A Landscape Approach used in Designing a Representative Reserve System for the Eastern Cape Province of South Africa

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SUMMARY

STUDY OVERVIEW

This study was undertaken in order to propose a representative system of reserves which would protect the biodiversity within the study area. A technique based on the "Gap Analysis Programme" was used. This involved the determination of the representativeness of natural landscapes within the existing reserves, the identification of species richness, endemism and conservation status hotspots. Rules were formulated according to a broad conservation strategy.

Once the rules had been set a reserve selection algorithm was run. Four scenarios were looked at: the first scenario merely modelled a reserve system based on the rule that 10 % of the landscape should be protected; the second looked at protecting 10 % of each landscape, but the proposed system had to include the important species hotspots; the third scenario proposed a reserve system based on the 10 % rule which included all existing reserves; and the final scenario included the hotspots, all existing reserves and met the 10 % protected landscape rule.

LANDSCAPE ANALYSIS

Land cover types were used as the Landscapes for the study. These land cover types were derived from satellite imagery of the study area. Twenty three classes of land cover were described (Table 2.2). Twelve of these land cover types were defined as natural land covers, five as agricultural land covers and four as disturbed land covers.

The initial land cover analysis revealed that the study area was very fragmented, in terms of natural land cover types Twelve land cover types, with a total area of

5470695 ha were fragmented into over 20 000 individual land cover polygons. Interspersed with these natural land cover areas are over 7000 agricultural land cover polygons and over 4500 disturbed land cover polygons.

All land cover patches with an area less than 100 ha were eliminated from the study with exception of those land cover types which only consisted of polygons smaller than 100 ha. This was done because it was reasoned that these polygons where not ecologically viable and that while they made up the majority of individual polygons, they only contributed less than 7 % of the total area.

HOTSPOT ANALYSIS

Species richness has been correlated with habitat diversity, it was, therefore, decided to identify quarter degree squares which were high in species richness, endemic species and red data book species. Data was only available for five vertebrate taxa, namely frogs, snakes, tortoises, birds and some species of mammals.

These data were analysed and manipulated on Geographic Information System software in order to identify "hotspots" for each of the categories and taxa. A hotspot is defined as a quarter degree square that represents the top 5 % of all data containing quarter degree squares. Within taxon and between taxa hotspots were identified.

The within taxon analysis looked at the coincidence of species richness hotspots, endemic species hotspots and red data book hotspots. The quarter degree squares where all three types of hotspots overlapped, for a particular taxon, were considered to be a critical hotspot.

Frogs, snakes and mammals were the only taxa that showed overlap of all hotspot types. The nine critical hotspots identified are tabled in Table 3.2.

The between taxa critical hotspots were those which exhibited overlap of all taxa. Both species richness hotspots and endemic species hotspots had only one quarter degree square that showed overlap of all taxa. In both cases this square was 3326BC. The red data book species category showed no more than two taxa overlapping and as such no square was considered to be critical.

The nine within taxon and one between taxa critical hotspots are shown in Table 3.6. Of particular interest is that five of the nine hotspots cover the area of the Amatola Mountains.

RESERVE REPRESENTATION

Land cover type and the critical hotspot representation within the existing reserve system were analysed. The reserve system used in the study included all areas administered by Eastern Cape Nature Conservation, National Parks Board, the former Ciskei Nature Conservation and the Algoa Regional Services Council. The combined area of these reserves make up slightly over 2 % of the total study area.

Land cover types within the existing reserves varied in degree of representation, from the land cover type Bare rock and Sand being represented well over the IUCN's recommended 10 % to saltmarshes, vleis, pans and closed canopy woodland not being represented at all. Table 4.3 shows to what degree the natural land cover types are represented within the existing reserve system.

Only three of the critical hotspot quarter degree squares coincided with existing reserves. The squares 3325CC, 3326AD and 3326BC either enclose small reserves within them or contained portions of larger reserves. Figure 4.2 shows the location of the critical hotspots in relation to the existing reserve system.

RESERVE SELECTION

Reserve selection was undertaken using a heuristic iterative algorithm. This algorithm identified sites for potential reserves, in an iterative process, based on various rules that are used in the model. The rules used in this model were:

- Each natural landscape should have at least 10 % representation within the reserve system.
- The most important hotspots should be included within the reserve system
- Existing reserves should be included in identifying the representative reserve system.

The model was run using four scenarios: the first determined a reserve system based only on representation of the land cover features; the second scenario identified a reserve system based on representation of the land cover features and the critical hotspots; the third scenario identified a reserve system based on representation of the land cover features and the existing reserve system and the final scenario identified a reserve system based on representation of the land cover features, critical hotspots and the existing reserve system.

Scenario one requires only fifteen quarter degree squares to represent 10 % of all natural land cover types, while in scenario two, twenty one quarter degree squares are needed. Forty two are needed in scenario three and forty nine for scenario four.

CONCLUSIONS AND RECOMMENDATIONS

From the results of the study, the following conclusions can be drawn:

- In most cases more than the required area of land cover types, used in this study, are found within quarter degree squares in which the existing reserves and critical hotspots fall.

- Based on the the rules laid out for the analysis the land cover types requiring special attention are Grassland, Wooded Grassland and the various types of Wetlands.

- The quarter degree square covering the Amatola Mountain region is significant due to it having a high critical hotspot representation..

It is, therefore recommended that the areas around the existing reserves be looked at for extending the existing reserve system. It is further suggested that this be achieved by the establishment of a buffer of conservancies around the reserves.

Special attention should be given to those land cover types which are either not presently represented or are poorly represented as well as to the critical hotspot areas. Of particular importance is the area of the Amatola mountains. Here it is suggested that the conservation agencies target the forestry companies in order to set up conservancies or private reserves.

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GLOSSARY

Biodiversity. The diversity of biological organisms and systems.

Biogeographic. The geographical processes of biological organisms and systems.

Digital Elevation Model. A regular array of elevations, normally in a square grid or hexagonal pattern, over a terrain.

Environmental Gradients. Gradients of environmental features, these gradients could be of elevation, rainfall or any other environmental variable.

Fragmentation. The change in a landscape from one large single landscape to many smaller "fragments" of that landscape.

Hotspots. A site of particular importance in terms of conservation, such as high species richness.

Karroid. Veld type found in the karoo regions of South Africa. Made up of low hardy shrubs.

Phytogeographical. Geographical processes as they relate to plants.

Pioneer species. First species to colonise an area. These species are usually hardy, fast growing with a short life cycle.

Polygon. Spatial term used to denote an area.

SLOSS. Single large reserve or several small reserves. Term coined during the debate on which reserve system optimises biodiversity, a single large reserve or several smaller reserves.

1. INTRODUCTION

1.1 RATIONALE BEHIND THE STUDY

Biodiversity loss

Population growth and habitat destruction have not spared South Africa. The World Bank (1994) estimates that South Africa's annual population growth is at present 2.2 % with approximately 22 % of the land surface being transformed in one way or another (MacDonald 1989). This habitat transformation will cause species that are presently at risk to disappear, and the status of species not currently at risk, to deteriorate (Margules 1989). Conservationists cannot secure the future for each species individually and the rescue of endangered species from extinction can be a controversial, time consuming and costly process, as the Californian Condor project has shown (Scott *et al.* 1993). Scott *et al.* (1993) propose that the most effective way to conserve biodiversity is through effective reserve placement and management that prevents any future species becoming extinct.

Species extinction is a natural process, however, it is estimated that the rate of species loss is 1000 to 10000 times the rate before human intervention (Wilson 1988). Approximately 5 % of the conservatively estimated five million species on earth are vertebrates and vascular plants with invertebrates making up in the region of 90 % of the total (Franklin 1993). Many of these invertebrate species are unknown, and might never be known unless ecosystems rather than individual species are protected.

Outline of broad study objectives

It is the objective of this study to look at biodiversity on a macro scale, such as the ecosystem or landscape level. It is envisaged that by protecting a representative area of each natural landscape, together with centres of vertebrate taxas' richness, endemism and rarity, a comprehensive reserve system will be proposed, which will protect most plant, vertebrate and invertebrate species.

The value of reserves to biodiversity

The important factors in effective conservation management, for biodiversity, are those of reserve selection and the status of the matrix of transformed land surrounding reserves (Lombard 1995a; Noss 1993). It is these areas that could form linkages between reserves. Much has been written about other factors that come into play in reserve design. Some of these factors, namely reserve size and reserve shape, were discussed during the SLOSS debate (Soulé and Simberloff 1986). However, without adequate biodiversity being represented in a reserve in the first place, there is little point in managing that reserve for biodiversity (Margules 1989), and even less point in debating whether or not a single large reserve is better than many small reserves.

The importance of the matrix of surrounding land, and corridors connecting the reserves within the matrix can be further emphasised when population viability is considered. Many of the present reserves are too small to support viable populations of many species. Therefore, by linking these areas to the matrix of untransformed land outside the reserve the maintenance of certain populations' viability will be enhanced.

Well planned reserves play an important role as sources of biodiversity. They provide refuges for species, in the short term, and if planned properly (with representative

environmental gradients), in the longer term, provide areas for species to move into in the event of global warming (Noss 1993).

1.2 STRATEGIES EMPLOYED TO IDENTIFY AREAS FOR PROTECTION

One of the primary goals of the International Union for the Conservation of Nature and Natural Resource's (IUCN) (1984) Commission on National Parks and Reserves was the conservation of representative natural areas. Various researchers have divided the world into biogeographic regions for the purpose of assessing the degree of biodiversity conserved in the world's natural areas (Dasmann 1972; Udvardy 1984). Dasmann (1972), however, pointed out that this broad classification was not sufficient to conserve all species as the larger the area, the more variable are the species within it. Recently many different strategies have been employed in reserve design and these will now be discussed.

The Nature Conservancy (Element Ranking, Scorecards)

The Nature Conservancy in the United States of America has set up conservation data centres around the United States. These centres gather information on the status and occurrence of rare plants, animals, and natural communities (Jenkins 1988). Conservationists set priorities using a ranking system that was developed for species, communities and sites. This technique concentrates on the rare and endangered species only, not on all species.

Protection of endemic species

This approach, put forward by Terborgh and Winter (1983) and Kepler and Scott (1985), maps the ranges of endemic birds and identifies areas rich in these endemic species. They assume that by protecting "hotspots" of endemic bird species other species might also be protected. It has, however, been shown that hotspots of richness or endemism seldom coincide within or between taxa (Crowe 1990; Siegfried 1992; Lombard 1995b).

Environmental gradient approach

Diamond (1986) argued that a simple and effective way of ensuring that most community types are protected is to include elevation and latitudinal gradients, in a proposed reserve system. He also proposed that reserves should be set up around isolated mountain ranges, as these are likely to be home to many endemic species. In reality, these "hotspots" of species richness seldom coincide with existing reserves, although Lombard (1995b) has shown some correlation between hotspots and nature reserves within South Africa. The environmental gradient approach is particularly relevant when considered together with global warming. By providing an environmental gradient within a reserve, species will be able to migrate up or down the gradient should global warming change their living environment sufficiently (Noss 1993).

Iterative approaches

Australian researchers have been leaders in the field of identifying land for conservation. Robertson (1974) recommended that a reserve system should represent each of the plant communities in a region. Bolton and Specht (1983) and Kirkpatrick

(1983) performed systematic geographical analyses of distribution data, to propose a system of representative reserves for a number of Australian regions. Kirkpatrick (1983) used an iterative algorithm to identify a system of reserve sites for Tasmania. This technique was the basis for the more recent work undertaken by Australian researchers.

Margules and Nicholls (1987), Margules *et al.* (1988), Nicholls and Margules (1993), Pressey and Nicholls (1989a,b) and Pressey and Nicholls (1991), used iterative algorithms and complementarity to make the reserve selection process more efficient. The simplest algorithm selected sites with unique features, then sites with the next rarest feature with the largest number of underrepresented features. The most important features of the iterative algorithm method are that all habitats, or all species in a data set, are represented in the minimum area possible.

Pressey *et al.* (1994) proposed a technique of reserve selection based on the "irreplaceability" of the site to the reserve system. This "irreplaceability" is a measure of the conservation value of the site in terms of its contribution to the achievement of the reserve systems goals.

Coarse filter approach (Gap Analysis)

The coarse filter approach proposes that common species will be protected if examples of all natural community types are protected (Noss 1987). It is this rationale that forms the basis of the "Gap Analysis" technique.

The "Gap Analysis" project is a nation wide project in the United States, to identify conservation areas using the above rationale (Scott *et al.* 1993). "Gap Analysis" is a technique that identifies the gaps in representation of biological diversity in areas

managed exclusively or primarily for the long term maintenance of populations of native species and ecosystems. Once identified, gaps are filled through new reserve acquisition or changes in management policies (Scott *et al.* 1993)

The "Gap Analysis" technique is a two part technique. The first component is the coarse filter component in which potential reserves are identified according to habitat or landscape diversity. The second component or the fine filter component addresses the actual richness of species.

Many reserve system design projects are based on species (Thomas *et al.* 1990) or landscape/land cover (Mackey *et al.* 1989). In this study both methods are combined as they both have merit, as a fine and a coarse filter respectively. This technique loosely follows the "Gap Analysis" technique.

1.3 OBJECTIVES OF THIS STUDY

This study loosely follows the two component "Gap Analysis" approach. The first component identifies potential reserves based on their complete representation of natural land cover types. This will then be refined to ensure that areas of vertebrate species richness, endemic vertebrate species richness and rare vertebrate species are included in the reserve system.

More specifically the study's objectives are:

1. To classify landscape or land cover types

2. To determine extents of landscapes and to what degree they are protected

3. To identify areas of vertebrate species richness, endemism and rarity

4. To use the information in points 2 and 3 to identify "gaps" in the existing reserve system. These "gaps" are areas within the matrix surrounding the reserves which either contain underrepresented landscapes or significant vertebrate species richness, endemism or rarity.

5. To test the utility of the technique used, identifying any shortfalls or limitations with the technique.

1.4 STUDY AREA

Extent

The study area chosen for this study is a portion of the Eastern Cape Province which falls, almost exclusively, within an area bounded in the west by 25°E, in the east by 29°E, in the north by 31°S and in the south by 34°S. Figure 1.1 indicates the bounds of the study area, as well as the major towns, settlements and roads falling within the study area.

Topography.

The Eastern Cape Province is an area of both climatic and topographic variability and diversity (Gibbs-Russell and Robinson 1981; Lubke *et al.* 1988). The altitude of the area varies from sea level in the south and south east to over 2000 m in the north. The ranges in altitude are best shown in Figure 1.2. Three major mountain ranges are found in the study area, the Amatola / Winterberg complex in the centre of the study area, the southern Drakensberg in the north and the eastern most part of the Cape Fold mountains in the south west. As a consequence of the numerous rivers dissecting the area, the topography is diverse with little flat country.

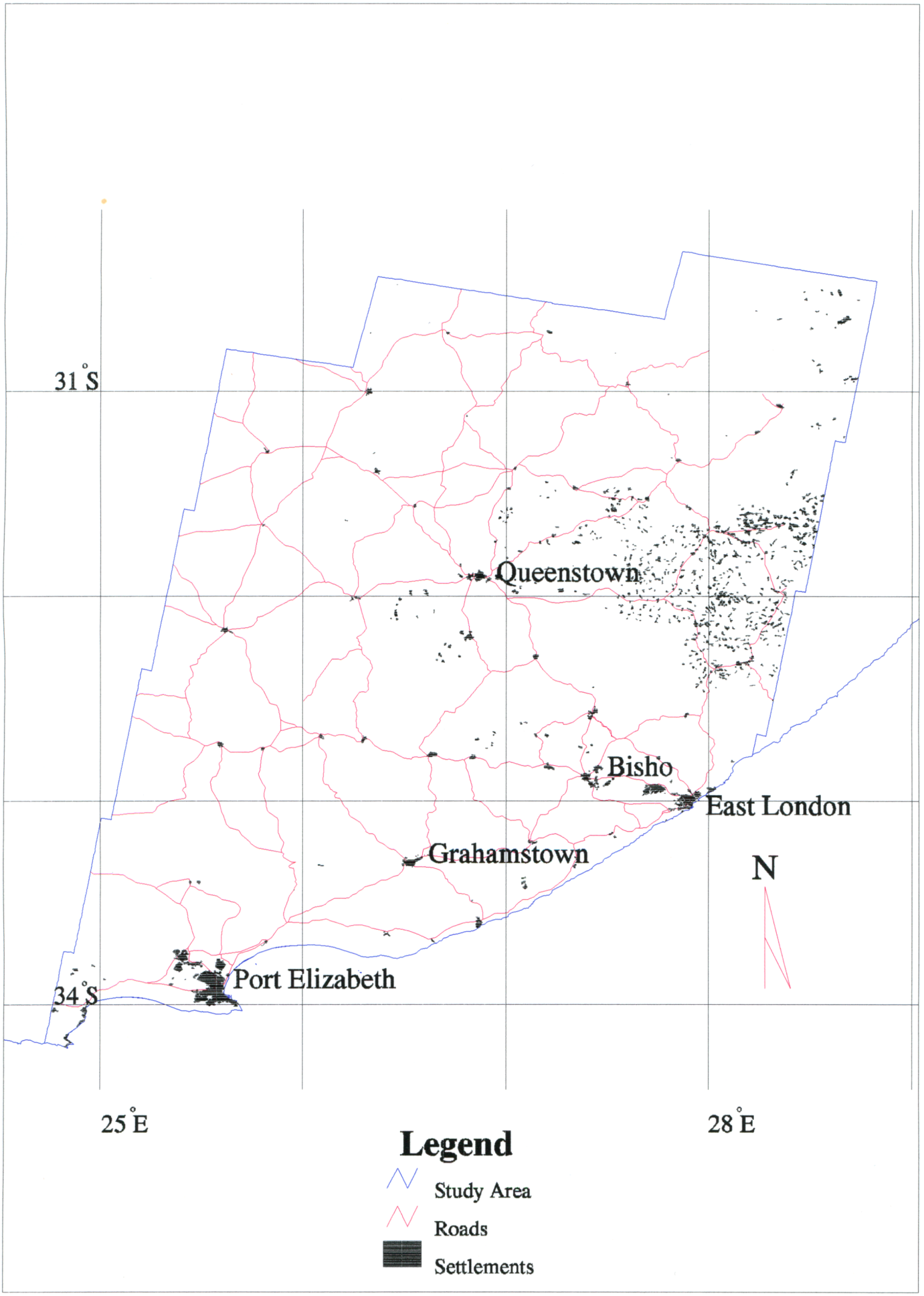

Figure 1.1 Boundaries of the study area showing major towns, settlements and roads

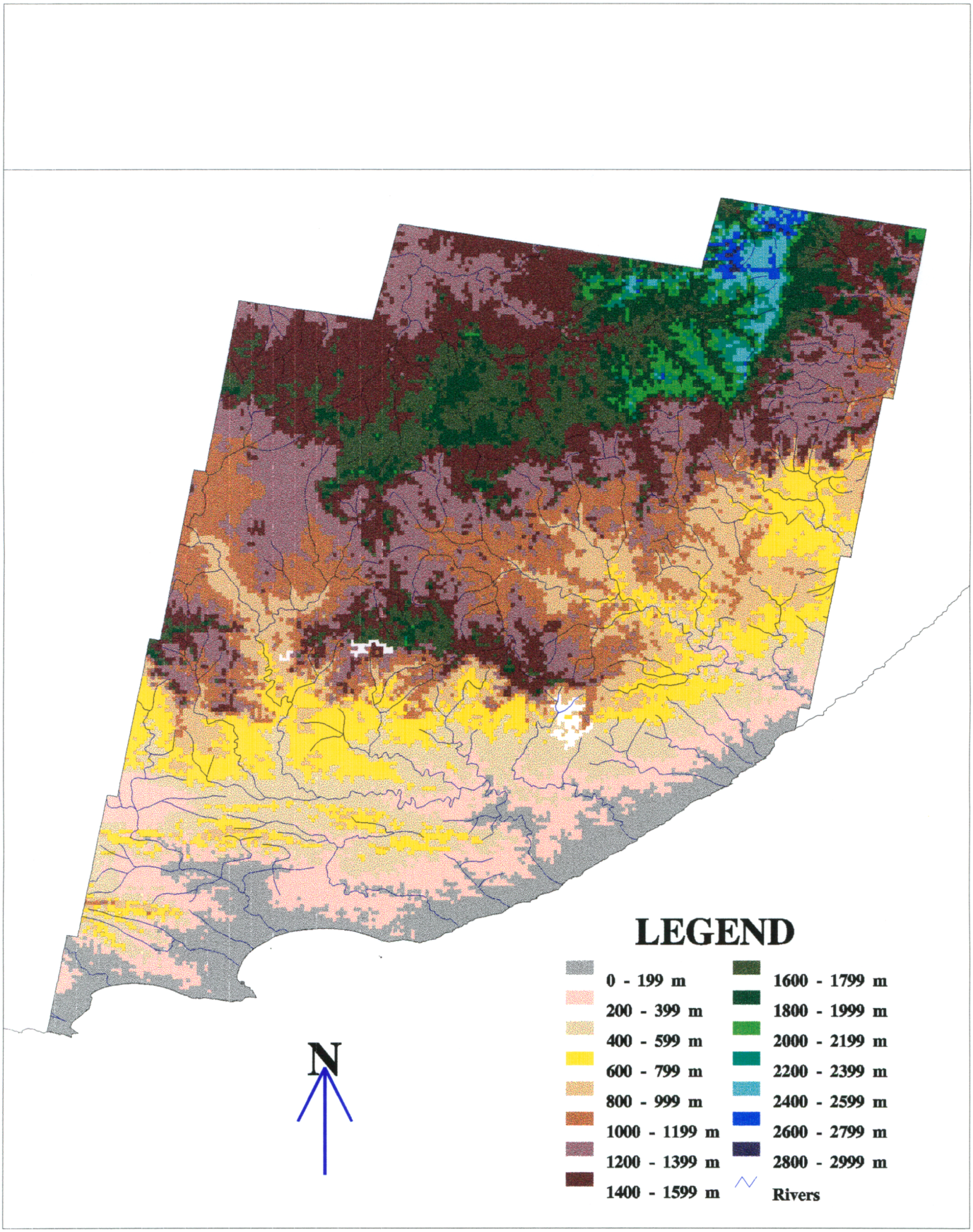

Figure 1.2. Rivers and altitude ranges within the study area, at 200 m intervals.

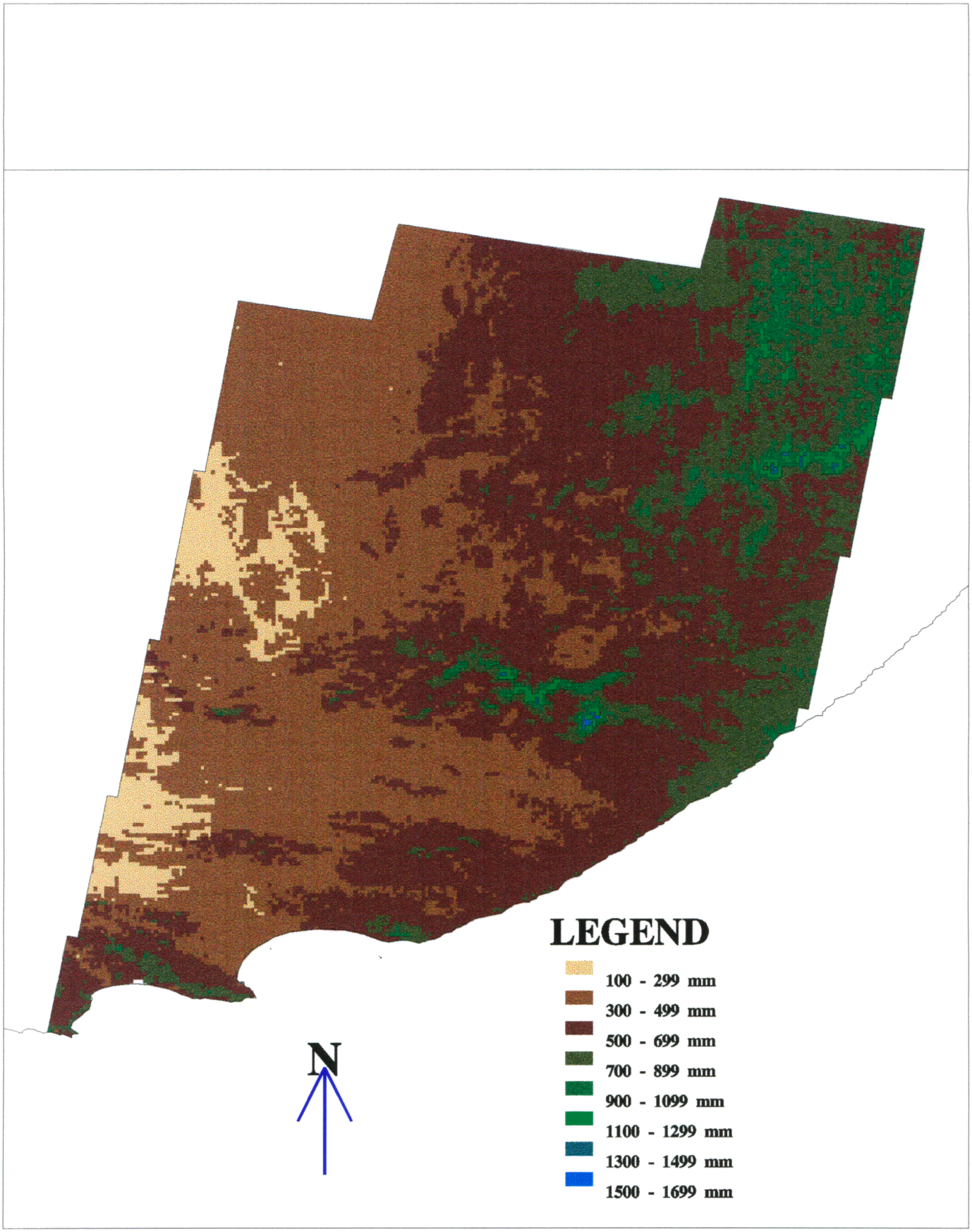

Figure 1.3. Mean Annual Precipitation within the study area, at 200 mm intervals.

Climate

Rainfall increases from inland to the coast and from the west to east, Figure 1.3; the highest rainfall is found on the southern slopes of the Amatola mountains, however, most of the area is semi-arid. The area also experiences two different rainfall seasons. Much of the coastal area, south of 33°S is in a winter / all year rainfall belt, while the rest of the study area exhibits summer rainfall patterns (Gibbs-Russell and Robinson 1981).

Temperatures also vary between inland and the coast. Table 1.1 shows maximum and minimum temperatures for summer and winter (Weather Bureau 1965).

Table 1.1 Summer and winter maximum and minimum temperatures ranges for the coastal and inland locations within the study area.

	Summer	Winter
Maximum	25-32°C	14-19°C
Minimum	16-21°C	2-10°C

The highest extremes in temperatures are found in the north west of the study area. Frost and snow commonly occur at higher altitudes.

Geology and soils

The geology of the study area is characterised by shales and sandstones of the Beaufort and Ecca Series (Haughton 1963). Throughout these series, intrusions of dolerite are common. In the north, sandstones make up most of the mountainous regions.

As a result of the shale and sandstone the soils exhibit characteristics of both these rock types.

Vegetation

The diversity of climate, topography and substratum result in phytogeographical complexity. The area is a transition zone between the Cape flora, characterised by the various forms of fynbos and a tropical one, characterised by savanna and bushveld (Lubke *et al.* 1988). All major vegetation biomes found in southern Africa - forest, grassland, savanna, thicket, karoo and fynbos - occur within the study area, forming a complex mosaic of communities.

1.5 STRATEGIES EMPLOYED TO IDENTIFY "GAPS" IN THE EXISTING RESERVE SYSTEM

1. Examine methods to classify land cover types, using available data. These data includes:

- Digital Elevation Model (Giving Aspect, Slope and Ruggedness)
- Land Cover (23 classes including natural, agricultural and disturbance classes)
- Vegetation
- Annual Rainfall
- Soil and/or Superficial Geology

Choose the most appropriate method and identify land cover types for the study area.

2. Using 1, evaluate each land cover type region in terms of area conserved, area available to be conserved and area required to be conserved.

3. Using vertebrate species distribution data identify hotspots of species richness, endemism and rarity.

4. Using the information accumulated during the study, propose a reserve system which will meet various criteria. Results will be derived from these criteria. It must be stressed that different criteria could be used which would result in a different scenario being put forward. A method of heuristic minimum set algorithms will be used for locating this reserve system.

1.6 SCOPE AND LIMITS OF THE STUDY.

Geographical area

The study area was defined by the data set with the most limited area, that of the land cover map.

Taxa considered

Only taxa where good data sets exist were used for the study. These included frogs, snakes, tortoises, birds and various mammal species. Insufficient data on other vertebrate taxa and all invertebrate taxa were available for the study area.

Reserves

The reserves identified for this study were those protected by traditional conservation agencies, these include the National Parks Board, Eastern Cape Nature Conservation, former Ciskei Conservation and Algoa Regional Services Council.

Other reserves (both public and private, including national heritage sites), were not included either owing to lack of information or owing to their questionable contribution to conservation.

1.7 RESEARCH TECHNOLOGY

The spatial patterns and relationships among the various data sets were examined using a geographic information system (GIS). A GIS is a computer system used to input, analyse and visualise spatial data (Haines-Young *et al.* 1993). A GIS is ideal for this study, as all data sets have a spatial component, and it is this component that is being investigated.

1.8 STATEMENT OF EXPECTED RESULTS

1. There are large areas of differing land cover types that are underrepresented, within the existing system of reserves.

2. Many reserves are not optimally situated for the best conservation results. The results of this study will be used to ensure long term viability of species, or adequate representation of all the different land cover types within reserves.

2. LANDSCAPES IN THE EASTERN CAPE: DETERMINATION AND ANALYSIS

2.1 INTRODUCTION

Lack of biogeographic data, particularly vegetation distribution data, often constrains the understanding of the depletion and degradation of natural environments (Belbin 1993). Addressing these gaps in the biological data is often an expensive exercise, time is spent on planning the best ways to collect the required data even before the survey begins. Once the survey has started costs accumulate, both financial and in time (Majer 1993; Burbidge 1991), so alternative strategies need to be used in order to evaluate the state of the natural environment. Abiotic factors, such as climate, substratum and topography have been used to identify factors that control the distribution and abundance of fauna and flora. Austin *et al.* (1990) used abiotic factors in generalised linear models to predict the distribution of eucalyptus species. In South Africa, Lloyd (1990) used abiotic factors to evaluate potential conservation areas along the Orange River, and Briers *et al.* (1993) used similar methods to assess the conservation value of land in the north Eastern Cape Province.

One of the challenges when using a number of biotic or abiotic environmental variables to classify landscapes, is the classification of these data into meaningful groupings. Classification can be defined qualitatively, using intuitive methods (Mabbutt 1968), or quantitatively using numerical methods (Mackey *et al.* 1989).

Spatial classification methods

Classification of data is essential in spatial information analysis, as it resolves these data into patterns that we are able to understand. Without classification or generalisation our brains would become "swamped" by detail (Burrough 1986).

The techniques developed for generalising data into a workable number of classes vary greatly; from classification based on heuristic knowledge of the data to stringent multivariate statistical techniques. Davis (*in litt.*) summarised different methods for classifying landscapes (Table 2.1). The most commonly used techniques can be divided into two broad categories, namely numerical methods and intuitive methods. Both these broad categories have been used in the past to classify landscapes and land cover types.

Table 2.1 Different landscape classification techniques as defined by Davis (*in litt.*)

Landscape Classification Techniques
1. Cluster Analysis of Environmental Variables
2. Mutual Information Analysis
3. Regression and Classification Trees
4. Use Soil Complexes in Elevational Life Zones on Uniform Lithology
5. Visual Interpretation of Photographs or Imagery (Technique Used)
6. Analysis of Point or Plot Data to Establish Environmental Relationships

Numerical Methods:

Numerical methods generally calculate either the similarity between areas, or their dissimilarity. This is done first by developing association matrices using techniques such as the Bray-Curtis coefficient (Bray and Curtis 1957). A clustering strategy is then applied to the association matrices in order to define classes. Two possible alternatives used for clustering are:

Agglomerative Hierarchical Methods. These methods operate on association or similarity matrices. An example of an Agglomerative Hierarchical Method is single linkage or nearest neighbour analysis (Digby and Kempton 1987). This technique can be described by considering an ordination of units in multidimensional space. The join that merges any unit with, either, another unit or a group involves the unit's nearest neighbour. The term single linkage is derived due to the single links between units and their nearest neighbour, that establish the clustering.

Divisive Hierarchical Methods. Divisive Hierarchical Methods are recommended over agglomerative methods (Hill *et al.* 1975) for the classification of features into broad categories. The simplest form of this method involves binary data (1 or 0; present or absent), where each group division is based on the state of a single feature. An alternative method is to divide the samples according to their score on the principal axis of an ordination. Group divisions are based on all units. Initially two groups are formed which are subjected to further ordination and division to form four groups, and so on (Digby and Kempton 1987). Hill *et al.* (1975) developed a hybrid of both of these methods which involves the selection of five indicator units which closely reproduce the initial one dimensional ordination. Each sample is scored for

presence/absence of each of these units, leading to an overall score on a six point scale which is divided to form two groups. These groups are then further divided by another ordination (Digby and Kempton 1987), thus the sample is divided hierarchically. In practice it is best to produce an exhaustive classification initially, then, later, to decide on the level of agglomeration (Lance and Williams 1986).

These two methods are the typical methods used in classification, with the divisive methods being the more common in ecology (Hill *et al.* 1975).

Intuitive Methods:

Intuitive or heuristic methods do not rely on rigorous mathematical modelling, but instead are based on the knowledge of individuals about the area being classified. There are many different examples and methods of non-numeric classification:

- Mabbutt (1968) identified a land classification scheme for Australia using a range of factors defined intuitively, the factors used included recurring patterns of landform, soil and vegetation. These were defined subjectively from aerial photograph interpretation.
- In Newfoundland land was classified, again heuristically, into ecoregions, based on land cover homogeneity, topography, soil and dominant vegetation type, the rationale being that an ecoregion has a distinctive, recurring pattern of vegetation and soil development which is controlled by regional climate (Damman 1983).
- Similarly, in South Africa, an ecoregion approach was used to identify landscapes, based on predicted vegetation, topography, mean annual rainfall, and geology (Everett and Quibell 1995).

Another classification technique is to classify areas, in the form of land cover type classes derived from remotely sensed data, using intuitive or heuristic methodology. This technique has been used in the past for the land cover type classification for the Californian Gap Analysis Program (Davis *et al.* 1994). This technique was used recently to produce a land cover map for a portion of the Eastern Cape Province (Thomas 1995) and provides the basis for the landscapes used in this study.

All these methods have provided workable results. Whether or not the results are comparable with those classified numerically is open to conjecture. A comparison between these two techniques would constitute a separate study.

The classification used in this study needed to provide results reasonably quickly and easily, but also needed to be defensible. It was decided to use the areas classified from Satellite Imagery (Thomas 1995). The rationale for using the land cover classification was based on the following:

1. Previous studies (Jennings in press) have shown that homogeneous types of natural land cover are important in providing spatially explicit information for the conservation of biological diversity.

2. There is a lack of supplementary data to undertake other classification techniques.

3. The available environmental, climatic and topographic data varies in scale from 1 : 250 000 to 1 : 1 500 000 which makes the meaningfulness of any resultant classification questionable.

2.2 *METHODS USED TO DERIVE LAND COVER TYPES*

Field reconnaissance

Prior to visual classification, the study area was "ground truthed". This involved flying over the study area, at an altitude of 1000 m above the ground, and marking prominent land cover type features, seen on the flight path, on prints of the satellite images. Figure 2.1 shows the flight path used for the aerial reconnaissance undertaken for the study.

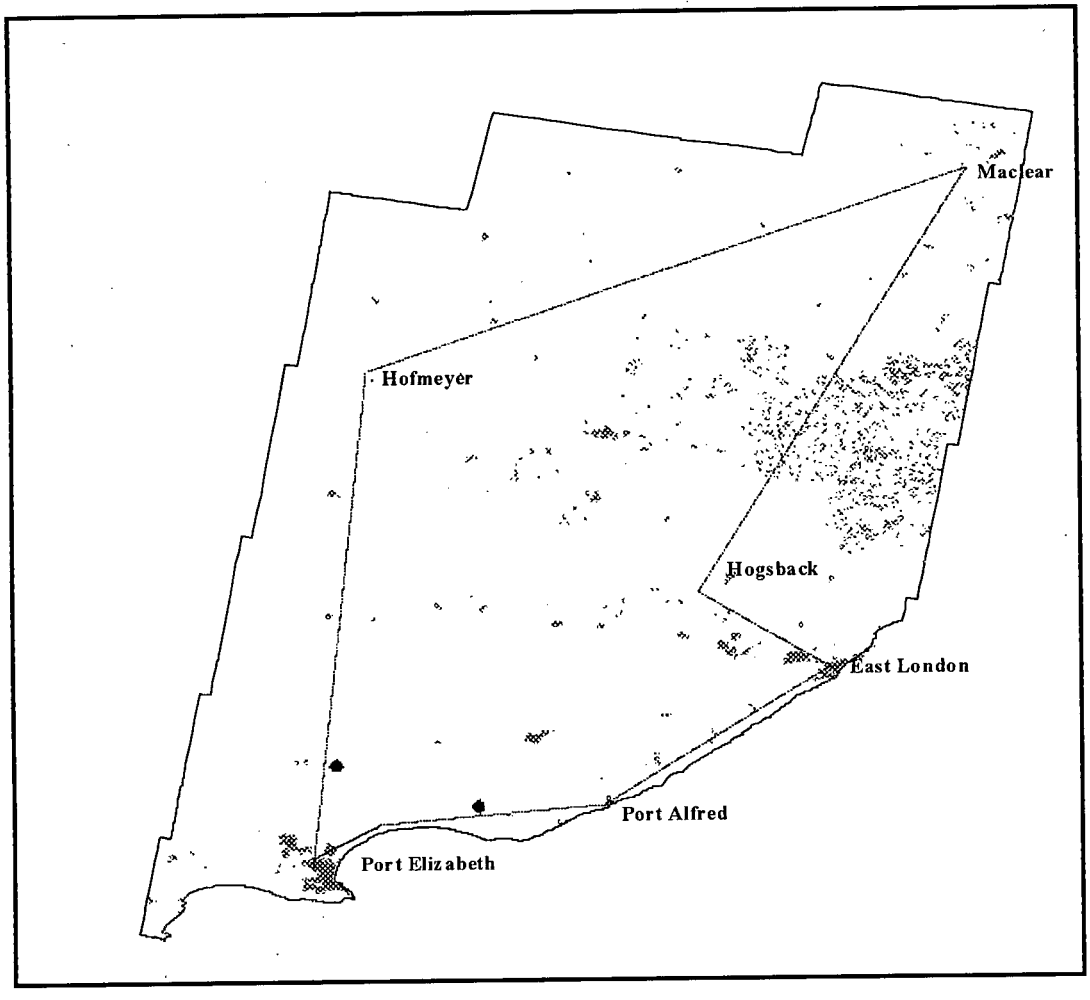

Figure 2.1 Aerial reconnaissance flight path across the study area. Undertaken in order to identify features prior to the visual classification of the satellite images.

Further field reconnaissance was carried out by car and foot during the classification phase in order to confirm or check classifications (Thomas 1995).

Mapping strategy

Land cover types were derived by visual interpretation of Satellite Imagery. The classification was done visually, rather than computer assisted. The advantage of visual classification over computer assisted classification is that humans are able to detect spatial patterns where as computers analyse the image one pixel at a time (Estes *et al.* 1983). In this way, polygons can be drawn around homogeneous land cover types.

Classification

The Landsat TM images used were from September 1992 and October 1993 and were in bands 4, 5 and 3. These bands were used to enhance vegetation visualisation. The classification scheme used was based on that derived by Thompson (in press). See Appendix 1.

The process of land cover type classification, from the satellite images, was similar to that undertaken by the Californian Gap Analysis Program (Davis *et al.* 1994). However, instead of the land cover type classes being digitised directly on screen using Arc/Info's Image Integrator module (ESRI 1995), the polygons of each land cover class were traced onto acetate film which covered the enlarged hardcopy 1:125 000 Landsat 5 Thematic Mapper (TM) images. The traced polygons were then converted into digital information via manual digitising using a digitising tablet linked to the Arc/Info software (ESRI 1995).

Species composition cannot be identified with any degree of accuracy from Landsat TM images, thus the vegetation classes could only be mapped according to land cover type. A study of the accuracy of the interpretation of the Landsat images is being undertaken by Fairbanks *et al.* (submitted).

Table 2.2 The land cover classes derived for the study were:

Natural land cover types	Agricultural land cover types	Disturbed land cover types
Bare Rock/Sand	Dryland Commercial Agriculture	Degraded Areas
Bushland/Thicket	Forest Plantations	Erosion Scars/Dongas
Grassland	Irrigated Commercial Agriculture	Industria
Indigenous Forest	Mixed Agriculture	Settlement
Low Shrubland (Fynbos)	Subsistence Agriculture	
Low Shrubland (Karoo)		
Pans (Wet and Dry)		
Rivers and Open Water Bodies		
Saltmarshes		
Vlei Wetland		
Wooded Grassland (Open Canopy)		
Woodland (Closed Canopy)		

The final delineation of the land cover type units was an iterative process based on evidence from the satellite imagery, existing vegetation maps and field reconnaissance. See map Figure A1 in Appendix 1.

Land cover type analysis

Summary statistics for the various land cover type classes were determined. These were:

- Total area of each land cover type
- Percentage of study area covered by each land cover type class
- Number of polygons of each land cover type
- Frequency of polygons occurring in the following two classes:

  Less than 100 ha

  Greater than 100 ha

Note: The term polygon is used to describe an isolated unitary land cover area.

2.3 RESULTS

Natural land cover types

The natural land cover types were analysed first. Figure 2.2 shows the extent of the natural land cover types within the study area.

Table 2.3 lists the summary statistics of the natural land cover types in the study area. In this table it can be seen that the greatest area of all the land cover types are found in the polygons greater than 100 ha in extent, however, the majority of all polygons are areas less than 100 ha. There is a high degree of fragmentation amongst the land cover types leading to most polygons being under 100 ha. Table 2.4 summarises these findings. The table lists the percentage of polygons, of each land cover type, that are less than 100 ha. The proportion of land cover type "fragments" making of the total area of the land cover type are also listed.

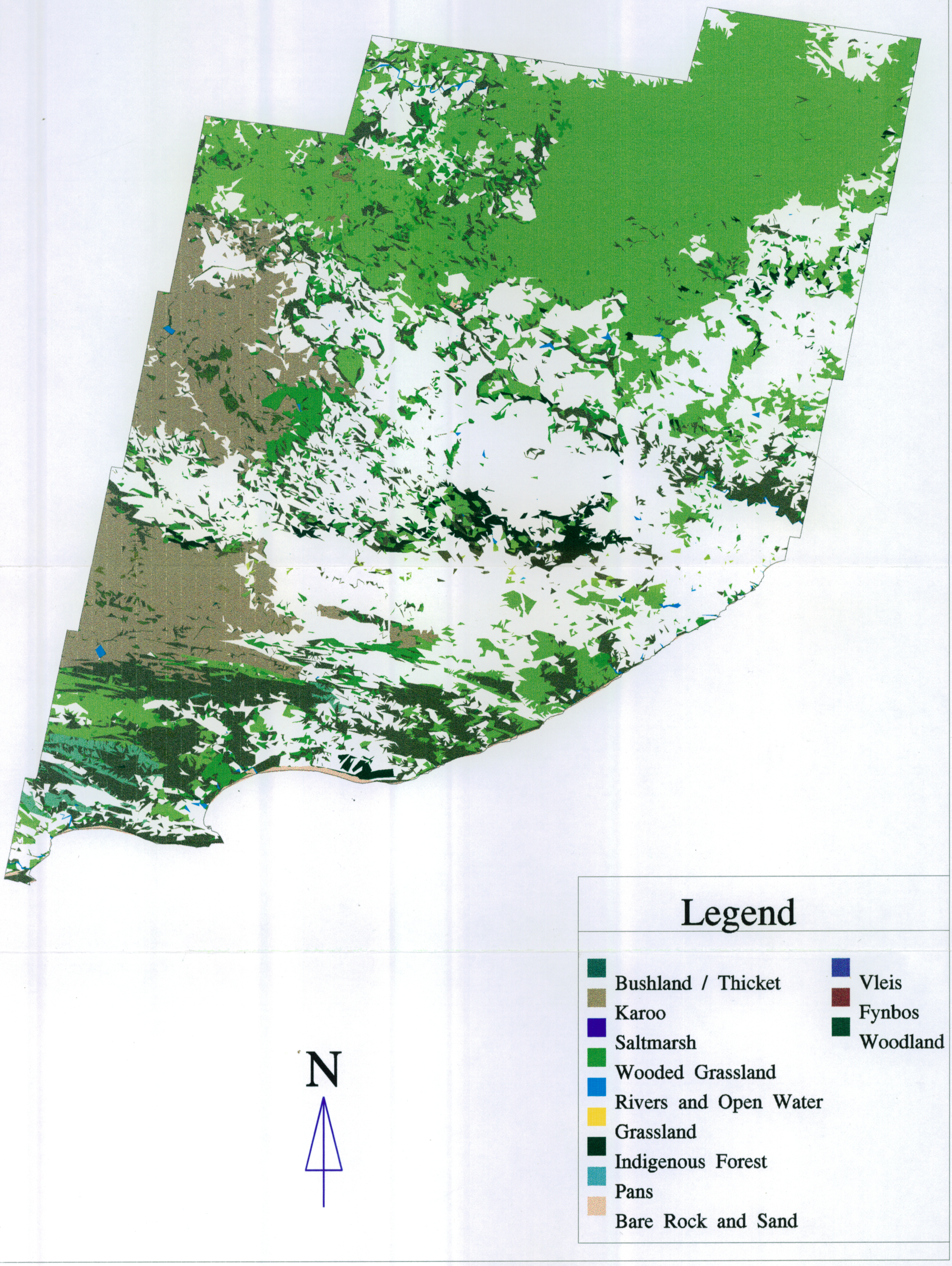

Figure 2.2. Extent of natural landscapes within the study area.

While fragments under 100 ha of each land cover type make up the majority (in all cases except the Karoo land cover type) of the number of polygons comprising a land cover type class, they are insignificant when compared to the proportion of the total area they comprise.

Table 2.3 Summary statistics of the extent of natural land cover types within the study area. (n represents the number of polygons in each category. Mean represents the mean area of polygons in each land cover type and SD represents the standard deviation around that mean).

Land cover type	Area of land cover type (ha)	% of total study area covered by land cover type	Total area of polygons greater than and equal to100 ha	Total area of polygons less than 100 ha
Study Area	10059446	100 %		
Bare rock & Sand	29597 Mean = 126 SD = 730	0.3 %	24222 (n = 31)	5376 (n = 235)
Bushland / Thicket	1099701 Mean = 129 SD = 1601	10.9 %	913967 (n = 1413)	185734 (n = 7092)
Fynbos	73987 Mean = 289 SD = 1600	0.7 %	68609 (n = 64)	5379 (n = 192)
Grassland	2590235 Mean = 1371 SD = 38051	25.8 %	2552760 (n = 711)	37474 (n = 1178)
Indigenous Forest	132672 Mean = 135 SD = 1032	1.3%	115856 (n = 145)	16817 (n = 838)
Karoo	896816 Mean = 7867 SD = 53390	8.9 %	895558 (n = 72)	1258 (n = 42)
Pans (Wet & Dry)	1700 Mean = 32 SD = 94	0.0 %	1335 (n = 4)	366 (n = 50)
Rivers & Open Water	24546 Mean = 16 SD = 89	0.2 %	14736 (n = 33)	9810 (n = 1466)
Salt Marsh	10 Mean = 10 SD = 0	0.0 %	0	10 (n = 1)
Vleis	329 Mean = 12 SD = 12	0.0 %	0	329 (n = 28)
Wooded Grassland	620536 Mean = 95 SD = 398	6.2 %	455444 (n = 1298)	165092 (n = 5204)
Woodland	566 Mean = 38 SD = 45	0.0 %	184 (n = 1)	382 (n = 14)
Total area of natural land cover type	5470695	54.3 %	5042669 (n = 3772)	428026 (n = 16340)

Table 2.4 List of the percentage of each polygon less than 100 ha and the proportion these polygons make up of the total study area.

Land cover type	Number of polygons greater than 100 ha	Number of polygons less than 100 ha	Percentage of polygons less than 100 ha	Percentage of each land cover area made up of polygons less than 100 ha
Bare rock & Sand	31	235	88.4 %	18.1 %
Bushland / Thicket	1413	7092	83.4 %	16.9 %
Fynbos	64	192	75.0 %	7.2 %
Grassland	711	1178	62.4 %	1.4 %
Indigenous Forest	145	838	85.3 %	12.7 %
Karoo	72	42	36.8 %	0.1 %
Pans (Wet & Dry)	4	50	92.6 %	21.5 %
Rivers & Open Water	33	1466	97.8 %	39.9 %
Salt Marsh	0	1	100.0 %	100 %
Vleis	0	28	100.0 %	100 %
Wooded Grassland	1298	5204	80.0 %	26.6 %
Woodland	1	14	93.3 %	67.5 %

Agricultural land cover types

Figure 2.3 shows the extent of the agricultural land cover types within the study area and Table 2.5 provides the summary statistics of these agricultural land cover types.

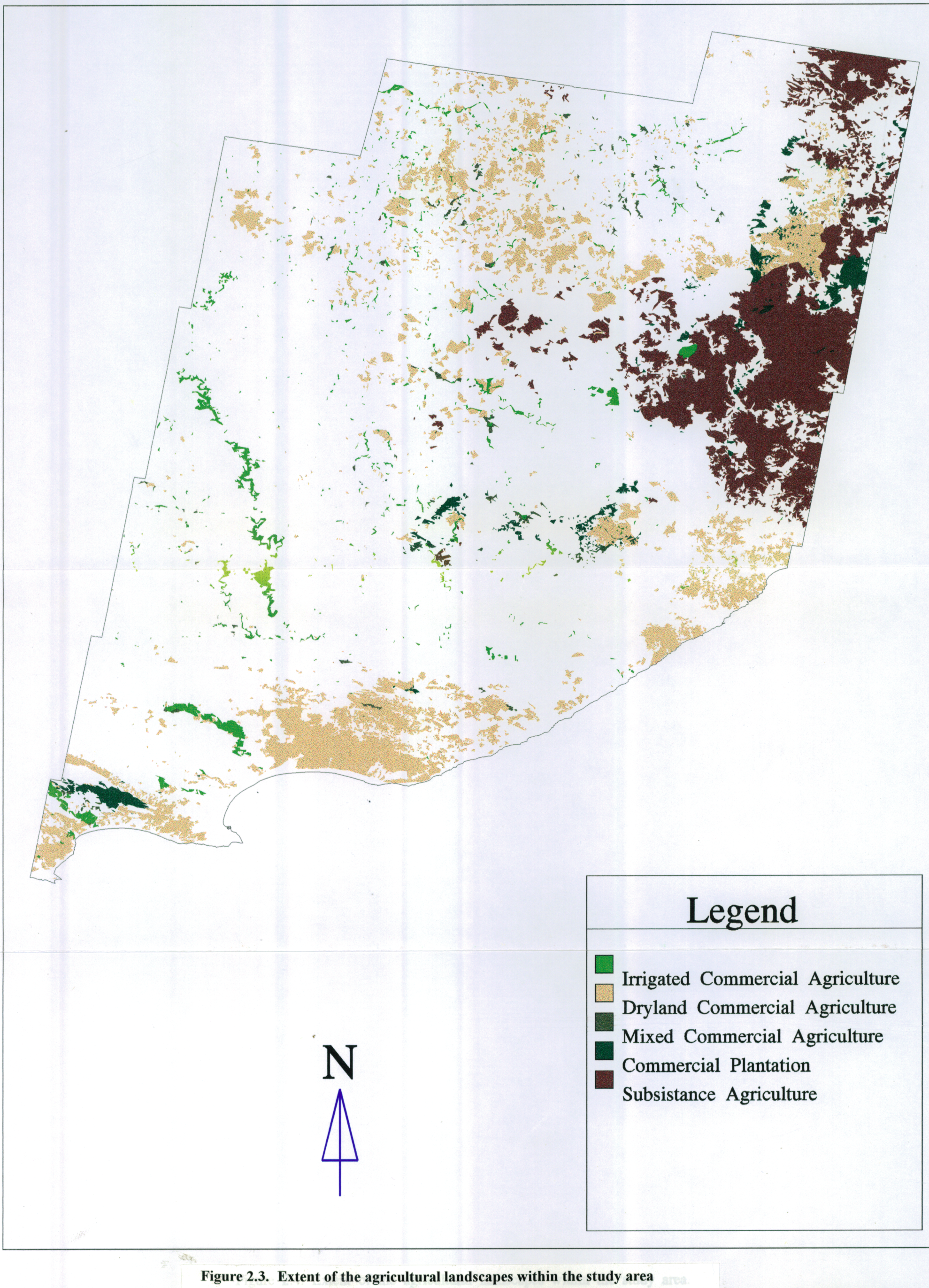

Figure 2.3. Extent of the agricultural landscapes within the study area

Table 2.5 Summary statistics of the agricultural land cover types within the study area. (n represents the number of polygons in each category. Mean represents the mean area of each land cover type and SD represents the standard deviation around that mean).

Land cover type	Area of land cover type (ha)	% of total study area covered by land cover type	Total area of polygons greater than and equal to100 ha	Total area of polygons less than 100 ha
Study Area	10059446	100 %		
Dryland Commercial Agriculture	810481 Mean = 351 SD = 2593	8.1 %	758624 (n = 780)	51857 (n = 1529)
Irrigated Commercial Agriculture	131915 Mean = 99 SD = 446	1.3 %	97382 (n = 182)	34533 (n = 1155)
Mixed Commercial Agriculture (Dryland & Irrigated)	28008 Mean = 129 SD = 176	0.3 %	22062 (n = 79)	5946 (n = 138)
Commercial Forestry Plantations	108232 Mean = 38 SD = 475	1.1 %	85126 (n = 114)	23106 (n = 2752)
Subsistence Agriculture	678074 Mean = 1899 SD = 17042	6.7 %	670534 (n = 199)	7540 (n = 178)
Total area of agricultural land cover type	1756709	17.5 %	1633728 (n = 1354)	122981 (n = 5752)

As with the natural land cover types, most of the agricultural land cover type polygons are less than 100 ha in area, with the exception of subsistence agriculture. Table 2.6 shows the proportion of polygons of the various agricultural land cover types which are less than 100 ha in extent together with the proportion, in area, that they represent of the total land cover type area.

Table 2.6 List of the percentage of each agricultural land cover type that is found in areas less than 100 ha and the proportion these polygons make up of the total land cover type area.

Land cover type	Number of polygons with areas greater than 100 ha	Number of polygons with areas less than 100 ha	Percentage of land cover type made up of polygons less than 100 ha	Percentage of each land cover area made up of polygons less than 100 ha
Dryland Commercial Agriculture	780	1529	66.2.%	6.4 %
Irrigated Commercial Agriculture	182	1155	86.4 %	26.2 %
Mixed Commercial Agriculture (Dryland & Irrigated)	79	138	63.6 %	21.2 %
Commercial Forestry Plantations	114	2752	96.0 %	21.4 %
Subsistence Agriculture	199	178	43.2 %	0.7 %

Proportions of areas under 100 ha, for the agricultural areas, show similar trends to the natural areas, namely most (over 60 %) of the total number of polygons representing a particular land cover type are found in polygons smaller than 100 ha, with the exception of subsistence agriculture. Again, these areas under a 100 ha make up an insignificant proportion of the total area.

Disturbed land cover types

Figure 2.6 shows the extent of the disturbed land cover types within the study area and Table 2.7 gives the summary statistics of the disturbed land cover types in the study area. Similar trends appear if one compares the natural area and agricultural land cover types, with a high proportion of the number of polygons making up a particular land cover type being under 100 ha in area.

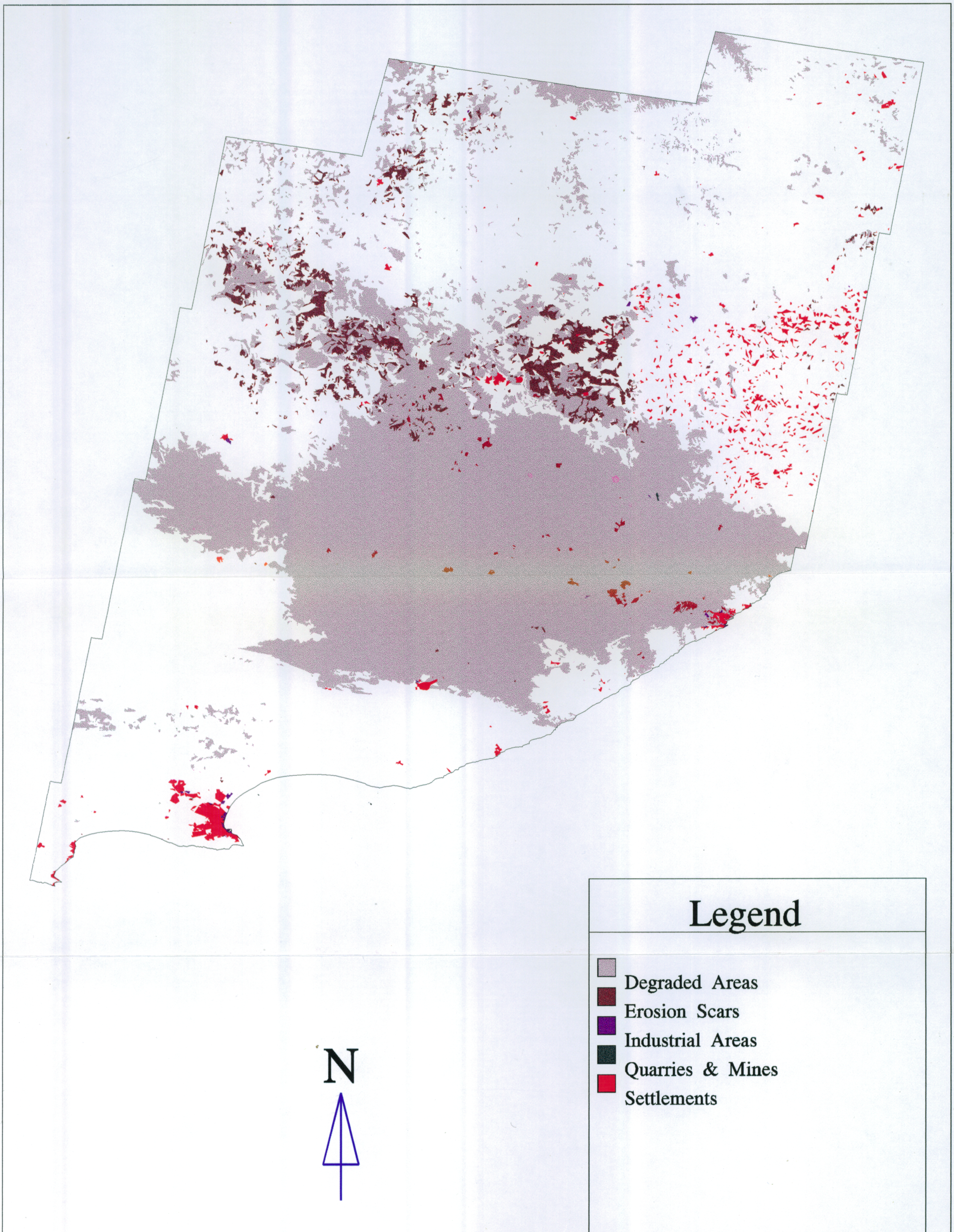

Figure 2.4. Extent of the disturbed landscapes within the study area

Table 2.7 Summary statistics of the disturbed land cover types within the study area.

Land cover type	Area of land cover type (ha)	% of total study area covered by land cover type	Total area of polygons greater than and equal to100 ha	Total area of polygons less than 100 ha
Study Area	10059446	100 %		
Degraded Land	2481679	24.7 %	2419798	61881
	Mean = 904		(n = 899)	(n = 1845)
	SD = 28446			
Erosion Scars	191567	1.9 %	167926	23641
	Mean = 192		(n = 247)	(n = 749)
	SD = 975			
Industry	3896	0.0 %	3147	749
	Mean = 130		(n = 12)	(n = 18)
	SD = 147			
Quarries	286	0.0 %	261	25
	Mean = 95		(n = 2)	(n = 1)
	SD = 143			
Settlement	116386	1.2 %	90522	25863
	Mean = 146		(n =257)	(n = 540)
	SD = 611			
Total	2793814	28 %	2681654	112160
			(n = 1417)	(n = 3153)

Table 2.8 List of the percentage of each agricultural land cover type that is found in areas less than 100 ha and the proportion these polygons make up of the total land cover type area

Land cover type	Number of polygons greater than 100 ha	Number of polygons less than 100 ha	Percentage of polygons less than 100 ha	Percentage of each land cover area made up of polygons less than 100 ha
Degraded Land	899	1845	67.2 %	2.5 %
Erosion Scars	247	749	75.2 %	12.3 %
Industry	12	18	60.0 %	19.2 %
Quarries	2	1	33.3 %	8.7 %
Settlement	257	540	67.8 %	22.2 %

2.4 *DISCUSSION*

Overview

From a total study area of 10059446 ha, made up of a total number of 31788 separate land cover type polygons, 25245 or 79 % of polygons are smaller than 100 ha. However, these polygons only constitute 663167 ha or 7 % of the total study area.

The natural land cover types of the study area comprise at least 54 % of the study area with a total of 3772 polygons over 100 ha in area and a total of 16340 polygons under 100 ha. The other two categories of land cover type, namely agricultural and disturbed, combined, represent 45 % of the study area, a total of 2771 polygons over 100 ha and 8905 polygons under 100 ha. These figures indicate, that while there are significant natural areas over 100 ha in extent, the whole study area displays a high degree of fragmentation, with almost as many disturbed and agricultural polygons, over 100 ha, as there are natural land cover type polygons. There are also almost twice as many natural land cover polygons under 100 ha as there are combined agricultural and disturbed land cover types under 100 ha.

Two points must be noted:

1. The total percentage of the natural, agricultural and disturbed land cover type categories does not add up to 100 % as a small percentage (0.35 % or 38227 ha) of the Landsat scenes were obscured by cloud cover.

2. It was stated that at least 54 % of the study area was made up of natural land cover types. Some of the degraded areas and agricultural areas could have been misinterpreted from the satellite images. According to La Cock (pers. comm.) and

Palmer (pers. comm.) the severe drought of 1992 and 1993 could have given some of the natural areas an appearance of degradation. Palmer and Avis (1995) recently undertook a study in the Great Fish River Valley, an area that falls within the degraded classification of this study. They identified three levels of degradation:

a. Severe degradation: production potential of the natural rangeland approaching zero, and having no chance of recovery to a more productive state.

b. Degradation: production potential of the natural rangeland is significantly reduced but potential for improvement exists.

c. Marginal degradation: production potential of the natural rangeland retains most of its ecological stability and production potential.

The degraded land cover type classification used in this study was very broad, and it is possible that some of the degraded areas fall within Palmer and Avis's (1995) marginal degradation category. As such, when more favourable conditions prevail, the land cover types could recover enough to be classified as a natural land cover type.

La Cock (pers. comm.) also notes that some of the grasslands alongside the Fish River can be mistaken for agricultural lands.

Results of natural land cover type fragmentation

The effects of landscape fragmentation are well documented. MacArthur and Wilson (1967) have predicted that remnants of habitats will lose species at a measurable and predictable rate. Further, they predict that if the remnants are isolated and small, the number of species will decline to zero. Increased fragmentation increases the edge

effect on the landscape, owing to an increase in the relative boundary of each landscape (Wilcox 1980).

In a project undertaken in Western Australia, the effects of landscape fragmentation were studied (Saunders *et al.* 1993). It was found that the hydrological balance of the soil changed in cleared areas resulting in increasing salinity, erosion, acidification and compaction of the soil. The clearing eventually had an effect on the arable farm land, by increasing salinity of the soil. Saunders *et al.* (1993) also found that there was a bias to which areas were cleared, tending toward clearing accessible areas and leaving inaccessible areas. They also found that there was a stimulation of weed (pioneer species) which invaded the landscape fragments, all these factors giving rise to an extinction of many plant species. As a consequence of the loss of habitat, vertebrate species numbers also declined.

The minimum viable area for a natural landscape varies from one landscape to the next. Large tracts of land are needed to sustain a viable karroid or grassland land cover type (Palmer and Avis 1995), whereas far smaller areas are needed to sustain a viable vlei or fynbos land cover type (Cowling and Bond 1991), this is not to say that species will not be lost, just that natural processes will be able to function on a smaller area.

Resolutions and considerations

The following resolutions can be taken forward to the reserve selection section of this study:

1. Only natural land cover types will be used to identify a potential reserve system. No information was available on cultural and aesthetic features, so these factors cannot be considered for the study.

2. Only areas greater than 100 ha will be used for the identification of a potential reserve system. This reduces the number of polygons to be processed without severely affecting the areas of land cover types being considered. This also removes areas which are possibly too small to be viable. Exceptions to this are where a land cover type consists only of areas smaller than 100 ha, these land covers are those that naturally occur in small patches, such as wetland types and woodland.

Considerations taken into account were; that the land cover types within this classification represent only a "snapshot" in time; and that the prevailing seasonal and long term climatic events as well as land management strategies have produced the land cover type as classified for this study. However, all these factors are dynamic, and as such, the land cover types are dynamic and subject to change.

3. EASTERN CAPE VERTEBRATE SPECIES RICHNESS

3.1 INTRODUCTION

Hotspots of both flora and fauna species richness, endemism and red data book richness are often used in the assessment of an area's conservation potential (Williams *et al.* submitted; Williams and Gaston 1994; Kershaw *et al.* 1994; Scott *et al.* 1993; Garcia 1992; Rafe *et al.* 1985). It is well known and documented that species richness, or α (alpha) diversity is correlated with habitat diversity, or χ (Gamma) diversity (Rafe *et al.* 1985; Ryti 1992; James and Wamer 1982; Cornell and Lawton 1992; Faith and Norris 1989; Hejl 1992).

Do "Hotspots" for different taxa correspond?

The use of the concept of correspondence of hotspots for different taxa for identifying potential reserves is a debatable point. In most studies, hotspots of one taxon infrequently coincide with hotspots of other taxa (Ryti 1992; Sætersdal *et al.* 1993; Prendergast *et al.* 1993; Lombard 1995b). However, Lombard (1995b) maintains that special attention must be focused on areas where congruency does occur between taxa. Lombard (1995b) stresses the importance of not using the hotspot method in isolation, but to use it in conjunction with other measures of conservation potential. In this study, species hotspots are used in conjunction with land cover representation, to identify areas of high conservation potential.

Completeness of species databases

The unavailability of complete databases in South Africa is well documented, with many authors expressing concern about this lack of data (Lombard *et al.* 1992;

Lombard 1993, Van Jaarsveld and Lombard 1995). These authors have identified the need for a national strategy to update these databases. However, important information can be derived from the present data sets, particularly when used in conjunction with land cover data.

In this study the following definitions apply:

- Species richness:- Number of species breeding in the study area
- Endemic species:- Species occuring only within the southern African subregion.
- Red data book species:- Species listed as being under threat by the various taxas' red data books

3.2 METHODS

Data

The data sets used for this study comprised presence-only data, per quarter degree square (QDS = 15 min x 15 min) for five vertebrate taxa within the study area. As with Lombard (1995b), the data were obtained from various sources (Table 3.1).

Table 3.1 Taxa included in the "hotspot" study, and the sources of each taxon's presence-only data

TAXON	DATA SOURCE
Frogs	D. Drinkrow. South African Museum
Snakes	A.T. Lombard. Percy FitzPatrick Institute of African Ornithology
Tortoises	W. Branch. Port Elizabeth Museum
Birds	Southern African Bird Atlas Project (Harrison 1992)
Mammals	G. Bronner. Transvaal Museum

Not all taxa are fully represented:

1. Mammal data include the orders Carnivora, Chiroptera and Insectivora, and endemic or Red Data Book species (Smithers 1986) within the orders Lagomorpha, Macroscelidea and Rodentia. Other orders were not considered on the basis of incomplete taxonomy or poor data.

2. Bird data were used only for those species that breed within South Africa.

3. Tortoises include both tortoises and terrapins.

Analytical techniques

A spatial database was compiled using the species distribution data. This database was then manipulated and queried using the Arc/Info and ArcView Geographic Information Systems (GIS) software (ESRI 1995). Hotspots of species richness, endemic species richness and Red Data Book (RDB) species richness, for each taxon, were visualised at a quarter degree square (QDS) scale.

Using the definition given by Lombard (1995b), a hotspot is defined as a QDS that represents the top 5 % (richest) of all data containing QDS. For example if 100 QDS contain bird data, then the bird hotspots are the 5 richest QDSs. If QDS 94 - 96 contain the same number of bird species, then the cut off for the hotspots is taken as QDS 94 - 100. The hotspot data for each of the taxa were then compared with the hotspot data from the other taxa. This was done to determine whether or not hotspots of species richness, endemic richness or RDB species are coincident within and between taxa. Much of this analysis is based on work undertaken by Lombard (1995b), which identified hotspots throughout South Africa.

3.3 RESULTS

Hotspot identification

Total species, endemic species and RDB species hotspots for each taxon are shown in Figure 3.1 a, b and c respectively. It must be noted that no red data book species of tortoises were found in the study area.

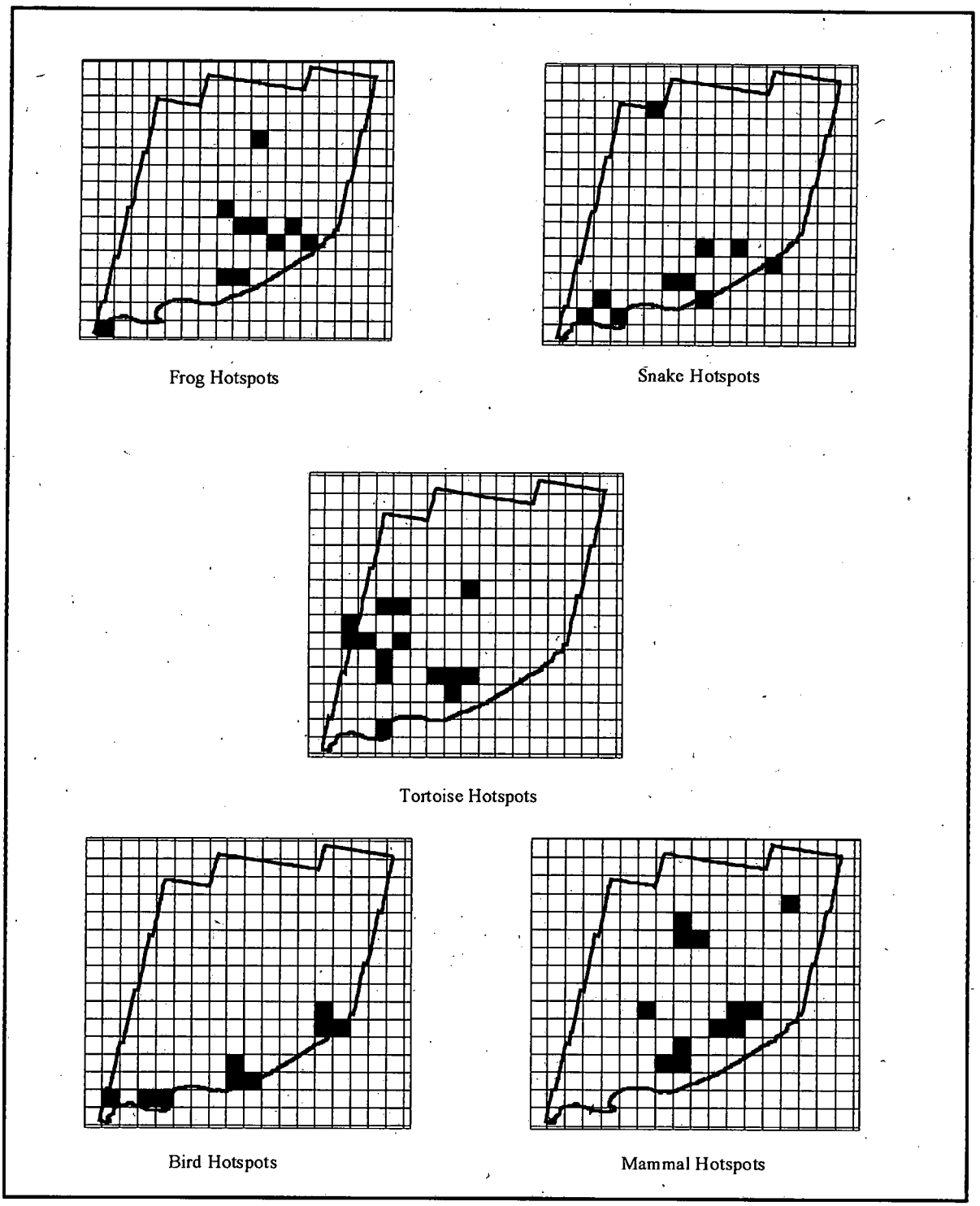

Figure 3.1a Species richness hotspots for five vertebrate taxa, within the study area.

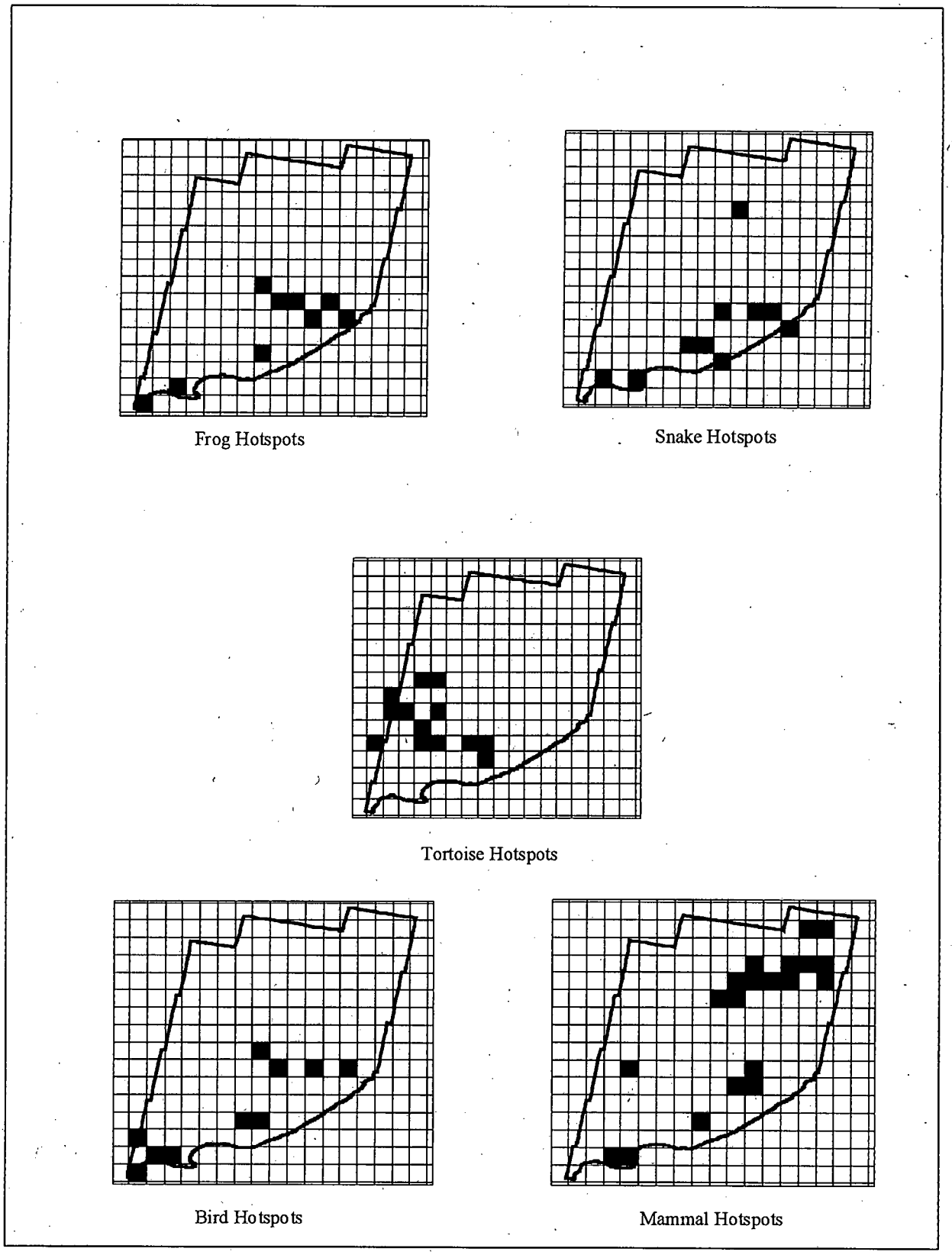

Figure 3.1b Endemic species hotspots for five vertebrate taxa, within the study area.

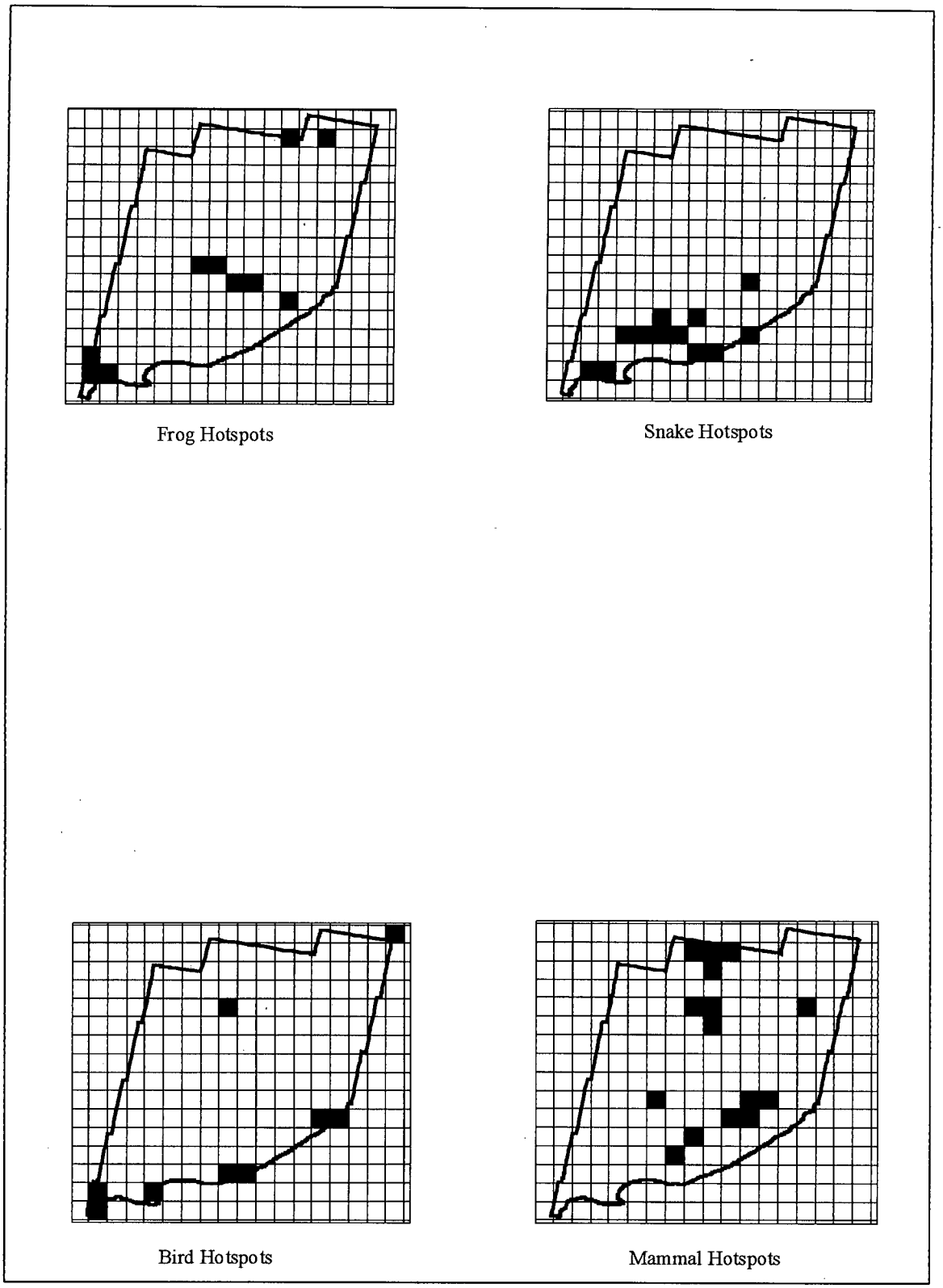

Figure 3.1c Red Data Book species hotspots for four vertebrate taxa, within the study area.

Within Taxon Analysis

The coincidence of species richness (HS), endemic species hotspots (EHS) and Red Data Book species hotspots (RDBHS) within taxa was analysed. Table 3.2 lists the number of QDS overlapping between the three different types of hotspots. Frogs, snakes and mammals were the only groups that exhibited overlap among all the types of hotspots.

Table 3.2 Number of overlapping hotspots between hotspots (HS), endemic species hotspots (EHS) and Red Data Book species hotspots (RDBHS) within the five terrestrial vertebrate taxa found within the study area. The nine QDS in which all three categories of HS overlap within a taxon are listed below their relevant taxon.

	Frogs	Snakes	Tortoises	Birds	Mammals
No. of HS=EHS	8	8	11	3	6
No. of HS=RDBHS	3	3	0	1	3
No. of EHS=RDBHS	3	4	0	6	8
No. of HS=EHS=RDBHS	3	3	0	0	3
	3226BC	3227CC			3126DB
	3226DB	3325CC			3227CB
	3227CA	3326AD			3227CD

Between taxa analysis

Table 3.3 Shows the QDS which exhibit overlap of the study taxas' hotspots. The crosses in the table indicate which taxa hotspots overlap.

Table 3.3 QDS where an overlap of hotspots occurs between taxa. Percentages in parentheses are ratios between number of hotspots of a particular taxon and the total number of hotspots for all taxa. Taxon marked with an x for a particular QDS all overlap with another taxon.

a) Species Hotspot Overlap

QDS	Frogs	Snakes	Tortoises	Birds	Mammals
3227CD	x	x			x
3227DA	x				x
3227DD	x			x	
3325DC		x		x	
3326AD		x			x
3326BA			x		x
3326BC	x	x	x	x	x
3326DB		x		x	
TOTAL	4(50 %)	5(62 %)	2(25 %)	4(50 %)	5(62 %)

b) Endemic Species Hotspot Overlap

QDS	Frogs	Snakes	Tortoises	Birds	Mammals
3127AC		x			x
3226BC	x			x	
3226DB	x			x	
3227CB				x	x
3227CD	x	x			x
3325CC		x		x	
3325CD	x			x	x
3325DC		x			x
3326AD		x		x	
3326BC	x	x	x	x	x
3424BB	x			x	
TOTAL	6(55 %)	6(55 %)	1(10 %)	8(73 %)	6(55 %)

c) Red Data Book Hotspot Overlap

QDS	Frogs	Snakes	Tortoises	Birds	Mammals
3126BC				x	x
3227CB		x			x
3324DD	x			x	
3325CC	x	x			
3326AD		x			x
3326BA		x			x
3326DA		x		x	
3326DB		x		x	
TOTAL	2(25 %)	6(75 %)	0	4(50 %)	4(50 %)

In Table 3.3a the species richness hotspots indicate no immediate discernible pattern, only one QDS (3326BC) is a species richness hotspot for each taxon. Snakes and mammals showed the highest overlap of hotspots (62 %).

Table 3.3b shows the overlap of endemic species hotspots. Again, the hotspots of all taxa overlap in only one QDS (3326BC). Birds show the highest degree of overlap with other taxa (73 %).

The RDB hotspots show the lowest level of overlap, with no more than two taxa overlapping at a time. 75 % of snakes hotspots overlap with hotspots of other taxa (Table 3.3c).

Table 3.4 shows the percentage overlap among the hotspots of the various taxa.

Table 3.4 The percentage overlap of species richness hotspot, endemic species hotspots and Red Data Book hotspots among five terrestrial vertebrate taxa in the Eastern Cape study area.

a) Species richness hotspots

	Frogs	Snakes	Tortoises	Birds	Mammals
Frogs	-	25 %	13 %	25 %	38 %
Snakes		-	13 %	38 %	38 %
Tortoises			-	13 %	25 %
Birds				-	13 %
Mammals					-

b) Endemic species hotspots

	Frogs	Snakes	Tortoises	Birds	Mammals
Frogs	-	18 %	9 %	46 %	27 %
Snakes		-	9 %	27 %	36 %
Tortoises			-	9 %	9 %
Birds				-	27 %
Mammals					-

c) Red Data Book species hotspots

	Frogs	Snakes	Birds	Mammals
Frogs	-	13 %	13 %	0 %
Snakes		-	25 %	38 %
Birds			-	13 %
Mammals				-

The lowest proportion of overlap between the species richness hotspots of the different taxa (Table 3.4a) occurs between the following pairs of taxa, firstly; mammals and birds, secondly; tortoises and birds, thirdly; tortoises and frogs and finally; tortoises and snakes. This proportion of overlap is at the 13 % level. Two pairs of taxa exhibit the highest proportion of overlap of species richness hotspots, at a 38 % level. These taxa are frogs and mammals, and snakes and mammals.

Of the endemic species hotspots (Table 3.4b), tortoises have the lowest proportion of overlap with all the other taxa (9 %). The highest percentage of overlap occurs between birds and frogs (45 %).

As no tortoises were represented as Red Data Book species within the study area, the proportion of overlap between Red Data Book species hotspots was limited to an analysis of the remaining four taxa. No overlap occurs between mammals and frogs, whereas snakes and mammals overlap by 38 %.

Table 3.5 Summary of the number of species richness hotspots (HS), endemic species hotspots (EHS) and Red Data Book species hotspots (RDBHS) that are common between the five taxa studied.

No. of taxa	No. of HS in common	No. of EHS in common	No. of RDBHS in common
5	1	1	0
4	0	0	0
3	1	2	0
2	6	8	8

Table 3.5 shows that only one QDS was a HS common to all five taxa. Similarly only one QDS was a EHS for all five taxa. In both cases the QDS was 3326BC. No RDBHS QDS was common to more than two taxa. While one and two QDS were common to three HS taxa and EHS taxa respectively.

Figure 3.2a shows the QDS where overlap between the hotspots of different taxa occurs. The QDS where the HS of two, three and five taxa overlap are also shown. Similarly Figure 3.2b and Figure 3.2c show the overlap between EHS and RDBHS respectively.

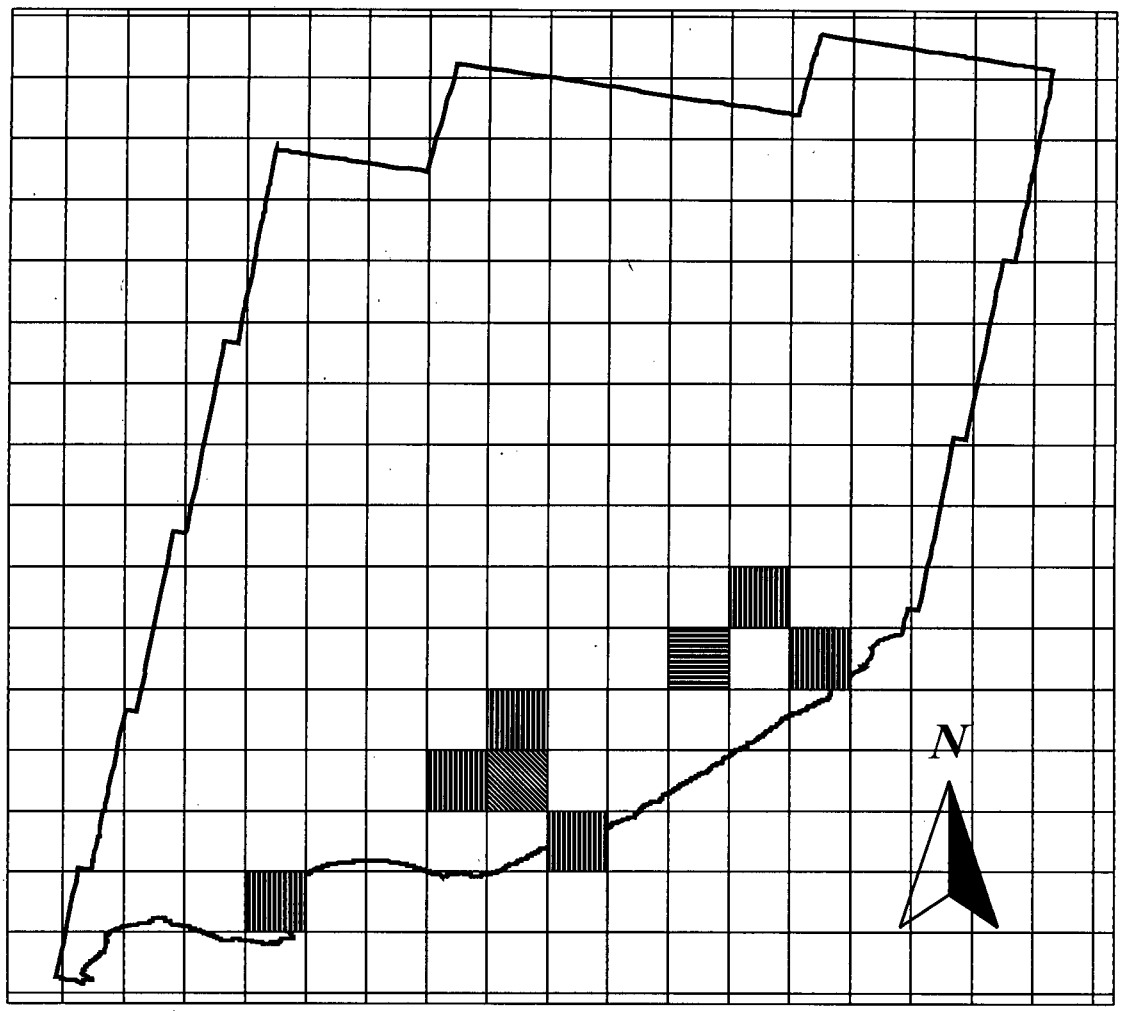

Figure 3.2a. Quarter degree squares where overlap occurs between species richness hotspots of the different taxa. Two taxa overlapping is indicated by vertical hatching, three taxa overlapping by horizontal hatching and five by diagonal hatching. Quarter degree squares represented are given in Table 3.6a.

Table 3.6a shows the squares where overlap of HS taxa occur.

Two taxa overlap on squares	Three taxa overlap on squares	Five taxa overlap on squares
3227DA	3227CD	3326BC
3227DD		
3325DC		
3326AD		
3326BA		
3326DB		

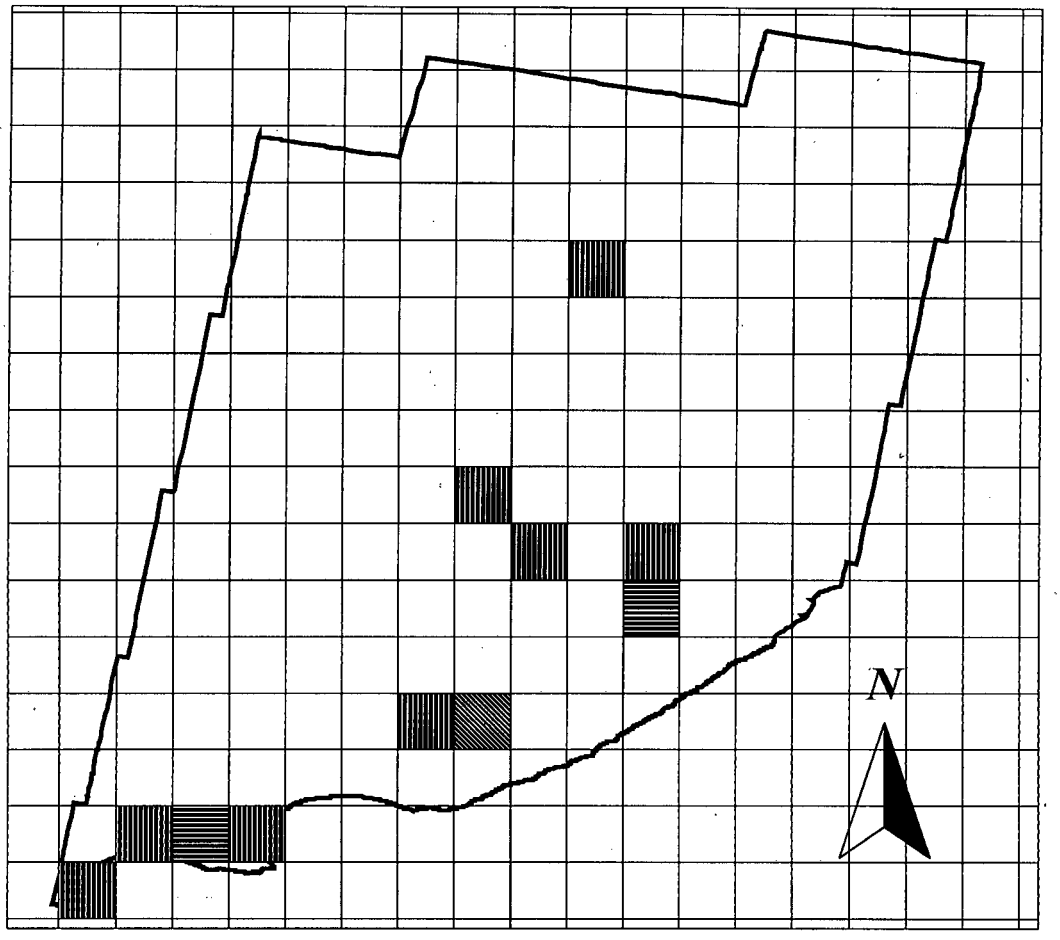

Figure 3.2b Quarter degree squares where overlap occurs between endemic species hotspots of the different taxa. Two taxa overlapping is indicated by vertical hatching, three taxa overlapping by horizontal hatching and five by diagonal hatching. Quarter degree squares represented are given in Table 3.6b.

Table 3.6b shows the squares where overlap of EHS taxa occur.

Two taxa overlap on squares	Three taxa overlap on squares	Five taxa overlap on squares
3127AC	3227CD	3326BC
3226BC	3325CD	
3226DB		
3227CB		
3325CC		
3325DC		
3326AD		
3424BB		

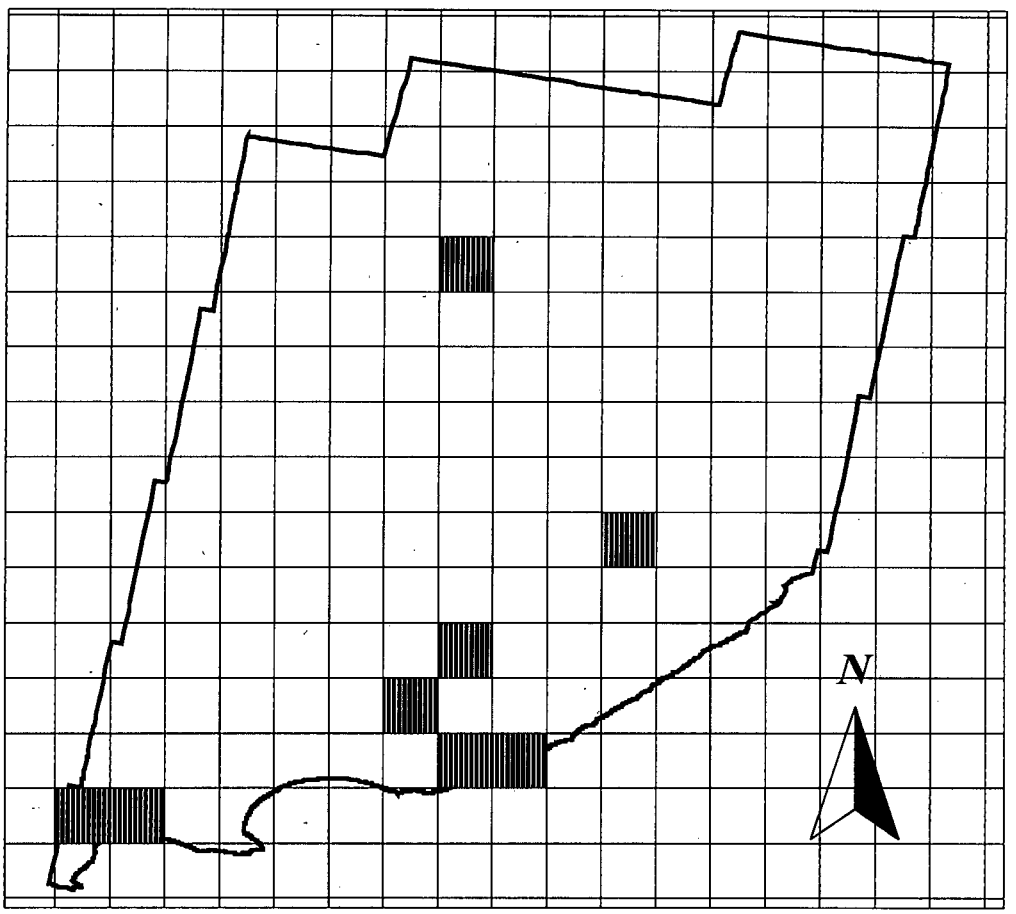

Figure 3.2c Quarter degree squares where overlap occurs between red data book species hotspots of the different taxa. Two taxa overlapping is indicated by vertical hatching. Quarter degree squares represented are given in Table 3.6c.

Table 3.6c shows the squares where overlap of RDBHS taxa occur.

Two taxa overlap on squares
3126BC
3227CB
3324DD
3325CC
3326AD
3326BA
3326DA
3326DB

Important areas

Important areas are considered to be those where the three types of hotspots coincide within each taxon (Table 3.2) and those areas where the three types of hotspots are common to the largest number of taxa. There are nine squares meeting the first category and just one meeting the second.

Table 3.6 Critical hotspot QDS identified from within and between taxon hotspot analysis and their corresponding place name. Category 1 QDS are those including "within" taxon hotspots and category 2 QDS are "between" taxon hotspots.

Quarter Degree Square	Square Name	Category
3126DB	Vaalbank	1
3226BC	Hackney	1
3226DB	Seymour	1
3227CA	Keiskammahoek	1
3227CB	Stutterheim	1
3227CC	Debe Nek	1
3227CD	King William's Town	1
3325CC	Loerie	1
3326AD	Salem	1
3326BC	Grahamstown	2

3.4 DISCUSSION

Within taxa there was a comparitively high degree of coincidence. Nine QDS were identified as having coincidence between HS, EHS and RDBHS. This was, however, only the case within three taxa, namely frogs, mammals and snakes.

As with Lombard's (1995b) study and studies by Sætersdal *et al.* (1993) and Prendergast *et al.* (1993), this study shows little indication that species hotspots (species richness, endemic species or Red Data Book species hotspots) coincide among different taxa. Of the 188 QDS within the study area, only one showed coincidence among all taxa, and this was only for HS and EHS.

The ten critical hotspot QDS identified by the "within" and "between" taxon analysis (Table 3.6) are important, and will be used in the identification of areas requiring protection. Of particular interest are the Seymore, Keiskammahoek, Stutterheim , Debe Nek and King Williams Town squares. All these QDS either cover the Amatola Mountains or their foothills. These mountains have been identified as centres of endemism (Briers pers. comm.).

4. LAND COVER AND HOTSPOT REPRESENTATION WITHIN RESERVES

4.1 INTRODUCTION

Various studies have been undertaken which discuss the extent of areas conserved according to various broad classifications. On a national level, Scheepers (1983) identified reserves according to two classification parameters the first being Acocks veld types (Acocks 1975) and the second being biomes, as defined by Scheepers (1983). Siegfried (1989) assessed the protection of biomes, as defined by Rutherford and Westfall (1986).

More specific to the study area, Everard (1985) assessed the conservation status of Acocks vegetation types within the Eastern Cape. Lubke *et al.* (1986) undertook a similar study, however, it was based on a revised vegetation map of the area. This map was based on Acocks (1953) and Pole Evan's (1936) vegetation maps of the Eastern Cape. Other studies, specifically targeted at the conservation status of specific vegetation types have also been undertaken. Of particular significance to the study area was the assessment of the area and conservation status of Valley Bushveld (La Cock *et al.* 1993).

Conservation areas within the study area

According to Lubke *et al* (1986) public conservation areas cover 3 % of the Eastern Cape, well below the IUCN (1984) recommendations of 10 % . The area that Lubke *et al.* (1986) took into consideration was an area of over 15 million ha, almost 6 million ha larger than the present study area.

Another factor that will have influence on the area conserved within the study area is the definition of what is identified as a conservation area. In this study, areas managed by Algoa Regional Services Council, former Ciskei Nature Conservation, Eastern Cape Nature Conservation and National Parks Board are considered. Areas excluded from the study, which could be considered by some as conservation areas are the indigenous forests managed by the Department of Water Affairs and Forestry and the former Ciskei Department of Forestry, Conservancies and Private Nature Reserves. For the former two, no information is available on the extent of these areas. For the latter, while the indigenous forests within the old South African boundaries appear to be conserved, the forests within the old Ciskei have been seriously depleted. The conservation status of the existing forests is questionable, consequently these areas have not been included in the present study. Figure 4.1 shows the conservation areas included in the study.

Reserve representation analysis

Two aspects of reserve representation need to be addressed, the first being what percentage of the total study area is represented by reserves. The second being what land cover types are represented within these reserves, and what proportion of the total land cover types are protected. As the species hotspots are based on QDS, it is difficult to determine if species occur on the existing reserves, particularly if the reserves are smaller than the QDS.

METHODS

In order to obtain the information on which land cover types are conserved in the existing system of reserves, the land cover layer was sampled using the Arc / Info

Figure 4.1 Reserves controled by the various conservation authorities, which were included in the study.

CLIP command (ESRI 1995). Using the reserve layer in the GIS, the land cover relating to the reserved areas were "clipped" out of the original land cover layer. The areas of each land cover type within each reserve were then analysed. The information identified in the study included:

- Percentage of total study area protected by the four conservation organisations
- Percentage of each land cover type protected by the four conservation organisations
- Which land cover types are not protected ?
- Which land cover types fall short of the IUCN's suggested 10 % area protected and to what extent ?

From these data, rules were set which were then used in the reserve selection exercise.

4.3 RESULTS

Land cover type representation of Eastern Cape reserves

The reserved areas in this study cover an area of 200963 ha or 2 % of the study area. Table 4.1 shows the area as well as percentage representation of each of the four reserve categories.

Table 4.1 Areas and percentages of reserve areas managed by the four conservation organisations within the study region.

	CNC	NPB	Ciskei	ARSC	TOTAL
Area of Reserves (ha)	99694	58512	38324	44334	200963
Percentage of total study area	1 %	0.6 %	0.4 %	0.0 %	2 %
Percentage of total reserve area	50 %	29 %	19 %	2 %	100 %

The land cover types within these reserves are varied. Most land cover types fall within the natural land cover type category, however, land cover types from the agricultural and disturbed categories are also present. The Table 4.2 summarises the land cover types represented within reserves.

Table 4.2 Areas of land cover types found within the reserve areas and the proportion that these protected land cover types make up of the total land cover type.

Land cover type	Total area of land cover (ha)	Area of land cover within reserves (ha)	Percentage of total land cover type within reserves
Bare rock and Sand	29597	10828	36.6
Bushland / Thicket	1099701	69731	6.3
Fynbos	73987	13488	18.2
Grassland	2590235	7642	0.3
Indigenous Forest	132672	11064	8.3
Karoo	896816	7523	0.8
Pans *(Wet & Dry)*	1700	0	0.0
Rivers & Open Water	24546	872	3.6
Salt Marshes	10	0	0.0
Vleis	329	0	0.0
Wooded Grassland	620536	13204	2.1
Woodland	566	0	0.0
Degraded Areas	2481679	58079	2.3
Erosion Scars / Dongas	191567	983	0.5
Settlements	116386	34	0.0
Dryland Commercial Agriculture	810481	5342	0.7
Commercial Forestry Plantations	108231	1745	1.6
Irrigated Commercial Agriculture	131915	297	0.2
Mixed Agriculture *(Irrigated & Dryland)*	28008	130	0.5
Other Land cover types	720770	0	0.0
TOTAL	10059446	200963	

Only natural land cover types and other land cover types represented within the reserves are specified in the above table. The row "Other Land cover types" summarises the total areas for the land cover types not represented within reserves.

In this study only natural land cover types are of conservation interest. Table 4.3 indicates which land cover types are represented within the reserve system. Those land cover types that meet and exceed the IUCN's 10 % recommendation are given as positive percentages. Any land cover type falling short of the required level are shown as negative percentages. The area required to meet the 10 % level is given. This area will be used in the reserve selection algorithm.

Table 4.3 Percentage of total land cover types found within reserves, and the percentage area these land cover types exceed or fall short of the suggested 10 %. (Exceeding percentages are positive and percentages falling short of the suggested level are negative).

Land cover type	Percentage of land cover within reserves	Percentage exceeding or falling short of 10 %	Additional area required to conserve 10 % of land cover (ha)
Bare rock & Sand	36.6	+26.6	0
Bushland / Thicket	6.3	-3.7	40249
Fynbos	18.2	+8.2	0
Grassland	0.3	-9.7	251253
Indigenous Forest	8.3	-1.7	2202
Karoo	0.8	-9.2	82148
Pans (Wet & Dry)	0.0	-10.0	170
Rivers & Open Water	3.5	-6.5	1583
Salt Marshes	0.0	-10.0	1
Vleis	0.0	-10.0	33
Wooded Grassland	2.1	-7.9	48836
Woodland	0.0	-10.0	57

Hotspot representation within Eastern Cape reserves

Of the ten critical hotspots identified in the study (Table 3.6) only three contain reserves. QDS 3325CC, 3326AD and 3326BC either have small reserves within them or contain portions of larger reserves. Figure 4.2 illustrates the reserve representation within these hotspot squares.

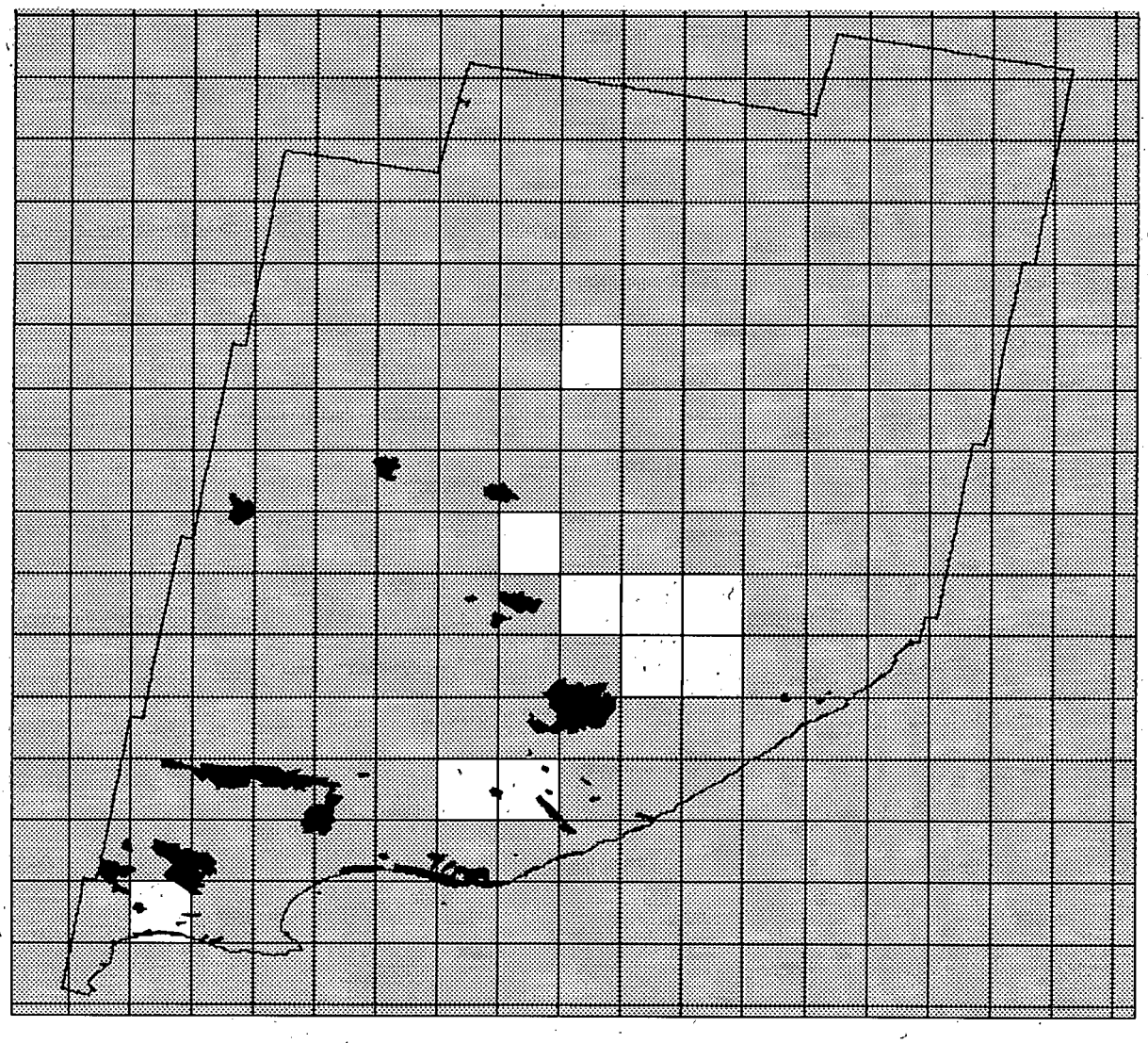

Figure 4.2 Reserves (in black) corresponding to the ten critical hotspot quarter degree squares identified in Table 3.6 (unshaded).

4.4 DISCUSSION

Land cover type anomalies

As seen in the study, some of the reserves are made up of agricultural land cover types. Explanations for this are that many of the proclaimed reserves are former farm land, and areas on these reserves consist of "old lands" which were used for commercial agriculture at some stage. In addition, as discussed in a previous chapter, some of the natural grasslands have the appearance of agricultural lands when classified from

satellite images (La Cock pers. comm.). Other agricultural land within reserves include exotic forestry plantations, which are found on a number of the former forestry nature reserves.

Settlements on reserves are a factor seen particularly on the coastal reserves around East London. These settlements are generally informal.

Land cover types of particular importance

The land cover types least represented within reserves are woodland, pans, saltmarshes and vleis. While these are small areas (generally under 100 ha in extent) they are important. The wetlands are breeding grounds for many birds and amphibians. They are also prime areas for agricultural development due to their moisture rich, fertile soil. They are also at risk from agricultural pollutants. These factors place these wetlands under constant threat.

The woodland land cover type is mainly found in kloofs and gorges and as such is, generally, inaccessible. Those areas that are accessible are often subjected to threat from wood collectors. (La Cock pers comm.).

Due to the small extent of these land cover types and their vulnerability, protection of these land cover types is important. However, they are some of the least represented land cover types in the Eastern Cape reserve system.

Critical hotspot representation on Eastern Cape reserves

Most of the areas where the vertebrate species ten critical hotspots occur are not represented in the existing reserve system. In addition, reserves that fall within hotspots only make up a very small percentage (an average of 5.09 %) of the hotspots in which they fall.

Conclusions

According to the results in Table 4.3, a total of 426532 ha of land is required to meet the goal of protecting 10 % of each land cover type. This area could, however, be less than this amount, considering that some of the degraded land could be dormant natural land cover type (Palmer pers. comm.). While this bias is noted, the study can be conducted only on known values, and as such the values for each land cover type, as they stand in Table 4.3, will be used in the design of the reserve system.

The QDS which represent the ten critical species hotspots are either totally unrepresented or have a very small representation within the reserve system, as such it is recommended that all ten of these squares be included in the reserve selection.

5. RESERVE SELECTION

5.1 INTRODUCTION TO RESERVE SELECTION

Reserves are essential when devising any strategy to maintain biological diversity. In the past, reserves have not been selected according to any defined objective, but rather on an *ad hoc* basis. This is true not only in South Africa (Siegfried 1989) but also in Australia (Pressey and Nicholls 1989a; Margules *et al.* 1988) and the United States (Scott *et al.* 1993).

With the realisation that our natural resources are finite there has been an awakening as to the need to conserve our resources, not in an *ad hoc* way, as discussed above, but in a planned systematic way. This shift in paradigm has lead to new ways of assessing and planning reserves. Initially much of the interest was focused on the SLOSS debate (Soulé and Simberloff 1986). This debate focused on whether a single large reserve protected more or less biodiversity than many small reserves. The interest has eventually shifted to identifying where the reserves should be located (Kirkpatrick 1983; Austin & Margules 1986; Margules *et al.* 1988; Rebelo and Siegfried 1990; Ryti 1992; Rebelo and Siegfried 1992; Bedward *et al.* 1992; Scott *et al.* 1993; Willis *et al.* in press).

Three basic principals for reserve selection have emerged in recent literature (Pressey *et al.* 1993):

- Complementarity: Reserves should complement each other in terms of protected features and should not duplicate each other.

- Flexibility: There are many combinations of sites in a representative reserve system, some sites are essential but many can be substituted with other sites at a measurable cost.

- Irreplaceability: There are sites that are essential for the reserve system as they encompass unique features or endangered species. These are irreplaceable sites that, although usually few in number, must be included in the reserve system.

Iterative selection procedures or heuristic algorithms

The technique most commonly used to incorporate these three principles is that of iterative selection procedures (Margules and Meyers 1993). These procedures have been used world wide, however, more specifically in Australia and South Africa (Kirkpatrick 1983; Pressey and Nicholls 1989a; Margules *et al.* 1988; Rebelo and Siegfried 1990; Rebelo and Siegfried 1992; Bedward *et al.* 1992; Willis *et al.* in press). Iterative selection procedures proceed in a stepwise fashion, adding additional complementary sites to those already identified as "reserve sites". According to Pressey and Possingham (submitted) there are three main approaches to iterative selection procedures:

- Richness Algorithms: This is the approach taken by Kirkpatrick (1983). The algorithm starts with the richest site in terms of unprotected features, then it adds sites singly according to which site includes the next richest unprotected features.

- Rarity Algorithms: The rarity algorithm begins with sites which contain unique features and add sites progressively, based on sites which contain the next rarest unrepresented feature. This was the technique used by Margules *et al.* (1988).

- Combination Algorithms: A combination of both richness and rarity algorithms is possible. Rebelo and Siegfried (1992) developed an algorithm based on the sum of rarity fractions for each species in each site, dominated by the measurement of rarity but effectively combining rarity and richness.

In all these algorithms, rules are needed to govern the resolution of sites which contain equally rare and unrepresented feature. Which site does one choose out of three when each contains equal populations of Riverine Rabbits, an endangered species? This choice, according to Pressey and Possingham (submitted), can either be made randomly or based on one or more criteria which would either lead to an effective solution or achieve another goal. The rules for the optimum solution are not readily identifiable, as such, the algorithms are heuristic, ie. based on the researcher's own knowledge and experience.

Optimality of reserve selection

The optimality of reserve selection has been subject to debate. Underhill (1994) questioned the optimality of heuristic iterative algorithms (HIA) over logistic equations. This lack of optimality of HIAs has been demonstrated with various studies which use both HIAs and logistic equations (Sætersdal *et al.* 1993; Willis *et al.* in press). Pressey *et al.* (submitted), however, expresses a number of advantages of the HIA approach over the logistic equation approach. Based on the advantages of the HIA method, this method was used in this study.

The advantages of the HIA over logistic equations are that computer running time is far less for the HIA than for the logistic equation. This makes HIAs useful for running scenarios in real time or close to real time situations. When working with a problem

where data are represented as a percentage area of a land type, logistic equations can be inflexible, but these problems can be easily solved using HIAs. As this is the type of problem to be tackled in this study, HIAs were chosen above logistic equations.

5.2 HEURISTIC ITERATIVE ALGORITHM METHODS

Reserve representation targets

For this study, a single target has been identified in order to model a representative reserve system. It must be stressed that many different targets may be defined for the analysis of reserve representation. These targets will be defined by conservation authorities based on their strategic requirements. The target defined is to identify a reserve system that will include:

- The minimum number of QDS sites needed to represent at least 10 % of all land cover types taking into account present reserves and including the 10 critical hotspots.

A rarity algorithm was used in order to identify the minimum set of QDS required to meet the above target. The rules used for this algorithm were:

1. Identify mandatory sites (sites that must be included in the algorithm. For example, the 10 critical hotspots)

2. Identify non-mandatory, but unique sites (sites that contain a unique feature, in this case land cover type)

3. Identify the next rarest non-mandatory sites

4. Identify sites that provide the maximum rarity of unrepresented features

5. Identify sites that provide the maximum percentage contribution of unrepresented features

6. Random selection of sites.

The algorithm was run using four different scenarios:

- Reserve selection with no mandatory sites
- Reserve selection with critical hotspots as mandatory sites
- Reserve selection with existing reserves as mandatory sites
- Reserve selection with critical hotspots and existing reserves as mandatory sites.

Not included in this algorithm were rules to ensure that where ever possible, sites selected would be adjacent to one another. Adjacency of the sites was not taken into account, as it was felt that at a scale of a QDS, any adjacency selections would not have as much relevance as it would at a finer scale.

This analysis was conducted by Dr R. L. Pressey of the New South Wales National Parks and Wildlife Service.

5.3 RESULTS

The first scenario was to determine a reserve system based only on land cover features. The only rule was that 10 % of each land cover type must be protected, except where the land cover type is made up only of polygons 100 ha or less in area. In this case 100 % of the land cover type must be protected. These land cover types, where 100 % of

the land cover type must be protected include Pans, Salt marshes, Vleis and Woodland. None of these land covers are presently protected. This first scenario models a reserve system based on the assumption that the study area has no existing reserve system. The second identified a reserve system based on representation of the land cover features and the critical hotspots; the third scenario scenario identified a reserve system based on representation of the land cover features and the existing reserve system and the final scenario identified a reserve system based on representation of the land cover features, critical hotspots and the existing reserve system.

Table 5.1 lists the results of the analysis. The resultant selected sites are shown in Figure 5.1.

Table 5.1 Summary of information used and derived from the reserve selection with no mandatory sites (scenario 1), critical species hotspots as mandatory sites (scenario 2), existing reserve quarter degree squares as mandatory sites (secenario 3) and both critical species hotspots and existing reserves quarter degree squares as mandatory sites (scenario 4). Total study area = 10006469 ha, Total area of natural land cover types = 4930790 ha, Total number of QDS in study area = 184, Total number of land cover types = 14.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Number of selected sites	15	21	45	52
Number of mandatory sites	0	10	42	49
Number of algorithm iterations after mandatory and unique sites have been selected	11	6	2	2

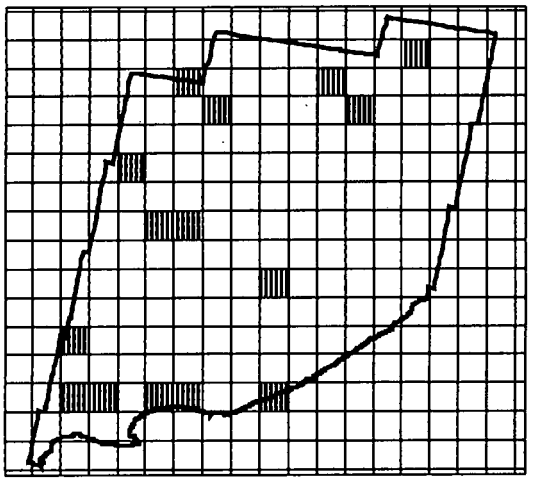

Figure 5.1a

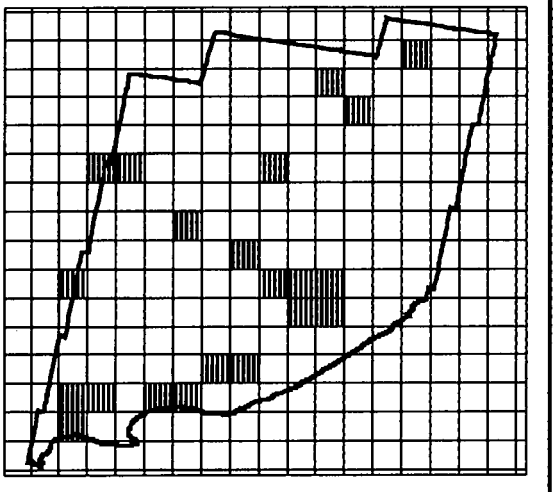

Figure 5.1b

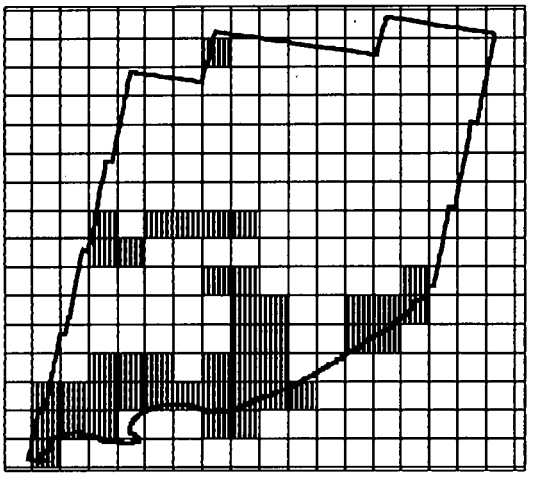

Figure 5.1c

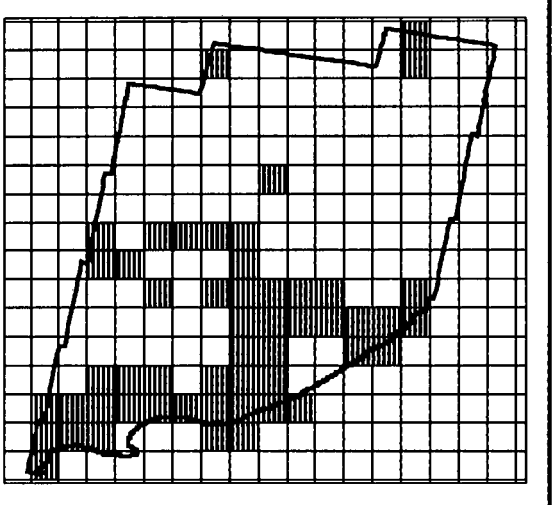

Figure 5.1d

Figure 5.1 Shows the different quarter degree squares selected for the different mandatory sites. Figure 5.1a = scenario 1. Figure 5.1b = scenario 2. Figure 5.1c = scenario 3 and Figure 5.1d = scenario 4.

It is evident that as mandatory sites are introduced, more sites are included in the selection, and less iterations of the algorithm are needed to meet the goals and the reserve selection becomes less flexible.

Table 5.2 lists the actual areas of the land cover types in the reserve system proposed by the final analysis as shown in Figure 5.1d

Land cover type	Area required for representation (ha)	Actual area represented (ha)
Saltmarshes	10	10
Dams/Rivers	1583	3937
Vlei Wetlands	33	36
Pans (Wet/Dry)	170	209
Grassland	251253	355618
Low Shrubland (Fynbos)	0	0
Bare Rock/Sand	0	0
Low Shrubland (Karoo)	82148	108899
Woodland (Closed Canopy)	57	599
Wooded Grassland (Open Canopy)	48836	155164
Bushland/Thicket	40249	451211
Indigenous Forest	2202	77331

Table 5.2 shows that, owing to the large number of mandatory sites in the reserve selection algorithm, in most cases, there is a very large difference between the required area and the actual proposed area. This is termed "over-representation".

5.4. DISCUSSION OF RESERVE SELECTION RESULTS

This analysis has shown that if no reserves existed in the study area (scenario 1), it would only take fifteen QDS to meet the requirements laid down for the study. The fifteen QDSs chosen, however, might not be the only combination of sites that meets this requirement. The more mandatory sites that one introduces into the algorithm, the less flexible the siting of the reserve system becomes, as seen by the other three scenarios. With fewer mandatory sites it is easier to more precisely meet the

protection requirements for an area rather than exceed it as seen when a number of mandatory sites are included in the analysis.

In scenario 4, the mandatory sites come close to meeting the requirements for the study. This results in their being little flexibility in reserve system design thus it leaves little room for using the non-mandatory sites for other purposes, for instance, as corridors or buffer areas. The need for these corridor or buffer sites is vital, especially in such a fragmented landscape. In Figure 5.1d most of the selected sites are adjacent to one another, which gives the impression that the proposed reserve system is made up of a few large continuous reserves. This impression is misleading as QDSs are used to represent the existing reserves, most of which are smaller than a QDS and thus might not be adjoining reserves in an adjacent QDS.

Another limitation of the sites selected by scenario 4 is that it forces the selected site system into the lower half of the study area, with very few selected sites in the northern half of the study area. This is a problem for a number of reasons; firstly, it does not allow for the inclusion of the north-south altitude gradient, namely from the Drakensburg mountains in the north to the coast in the south. Secondly, there is also the strong possibility that important sub-divisions of various land cover types might be excluded from protection, for instance, the afromontane grasslands of the Drakensburg mountains. This is, however only speculation as these sub-divisions have not been included in this study.

6. GENERAL DISCUSSION AND RECOMMENDATIONS

From this study a number of interesting observations and conclusions can be drawn. Firstly it must be stressed that the reserve system proposed in Figure 5.1d is not the definitive system. By changing the selection criteria according to different conservation goals, different potential reserve systems can be generated. Examples of differing criteria could include: changing the percentage protected area criteria; including or excluding land cover types; or placing constraints on the analysis, such as, any proposed reserve must be within five kilometers of a major road. Even if the criteria used in this study meet the conservation goals for the study area, the proposed reserve system should not be seen as final, rather as a starting point from which planning might procede.

6.1. DISCUSSION RELATING TO DATA RESOLUTION

Two types of data were used in this study: land cover type data and species data:

- Land cover type data: The land cover data form part of the the South African National land cover database project. Land covers were defined by manual interpretation of Landsat TM images (Thompson in press). The resultant maps have a minimum mapping unit of 25 ha, but in this study a functional minimum mapping unit of 100 ha was used. A mapping accuracy of 85 % has been aimed at (Fairbanks *et al.* submitted). In the study area, no reserves were smaller than 100 ha, thus the land cover type makeup of each reserve could be established.

- Species Data: Unlike the land cover type data, the species data are based on a "coarse" grid system using quarter degree squares, which relate to the standard

1:50000 mapping sheets used for the whole country. A quarter degree square is in excess of 60000 ha.

The differences in scale between the data sets has resulted in the coarsest of the scales being used for the study (QDS scale). By using the coarsest scale, all data are able to be generalised and viewed on an equal footing, this would not be the case if a finer scale was used.

6.2. DATA COMPLETENESS

In an analysis such as the one undertaken in this study, the better the data set the greater the variety of decisions that can be made using the data. While important decision-making information can be derived from this study, if a more complete and varied data set were available then a more diverse number of senarios could be explored. For instance in this study the land cover type classes were defined by using a land cover classification from a satellite image. There are, however, many different ways to classify landscapes (Table 2.1) and with each classification, the result of the reserve selection analysis can be expected to be different.

In order to undertake these studies, different data sets are required such as landform, elevation soils and geology and at present these data sets are not all available for the study area, or are available at different scales. Once these data sets become available, the analysis can be rerun using the different definitions of landscapes. The landscape might in future be vegetation based or land form based. These different definitions of landscape could be used to satisfy differing strategic requirements, such as, identification of reserve systems based on physical features or on vegetation classes.

The most incomplete data sets are those relating to species distributions. The use of these data also needs rethinking as most of these data of species distribution have been collected at the QDS level which provides for coarse distributional information. This coarse information does not make provision for species with microhabitat requirements. The technology is now available to undertake distribution atlas-type projects at a point sighting resolution. This type of point distribution project is presently being undertaken with the Protea Atlas Project (Rebelo 1992). However, other distribution projects continue to use QDS such as the Southern African Bird Atlas (Harrison 1992) and the Frog Atlas Study (Bishop 1996). In order to ensure that species with very limited distributions and specific habitat requirements are included in future reserve analysis, species point data are vitally important.

If species point data could have been used for this study, the analysis would not have been confined to a QDS resolution. Reserves could have been defined according to individual land cover type polygons or species points. With this type of study it is also vitally important to consider adjacency algorithms. Adjacency algorithms ensure that selected polygons are adjacent rather than selecting distant polygons. Once adjacency can be taken into account, corridor analysis is simplified. Connectivity between reserves is important as it provides for the movement of species between reserves. This movement is important for a number of reasons, it allows for natural migrations between areas, it increases the gene pool available to species and it allows species movement caused by habitat and climate changes. However, in this study corridor analysis is meaningless; two QDS which are adjacent and give the impression of being a continuous area, might, in reality indicate two disparate reserves requiring a corridor to join them.

6.3. TEMPORAL ACCURACY OF SPATIAL DATA

Both the land cover type and the species distribution data have important temporal aspects. The land cover type data are derived from satellite images which are merely a "snapshot" in time. As discussed in chapter 2, this "snapshot" has lead to possible misinterpretations of the data. By ignoring the seasonality and rainfall patterns of the study area, land cover which might be dormant vegetation has been interpreted as degraded veld. The land cover maps are derived from a mosaic of images and these images are not from the same day let alone the same year. This discrepancy in the dates of the mosaic images compromises the continuity of the land cover data. However, as long as these limitations are realised, the land cover data used in this study, and future land cover maps, hold a great deal of utility in conservation projects of this sort. The reason for this is that up until now a land cover map series has not been available. Land cover maps will allow long term monitoring of land cover, provided they are updated at regular intervals. In future, complete land cover maps will allow for more informed conservation decision making.

As regards the species data, most data have been captured from museum specimens and many of these specimens are fairly old. Thus, these data are used on the assumption that these species still exist in the area, which might not be true.

6.4 CONSERVATION CONCLUSIONS AND RECOMMENDATIONS

More utility could be derived from the study if the species data was at a point scale, however, studies such as this cannot be put on hold until the correct data sets exist. This study, while not resulting in point accurate information, did provide useful results. The three most significant results identified in this study are:

- In most cases more than the required area of land cover types, used in this study, are found within the QDS in which the existing reserves fall and within the critical hotspot QDSs.

- Based on the the rules laid out for the analysis the land cover types requiring special attention are Grassland, Wooded Grassland and the various types of Wetlands.

- The QDS covering the Amatola Mountain region is significant due to it having a high critical hotspot representation..

From these conclusions the following conservation recommendations can be made.

Land acquisition for conservation is difficult due to the major land reform policies presently being enacted. This means that untraditional methods need to be employed to meet conservation goals. As most of the areas of land cover required to meet the IUCN's 10 % protection goal are found in the QDS which contain most of the existing reserve system, most of the conservation attention should, therefore, take place in and around the existing reserves. The reserves are smaller than the QDSs that contain them, so the whole QDS must be looked at in terms of conservation. The inclusion of these areas surrounding reserves into the reserve system might be done by buffer systems provided by conservancies. This will require a great deal of community consultation and participation, which in turn, will hopefully ensure that the communities surrounding the reserves will show a commitment to the reserve.

Particular attention should be given to conserving those land cover types that have little or no representation in the existing reserve system. These include: Grassland,

Wooded Grassland and Wetland types. Wetlands are of particular concern as they constitute a very small percentage of all the land cover types. For instance, there is only 10 ha of saltmarsh in the whole study area. Wetland areas consist of many isolated small areas.

Conservation attention should be focused on the area of the Amatola Mountains. This area is poorly protected even though it contains a number of hotspots for various vertebrate species. It is also an important watershed for the southern Eastern Cape which has a particularly high vascular plant diversity (Phillipson 1987). The area is, however, under constant threat of deforestation of the indigenous forest and the expansion of exotic plantations. Acquisition of land for conservation is not possible without the involvement of the large commercial forestry companies that own most of the land in the area. Again consultation and participation, between these companies, conservation authorities and the local communities is required in order to develop a conservation strategy for the area.

6.5 RECOMMENDATIONS FOR FUTURE STUDIES

The recommendations for future studies can be divided into four parts:

I. Study area:- Land cover data sets are now available for the whole of the Eastern Cape Province, therefore, in the short term, this study should be extended to cover the whole province including the former Ciskei and Transkei areas. However, even at a provincial scale, the analysis does not take into account the conservation status of land cover types found outside the study area. It is therefore proposed that in the long term, the national land cover series (Thompson in press) be used to obtain a nationwide perspective on the conservation status of our existing land cover

types. This will allow conservation authorities to optimise the National Reserve System.

II. Data:- Data can be sub-divided into two categories:

i. Land cover type data. Experimentation should be undertaken to look at the different methods of classifying land cover types. To this end, new data sets that might be used in the classification of these land cover types should be identified and collected. Use of the land cover data should, however, continue, as this is a very valuable existing data set. More stringent field checks, as well as use of images over different seasons should also be used. This will reduce the chances of possible errors such as those suspected in this study, especially with respect to the degraded lands.

ii. Species data. Species data sets are limited in their availability. While generalised decisions can be taken on the existing data, there are large gaps in the species distribution coverage. Most of the digital data available are of vertebrate species. Even though there is a wealth of both vertebrate and invertebrate data residing in collections in museums around the country, little of it has been captured in a digital form. Another limitation is that of data capture resolution. While it is realised that most of the historical distribution data is at a coarse resolution (QDS), future sampling should be done on a point basis. Technologies such as Global Positioning Systems, which give point coordinates, are now readily available. It must be stressed that distributional data collection, even if only sighting data, should be actively continued.

III. Techniques. The techniques used in this study were reasonably simple. A vector GIS was used to analyse and visualise the data and a simple reserve selection algorithm was used. In future studies the following techniques might be investigated:

i. Use of a raster based GIS. This will allow for the use of more stringent spatial modelling of the land cover data. It would, however, have to be used together with point data from a vector based GIS as a raster GIS would generalise any species point data.

ii. Use of more complicated reserve selection algorithms which will take adjacency into account.

iii. Apply different selection criteria based on differing conservation strategies, this will give the system a "what if" capability. Examples of these different criteria could include an increased area for conservation or rules to ensure reserves are within a certain distance of a major town. These criteria would be dependant on the conservation goals and strategies of the regional conservation authority.

In final conclusion, the proposed reserve system should be seen as a starting point from which consultations between conservationists and stake holders might procede and from which recommendations to decision makers can be made. While important decision-making information can be derived from this study, a more complete and varied data set is imperative in order to create a more diverse range of scenarios. It is also crucial that nature reserve systems be looked at on both a national and regional scale for optimal conservation of biodiversity.

7. REFERENCES

Acocks, J.P.H. (1953). Veld types of South Africa. *Memoirs of the Botanical Survey of South Africa* No. 28.

Acocks, J.P.H. (1975). Veld types of South Africa. 2nd edn. *Memoirs of the Botanical Survey of South Africa* No. 40.

Austin, M. P. and Margules, C. R. (1986). Assessing representativeness. In. *Wildlife Conservation Evaluation*. Ed. Usher, M.B., Chapman and Hall, London, 45-67.

Austin, M. P., Nicholls, A. O. and Margules, C. R. (1990). Measurement of the realized qualitative niche: Environmental niches of five *Eucalyptus* species. *Ecol. Monogr.* **60**, 161-177.

Bedward M., Pressey, R.L. and Keith, D.A. (1992). A new approach for selecting fully representative reserve systems: addressing efficiency, reserve design and land suitability with an iterative analysis. *Biol. Conserv.* **62**, 115-125.

Belbin, L. (1993). Environmental Representativeness: Regional Partitioning and Reserve Selection. *Biol. Conserv.* **66**, 223-230.

Bishop, P. (1996). Friends in low places. *Arena* 3, 6-9.

Bolton, M. P. and Specht, R. L. (1983). A method for selecting nature conservation reserves. *Australian National Parks & Wildlife Service, Occasional Paper.* **8**, Canberra.

Bray, J.R. and Curtis, J.T. (1957). An ordination of the upland forest land cover types of southern Wisconsin. *Ecol. Monogr.* **27,** 325-349.

Briers, J.H., Loubser, D.I. and Powell, M. (1993*). Identification and Preliminary Evaluation of Potential Conservation Areas in the Afromontane Grasslands of the north eastern Cape Province*. Draft Report to Mondi Forests.

Burbidge, A. A. (1991). Cost constraints on surveys for nature conservation. In. *Nature Conservation: Cost-effective Biological Surveys and Data Analysis*. Eds. Margules, C. R. and Austin, M. P., CSIRO, Melbourne, 3-6.

Burrough, P. A. (1986). *Principles of Geographic Information Systems for Land Resource Assessment*. Clarendon Press, Oxford.

Cornell, H. V. and Lawton, J.H. (1992). Species interactions, local and regional processes, and limits to the richness of ecological communities: a theoretical perspective. *Journal of Animal Ecology*. **61,** 1-12.

Cowling, R.M. and Bond, W.J. (1991). How small can reserves be? An empirical approach in Cape fynbos, South Africa. *Biol. Conserv.*, **58**, 243-256.

Crowe, T. M. (1990). A quantitative analysis of patterns of distribution, species richness and endemism in southern African vertebrates. In. *Vertebrates in the Tropics*. Eds. Peters, G. and Hutterer, R., Museum Alexander Koenig, Bonn.

Damman ,. A. W. H. (1983). An ecological subdivision of the Island of Newfoundland. In *Biogeography and Ecology of the Island of Newfoundland*. Ed. South, G.R., W Junk. Publishers, The Hague.

Dasmann, R. F. (1972). Towards a system for classifying natural regions of the world and their representation by national parks and reserves. *Biol. Conserv.* **4**, 247-255.

Davis, F.W., Stine, P.A. and Stoms, D.M. (1994). *Remote Sensing and GIS applied to Phytogeographic Analysis and Conservation Planning in Southwestern California.* Unpublished Report.

Diamond, J. (1986). The design of a nature reserve system for Indonesian New Guinea. In. *Conservation Biology: The science of scarcity and diversity.* Ed. Soulé, M. E., Sinaurer Associates, Inc., Sunderland, Massachusetts. 485-503.

Digby, P. G. N. and Kempton, R. A. (1987). *Multivariate Analysis of Ecological Landscapes.* Chapman and Hall, London.

ESRI (1995). *Understanding GIS the Arc / Info method.* Environmental Systems Research Institute. INC, Redlands.

Estes, J. E., Hajic, E. J. and Tinney, L. R. (1983). *Fundamentals of image analysis: Analysis of visible and thermal infrared data.* In. Manual of Remote Sensing. Ed. Colwell, R. N., *American Society of Photogrammetry.* **1,** 987-1124.

Everard, D.A. (1985). *Conservation status of some unique plant communities and floral elements in the eastern Cape.* Unpubl M.Sc. thesis, Rhodes University, Grahamstown.

Everett, M. J. and Quibell, G. (1995). *The feasibility of using a Physiographic Approach in Water Quality Management. Phase II - Protocols towards Physiographic Boundary Verification using the eastern Transvaal Regions as an example*. Interim Report, Department of Water Affairs and Forestry.

Fairbanks, D.H.K., Thompson, M.W. and Everard, D. (submitted). Assessing Land Cover Map Accuracy for the South African Land Cover Database. *S. Afr. J. Sci.*

Faith, D. P. and Norris, R. H. (1989). Correlation of Environmental Variables with Patterns of Distribution and Abundance of Common and Rare Freshwater Macroinvertebrates. *Biol. Conserv.* **50,** 77-98.

Franklin, J.F. (1993). Preserving Biodiversity: Species, Ecosystems, or Landscapes? *Ecol. Appl.* **3,** 202-205.

Garcia, A. (1992). Conserving the species-rich meadows of Europe. *Agriculture, Ecosystems and Environment.* **40,** 219-232.

Gibbs-Russell, G.E. and Robinson, E.R. (1981). Phytogeography and speciation in the vegetation of the eastern Cape. *Bothalia.* **13**(3&4), 467-472.

Haines-Young, R., Green, D.R. and Cousins, S. (1993). Land cover type ecology and geographical information systems. In. Land cover *type Ecology and GIS,* eds. Haines-Young, R., Green, D.R. and Cousins, S., Taylor and Fransis, London.

Harrison, J.A. (1992). The Southern African Bird Atlas Project: five years of growth. *S. Afr. J. Sci.* **88,** 410-413.

Haughton, S.H. (1963). *Stratigraphic history of Africa south of the Sahara*. Oliver and Boyd, Edinburgh.

Hejl, S. J. (1992). The Importance of Land cover type Patterns to Bird Diversity: A Perspective from the Northern Rocky Mountains. *The Northwest Environmental Journal*. **8,** 119-137.

Hill, M. O., Bunce, R. G. H. and Shaw, M. W. (1975). Indicator species analysis, a divisive polythetic method of classification, and its application to a survey of native pinewoods in Scotland. *J. Ecol.* **63**, 597-613.

IUCN. Commission on National Parks and Reserves. (1984). Categories, objectives and criteria for reserves. In. *National Parks Conservation and Development*. Eds. McNeeley, J.A. and Miller, K.R., Smithsonian Institution Press, Washington DC.

James, F. C. and Wamer, N. O. (1982). Relationships between temperate forest bird communities and vegetation structure. *Ecology*. **63,** 159-171.

Jenkins, R.E., Jr. (1988). Information management for the conservation of biodiversity. In *Biodiversity,* Ed. Wilson, E.O., National Academy Press, Washington DC. 231-239.

Jennings, M. D. (In press). Nomenclature and mapping units for gap analysis land cover data. *Gap Analysis Symposium Proceedings*: The Conceptual Development of GAP. American Society of Photogrammetry and Remote Sensing, Charlottsvill, NC, USA.

Kepler, C.B. and Scott, J.M. (1985). Conservation of island ecosystems. *ICBP Technical Publication* No. 3: 255-270.

Kershaw, M., Williams, P. H. and Mace, G. M. (1994). Conservation of Afrotropical antelopes: consequences and efficiency of using different site selection methods and diversity criteria. *Biodiversity and Conservation.* **3,** 354-372.

Kirkpatrick, J.B., (1983). An iterative method for establishing priorities for the selection of nature reserves: an example from Tasmania. *Biol.Conserv.*, **25,** 127-134.

La Cock, G.D., Palmer, A.R. and Everard, D.A. (1993). Re-assessment of the area and conservation status of Subtropical Transitional Thicket (Valley Bushveld) in the Eastern Cape, Southern Africa. *S. Afr. J. of Photogrammetry, Remote Sensing and Cartography.* **15,** 231-235.

Lance, G. N. and Williams, W. T. (1968). Note on a new information-statistic classification program. *Computer Journal.* **11,** 195.

Lloyd, J. W. (1990). *The identification and evaluation of potential conservation areas along the Orange River between Boegoeberg dam and Prieska, Northern Cape*. Chief Directorate: Nature and Environmental Conservation, Cape Provincial Administration. Internal Report No. .3

Lombard, A. T. (1993). Multi-species conservation, advanced computer architecture and GIS: where are we today? *S. Afr. J. Sci.* **89,** 415-418.

Lombard, A.T. (1995a). Introduction to an evaluation of the conservation status of South Africa's vertebrates. *S. Afr. J. Zool.* 30(3), 63-70.

Lombard, A. T. (1995b). The problems with multi-species conservation: do hotspots, ideal reserves and existing reserves coincide? *S. Afr. J. Zool.* **30**(3), 145-163.

Lombard A. T., August P. V. and Siegfried W. R. (1992). A proposed Geographic Information System for assessing the optimal dispersion of reserves in South Africa. *S. Afr. J. Sci.* **88**, 136-140

Lubke, R.A, Everard, D.A. and Jackson, S. (1986). The biomes of the eastern Cape with emphasis on their conservation. *Bothalia.* **16**(2), 251-261.

Lubke, R.A., Tinley, K.L. and Cowling, R.M. (1988). Vegetation of the Eastern Cape. In. *Towards an Environmental Plan for the Eastern Cape,* Eds. Bruton, M.N. and Gess, F.W., Grocott and Sherry, Grahamstown.

Mabbutt, J. A. (1968). Review of concepts of land classification. In. *Land Evaluation.* Ed. Stewart, G. A., MacMillan Publishers, Melbourne. 11-28.

MacArthur, R.H. and Wilson, E.O. (1967). *The theory of island biogeography.* Princeton University Press, Princeton NJ.

MacDonald, I.A.W. (1989). Man's role in changing the face of southern Africa. In *Biotic Diversity in Southern Africa,* ed. Huntley, B.J. Oxford University Press, Cape Town, 51-71.

Mackey. B., Nix, H. A., Stein, J. A., Cork, S. E. and Bullen, F. T. (1989). Assessing the representativeness of the wet tropics of Queensland World Heritage property. *Biol. Conserv.* **50,** 279-303.

Majer, J.D. (1993). The Financial Cost of Biodiversity Assessment. In, *Rapid Biodiversity Assessment.* Proceedings of the Biodiversity Assessment Workshop. Macquarie University. 35-40.

Margules, C.R. (1989). Introduction to some Australian developments in conservation evaluation. *Biol. Conserv.* **50,** 1-11.

Margules, C.R. and Meyers, J.A. (1993). *The location and management of natural areas in the forestry context: an Australian perspective*. Workshop on the relevance of island biogeographic theory in commercial forestry. FRD, Pretoria.

Margules, C.R. and Nicholls, A.O. (1987). Assessing the conservation value of remnant habitat islands': mallee patches on the Western Eyre Peninsula, South Australia. In *Nature conservation: the role of remnants of native vegetation,* Eds. Saunders, D.A., Arnold, G.W., Burbidge, A.A. and Hopkins, A.J.M., Surrey Beatty & Sons, in association with CSIRO and CLAM, Sydney. 89-102.

Margules, C.R., Nicholls, A.O., and Pressey R.L. (1988). Selecting networks of reserves to maximise biological diversity. *Biol. Conserv.* **43,** 63-76.

Nicholls, A.O. and Margules, C.R., (1993). An upgraded reserve selection algorithm. *Biol. Conserv.* **64,** 165-169.

Noss, R.F. (1987). From plant communities to land cover types in conservation inventories: a look at The Nature Conservancy (USA). *Biol. Conserv.* **41,** 11-37.

Noss, R.F. (1993). The Wildlands Project Land Conservation Strategy. *Greendisk, Paperless Environmental Journal.* **1**(5).

Palmer, A. R. and Avis A. M. (1995). Mid-Fish River zonal study: *The description, mapping and evaluation of recent changes in the contemporary vegetation patterns*. Report for the Land and Agriculture Policy Centre.

Phillipson, P.B. (1987). A checklist of vascular plants of the Amatola Mountains, eastern Cape Province/Ciskei. *Bothalia* **17**(2), 237-256.

Pole Evan, I.B. (1936). A vegetation map of South Africa. *Memoirs of the Botanical Survey of South Africa* No 15.

Prendergast, J. R., Quinn, R. M., Lawton, J. H., Eversham, B. C. and Gibbons, D. W. (1993). Rare species, the coincidence of diversity hotspots and conservation strategies. *Nature.* **365,** 335-337.

Pressey, R.L and Nicholls, A.O. (1989a). Application of a numerical algorithm to the selection of reserves in semi-arid New South Wales. *Biol. Conserv.* **50,** 263-278.

Pressey, R.L. and Nicholls, A.O. (1989b). Efficiency in conservation evaluation. *Biol. Conserv.* **50,** 199-218.

Pressey, R.L. and Nicholls, A.O. (1991). Reserve selection in the Western Division of New South Wales: development of a new procedure based on land system mapping. In *Nature Conservation: cost effective biological surveys and analysis,* Eds. Margules, C.R. and Austin, M.P., CSIRO Publications, East Melbourne. 98-105.

Pressey, R.L. and Possingham, H.P.' (submitted). Effectiveness of alternative heuristic algorithms for identifying indicative minimum requirements for conservation reserves. *Biol. Conserv.*

Pressey, R.L., Johnson, I.R. and Wilson, P.D. (1994). Shades of irreplaceability: towards a measure of the contribution of sites to a reservation goal. *Biodiversity and Conservation.* **3,** 242-262.

Pressey, R.L., Possingham, H.P. and Margules, C.R. (submitted). Optimality in reserve selection algorithms: when does it matter and how much? *Biol. Conserv.*

Pressey, R.L., Humphries, C.J., Margules, C.R., Vane-Wright, R.I. and Williams, P.H. (1993). Beyond Opportunism: Key Principals for Systematic Reserve Selection. *TREE.* **8(4),** 124-128.

Rafe, R. W., Usher, M. B. and Jefferson, R. G. (1985). Birds on Reserves: The Influence of Area and Habitat on Species Richness. *Journal of Applied Ecology.* **22,** 327-335.

Rebelo, A.G. (1992). Protea Atlas Project Manual. Protea Atlas Project. University of Cape Town.

Rebelo, A.G. and Siegfried W.R. (1990). Protection of Fynbos vegetation: ideal and real world options. *Biol. Conserv.* **54**, 15-31.

Rebelo, A.G. and Siegfried, W.R. (1992). Where should nature reserves be located in the Cape Floristic Region, South Africa? - models for the spatial configuration of a reserve network aimed at maximising the protection of floral diversity. *Conserv. Biol.* **6,** 243-252.

Robertson, R. (1974). Forward, In. *Conservation of major plant communities in Australia and Papua New Guinea,* Eds. Specht, R.L., Roe, E.M. and Boughton, V.H., *Australian Journal of Botany,* Supplementary Series No. 7.

Rutherford, M.C. and Westfall, R.H. (1986). Biomes of southern Africa - an objective categorization. *Memoirs of the Botanical Survey of South Africa* No **54**.

Ryti, R. T. (1992). Effect of focal taxon on the selection of nature reserves. *Ecol. Appl.* **2,** 404-410.

Sætersdal, M., Line, J. M. and Birks, H. J. B. (1993). How to maximise biological diversity in nature reserve selection: vascular plants and breeding birds in deciduous woodlands, western Norway. *Biol. Conserv.* **66,** 131-138.

Saunders, D.A., Hobbs, R.J. and Arnold, G.W. (1993). The Kellerberrin project on fragmented landscapes: a review of current information. *Biol. Conserv.* **64,** 185-192.

Scheepers, J.C. (1983). The present status of vegetation conservation in South Africa. *Bothalia.* **14,** 991-995.

Scott M. J., Davis, F., Csuti, B., Noss, R., Butterfield, B., Groves, C., Anderson, H., Caicco, S., D'Erchia, F., Edwards, T. C., Ulliman, J. and Wright, R. G. (1993). Gap Analysis: A Geographic Approach to Protection of Biological Diversity. *Wildl. Monogr.* **123,** 1-41.

Siegfried, W.R. (1989), Preservation of species in southern African nature reserves. In *Biotic Diversity in Southern Africa: Concepts and conservation*, Ed. Huntley, B.J., Oxford University Press, Cape Town,186-201.

Siegfried, W.R. (1992). Conservation status of South African endemic avifauna. *S. Afr. J. Wildl. Res.* **22**(3), 61-64.

Smithers, R. H. N. (1986). *South African Red Data Book - Terrestrial Mammals.* South African National Scientific Programmes Report No. **125**.

Soulé, M.E. and Simberloff, D. (1986). What do genetics and ecology tell us about the design of nature reserves? *Biol. Conserv.* **35,** 19-40.

Terborgh, J. and Winter, B. (1983). A method for siting parks and reserves with special reference to Colombia and Ecuador. *Biol. Conserv.* **27,** 45-58.

Thomas, J.W., Forsman, E.D., Lint, J.B., Meslow, E.C., Noon, B.R. and Verner, J. (1990). *A conservation strategy for the Northern Spotted Owl.* United States Government Printing Office, Washington D.C.

Thomas, M. (1995). Land-cover assessment of the Eastern Cape. *Forestek Report* FOR-DEA 893, CSIR, Pretoria.

Thompson, M. (in press). A standard land-cover classification scheme for remote sensing applications in South Africa. *S. Afr. J. Sci.*

Udvardy, M.D.F. (1984). A biogeographical classification system for terrestrial environments. In. *National Parks Conservation and Development,* eds. McNeeley, J.A. and Miller, K.R., Smithsonian Institution Press, Washington DC, 34-38.

Underhill, L.G. (1994). Optimal and Suboptimal Reserve Selection Algorithms. *Biol. Conserv.* **70,** 85-87.

Van Jaarsveld, A. S. and Lombard, A. T. (1995). Towards the establishment of a national environmental information network. *S. Afr. J. Sci.* **91,** 9-10.

Weather Bureau, (1965). *Climate of Southern Africa, part 8, general survey.* Weather Bureau WB 28.

Wilcox, B.A. (1980). Insular ecology and conservation. In. *Conservation biology: An evolutionary-ecological perspective*, Eds Soulé, M.E. and Wilcox, B.A., Sinauer, Sunderland, Mass., 95-117.

Williams, P. H. and Gaston, K. J. (1994). Measuring more of Biodiversity: Can Higher-Taxon Richness Predict Wholesale Species Richness. *Biol. Conserv.* **67,** 211-217.

Williams, P. H., Gibbons, D., Margules, C. R., Rebelo, A. G., Humphries, C. J. and Pressey R. L. (submitted). Hotspots, rarity areas and complementary areas - a comparison of three area-selection methods for conserving diversity using British breeding birds. *Conserv. Biol.*

Willis, C.K., Lombard, A.T., Cowling, R.M., Heydenrych, B.J. and Burger, C.J. (in press). Reserve systems for limestone endemic flora of the Cape lowland fynbos: iterative versus linear programming techniques. *Biol Conserv.*

Wilson, E.O., (1988). The current state of biological diversity. In. *Biodiversity,* ed. Wilson, E.O., National Academy Press, Washington DC, 3-18.

APPENDIX 1. CLASS NAMES AND DESCRIPTIONS.

LEVEL 1	Definition	LEVEL 2	Definition	LEVEL 3	Definition
Forest & Woodland	All wooded areas with greater than 10 percent tree canopy cover(1), where the canopy is composed of mainly self-supporting, single stemmed(2), woody plants > 5 metres in height. Essentially indigenous tree species(3), growing under natural or semi-natural conditions (although it may include some localised areas of self-seeded exotic species). Excludes planted forests (and woodlots). Typically associated with the Forest and Savanna biomes in South Africa.	**Forest**	Tree canopy cover > 70 percent. A multi-strata community, with interlocking canopies, composed of canopy, sub-canopy, shrub and herb layers.		
		Woodland	Tree canopy cover between 40-70 percent. A closed-to-open canopy community, typically consisting of a single tree canopy layer and a herb (grass) layer.		

Thicket, Bushland, Scrub Forest and High Fynbos	Communities typically composed of **tall**, woody, self-supporting, single and/or multi-stemmed plants (branching at or near the ground), with, in most cases no clearly definable structure. Total canopy cover > 10 percent, with canopy height between 2 - 5 metres. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some localised areas of self-seeded exotic species, especially along riparian zones). Typical examples are Valley Bushveld, Mopane bush, and tall Fynbos. Dense bush encroachment areas would be included in this category.	**Thicket and Scrubforest**	Areas of densely interlaced trees and shrub species (often forming an impenetrable community). Composed of multi-stemmed plants with no clearly definable structure or layers, with > 70 percent cover. A typical example would be Valley Bushveld. May be intermediate in structure between true forest and thicket. Also associated with invasive *Acacia* sp. self-seeded along water courses. Due to shadowing on south facing slopes, this class may be locally over-classified in extent; in some locations more accurate cover classifications may be either **bushland** or **grassland**.
		Bushland	Similar to "thicket", but more open in terms of canopy cover levels. Composed of multi-stemmed plants with no definable structure or layers, and with < 70 percent cover. A example would be Mopane Bush. May also be associated with, or indicative of, degraded areas.

Shrubland and Low Fynbos	Communities dominated by **low**, woody, self-supporting, multi-stemmed plants branching at or near the ground, between 0.2 - 2 metres in height. Total tree cover < 1.0 percent. Low shrublands and heathlands are combined at Level 1 due to similar overall physiognomic structure and (in many cases) appearance on remotely sensed imagery. Examples would include low Fynbos, Karoo and Lesotho (alpine) communities.	**Shrubland (Karroid)**	Typically broad-leaved or bushes, frequently deciduous. Associated with variable grass-cover which is often ephemeral. This class is indicative of the Karoo biome.
		Low Fynbos (Heathland)	Typically small-leaved (i.e. nanophyllous(4)), sclerophyllous, evergreen plants growing on infertile soils. Proteaceae, Ericaceae and Restionaceae frequently dominate. Individual trees between 3 and 5 meters may be sparsely distributed throughout.
Grassland	All areas of grassland with less than 15 percent tree and/or shrub canopy cover, and greater than 0.1 percent total vegetation cover. Dominated by grass-like, non-woody, rooted herbaceous plants. Essentially indigenous species, growing under natural or semi-natural conditions. Often exploited for grazing, either for commercial or subsistence agriculture. Management blocks (e.g. tenure, possibly extensive) may be inferred from imagery by variable cover/state though field units are not evident. Typically associated with the Grassland Biome.		

Forest Plantations	All areas of systematically planted, man-managed tree resources, composed of primarily exotic species (including hybrids). Category includes both young and mature plantations that have been established for commercial timber production, seedling trials, and woodlots/windbreaks of sufficient size to be identified on satellite imagery. Will often include clear-felled stands *within* plantations. Excludes all non-timber based plantations such as tea and sisal, as well as orchards used in the production of citrus or nut crops, but includes associated land-cover/uses such as roads, fire-breaks and building infrastructure if these are too small to be clearly mapped off the satellite imagery. Species typically include pine, eucalyptus and wattle.		
Wetlands	Natural areas where the water level is at (or very near the land surface) on a permanent or temporary basis. The category includes both fresh, brackish and salt water conditions. Examples include saltmarsh, pans (with non-permanent water cover), reed-marsh or papyrus-swamp and peat bogs.	**Vleis and saltmarshes**	Areas subject to soil waterlogging and dominated by emergent hydrophillic vegetation. Water levels may be ephemeral, but the normal state is toward waterlogging. In high catchment tributaries, vleis may act as the sources and regulators of river systems. Associated with alpine / sub-alpine and coastal areas.
		Pans	Areas where the watertable meets the surface; thus the level is determined by the fall and rise of the watertable. These areas are often dry and can only support a specialised ecology which tolerates very high sodic concentrations. *Local example: in the Hofmeyer area.*

Waterbodies	Areas of natural and man-made water bodies, which are either static or flowing, and fresh, brackish and salt water conditions. Identifiable dry farm dams are included. This category includes features such as rivers, dams (i.e. reservoirs), lakes, and lagoons.				
Barren lands	Non-vegetated areas, or areas of very little vegetation cover (excluding agricultural fields with no crop cover, and opencast mines and quarries), where substrate or soil exposure is clearly apparent.	**Degraded land**	Permanent or seasonal man-induced areas of low or very low vegetation cover (i.e. removal of tree, bush and/or herbaceous cover) *in comparison to the surrounding natural vegetation cover*. Typically associated with subsistence level farming and rural population centres, where overgrazing of livestock and/or wood-resource removal has been excessive. Often associated with severe soil erosion problems. Characterised on satellite imagery by significantly higher	**Erosion scars & dongas**	Localised areas of permanent and/or semi-permanent linear exposures of lower soil horizons (- possibly to base rock). Often characterised as erosion gullies that form severe scars (dongas) or sheet erosion scars.

			overall reflectance levels (i.e. whiter appearance) and lower NDVI values (in comparison to surrounding vegetation).		
		Bare rock/soil	Natural areas of exposed sand, soil, or rock, with no, or very little vegetation cover during any time of the year. Excluding agricultural fields with no crop cover, and opencast mines and quarries.		
Cultivated Land	Areas of land that are ploughed and/or prepared for raising crops (excluding timber production). The category includes areas currently under crop, fallow land(5) and land being prepared for planting.	**Subsistence agriculture**	Characterised by a mosaic of small fields within close proximity to rural population centres. Typically dryland crops produced for individual or local (i.e. village) markets. Low level of mechanisation. Includes temporarily out-of-production fields are clearly visible in the patterns.		

	Unless mapping scales allow otherwise, physical class boundaries are broadly defined to encompass the main areas of agricultural activity, and are not defined on exact field boundaries. As such the class may include small inter-field cover types (i.e. hedges, grass strips, small windbreaks etc), as well as farm infrastructure.		
		Irrigated commercial agriculture **Dryland commercial agriculture**	Areas of high value crops in the proximity to regular sources of fresh water (e.g. dams, reservoirs and rivers). Irrigated by means of overhead spray booms, sprinkler systems, and canal systems. Typical crops include market garden produce and livestock fodder in the highlands. Characterised by large, uniform, well managed field units, with the aim of supplying both regional, national and export markets. Often highly mechanised. Improved pasture and paddock areas are included.
		Mixed agriculture	Areas which exhibit in imagery a seemingly inconsistent pattern in agricultural treatment/practice in individual fields within discrete localised blocks, indicating a variable use of irrigation. These areas are always associated with a permanent water supply, and are commonly located at the periphery of large irrigation schemes. It is possible that the seemingly inconsistent pattern may be because they are either fallow or due to variable ages of crops at time of image acquisition.

Urban / Built-up Land	An area where there is a permanent concentration of people, buildings, and other man-made structures and activities, from village to city scale. Areas also associated with economic activity (e.g. industrial and service).	**Settlement**	*Built-up* areas in which people reside on a permanent or near-permanent basis. The category includes both *formal* (i.e. permanent structures) and *informal* (i.e. no permanent structures or, permanent land-use) settlement areas, ranging from high to low building densities, (including smallholdings on the urban fringe). Central business district areas are included. Highly vegetated areas within the confines of settlements (e.g. municipal parks, caravan parks and camp sites, golf courses, etc.) are included unless these have boundaries that lie on the periphery and are consistent with the neighbouring cover-type (e.g. golf courses bordering with grasslands).
		Industrial and transport	Non-residential areas with major industrial (i.e. the manufacture and/or processing of goods or products) or transport related infrastructure. Examples would include power stations, steel mills, dockyards and airports.
		Mines & Quarries	Areas in which mining activity has happened or is happening. Includes both opencast mines and quarries, as well as surface infrastructure, mine dumps etc, associated with underground mining activities.
Cloud	Areas obscured by cloud and cloud shadow.		

Figure A1