4.4.6 Basal area

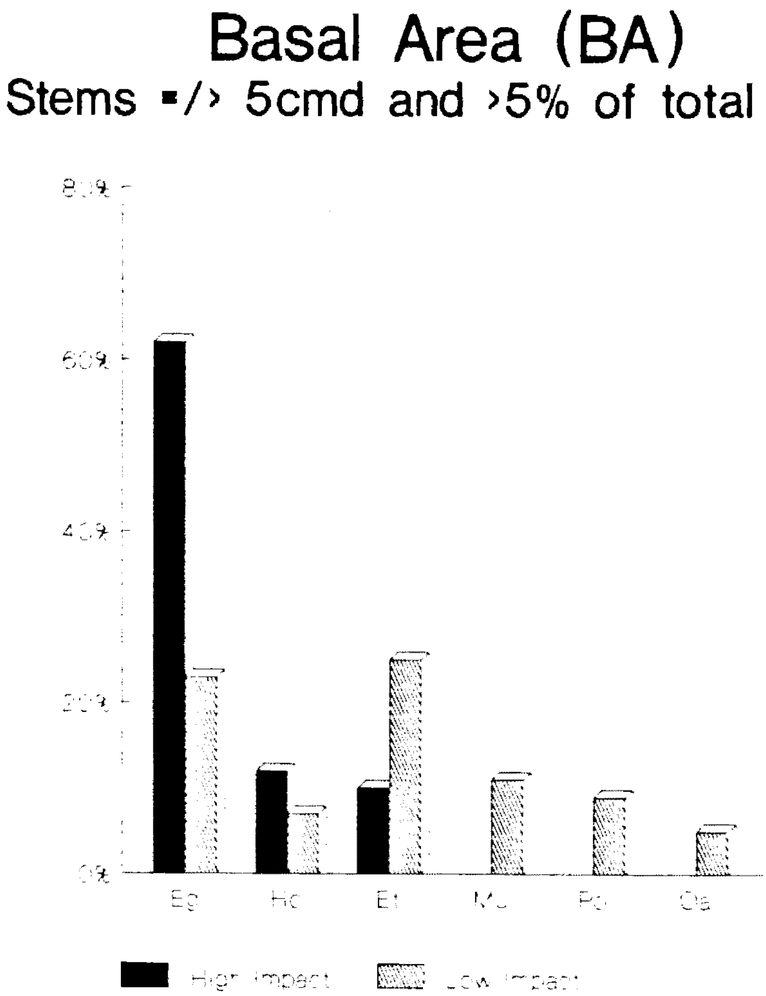
The total basal area for woody stems greater than 5cm in diameter was as follows:

- Low impact site - 125,92 m^2 per hectare
- High impact site - 109,42 m^2 per hectare

The low impact site, therefore, had 13,1% greater basal area. At the low impact site, *Euphorbia spp* comprised 60,67 m^2 per hectare or 48,2% or the total basal area. At the high impact site, *Euphorbia spp* comprised 78,9 m^2 per hectare or approximately 70% of the total basal area of stems greater than 5 cm diameter.

The high impact site was dominated by *Euphorbia grandidens* comprising 53,5% of the total basal area as shown in Figure 4.13. *Harpephyllum caffrum* was next at 16% and *Euphorbia triangularis* at 13%. None of these was a fuelwood species. No other species contributed more than 5% of the total basal area.

The low impact site was dominated by *Euphorbia triangularis* with 25% followed by *Euphorbia grandidens* with 24%. *Harpephyllum caffrum, Maytenus undulata*, *Ptaeroxylon obliquum* and *Ochna arborea* each contributed between 5% and 10%.



Eg Euphorbia grandidens
Et Euphorbia triangularis
Hc Harpephyllum caffrum
Mu Maytenus undata
Po Ptaeroxylon obliquum
Oa Ochna arborea

Figure 4.13 Species contributions to basal area for stems of 5cm diameter and greater and of 5% or greater of total basal area.

4.4.7 Stem diameter:

Insufficient data were collected on stems in the preferred fuelwood size to permit more meaningful analysis. However, the data gathered suggest that the high impact site has 26% more stems in class 1, ie <5cm diameter, than the low impact site. Class 2, the most important for fuel, comprised only 10% of stems in the high impact site and 17% at the low impact site. The low impact site has greater numbers of classes 4, 5 and 6. These values are shown in Figure 4.14

4.4.8 Canopy cover

Canopy cover measured along the transects gave a value of 97,2% cover for the low impact site and 73,2% for the high impact site. Although cover was therefore still substantial at the high impact site, the canopy was much lower as is clearly shown by the profile diagrams.

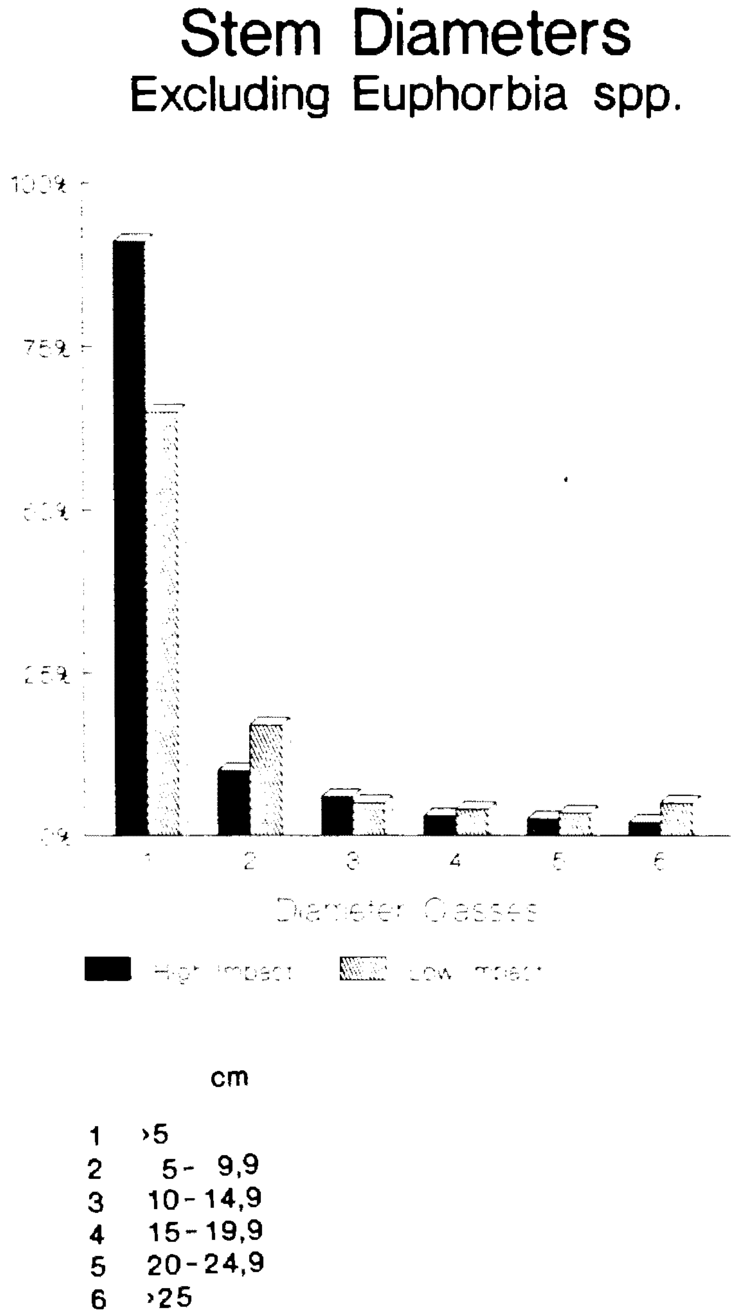


Figure 4.14 Stem diameters.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Based on the available literature and on the results obtained from this study, woody vegetation suitable for fuel and constructional timber in the study area is a limited and vulnerable resource. Trollope (1974) cites fire as an important controlling factor which limits the spread of thickets and burns were evident in the grasslands of the study area on the images and in the field. Thicket communities are also limited by edaphic components (Heydorn and Tinley 1980; Cowling 1984). Thicket communities have therefore probably never occurred over the upland grasslands and have always been a limited resource. Population growth and a dwindling fuel supply has caused increasing pressure on the woody vegetation. Everard (1985) identified a variety of threats to thicket communities. Of relevance to this study are the direct and indirect human impacts on these woody communities. Direct human impacts are those which involve clearance of land for agriculture or for industrial and urban development. Poor farming activities, particularly overgrazing, constitute major threats. According to Aucamp (in Everard 1985) 150 000 hectares of thicket in the Eastern Cape are so badly overgrazed that recovery is impossible.

5.1.1 Impact caused by collection of wood in the Eastern Cape/Ciskei

Human impacts on the woody vegetation communities in the Eastern Cape/Ciskei region are severe. At the high impact study site, impacts have been so great that the thicket vegetation is probably beyond the point of recovery. Collection of firewood has changed vegetation community structure in such a way that few useful species of a useful size remain. The canopy height of the thicket has been reduced by 50% and there is little evidence of seedling regeneration. Most of those species which are useful for firewood or constructional timber have been repeatedly cut and remain as small-diameter coppice remnants. With the loss of the canopy, species composition has changed and most of the useful constructional species have been replaced by others. This situation is exacerbated by uncontrolled grazing and browsing by stock. This degraded vegetation is not able to provide for the fuelwood and constructional timber needs of local people. In addition, these human impacts pose a severe threat to the species diversity of the Eastern Cape flora.

5.1.2 The feasibility of using remote sensing

The extreme differences described in the woody vegetation in this study showed that panchromatic aerial photography at the small scales currently available is not adequate for the monitoring of qualitative vegetation change as described in the results. These structural changes can be measured satisfactorily and accurately only when the scale is 1:12 000 or greater (Aldred and Kippen 1967, Aldred and Sayn-Wittgenstein 1972 and Edwards and Jarman 1972). If qualitative vegetation analyses are required, large-scale photography is essential and if the work must be conducted by means of aerial photography then photography of the necessary scale must be specially flown.

Satellite images have severe limitations in this kind of study. They are, however, useful in rapid visual mapping programmes. Landsat is adequate for monitoring of broad boundaries over large areas at small scales. Of the satellite images available, SPOT is far superior to Landsat. SPOT FCC paper prints at a scale of 1:100 000 provide a very quick and accurate method of mapping boundaries of broad vegetation types. The high cost of a SPOT image is far outweighed by the immense savings in time, equipment and level of expertise required for accurate mapping of vegetation boundaries.

Where vegetation mosaics and terrain are complex, severe limitations are imposed upon qualitative interpretation using not only SPOT but all satellite imageries. If vegetation quality is to be monitored, extensive field support studies are essential. SPOT and other satellite images may be most useful in this kind of study by allowing identification of clearance for agriculture and urban development and expanding areas of low socio-economic settlement. These areas invariably have severe impacts upon the surrounding woody vegetation. Identification of such areas would be sufficient reason to establish vegetation monitoring plots in the field.

5.2 RECOMMENDATIONS

If the fuelwood and constructional timber needs of low-income communities are to be met, optimal use of a variety of resources is necessary. Clearance of invasive bush from agricultural land could be used for charcoal. For example, in Kenya, *Tarchonanthus camphoratus* clearance yields raw material for charcoal production (Gandar 1983). Forest wastes and improved processing of wood for charcoal would greatly increase fuel supplies. The recommendations relate to measures for monitoring woody vegetation change and to alleviate pressure on indigenous fuelwood supplies. These focus on monitoring and planting strategies.

5.2.1 Monitoring

SPOT FCC paper prints at a scale of 1:100 000 should be used from time to time according to the vulnerability of an area, to identify areas of new settlement, agricultural and industrial expansion, and areas of accelerated erosion or other degradation. These areas could be rapidly mapped using a digitiser and stored on a data base. Subsequent mapping would allow changes in landcover to be identified. Areas of increased human impacts should be investigated in the field. Fixed plots and transects should be established to permit ongoing monitoring of human impacts in areas of impact and vulnerability.

5.2.2. Utilisation of indigenous vegetation

Where possible, sustained yields of woody vegetation should be at least estimated to permit some kind of controlled harvesting strategy to be implemented.

Research programmes to investigate the sustained yield potential of woody vegetation communities must be established.

5.2.3. Tree planting strategies

A multi-faceted nation-wide education programme to promote tree-planting must be implemented. The present Arbor Day and Tree of the Year programmes are totally inadequate and have no meaning to most of the rural inhabitants of the study area. It is reasonable to suppose that this is the case throughout the country.

A multi-lingual, multi-media programme is essential. This must be seen to have the full support of popular and authority figures and should draw on charismatic figures from a wide range of fields. The prime target group must be the black communities who most need the benefits of tree-planting.

A national plan for the establishment of nurseries and demonstration projects from which rural people can choose and purchase trees, must be established. This must be augmented by all kinds of planting strategies, as described in Appendix 1 to this document. Different approaches will be necessary in different areas.

Government departments responsible for forestry, agriculture and nature conservation should approach the problem as one of shared responsibility. All should be involved in planting of woodlots which will provide employment, learning opportunities and entreprenurial marketing opportunities. These should only be established with due regard for the constraints described in Appendix 1. At present, it is these departments which have the infrastructures to establish such a programme. The concept of agroforestry should be more widely promoted.

Whilst trials of possible fuel and construction species are in progress, trees which are known from experience elsewhere to have proven successful, should be planted. The problem of invasives is well understood but many of the good fuel species are invasive only under specific conditions. There may well be situations where the choice is between the planting of potentially invasive species or complete loss of soil and a complete lack of energy resources for increasingly impoverished communities

Trials and plantings with indigenous species, particularly various *Acacia* species should be begun without delay. *Acacia karroo* is considered by some to be the best woodlot species since it yields good coals and is familiar to rural people (Bond W J 1988 pers comm). *Acacia albida* has been widely used to combat desertification in the Sahel (Kirmse and Norton 1984).

We should not be spending years on experiment and discussion before embarking on a programme. The needs of communities dependent on dwindling energy supplies are urgent and they cannot wait for the ideal tree in order to cook their next meal.

REFERENCES

Acocks J P H 1953. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 28, 1-128.

Aldred A H and Kippen J A 1967. Plot volumes from large scale 70mm air photographs. Forestry Science 13, (4).

Aldred A H and Sayn-Wittgenstein L 1972. Tree diameters and volumes from large scale aerial photographs. Forestry Management Institute, Inf. Report FMR-X-40, Department of Environment. Canada.

Allen J P and Richards T S 1983. Remote sensing for identifying low density vegetation cover in semi-arid, coastal, north-west Egypt. Remote sensing for rangeland monitoring and management. Reading Remote Sensing Society, 69-74.

Anderson J R, Hardy E E, Roach J T, and Witner R E 1976. A land-use and landcover classification system for use with remote sensor data. Geological Survey Professional Paper 964, Washington DC.

Ashton M 1952. In: Best M 1979. The scarcity of domestic energy: a study in three villages. SALDRU working paper No 27. Cape Town.

Aucamp A J and Barnard H H 1980. Die ontplooiing van die veekundepotensiaal van die droegras-bosgemeenskappe in die oos-kaap. Hand. Weidingsveren Suid Afrika, 15, 137-140

Barrett E C and Curtis L F 1976. Introduction to environmental remote sensing. Chapman and Hall. London.

Bazzaz F A 1983. Characteristics of population in relation to disturbance in natural and man modified systems. In: Mooney H A and Gordon M (eds) Disturbance and ecosystems. Springer Verlag, Berlin and New York. 259-277.

Bembridge T J and Tarlton J E 1986. Ciskei woodlot survey and fuelwood strategy. Internal project report. University of Fort Hare, Ciskei.

Best M 1979. The scarcity of domestic energy: a study in three villages. SALDRU working paper 27. University of Cape Town.

Bossi L 1983. Mapping the vegetation of the Fynbos Biome with the aid of Landsat imagery. MSc thesis. University of Cape Town.

Breytenbach G J 1986. Impacts of alien organisms on terrestrial communities of the south western Cape. In: Macdonald I A W, Kruger F J, Ferrar A A (eds) The ecology and management of biological invasions in southern Africa. Oxford University Press, Cape Town.

Brown C J and Gubb A A 1986. Invasive alien organisms in the Namib desert, upper Karoo and the arid and semi-arid savannas of western southern Africa. In: Macdonald I A W, Kruger F J, Ferrar A A (eds) The ecology and management of biological invasions in southern Africa. Oxford University Press, Cape Town. 93-108.

Brough P J and Bromley K A 1984. An experimental land cover map of the Natal midlands using Landsat imagery. Natal Town and Regional Planning Supplementary Report No 4. Pietermaritzburg.

Burki S J and Ul Haq 1985. In: Le Roux P J du P (ed) Basic needs in rural areas: A report on a seminar held in Cape Town on 19 February 1985. SANSP Report 116. FRD, CSIR, Pretoria.

Cameron M et al 1988. In: McKenzie B (ed) Guidelines for the sustained use of indigenous forests and forest products. Occasional Report No 35. FRD CSIR Pretoria. 12-26.

Claveran R A 1966. Two modifications to the vegetation photographic charting method. Journal of Range Management, 19, 371-373.

Colwell R N and Poulton C E 1985. SPOT simulation imagery for urban monitoring: a comparison with Landsat TM and MSS imagery and with high altitude colour photography. Photogrammetric Engineering and Remote Sensing, 51, (8), 1093-1101.

Cowling R M, Moll E J and Campbell B M 1976. The ecological status of the understory communities of pine forests on Table Mountain. South African Forestry Journal 99, 13-24.

Cowling R M 1982a. Vegetation studies in the Humansdorp region of the Fynbos Biome. Unpublished PhD thesis, University of Cape Town.

Cowling R M 1982b. Patterns of plant endemism in the south-eastern Cape. The Naturalist, 27, 17-20.

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

Cunningham A B 1985. The resource value of indigenous plants to rural people in a low agricultural potential area. PhD thesis. University of Cape Town.

Cunningham A B and Gwala B R 1986. Building material and plant species used in Thembe-Thonga hut construction. Annals Natal Museum, 27 (2), 91-511.

Cunningham A B et al 1988. In: MacKenzie B (ed) Guidlines for the sustained use of indigenous forests and forest products. Occasional Report No 35. FRD, CSIR Pretoria. 2-11.

Curran P 1980. Multispectral remote sensing of vegetation amount. Progress in Physical Geography, 4 (3), 315-341.

Department of Agriculture 1984. Abstract of agricultural statistics. Agricultural Economic Trends Division, Department of Agriculture, Pretoria.

Department of Environment Affairs 1981/1982. Commercial timber resources and roundwood processing. Department of Environment Affairs, Pretoria.

Dowman I J 1981. The use of unconventional photographs in mapping. In: Proceedings of a symposium on ecological mapping from ground, air and space. Institute of Terrestrial Ecology, Monks Wood, United Kingdom.

Downing B H 1978. Environmental consequences of agricultural expansion in South Africa since 1850. South African Journal of Science, 74, 420-422.

Doyle F J 1985. The large format camera on shuttle mission 41-G. Photogrammetric Engineering and Remote Sensing.

Eberhard A A 1986. Energy consumption patterns in underdeveloped areas in South Africa. Energy Research Institute, University of Cape Town.

Edwards D and Jarman N G 1972. The role of aerial photography in vegetation survey. Unpublished paper read at a seminar on the application of aerial techniques to surveying natural resources. Natal Parks and Fish Preservation Board. Durban.

ElMahgary Y and Biswas A K 1985. Integrated rural energy planning, Butterworth Scientific, London.

Everard D A 1985. The conservation status of some unique plant communities in the eastern Cape. Unpublished MSc thesis, Rhodes University, Grahamstown.

Fenn T and Underwood M 1986. The role of agroforestry landuse systems in future development agriculture. Paper presented at symposium on development, University of Cape Town.

FAO 1982. 1980 yearbook of forest products. FAO, Rome.

Foley G and Barnard G 1984. Farm and community forestry. Earthscan, London.

Fox J 1982. Land use and environmental degradation in a Nepali village. 11th annual conference on South Asia, University of Wisconsin.

French D 1982. The 10 commandments of renewable energy analysis. World Development 10, 1.

Furness C K 1981. Some aspects of fuel-wood usage and consumption in African rural and urban areas in Zimbabwe-Rhodesia. Suid-Afrikaanse Bosboutydskrif 117, 10-12.

Gandar M V 1982. Some social and environmental aspects of the use of fuelwood in KwaZulu. In: Bromberger N and Lea J (eds) Rural studies in KwaZulu, University of Natal Press, Pietermaritzburg.

Gandar M V 1983. Wood as a source of fuel South Africa. Monograph 4, Institute of Natural Resources, Pietermaritzburg.

Gausmann H W 1974. Leaf reflectance of near infrared. Photogrammetric Engineering, 40, 183-191.

Geldenhuys C J 1983. A critical evaluation of indigenous forest management. Proceedings of the Jubilee Symposia, University of Stellenbosch, Foris 98, 497-524.

Geldenhuys C J , Le Roux P J and Cooper K H 1986. Alien invasions in indigenous evergreen forest. In: Macdonald I A W , Kruger F J and Ferrar A A (eds) The ecology and management of biological invasions in South Africa. Oxford University Press, Cape Town.

Gibbs-Russell G E and Robinson E R 1981. Phytogeography and speciation in the vegetation of the eastern Cape. Bothalia 13, 467-472.

Grainger A 1984. Quantifying changes in forest cover in the humid tropics: overcoming current limitations. Journal of World Forest Resource Management 1, Academic publishers, 3-63.

Griffiths G H and Collins W G 1983. Mapping the greenness of semi-arid rangeland vegetation in northern Kenya from Landsat digital data. In: Remote sensing for rangeland monitoring and management. Reading Remote Sensing Society, 108-122.

Harrison P 1987a. A green revolution for Africa. New Scientist 114 (1559), 35-39.

Harrison P 1987b. The greening of Africa. International Institute for Environment and Development- Earthscan, Paladin, London.

Hamburger H H 1985. Unpublished proceedings Nature conservation meeting, Department of Development Aid, Pretoria.

Henderson L and Musil K J 1984. Exotic woody plant invaders of the Transvaal. Bothalia 15, 1,2 297-313.

Henderson L and Wells M J 1986. Alien plant invasions in the grassland and savanna biomes. In: Macdonald I A W, Kruger F J and Ferrar A A, The ecology and management of biological invasions in southern Africa. Oxford University Press, Cape Town 109-117.

Heydorn A E F and Tinley K L 1980. Estuaries of the Cape, Part 1. Synopsis of the Cape coast. CSIR research report 380, CSIR, Pretoria.

Hoffer R M 1971. Remote sensing potentials for resource management. Biological effects on the hydrological cycle. Proceedings of the 3rd International Seminar for Hydrology Professors. UNESCO, New York.

Hoffer R M and Fleming M D 1978. Mapping vegetation cover by computer aided analysis of satellite data. LARS Technical Report 011178. Purdue University.

Hoskins M W 1982. Social forestry in West Africa: Myths and Realities. Paper presented at the American Association for the Advancement of Science annual meeting. Washington, D C.

Howard J A 1970. Aerial photoecology. Faber and Faber, London.

Huntley B J 1984. Characteristics of South African biomes. In: Booysen P de V and Tainton N M (eds) Ecological effects of fire in South African ecosytems. Springer-Verlag, Berlin, 2-17.

Jarman M L, Bossi L and Moll E J 1981. Remote sensing products for studying and mapping the Fynbos Biome: an investigation into the usefulness of various techniques. Department of Botany, University of Cape Town.

Jensen J R 1983. Educational image processing, an overview. Photogrammetric Engineering and Remote Sensing, 49 (8), 1151-1157.

Johnson C T 1983. The forests and trees of Transkei. Veld and Flora 68, 109-110.

Kaale 1982 In: Foley G and Barnard G 1984. Farm and Community Forestry, Earthscan, London.

Keeton G R 1984. The basic needs approach: a missing ingredient in development theory? Development Southern Africa 1 (3&4), 276-293.

Kirmse R D and Norton B E 1984. The potential of Acacia albida for desertification control and increased productivity in Chad. Biological Conservation, 29. Elsevier, United Kingdom 121-141.

Lane I R 1983. Estimation of carrying capacity of woody Tanzanian rangeland from Landsat. Remote sensing for rangeland monitoring and management 15. Reading remote sensing society, United Kingdom.

Le Roux P J du P 1985. The relevance of the basic needs approach to the South African situation. In: Basic needs in rural areas: A report on a seminar held in Cape Town on 19 February 1985. South African National Scientific Programmes Report No 116. CSIR, Pretoria, 1-10.

Liengme C A 1983. A study of wood use for fuel and building in an area of Gazankulu. Bothalia 14, 2, 245-257.

Lubke R A, Tinley K L and Cowling R M 1986. Vegetation of the eastern Cape: Tension zones and chorological complexity. In: Bruton M N and Gess F W (eds) Towards an environmental plan for the eastern Cape. Rhodes University, Grahamstown.

Mason 1981. In: Thomas I L, Benning V M and Ching N P 1987. Classification of remotely sensed images. Adam Hilger. Bristol.

Macdonald I A W, Kruger F J and Ferrar A A 1986. The ecology and management of biological invasions in South Africa. Oxford University Press, Cape Town.

Macdonald I A W and Richardson D M 1986. Alien species in terrestrial ecosystems of the Fynbos biome. In: Macdonald I A W, Kruger F J and Ferrar A A (eds) The ecology and management of biological invasions in southern Africa. Oxford University press. Cape Town, 77-91.

McGivern R, Martin D, Benjamin J 1972. Planimetric map revision with the Bausch and Lomb Zoom Transfer Scope. Proceedings Annual Meeting American Society of Photogrammetry, 38, 615-616.

McKenzie B (ed) 1988. Guidlines for the sustained use of indigenous forest and forest products. Occasional Report No 35, FRD, CSIR, Pretoria.

Milton M 1978. A portable handheld "Landsat" radiometer. Paper presented at the 5th annual conference of the Remote Sensing Society Durham.

Milton S J and Siegfried W R 1981. Above ground biomass of Australian acacias in the southern Cape, South Africa. Journal of South African Botany, 47, 4.

Mnzava E M 1982. Village afforestation: Lessons of experience in Tanzania. FAO, Rome.

Moller V 1985. Rural black's perceptions of basic need fulfilment. In: Basic needs in rural areas: A report on a seminar held in Cape Town on 19 February 1985 South African National Scientific Programmes Report No 116, CSIR, Pretoria, 67-94.

Murray G F 1983. Reforestation in Haiti. Earthscan seminar, Cartagena, Colombia.

National Academy of Science 1980. Firewood Crops. Shrub and tree species for energy production. Board on Science and Technology for International Development, NAS, Washington, DC.

Newby T S 1985. The use of digitally interpreted satellite imagery with special reference to topographical shadow effects as an aid to vegetation mapping in the Hottentots Holland Mountains catchment are in the western

Novaes R A 1979. Recent accomplishments and expectations of remote sensing applications to Brazil. Proc. Remote Sensing for Natural Resources. University of Idaho, Moscow, USA. 313-326.
Cape Province.

Palmer A R 1981. A study of the vegetation of the Andries Vosloo Kudu Reserve Cape Province. Unpublished MSc thesis. Rhodes University, Grahamstown.

Peterken G 1981. Woodland conservation and management. University press, Cambridge.

Prior J and Tuhoy J 1987. Fuel for Africa's fires. New Scientist, 115 (1571), 48-51.

Robinove C J, Chavez P Jr, Gehring D, and Holmgren R 1981. Arid land monitoring using Landsat albedo difference images. Remote Sensing of the Environment 11 (2), 133-156.

Sabins F F 1978. Remote sensing, principles and interpretation. W H Freeman and Co. USA.

Sagar G R and Harper J L 1961. Controlled interference with natural populations of Plantago lanceolata, P major and P media. Weed Research, 1, 163-176.

Scoggins D A and Piper S E 1985. Development of digital image processing techniques for use with aerial survey and as an aid to current research in remote sensing. University of Natal, Durban.

Sheddick 1954. In: Best M 1979. The scarcity of domestic energy. A study in three villages. SALDRU working paper No 27, University of Cape Town.

Simkins C 1984. What has been happening to income distribution and poverty in the homelands? Development Southern Africa 1 (2), 142-152.

Smith J H, Lewy and Doby 1960. Intensive assesment of factors influencing photocruising shows that local expressions of photo volume are best. In: Howard J A 1970. Aerial photoecology. Faber and Faber, London.

Steele and Ncholu 1983. Woodlot marketing study (north) final report. Lesotho Woodlots Project, Maseru.

Taylor G F and Soumare M 1983. Strategies for forestry development in the semi-arid tropics: Lessons from the Sahel. International symposium on strategies and designs for reforestation and tree planting, Agricultural University, Wagenheim, Netherlands.

Thalen D C P 1979. On photographic techniques in permanent plot studies. Vegetation 39 (3), 185-190.

Thomas I L, Benning V M and Ching N P 1987. Classification of remotely sensed images. Adam Hilger, Bristol.

Thomson J T 1979. Public choice analysis of institutional constraints on firewood production strategies in the West African Sahel. In: Russel and Nicholson (eds) Public choice and rural development. Choices for the future, Washington D.C..

Trollope W S W 1973. Fire as a method of controlling Macchia (Fynbos) vegetation in the Amatola mountains of the eastern Cape. Proceedings of the Grassland Society of South Africa, 8, 35-41.

Trollope W S W 1974. The role of fire in preventing bush encroachment in the eastern Cape. Proceedings of the Grassland Society of South Africa, 9, 67-72.

Tucker C J, Maxwell E 1976. Sensor design for monitoring vegetation canopies Photogrammetric Engineering and Remote Sensing 42, 1399-1410.

Tupper G J 1981. A preliminary evaluation of the applicability of Landsat for the assesment of range conditions in the semi arid woodland in the Cobar district of New South Wales. Technical Memorandum 81/2. CSIRO Division of Land Resources Management, Perth.

Van Wilgen B W and Richardson D M 1985. The effects of alien invasions on vegetation structure and fire behaviour in South African Fynbos shrublands: a simulation study. Journal of Applied Ecology, 22, 955-966.

Vujakovic P 1987. Monitoring extensive "buffer zones" in Africa: An application for satellite imagery. Biological Conservation 39, 195-208.

Weber 1982. In Foley G and Barnard G 1984. Farm and Community Forestry, Earthcan, London.

Wells K F 1971. Measuring vegetation changes on fixed quadrats by vertical ground stereography. Journal of Range Management 24, 233-236.

Wells M J, Balsinhas A A, Joffe H, Englebrecht V M, Harding G and Stirton C H 1986. Catalogue of problem plants of southern Africa. Memoirs of the Botanical Survey of South Africa 53. Government Printer, Pretoria.

Wells M J, Poynton R J, Balsinhas A A, Musil K J, Joffe H, van Hoepen E and Abbott S K 1986. History of the introduction of invasive alien plants to southern Africa. In: Macdonald I A W, Kruger F J and Ferrar A A (eds) The ecology and management of biological invasions in southern Africa. Oxford University Press, Cape Town 21-35.

Whittingham C P 1974. The mechanisms of photosynthesis. Edward Arnold, London.

Williams A T 1986. The potential for the production of energy from biomass in southern Africa. Unpublished MSc thesis, Department of Engineering, University of Cape Town.

Wilson R C 1949. The relief displacement factor in forest area estimates by dot templets on aerial photographs. Photogrammetric Engineering 15, 225-236.

White P S 1979. Pattern, process and natural disturbance in vegetation. Botanical Review 45, 229-299

Wickstead M 1984. Woodlot marketing study (south), Lesotho Woodlots Project, Maseru.

Wimbush D J, Marrow M D, and Costin A B 1967. Colour stereography for measurement of vegetation Ecology 48, 150-152.

Wyatt-Smith J 1982. The agricultural system in the hills of Nepal. The ratio of agricultural to forest land and the problem of animal fodder. In: Foley G and Barnard G 1984. Farm and community forestry. Earthscan, London.

REVIEW OF TREE PLANTING STRATEGIES

INTRODUCTION

This project has shown that whilst large-scale clearance of indigenous bush and trees can easily be monitored by remote sensing techniques, gradual depletion is much more difficult to monitor. In this study this has largely been due to the rugged terrain which introduces parallax problems causing the canopy to obscure the understory and ground layers. However, over any terrain the canopy can obscure understory. Complex vegetation mosaics can also complicate the interpretation of remotely sensed data thus making it difficult to monitor changes. Thus, using the techniques of this study, degradation is only discernible when it has reached an advanced stage. Foley and Barnard, (1984), state that " in the majority of countries, this (gradual depletion) is the greatest single cause of deforestation and the breakdown of traditional systems for managing tree resources."

In some areas, livestock grazing was found to be the greatest threat to environmental stability. Fox (1982), says of a region of Nepal, "The undue emphasis placed on firewood as the cause of deforestation has obscured the role played by livestock". Numerous authors have discussed the problems of overstocking throughout southern Africa. The total number of cattle in South Africa including the National States and the TBVC states (Transkei, Bophuthatswana, Venda and Ciskei) was estimated to be 10,3 million in 1983/84. The number in the TBVC States has remained at around 2 million for the past few years (Department of Agriculture, 1984). The number of goats is difficult to estimate. Throughout the study area cattle and goats freely grazed and browsed within the woodlands and although not quantified, casual observations showed a profusion of browsed plants and exposed roots of woody species.

Indigenous forests (including the woody thicket communities of this study) constitute the smallest biome in southern Africa (Huntley 1984). It nevertheless makes a considerable contribution to the basic needs of rural communities. Cunningham and Gwala (1986) stress the value of indigenous plants as building materials. These species provide a cheap and renewable resource which helps fulfill the urgent need for low-cost housing for a rapidly expanding population.

A variety of woody plants are used in construction. Timber collection for construction is potentially far more damaging to the plant communities in which this takes place than is collection of firewood. Livewood is collected for poles and laths. Dense and durable, termite resistant species are required for construction and these species have a low annual increment (Cunningham et al 1987). *Colophospermum mopane* is recommended as a suitable species for cultivation and it is favoured for construction by rural people in southern Africa in those areas in which it occurs (Liengme 1983, Cunningham 1985). In the Transkei, where forest species are very similar to those of the lower Fish River Valley, the species favoured for poles and laths are Pavetta lanceolata, Duvernoia adhatodoides, Chaetacme aristata, *Ptaeroxylon obliquum* and *Apodites dimidiata* (Johnson 1983). Where building timber is scarce then alternatives such as pine beams, gum poles and concrete blocks are used.

Indigenous forest exploitation is permitted on a limited scale in the Transkei. Unless forest products are specifically protected by the Transkei Forestry Act they may be sold for construction and other domestic use. Firewood may be collected under the "theza" system (where dead and fallen timber may be collected and removed free of charge). These products are not sold or harvested on a sustained yield basis and since most of the demand for livewood is for small diameter poles the forest structure is rapidly changing (Cameron et al 1987).

In the Ciskei the situation is less severe. Hughes R (1987, pers comm) reports that in the government owned forests, species such as *Ptaeroxylon obliquum*, *Olea europaea*, *Rapanea melanophloeos* are sold as sawlogs by the road. Here too "theza" collection is permitted but it is felt that in the long-term this will affect nutrient cycles and other systems and be detrimental to the forests. Forests in private hands are little utilised but are susceptible to complete clearance for agricultural or industrial expansion. Forests under control of a Headman are the most at risk and are being devastated due to a total lack of control.

According to the World Bank (in Harrison 1987b), 75% of the population in Asia and Africa use traditional fuels. The largest part of this is timber. In the third world 1,14 billion m^3 of wood are burned as fuel each year (FAO, 1982). As a result many projects have been funded to remedy the increasing discrepancy between the supply and demand for fuel. Foley and Barnard (1984), list 140 projects funded by international donor agencies over the last two decades. Of these, 71 are projects in Africa (outside of South Africa) and 47 of these have been implemented since 1980. The mean investment per African project was of the order of US$3,73 million and totalled some US$264,85 million. Five established projects are known for South Africa. In spite of this considerable investment there has been a poor record of successful projects in Africa. By contrast the Asian projects have been far more successful. The reasons for this are complex and are the result of soil and climatic variations between the two continents and differences in the socio-economic, philosophical and political bases (Harrison 1987).

In time some projects have expanded to become purely commercial ventures, often responsible for worsening of the fuelwood and sometimes food situation. This has come about because some projects have generated competition for land with the result that the more successful commercial farmers have expropriated the land of the less successful and turned agricultural land over to timber production. The timber products have then frequently been sold in distant urban areas where demand is high and prices frequently greater.

The demand for fuelwood and constructional timber is growing with the population and the consequent environmental stresses imposed on natural vegetation, soil and water resources by the fuelwood demand are severe. Thus it is imperative to evolve successful wood growing strategies.

CONSTRAINTS

It is appropriate to look first at constraints to wood production programmes. These range from socio-political to economic and perceptual. It is from within this framework of constraints that the problem and any proposed solutions must be viewed.

Cultural constraints

Tradition may mediate against the planting of trees close to homes for a variety of reasons, spurious or otherwise. These include the harbouring of pests, competition with crops for water, sunlight and nutrients and religious taboo.

Mnzava (1982), points out that some expressed antipathy towards trees may be an excuse not to participate in planting projects. This may be particularly so where there is direct government involvement in the project.

Perceptual constraints

The perception by a community of the problem of deforestation may be such that there is a lack of incentive to plant trees. During this study some local people in the Ciskei expressed the view that there was still wood available in the forest and if that supply were exhausted then it could be purchased from other areas. There was therefore little incentive to take on the extra work load which would be imposed by a planting programme. All agreed however that some kind of planting scheme would be a good idea.

A lack of education and extension, coupled with immediate economic problems also appears in part to be responsible for the lack of interest in long-term projects.

Land tenure

"The most favourable position for tree growing is where the land is privately owned and individuals hold secure title..." (Foley and Barnard, 1984). In many areas of Africa, including South Africa, rural peasants do not own the land they farm (Gandar 1982). Traditionally land tenure in Africa before colonial times was communal. Although the land was not owned by a particular farmer, he had rights to its produce and the produce of any trees which they planted (Harrison 1987). Where land is not owned by the peasants they cannot be reasonably expected to grow a crop whose harvest they may be unable to enjoy. This problem is exacerbated where there exists the threat of forced removal.

Communal grazing may also inhibit tree planting programmes since protection of tree seedlings may cause conflict through the restrictions placed on the grazier's stock.

The success of the various agroforestry and green belt schemes in Kenya is largely due to the fact that in that country the old communal user rights have been converted to permanent ownership. Most smallholders in Kenya therefore, own their land.

Ownership of trees

The question of the eventual ownership of trees, even where the land is privately owned may create problems.

Thomson (1979) noted problems in the Sahel where indigenous trees had been planted by farmers but permits had to be obtained before indigenous trees could be cut. This restriction intended to protect trees also alienated farmers. In Haiti, trees bought and planted by the government on rural peasants' land were seen as a step towards expropriation of the land by the government (Murray 1983)

Conflicting responsibilities

The scale of the contribution of women to household and subsistence farming in Africa has been highlighted by many authors (Gandar 1982, Eberhard 1986). Men frequently work in the cities away from their rural homes. Women therfore bear the burden of home and smallholding maintenance. They are also responsible for the management of any wood production programmes which involve the community whilst still carrying the responsibility of wood collection until the planted trees are harvested. Mnzava (1982), notes that in Tanzania "tree planting coincides with agricultural activities and naturally the latter get priority."

Men frequently see their responsibility as one requiring their migration to the urban areas to obtain paid employment.

These conflicts generate a labour shortage in a situation where human labour supplies 84% of the energy input into rural agriculture. This contrasts with the Asian situation where draft animals contribute twice as much energy to agriculture as do draft animals in Africa (Harrison 1987)..

<u>The time factor</u>

The long-term nature of tree growing is a serious constraint. However, if tree species are correctly chosen and growing conditions are not unduly hostile, then short-term benefits may be enjoyed within as little as two years. This is of particular relevance to the agroforestry situation.

TREE PLANTING STRATEGIES

These fall into 5 main categories:-

- farm forestry
- family tree growing
- community forestry
- agroforestry

Any of these approaches may be adapted to fit existing land tenurial systems or land may be re-allocated for use in one or other of the systems:

<u>Farm Forestry</u>

To date these systems have been used to promote commercial tree growing on privately owned land. In India, farming of *Eucalyptus spp* has become extremely lucrative yielding a return greater than from other cash crops

This approach was however less successful in the Phillipines (Foley and Barnard 1984). The yields are greatest where inputs are greatest and thus the poorest farmers may be unable to participate. According to French (1982), the desirability of subsidy should be carefully considered before embarking on a subsidised programme, as these have often failed. Market stability needs to be assesed and assured. This has been achieved in India through co-operatives. However, there are undesirable effects associated with this system. The more important of these have been recognised by various authors and the following are selected as the most important:-

The rich benefit most since they are best placed to take advantage of subsidies.

The system does not deliver the social and environmental benefits promised and expected. This is because the rich benefit most and thus utilise it most. It does not make economic sense, at least in the short term, to plant trees on marginal land where growth rates and survival will be lower.

It may be harmful to the poor since they cannot compete with the wealthy land owners and may therefore be forced to sell their land. Thus agricultural land is lost to commercial timber production. Even the eventual timber harvest may be sold to commercial concerns or by the land-owner himself, but in urban areas. Thus fuelwood and the other benefits accruing from the project are often unavailable to those whom the sytem was established to help.

Family Tree Growing

This type of programme relies on non-commercial incentives. It also depends upon local people perceiving a need for planting and according it sufficient priority. This approach has enjoyed relative success in Africa and elsewhere. This kind of project may require little input other than to provide access to appropriate seedlings and to provide technical advice through extension workers. The multiple-use tree Neem, *Azadirachta indica*, is potentially one of the most valuable of all arid area trees (National Academy of Science 1980). It is the most important plantation species in Nigeria (Harrison, 1987) and it has spread rapidly in the Sahel due to its acceptability to local people (Foley and Barnard, 1984). Its popularity is due to its rapid growth, resistance to pests and drought, ready coppicing and its unpalatability to stock, thus making protection of seedlings easier. Fencing of palatable seedlings to protect them from stock represents a major expense and labour input (Kirmse and Norton 1984). Unpalatable species however are less useful in some agroforestry systems.

In Kenya, *Leucaena leucocephala* has spread rapidly as a component of agroforestry systems and has been selected and planted by farmers at a family level (Fenn T 1986 pers comm). Many projects at this level have failed because of the assumption that fuelwood is the priority need whereas shade, fruit and food may be more important (Weber 1981). Thus species choice and location of the plantings may be other than expected by the development agency. It may be more appropriate to encourage people to plant trees at this level in small clumps within and bounding compounds. Common sense and the experience with *Azadirachta* suggests that multiple use trees would be the most attractive a proposition. This also highlights the value of the agroforestry approach since the trees serve important functions almost from planting.

This family approach to tree planting has, as a major advantage, the fact that the trees planted do not compete with crops or livestock for growing space or grazing and they may also provide environmental benefits. People will only plant trees in this situation if they want to and if the species are acceptable to them. If trees are planted, then survival rates are good. This kind of planting is also unlikely to compete with traditional labour demands. However, trees will only be planted if people perceive a need. If they live near to woody vegetation there may be little incentive to plant even if they recognise that deforestation is taking place. This system also demands that families have security of land tenure and can therefore anticipate benefits from the planting.

Research programmes are needed to determine best species for particular situations but there is sufficient information and urgency to establish programmes based on present knowledge immediately. What is of very great importance is an indication of the potential sustainable yields and possible management strategies for a variety of vegetation types within South Africa and the TBVC States.

In the Sahel region of Nigeria it had been estimated that indigenous trees would yield +/- 0,5m^3 of wood per year. Research showed the true yield to be two to four times greater. Controlled use of the natural vegetation for fuel avoided destruction of the natural vegetation for woodlots and an expenditure of US$700-500 per hectare on establishment of *Eucalyptus* or *Azadirachta* plantations (Harrison, 1987)

Community forestry

This has particular significance in the African situation because of the widespread communal land tenure system. A community forestry system may be driven by both commercial and noncommercial interests but, as in all systems, the participants must believe that they will reap substantial rewards.

China achieved great communal tree planting success through political motivation. More than 28 million hectares were planted in the 20 years up to 1978.

South Korea launched a 10 year planting programme in 1973 with a goal of 1 million hectares. The programme was underpinned by a network of village forestry associations which managed projects with government direction. 65% of the programme costs were provided by the government. 35% was provided by the communities and took the form of services and labour. The programme was accompanied by a broad range of socio-economic strategies and the community participated in a profit-sharing scheme. The planting goal was acheived 5 years ahead of target. It should be noted that at the start of the programme 75% of forests were privately owned and managed, thus an existing responsibility and skills structure could be easily adapted. The government was also in a position to inject large-scale funding to subsidise planting, nurseries and extension progammes. (Barnard and Foley, 1984)

In India, community forestry programmes have achieved success through schemes managed jointly by the village community and by the forestry departments. Initially trees were planted along roads, railways and canals. At harvest the proceeds were split between government and the community. Some villages allowed the establishment by the forestry department of four hectare woodlots on communal lands in return for the rights to fuel, food and fodder plus a 50% share in profits at harvest. After an initial period of suspicion these supervised woodlots expanded to over 28 000 ha in 8 years although in some schemes seedling survival has been very poor. Even so, this type of government-managed scheme has achieved greater success than similar projects which required the active participation of villagers.

In Africa the picture has been very different. In the Sahel, despite an estimated US$160 million spent on woodlot projects between 1975 and 1982, achievements have been poor. Of the estimated 25 000 ha planted, approximately 33% have grown so poorly that little if any wood is produced (Weber 1982). Similar failures have been reported in Tanzania where success has been achieved only where villagers have been employed as labourers in plantations established and managed by forestry departments (Tucker et al in Barnard and Foley, 1984). Hoskins (1982) said of the Sahel: "Some social scientists have gone so far as to suggest that no communal projects are possible..."

A major problem which can be anticipated in community forestry is that of access to the resource. This may be more than the problems associated with policing of harvesting, but also as a result of a hierarchically tiered community. The people do the work but the chief receives the lion's share of the products. This may extend into the domain of profit sharing. This is in line with the traditional control of the chief in community affairs in Africa. It is therefore obviously important to establish agreement on questions of work distribution, responsibility and profit sharing before commencement of the project. Failure to do so may result in community dissatisfaction and failure of the programme.

Community forestry is attractive from the point of view of surmounting the problems associated with projects under the communal land tenure system but it demands a good deal of community responsibility and cooperation and may therefore only be appropriate in selected situations.

Agroforestry

Agroforestry systems of one kind or another have been traditional components of some of the worlds agricultural systems. Trees have been used to shade coffee and tea crops and food crops have been intercropped with oil and coconut palm. The advantages of these systems are numerous and have been described by many authors. The benefits are related to increased protection for crops from sun and wind, soil enrichment roles where leguminous trees are grown, increased fodder supply if palatable species are used, fuelwood supply and environmental protection. Fenn and Underwood (1986), remark that most of the current agroforestry development is taking place in arid developing countries. International research is lead by the International Council For Research in Agroforestry (ICRAF). A variety of systems based on different species, agricultural regimes and edaphic conditions are currently under investigation. Some research in South Africa has been carried out by the ARDRI programme for agroforestry research at Fort Hare University in the Ciskei (Fenn and Underwood, 1986)

Research is also being undertaken by the Institute of Natural Resources at the University of Natal and by the Legume Research Centre at the Rietondale Experimental Farm of the Department of Agriculture and Water Supply in Pretoria. In particular, this latter organisation is investigating leaf yield of multi-purpose trees for fodder and mulch production.

Agroforestry systems have the potential to increase food production in rural areas and to improve the quality of life of people in these areas, not least by reducing the time which has to be spent collecting fuel. Any agroforestry development must be accompanied by an extension programme, demonstration plots and a nursery network. This is particularly important where the system is alien to traditional farming systems.

Kenya has the most developed agroforestry programme in Africa. The system is that of "alley cropping", where trees are grown in rows with crops between. The programme is based on six agroforestry centres managed by the Ministry of Energy but originally established through a USAID programmme. The centres are primarily for research and training. Of great interest is the departure from normal forestry planting and management methods. Trees are more closely planted both within and between rows. Coppiced or pollarded yields are increased up to tenfold (Harrison, 1987). The project provides cheap seedlings and allows the farmer to choose his own trees from a range of over 125 species. Demonstration plots allow farmers to see various species in an agricultural situation. Tendencies have been towards the selection of citrus, *Eucalyptus*, and the rapid growing, multi-purpose tree, *Leucaena leucocephala*. Harrison (1987) concludes his discussion by saying: "Agroforestry is arguably the most important discipline for the future of sustainable development in Africa". It is an approach which should be given great priority and support.

ESTABLISHMENT OF TREE PLANTING PROGRAMMES

Programmes may either be initiated and managed entirely by an agency outside the community of the region in which the project is developed, or the programmes may involve to a greater or lesser degree members of the community.

In the first instance, recommendations as to identifying suitable tree species, community priority needs and availability of land are of paramount importance. However, responsibility for the programme remains in the hands of a responsible organisation with expertise and infrastructure. The community may be involved as a source of paid labour which may in the long-term be of most benefit since, in the South African context, jobs in rural areas are badly needed.

Where the community is expected to participate voluntarily in any programme then the situation becomes more complex.

Forestry department nurseries are, by and large, orientated towards commercial production and this may have to change in order to provide the species acceptable to the local communitites. Appropriate species may be different from region to region, not just for climatic or edaphic reasons, but because of traditional utilisation patterns.

It should be borne in mind that rural people of a limited educational background tend to be resistant to change and to government interference in their traditional lifestyle. Any planting scheme involving the community should be properly introduced by an awareness programme followed by a continuous extension programme. At least in the early stages, traditional planting methods and familiar species should be used. New species and techniques should be introduced gradually.

Success in terms of community participation and seedling survival was achieved in Chad. Over a four-year period a community planting effort planted a total of 470 000 seedlings of *Acacia albida*, a familiar multi-use indigenous species. In the long term the programme failed because of inadequate extension and support services (Kirmse and Norton, 1984).

A network of nurseries is also essential. The people expected to participate in the planting programmes are for the most part poor and thus experience severe logistical problems with regard to transport of seedlings. In Kenya, demonstration plots associated with large scale nursery development have played an important role in generating considerable public interest in agroforestry (Fenn T 1986 pers comm).

Education and extension

It is evident that in South Africa, even amongst adequately educated whites, conservation awareness is severely retarded. Where awareness does exist there is little evidence of motivation to respond positively. Amongst the black community the situation is far worse. Any attempt to encourage tree planting would require an extensive and carefully planned and executed awareness programme. The KwaZulu Bureau of Natural Resources has achieved considerable success in generating nature conservation awareness by means of an intensive programme extending over several years. The support of the Chief Minister, Chief Buthlezi, has lent importance to this programme and community leaders at all levels have visited environmental projects. A similar kind of effort would be needed to promote tree planting. Tree planting is already promoted by nature conservation departments and by national institutions such as Arbor Day and World Environment Day. The present effort is however no more than a token, being largely ceremonial in character.

Publicity campaigns mounted in Tanzania have reportedly been successful in generating public awareness of the need for tree planting. (Kaale 1982 in

Foley and Barnard 1984), reports a five fold increase in demand for seedlings from forestry department nurseries during an awareness campaign. In India, an intensive campaign during 1972 resulted in a three fold increase in seedling demand. Political support is also very important. In Kenya on the other hand, President Moi has given tree planting priority and support. In 1980 he required every district commissioner and chief to establish a tree nursery. In 1983 this was extended to every school. By this time more than 1 300 government nurseries throughout the country had a stock of over 80 million seedlings. During the national soil and water conservation week over 3 million trees are planted (Harrison 1987). Any awareness campaign must extend throughout all strata of society and for a prolonged and continuous period. Such a programme must be accompanied by simultaneous development of a nursery network and other infrastructural components appropriate to the programme. Following creation of demand it is vital that the supply of seedlings is maintained and that negative associations relating to official forestry legislation and uniformed officers are eradicated. Harrison (1987), identifies the single, multi-purpose agricultural extension officer at the village level as the most valuable channel for the promotion of new ideas.

Availability and distribution of seedlings

This is only considered from the point of view of supplying seedlings for planting by individuals and communities. Two priorities are of the greatest importance. There must be a network of nurseries which is sufficiently extensive to enable seedlings to be accessible to anyone who wishes to plant. The seedlings must be big enough to have a reasonable chance of survival. Personal experience in the National States suggests that teacher training colleges and schools could and would greatly assist in establishment and management of nurseries and demonstration plots.

More than 66% of the 18 000 nurseries in Gujarat in India were school or privately owned nurseries (Foley and Barnard, 1984). In Kenya, non-government and voluntary organisations such as the Kenya National Council of Women are of particular significance to the tree planting programme (Fenn T 1987 pers comm).

Seedling distribution has been a problem because of the great weight of seedlings and soil in traditional polythene bags. In India seedlings have been grown in lots of 1 000 in shallow wicker baskets. Transport of large numbers of small seedlings is thereby possible but these must be transplanted into conventional polythene pots until large enough to plant out. This is important - a major cause of plantation failure has been planting of too small seedlings.

Seedlings grown in narrow polythene tubes in Haiti have enabled 60 times as many to be carried as would be the case using conventional polythene pots (Murray 1983).

Direct sowing of seeds reduces distribution costs and other problems but this method requires considerably more husbandry and failure rate is high. The method is, however, in use in Malawi and other parts of the world (Fenn T 1987 pers comm.). Seeds may be broadcast successfully where pest resistant, nutrient rich and water absorbent coatings are used. One person can broadcast tree seed over 6-8 hectares per day depending upon conditions. Considerable success has been achieved in the United States and New Zealand with aerial sowing of tree seed. Aircraft achieve sowing rates, under good conditions, of about 80 hectares per hour (National Academy of Science 1980).

Species

The concept of intensive, large scale tree planting programmes is a new one in the rural areas which need the trees. Rural people tend to be critical and suspicious of new approaches and technologies particularly if these are government directed. Failure of an early planting may very considerably reduce confidence in the programme. The choice of species and approach is therefore of prime importance. Reliability and resistance to drought and disease should be of more importance in the species choice than ultimate production capability. Species should also fulfill the needs of the people as seen by themselves. Additional benefits from the planting should be seen as valuable spin-off.

Species are extensively described in "Firewood Crops: shrub and tree species for energy production" (National Academy of Science 1980). Two of the most promising species are *Eucalyptus spp*, successfully and widely used, and *Leucaena leucocephala* which has displayed great success in some parts of the world. Both of these species are however susceptible to failure if the wrong varieties for a given situation are planted.

Indigenous species as candidates for wood production in plantations have been largely ignored in South Africa mainly due to their longer harvest cycle and the fact that many are difficult to establish. Indigenous species however have several advantages. They are familiar to rural people and are traditionally used, they are often multiple use species and they are suited to local environmental conditions. Use of these species is also more desirable from an environmental protection point of view. In some areas, management of existing bush may provide greater wood production than plantations of exotic species. In an area of less than 1 000 mm per annum rainfall in the Sahel, *Acacia senegal*, an indigenous species, has averaged the same wood production of 1,5 tons per hectare under no management, as have planted and managed *Eucalyptus spp* (Taylor and Soumare 1983). It would be economically advantageous to devise a management strategy for existing woody vegetation since there is no expenditure on clearance or planting. It may still be necessary to expend resources on seedling protection within the indigenous woody communities because of the need to exclude stock.

PROJECTS IN SOUTHERN AFRICA

For the purposes of this review, southern Africa includes the Republic of South Africa and its so-called National States within its borders, the Kingdom of Lesotho and the TBVC states (Transkei, Bophuthatswana, Venda and Ciskei) of South Africa.

1,2 million hectares of land in South Africa are given over to commercial forestry projects (Department of Environment Affairs 1981/1982). Only 6% of this falls within the TBVC states , where demands for timber as a fuel and constructional timber are great (Williams 1986). An additional 300 000 ha of land is covered by indigenous forests.

Commercial afforestation in South Africa is based on introduced species which provide timber principally for construction, mining, veneer, plywood and board and the paper and pulp industries (Williams 1986). Very little of this timber or the residues resulting from its processing are available for firewood. This is largely because of the logistics which make it uneconomical to pack and transport firewood long distances (Gandar M V 1986 pers comm). In addition, the energy requirements of drying kilns and sometimes of self-generated electricity require that all the residues be used *in situ* (Williams 1986).

Charcoal is currently produced in South Africa and in 1981/82 approximately 104 000 tonnes were produced of which only 31% was used for domestic purposes in South Africa. The rest was either exported or used in industrial applications (Williams 1986).

It is estimated that the total fuelwood demand in South Africa, the TBVC States and the National States is in the region of 4,4 million m^3 per year. The area of plantation required to provide this total is estimated to be 600 000 ha, half the present total area of commercial forestry. Existing woodlots cannot nearly meet this demand.

Table 1 Present areas of woodlot in Southern Africa (Gandar 1983).

REGION	AREA (HA)
Bophuthatswana	1 000
Ciskei	650
Gazankulu	140
KaNgwane	2 400
KwaNdebele	00
KwaZulu	7 600
Lebowa	1 100
Qwaqwa	400
Transkei	12 000
Venda	500
Total	25 790

There is therefore tremendous demand for the products of commercial timber production and competition between various industries is intense. Thus most fuelwood in South Africa and the TBVC States is obtained from indigenous resources supplemented by harvesting of alien invasive species such as *Acacia* in some parts of the country. A brief review of woodlot projects in southern Africa is presented here:

Transkei

In the early 1950's a community woodlot project was established in the Transkei. This totalled 12 000 ha and was comprised of 260 woodlots. The woodlots were established by the Transkei Department of Forestry and then given to Tribal Authorities for management. The project is considered to have failed because of poor management and over-utilisation and the woodlots have now reverted to the Department of Forestry (Eberhard A A 1986 pers comm). The reasons for the failure are unknown but it is known that many of the constraints in this report were not considered or even appreciated 30 years ago. It is known that many early projects in the Transkei such as the grazing strategies failed because of the failure of the responsible department to "carry the people along with the project". In other words there was frequently inadequate preparation, education and extension (Hamburger 1985).

The Transkei government recently applied for Development Bank funding to establish a forestry programme with an afforestation target of 9000 km^2 by the year 2020. Minimal community involvement was planned. This is in direct conflict with the pre-requisites for success presented in this report.

Ciskei

The present woodlots in the Ciskei are not making a significant contribution to either fuelwood or constructional timber supplies to rural communities. As a result the Ciskeian rural community does not perceive woodlots as a sufficient source of energy or constructional timber (Bembridge and Tarlton 1986). The Agricultural and Rural Development Research Institute (ARDRI), at the University of Fort Hare in the Ciskei has for some time had a programme of woodlot research to remedy this situation. This programme is based on an introduced tree, *Leucaena leucocephala*. This species, which has several hundreds of varieties, is a multi-purpose tree providing building poles, fuel, fodder, fertiliser (from the leaves) and since it is a legume, nitrogen fixing bacteria in nodules on the roots increase the nitrogen content of the soil. It is very fast growing and has acheived some of the highest total yields of biomass recorded (National Academy of Science, 1980). In addition it will grow in a variety of growth forms from trees to hedges and responds well to coppicing.

ARDRI is presently conducting trials under different climatic conditions and is researching this species' application in agroforestry systems.

KwaZulu

The South African Pulp and Paper Industry (SAPPI) together with funding from the Gencor Development Fund has established a timber project close to a major mill at Mandini. The project is designed to help rural communities as well as to supply the timber industry with timber. The aim of the project is not production of fuelwood but thinnings and other residues will be available to local communities for fuel.

Potential participants in the scheme undertake to sell timber to SAPPI at the prevailing market price. In return SAPPI provides seedlings and interest free funding to maintain the plantation until the timber is sold at which time outstanding loans must be paid. The project is underpinned by a supporting infrastructure of extension services and nurseries. As a result the project has met with a great deal of success and by 1985 the project had 67 participants and 104 ha under trees. Plantations are of a small size, the largest being 5,7 ha and the smallest 1,7 ha.

A woodlot project has been established at Embongolwane with the assistance of the Institute of Natural Resources of the University of Natal. A key factor in this project has been the support of the headman of the community who gave his own land to the project. The project is still in its early stages but it is attracting much interest and support. British Petroleum (BP) has produced an educational videotape which is being used by the KwaZulu Bureau of Natural Resources and other institutions to promote woodlots. As a result there have been a number of new participants to the project. The membership fee is used to expand the woodlot.

Lesotho

The most successful project to date is the one established in Lesotho. The project was well funded with a budget of over R4 million. The long-term goal of the project is to establish a viable afforestation programme supported by adequate and appropriate extension services. The area planned is in excess of 50 000 ha and is designed not only to provide fuel and constructional timber but also to stabilise catchments. As in most such projects, development was based on alien tree species, notably *Eucalyptus*. A major problem associated with monospecific developments such as this is their susceptibility to pests. More recently, *Eucalyptus* plantings are giving way to conifers which, however, do not coppice. Re-planting after harvesting increases costs and the production time. Present anticipated fuel production cycles are in the order of 7-12 years (Steele and Ncholu 1983, Wickstead 1984).

Although felling of the earlier plantings has commenced, difficulties have been experienced in selling the timber although it costs only 50 cents per headload. This problem seems related to the relative inaccessibility of plantations which are frequently on hilltops.

There are few other fuelwood planting strategies in Lesotho although some families obtain wood from their own trees or from communal forests (Steele and Ncholu, 1983). The balance of the fuel needs are supplied by alternative fuels such as dung, paraffin and scrub.

POTENTIAL IMPACTS OF ALIEN SPECIES PLANTED FOR FUEL

The most promising species for timber production, whether in plantations, woodlots or agroforestry systems, have the potential to be invasive. This is a major disadvantage but is inevitable since "good" species are necessarily vigorous.

The National Academy of Science (1983) opens its catalogue of fuelwood species with a warning. It states that the recommended species are agressive and grow rapidly. They are appropriate for areas in which there is an acute fuelwood shortage. In areas where fuelwood is still available these recommended species should be introduced with great care and in any trials, local species should be given priority. To date all the fuelwood projects established in southern Africa have used introduced species. The National Academy catalog, however, includes nine species and 14 genera which are indigenous to southern Africa. These are as follows:

Indigenous genera	Indigenous species
Duvernoia	*Acacia nilotica*
Albizia	*Acacia senegal*
Calliandra	*Acacia tortilis*
Cassia	*Balanites aegyptiaca*
Commiphora	*Brachylaena illicifolia*
Croton	*Colophospermum mopane*
Dalbergia	*Hibiscus tiliaceus*
Excoecaria	*Tarchonanthus camphoratus*
Sapium	*Tarchonanthus minor*
Tamarix	
Terminalia	
Trema	
Ximenia	
Zizyphus	

Wells (1986) lists 789 species of alien plants in South Africa. This total excludes approximately 200 other species which may have originated outside the country. Most of the species with the potential to transform habitats are woody shrubs and trees (Wells et al, 1986), the very kinds of plants needed as fuelwood. The spread and establishment of many of these species is facilitated by human impacts (Sagar and Harper 1961). These include clearance of indigenous vegetation, abandonment of agricultural land, collection of timber in indigenous communities and its consequent opening up of the canopy, and grazing and browsing pressures. Some species introduced in the past for forestry have since become invasive transformer species, for example *Acacia dealbata*, *A melanoxylon*, *Hakea sauveolens*, *Caesalpinia decapetala*and a variety of *Eucalyptus* and *Pinus* species (Wells et al 1986).

In spite of the potential impact of alien woody species on indigenous plant communities there has been very little research into the biology of these species outside of the fynbos biome. A notable exception is *Acacia melanoxylon* because of its impact in indigenous forests (Macdonald et al 1986).

The potential effects of alien invasive species differ from biome to biome according to climatic and competitive factors. Woody plants are popularly considered to reduce erosion but it has been shown that dense stands of some species such as *Pinus* can increase erosion rates particularly where stands are harvested and burned (Cowling et al 1976, Henderson and Wells 1986). This may be due to the reduced herb layer growing under dense alien canopies. Along river courses, some species such as *Acacia*, *Pinus* and *Sesbania* have been responsible for accelerated erosion. These species are not adapted to flash floods and are consequently easily torn out of the river bank and so dislodging and exposing large volumes of soil (Henderson and Musil 1984, Brown and Gubb 1986).

Fires in the fynbos biome are more intense and environmentally damaging where there are stands of alien vegetation (Van Wilgen and Richardson 1985). In the grassland biome this is also true since rapidly growing woody invaders increase the fuel load (Henderson and Wells 1986). This is likely to be true in all those situations where woody alien growth is more rapid than that of the indigenous species.

Acacia species invaders increase the nutrient levels in soils. In particular, nitrogen, phosphorus and carbon cycles are greatly changed. In indigenous communities this may have severe impacts on species adapted to low nutrient levels (Macdonald and Richardson 1986). Invasion of the fynbos by invasive species has reduced both floral and faunal species richness (Macdonald et al 1986).

In other biomes the phenological characteristics of a species may be responsible for its success. Earlier and more rapid germination, drought tolerance and high seed production with efficient dispersal mechanisms are major contributory factors in the arid and semi-arid biomes (Brown and Gubb 1986). Particular threats in this regard are *Prosopis* species and *Melia azedarach*. These two species, together with *Eucalyptus* species, are the most successful invaders of this region although *Caesalpinia gilliesii*, *Casuarina equisetifolia* and *Tamarix ramosissima* are also cause for concern. Expensive eradication programmes are in operation to control *Prosopis* around Windhoek and in the Swakop river but the species is still planted in other areas (Brown and Gubb 1986). The spread of these species is associated with human settlement and agriculture where it is planted, and seeds dispersed by way of water courses.

In the wetter grassland and savanna biomes alien species are again associated with human impacts such as abandoned lands, railways and roads (Henderson and Musil 1984). *Acacia* species, *Caesalpinia*, *Sesbania* and *Prosopis* are the major threats to these indigenous habitats. Invasions are particularly heavy in the eastern Cape, Ciskei and Transkei where there is a considerable overlap of the ranges of a number of alien species. This is because of the region's dense settlement, the rainfall patterns and the associated increased planting of aliens.

Forests represent less than 1% of the land area of South Africa estimated at 2 000km^2-3 000km^2 (Huntley 1984). Such a small biome is particularly at risk should it become threatened by invasive species.

In the past, forests have been exploited by commercial interests and by traditional peasant communities. This has resulted in their degradation. This has been exacerbated by clearance for agriculture and by grazing/browsing stock within the forests (Geldenhuys 1983). Impacts such as these open up the canopy and the gaps created are particularly susceptible to colonisation by alien invader species. Apart from the gaps and the forest margins however, the forests are generally resistant to invasion (Geldenhuys 1986). Indeed Geldenhuys observes further that indigenous species such as *Pterocelastrus tricuspidatus*, *Rapanea melanophloeos*, *Podocarpus species*, *Olea capensis* and *Ocotea bullata* have developed as understory vegetation in old stands of *Pinus* and *Eucalyptus*. There are however some alien species such as *Cestrum laevigatum*, *Pittosporum undulatum* and *Psidium guajava* which have shown the capacity to invade closed forest. This latter species is recommended by the National Academy of Science as a suitable fuelwood/fruit tree.

Finally, large scale plantings of alien species may seriously disrupt water tables. *Eucalyptus* species in particular are deep rooted trees which utilise large volumes of water. This is so to the extent that *Eucalyptus* have been planted in order to assist with the drainage and drying of marshlands. A particular example is that of the Coto de Donana in Spain where *Eucalyptus* plantations have had a major impact on the ecology of the marsh. A component of the conservation programme for the area has been to fell large areas (Axell H E pers comm).

CONCLUSIONS

There is a great and immediate need for wood fuel and constructional timber. This need will increase in the future with the increasing population. An enormous commitment on the part of the government is necessary if community living standards are to be even maintained at existing levels. When the needs for environmental conservation are taken into account the issue assumes even greater urgency and complexity. Any hope for a solution will require urgent and widespread action ranging from reserach into management strategies for indigenous and exotic woody vegetation to planting strategies and public awareness campaigns.

1:50 000 SOUTH AFRICA SUID-AFRIKA

3327AC PRUDHOE

Refer to this Map as SOUTH AFRICA 1:50 000 Sheet 3327AC PRUDHOE
Verwys na hierdie Kaart as SUID-AFRIKA 1:50 000 Vel SECOND EDITION TWEEDE UITGAWE

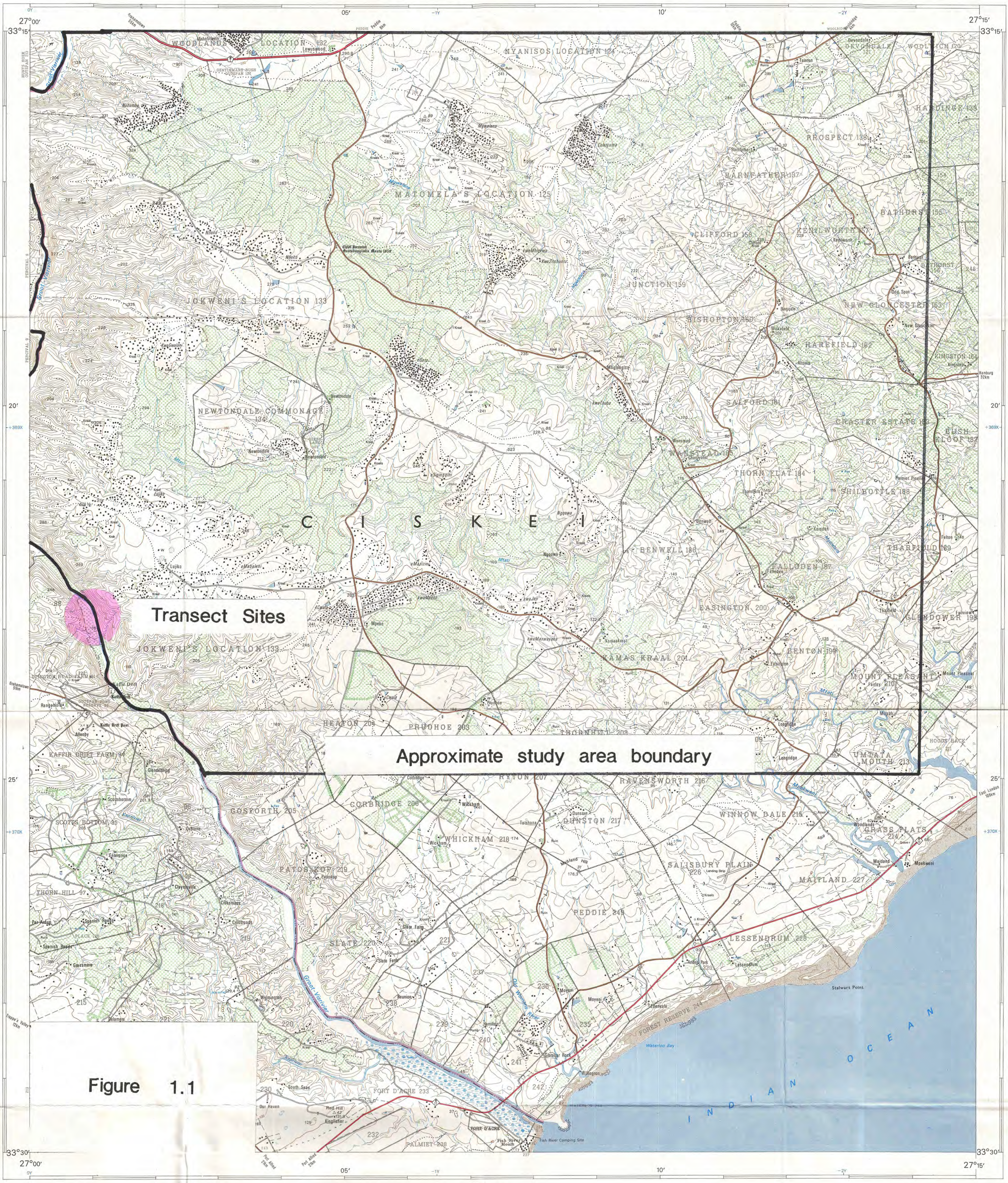


Figure 1.1

Published by the Chief Director of Surveys and Mapping, Private Bag Mowbray.
Gepubliseer deur die Hoofdirekteur van Opmetings en Kartering, Privaatsak Mowbray.

© State Copyright Staatsouteursreg

CONTOUR INTERVAL 20 METRES. KONTOERTUSSENRUIMTE 20 METER.

1:50 000

Printed by the Government Printer, Private Bag X85, Pretoria.
Gedruk deur die Staatsdrukker, Privaatsak X85, Pretoria.

Heights are in metres above mean sea level.
Hoogtes is in meter bo gemiddelde seespieël.

INDEX TO SHEETS INDEKS VAN VELLE

3327AC PRUDHOE SECOND EDITION TWEEDE UITGAWE 1981