Systematic conservation planning for the forest biome of South Africa

Approach, methods and results of the selection of priority forests for conservation action

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Abbreviations and acronyms

Agenda 21	Comprehensive plan of global, national and local action on the environment adopted at the United Nations Conference on Environment and Development ('Earth Summit') in 1992
ARC	Agricultural Research Council
C&Is	criteria and indicators for sustainable forest management
CAPE	Cape Action Plan for the Environment
CARA	Conservation of Agricultural Resources Act No. 43 of 1983
CBD	Convention on Biological Diversity
CBNRM	community-based natural resource management
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environmental Affairs and Tourism
DFID	UK Department for International Development
DWAF	Department of Water Affairs and Forestry
EA	enumerator area (local area defined for the national population census)
EC	Eastern Cape
ECA	Environmental Conservation Act No. 73 of 1989
EIA	environmental impact assessment
FCP	Forest Conservation Planning information system
FMU	forest management unit
FSC	Forestry Stewardship Council
GIS	Geographical information systems
IPCC	Intergovernmental Panel on Climate Change
IR	irreplaceability
IUCN	The World Conservation Union (formerly the International Union for Conservation of Nature and Natural Resources)
KZN	KwaZulu-Natal
LP	Limpopo (province)
MP	Mpumalanga (province)
NEMA	National Environmental Management Act No. 107 of 1998
NEMBA	National Environmental Management: Biodiversity Act No. 10 of 2004
NEMPAA	National Environmental Management: Protected Areas Act No. 57 of 2003
NFA	National Forests Act No. 84 of 1998
NFI	National Forest Inventory
NLC data	National Land Cover data
NR	nature reserve
NWA	National Water Act No. 36 of 1998
PA	protected area
PFM	participatory forest management
SANBI	South African National Biodiversity Institute
SDS	sixteen degree squares
SFM	sustainable forest management
SKEP	Succulent Karoo Ecosystem Programme
SRUPI	Subsistence Resource Use Pressure Index
STEP	Subtropical Thicket Environmental Planning
TK	Transkei
WC	Western Cape

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[1] Geographical information systems.

Preface

This document has two broad goals: firstly, to present the principles, approach and results of a systematic conservation plan for the forest biome, and secondly, to provide the computer based information systems developed for indigenous forest conservation planning.

This work has been commissioned by the UK Department for International Development on behalf of the Department of Water Affairs and Forestry. The target audience include forest scientists, managers, conservationists, regulators, and administrators involved with indigenous forests in South Africa.

The aim of conservation planning is the selection of priority planning units for conservation action. In the narrow sense, this implies inclusion of those areas, identified by systematic planning as being highly irreplaceable, and essential for inclusion within a protected area network for achieving targets. In the broader sense, conservation action may include a range of different activities, both inside and out side of protected areas. Conservation is not just about preserving biodiversity, it is also about the sustainable use of natural resources. Many valuable forested areas in South Africa are associated with communities who may be heavily or partially reliant on these forest resources. In this regard, there is an urgent need to implement the principles of community-based natural resource management as part of a forest conservation strategy and action plan.

This study used both forest patches and forest clusters as planning units. What is becoming increasingly apparent is the critical role that conservation planning needs to play in the maintenance of connectivity between increasingly fragmented forest patches. The use of forest patches as planning units has enabled important habitat patches to be identified while the use of clusters as planning units identified whole forested regions as priority areas, thus emphasising the need for planning to done at the broader landscape level. Critical habitat units need to be evaluated not just for their contribution to the biodiversity representivity targets, but also for their role in maintaining natural habitat pathways and ecological connectivity.

Although the management and conservation of the indigenous forest estate is increasingly being devolved to provincial and local levels of government, the responsibility of regulating and monitoring still resides nationally with DWAF (see discussion on criteria and indicators and the principles of the National Forests Act).

The planning and implementation of conservation of the forest biome provides a unique challenge, given the large number of administrative boundaries that fall within the planning domain. This implies the need for national level co-ordination and planning, specifically entailing the setting of national conservation targets, protected area gap analysis, and the identification of priority forests for conservation action. National-level planning is thus essential for providing a framework for finer scale planning necessary at provincial and local level, as well as facilitating integration with bioregional and spatial development framework planning.

Never has the urgency been greater to implement forest conservation planning. Land use pressures and demands for forest resources are on the increase, resulting in deforestation, degradation and fragmentation of irreplaceable habitats.

Forests are valued for many different reasons, of which, biodiversity is only one. Although occupying less than 0.4% of the surface area of South Africa, forests have the highest biodiversity per unit area of any biome in South Africa. It is also the most vulnerable, smallest and most fragmented biome. In addition, it is facing escalating pressure from strip mining, coastal and urban development, agriculture, illegal commercial and subsistence over-harvesting.

National government needs to play a key role in speeding up the implementation of conservation planning. One of the major blocks to implementation is lack of capacity and information necessary to ensure co-ordinated conservation action at different levels of government.

In theory, all forests are protected under the National Forests Act No. 84 of 1998 (NFA). However, only relatively few state forests are actually managed as protected areas. Almost all of the national forest types assessed fall well short of the national conservation targets set for strict protection and, given current and predicted levels of threat, there is an urgent need to increase the number of (statutory) forest protected areas in South Africa.

Forests play important roles in providing ecosystem services such as water retention, water purification, flood attenuation and carbon sequestration, all necessary for maintenance of healthy environments for human habitation. Because of this, all forests can be considered as having ‘high conservation value’. However, given the multiple demands on forest resources, not all forests can be set aside for strict biodiversity conservation.

One of the key outputs of this conservation planning project was identification of priority forests for conservation. This was done, independently at both the level of forest patch and forest clusters, using computer optimisation algorithms. Prioritisation was based on irreplaceability, threat, and livelihood analysis. C-plan was used for forest patch irreplaceability analysis, while Marxan was used for cluster analysis.

Internationally, South African forests can also claim global importance. Despite sharing more affinities with Afro-tropical forests, their position relative to the Equator qualifies them as ‘temperate forests’. Recent research has shown that South African forest have the highest biodiversity of any temperate forested region in the world.

Impressive as this may seem, it is unlikely to mean much to those whose livelihoods depended on the continual use of forests resources. In many areas forest are considered as a ‘safety net’ for the rural poor, as well as playing an important role in the spiritual, cultural and herbal-medicinal systems of rural communities. This study has realised the importance of addressing the socio-economic opportunities and constrains inherent in conservation planning. While no claim can be made to providing answers to the many complex issues of rural poverty and conservation, the computer tools developed and provided here will at least provide support for informed decision-making. For the first time, indices of forest conservation value, poverty and subsistence resource dependency are presented in conjunction with biodiversity indices.

The results and information systems (data base, map book and geographical information systems – GIS) are provided in a CD-ROM that accompanies this report.

Any information system is only as good as the data used. All effort has been made to use current data at the time of analysis. However, new information is being provided all the time and, for some datasets, updates will be needed almost annually. This is certainly true for improvements in forest cover mapping, identification of forest subtypes, improved land cover/transformation mapping, and changes in population statistics.

Indicators developed in this study were derived from various data sources and, in some cases, where no hard data was available, expert opinion was used. As such, indicators developed in this study need to be seen for what they are: relative, but objective measures of complex multifactor phenomena, expressed as scaled ratings. While being potentially valuable in planning and decision support, they should not be seen or used as absolute statistical measures. Conservation planning is an iterative process and as new information becomes available, revision and updating is essential.

Executive summary

This document describes the methodologies and results of systematic conservation planning for the forest biome. It addresses the urgent need for assessment and strategic planning of indigenous forests conservation in South Africa. Among its key recommendations are lists of priority forests patches and forest clusters requiring urgent conservation action.

One of the main aims of conservation planning is the identification of priority planning units for conservation action. Planning units that are evaluated as 'irreplaceable' are considered as essential for inclusion within a protected area network. Irreplaceability is a relative measure of the conservation value of a planning unit, based on its contribution toward meeting predefined targets. Targets are based on the requirements for achievement of biodiversity representivity and persistence. Irreplaceability was calculated using the systematic computer optimisation algorithms, C-Plan (for forest patches) and Marxan (for forest clusters and grids).

Results are presented in three formats:

a) Tables within the body of the report (for example gap analysis, priority forest patches and priority clusters).
b) Maps of priority forest clusters (presented in the appendix of this report).
c) The FCP (the Forest Conservation Planning information system) CD-ROM, comprising four modules:
    - FCP Access data base
    - FCP map book
    - FCP spatial (Arc Explorer/GIS shape files)
    - PowerPoint presentations and additional information resources.

The FCP CD-ROM accompanies this report. It also contains the GIS viewer Arc Explorer.

Given the size of the planning domain and the large number of administrative boundaries involved, implementation of forest conservation planning is challenging, requiring co-ordination between the different levels of government, and local communities. National level planning is essential for providing a framework for finer scale planning, necessary at provincial and local levels. There is also a need for facilitating the integration of national planning with the numerous bioregional and spatial development frameworks. The forest biome intersects with a number of bioregional conservation planning programmes including the Wild Coast, Subtropical Thicket Environmental Planning (STEP), KwaZulu-Natal (KZN), Mpumalunga province, Cape Action Plan for the Environment (CAPE) and Maputuland-Pondoland. The later two regions have also been identified by Conservation International as global biodiversity hotspot regions.

A total of 16 185 forest patches were evaluated, of which only 5 856 were larger than 10ha, and just over 800 patches are larger than 100ha. Southern Cape Afrotemperate, Amatole Mistbelt and Transkei Coastal Platform forests cover the largest area, while Western Cape Milkwood, Drakensberg Montane, Swamp, Mangrove and Western Cape Afrotemperate forests are the rarest forest types. The total area of forest in South Africa is calculated to be just over 4 867km^2.

The forest clusters analysis done in this study forms an important contribution to forest conservation planning. Forest clusters are made up of patches of forest closer than 1 000m apart. It is believed that these groupings form an ecological unit and need to be managed as such. A total of 3 016 forest clusters larger than 50ha were identified. These cover an area of around 16 040km^2. The total cluster area includes the inter-patch matrix and the 500m forest buffer area. Conservation of whole

forest clusters will ensure that ecological connectivity between patches is maintained, as well as conserving the often valuable inter-patch habitat.

Being highly fragmented, the forest biome is particularly vulnerable, and under ever-increasing threats from urban development, non-sustainable subsistence harvesting, agriculture, mining, invasive aliens and fires. Many high conservation value forests considered as being under threat are also important to the livelihoods of poor rural communities.

Global climate change is increasingly been considered as an important threat to biodiversity. Scientist contend that the most significant threats are drying trends, changes in rainfall patterns, changes in fire regimes and changes in seasonality, which in turn lead to changes in species distribution and composition. This project identifies forest clusters that are likely to be more resilient to climate change, based on the identification of important forest clusters situated along large river corridors. Prediction of the spatial effects of global warming on the forest biome, as well as the use of altitudinal gradients to improve on the analysis, will still need to be conducted.

Indicator ratings for each forest patch (and forest cluster) have been calculated and were used for prioritisation. These include, irreplaceability, threat, livelihood value, vulnerability to edge effects, poverty, population density, accessibility and habitat transformation of surrounding forest buffer areas.

Policy directives such as the Convention on Biological Diversity (CBD), the National Forests Act and the National Environmental Management: Protected Areas Act No. 57 of 2003 (NEMPAA) provide ample validation for a systematic conservation planning approach to forests conservation in South Africa. The two most appropriate legal instruments for doing this are Section 8(1) of the NFA and NEMPAA.

Outputs of this project include key focal areas 2 and 3 of the DWAF strategic plan 2003/4. In addition, this work underpins the monitoring of national criteria and indicators, specifically Criterion 1 (natural forests are protected), Criterion 2 (biodiversity of natural forests is conserved, as indicated by the area of natural forest conserved); and Criterion 3 (forest ecosystem structures are conserved and processes maintained, as indicated by the extent and connectivity of natural ecosystems).

The current network of strict protected areas in South Africa is significantly unrepresentative of forest biodiversity. This study has identified priority forests areas that are urgently needed for inclusion within a forest protected area network. The Gap Analysis module within the FCP database provides a detailed scorecard that can be used to monitor conservation progress and target achievement/shortfall for each forest type.

Gap analysis aimed to provide answers to four major questions.

- How much of each forest type is under some form of protection (Table 14)?
- How much forest is under strict protection, and what % of each forest type is still needed to achieve targets (Table 15)?
- For each forest type, what percentage of the 100% irreplaceable forests are in Type 1 protected areas (Table 16)?
- What is the provincial contribution to target achievement for each forest type (Table 17)?

Overall, 44 % of the total area of indigenous forest is under some form of protection (this includes Type1 and Type 2 protected areas, as well as state forests)

For most forest types, many of the highly valuable forests (100 % irreplaceable) are not under strict protection. Overall only 32.6% of the area covered by 100% irreplaceable forests falls within strict (Type 1) protected areas. Forest types with lowest levels (less than 5%) of 100% irreplaceable forests under strict protection include: Amatole Mistbelt, Eastern Cape Dune, Northern Mistbelt, Pondoland Scarp, Transkei Coastal Platform, Transkei Mistbelt and Western Cape Milkwood.

Forest types that are better protected under Type 1 protected areas (that is, have relatively more of their 100% irreplaceable forest areas under strict protection) include Drakensberg Montane, KwaZulu-Natal Coastal, Lowveld Riverine, and Mangrove forests.

Gap analysis also considered ‘target shortfall’, or the percentage of the forest type targets still outstanding. Only two forest types are reasonable close to meeting their conservation targets. These include Albany (0.5% outstanding) and KwaZulu-Natal Coastal (14.5% outstanding). Forest types with more than 70% of their target areas outstanding include: Amatole Mistbelt, Eastern Cape Dune, Eastern Mistbelt, Eastern Scarp, Northern KwaZulu-Natal Mistbelt, Northern Mistbelt, Pondoland Scarp, Transkei Coastal Platform, Transkei Mistbelt and Western Cape Milkwood.

The Eastern Cape has the largest share of the national forest estate with 46% occurring in this province. KwaZulu-Natal has the second most with 29%, the Western Cape has 13%, Mpumalanga 7%, and Limpopo only 5%. Very small amounts of forested area also occur in Gauteng and North West, but unfortunately no data was available for this analysis from these provinces.

Overall, Mpumalanga province and KwaZulu-Natal (KZN) have the highest levels of strict protection at 46.4% and 34.6% respectively. The Eastern Cape has the lowest levels of protection with only 4.75% under strict (Type 1) protection.

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1 Introduction

1.1 Policy context

Before embarking on conservation planning it was necessary to examine relevant forestry policy directives that underpin and inform the process.

The following framework was used:

- international and national obligations regarding biodiversity conservation
- legal instruments available for the establishment of protected areas
- obligations or guidelines that can inform conservation planning.

Perhaps the most important international policy directive of relevance to systematic conservation planning is the 1992 Convention on Biological Diversity. As a signatory, South Africa is obliged to 'establish and effectively manage a network of protected areas that are ecologically representative of the countries biodiversity'. This has been echoed in NEMPAA, as well as the White Paper on Biodiversity and is articulated in the National Biodiversity Strategy and Action Plan, a national planning processes leading towards development and implementation of CBD and Agenda 21.

Specific policy relating to forest biodiversity in the NFA is provision for the monitoring and reporting of a national set of criteria and indicators (C&Is) for sustainable forest management (SFM). Specifically relevant criteria are: Criterion 1 (Natural forests are protected), Criterion 2 (Biodiversity of natural forests is conserved) and Criterion 3 (Forest ecosystem structures are conserved and processes maintained)

The National Environmental Management: Biodiversity Act No. 10 of 2004 (NEMBA) is of particular importance. Section 52(1)(a) states that 'ecosystems that are threatened and in need of protection… may be declared nationally by the Minister , or provincially by an MEC[2] for environmental affairs by notice in the *Gazette*'.

This listing will theoretically, entitle these ecosystems to protection from certain activities or 'threatening processes'. A number of forest types have been suggested for listing (in Section 4.5 of this document).

Forest conservation planning aims to identify priority areas for inclusion within a protected area network that will ensure representivity and persistence of all forest biodiversity. As will be illustrated, most forest types in South Africa are, currently under-represented as strict (or Type1) protected areas.[3]

The two most appropriate legal instruments for declaring forest protected areas are:

a) Section 8(1) of the National Forests Act that provides for three types of specially protected areas in the forestry context – a forest nature reserve, a forest wilderness area and any type of protected area which is recognised in international law or practice

b) the National Environmental Management: Protected Areas Act. This provides for the declaration of a number of different types of protected areas including special nature

[2] Member of the (Provincial) Executive Council (a provincial Minister).

[3] For the purpose of this discussion, strict (or Type 1) protected areas are areas that have been declared as protected areas under national or provincial legislation and that are effectively managed as protected areas. Under this definition, state forests are not necessary protected areas, unless specifically declared as special protected areas under the National Forests Act.

reserves, national parks, nature reserves, (including wilderness areas), and protected environments.

Policy and legislation relevant to forest conservation planning is summarised in Table 1.

Table 1: Summary of policy and legislation relevant to forest conservation planning

Policy/ legislation	General implications	Specific implications for forest conservation
Convention on Biological Diversity	'Obligation for the establishment and effective management of *ecologically representative* protected areas using the ecosystem approach'	Establish and effectively manage ecologically representative networks of forest protected areas (forest protected areas should cover at least 10% of each of the remaining major forest types)
Southern African Development Community Forest Protocol	'State Parties shall take all necessary legislative, administrative and enforcement measures to address natural and human-induced threats to forests.'	Recognises importance of connectivity among *trans-boundary forests*
National Biodiversity Strategy and Action Plan (South African National Biodiversity Institute)	National planning processes leading towards the development and implementation of the CBD and Agenda 21[4]	Provide conservation planning framework based on bioregionalism and priority areas. Also listing of level of ecosystem endangerment and targets for all vegetation types (as described in the new vegetation map)
National Forestry Action Plan	Essentially a programme for implementing the new forestry policy as set out in the White Paper on Sustainable Forest Development in South Africa	Paragraphs 12.34 to 12.55 set out the principles and requirements for developing SFM C&Is. Also refers to the need to address the issue of monitoring the extent and current condition of forests and woodlands
White Paper on Biodiversity	Goal 1 of the White Paper is to *conserve the diversity of landscapes, ecosystems, habitats*, communities, populations, species and genes in South Africa	Policy Objective 1.3 specifies the need to establish and manage efficiently a *representative and effective system of protected areas*
White Paper on Sustainable Forest Development in South Africa	Recognises the special value of natural forests….. acknowledges our obligation to the global community to adequately protect the forests and biodiversity of the world	
The National Forests Act No. 84 of 1998	Aims to promote the sustainable management and development of forests for the benefit of all; create the conditions necessary to restructure forestry in state forests; provide special measures for the protection of certain forests and trees	Section 3 (principles) includes '(c) forests must be developed and managed so as to— (i) conserve biological diversity, ecosystems and habitats'. Section 4(6)(a)(iii)) refers to the need for *conservation of processes* ('The health and vitality of forests is promoted and maintained') The NFA also provides for monitoring criteria and indicators Section 8(1) provides for three types of specially protected areas in the forestry context

[4] The comprehensive plan of global, national and local action on the environment adopted at the United Nations Conference on Environment and Development ('Earth Summit') in 1992.

Policy/ legislation	General implications	Specific implications for forest conservation
National criteria and indicators	Principle 1: The forest resource base is secured Principle 2: Biological diversity in forests is conserved Principle 3: The health and vitality of forests is promoted and maintained	Criterion 1: Natural forests are protected Criterion 2: Biodiversity of natural forests is conserved Indicator 1: Area (ha) of natural forest conserved Indicator 2 : The extent of forest type occurring in protected areas Criterion 3 Forest ecosystem structures are conserved and processes maintained Indicator: extent and connectivity of natural ecosystems
National Environmental Management: Biodiversity Act	Enables specific ecosystems or species within an ecosystem that are perceived to be endangered to be listed	Ecosystems that are threatened and in need of protection may be declared nationally by the Minister, or provincially by an MEC for environmental affairs by notice in the *Gazette,* (Section 52(1)(a))
National Environmental Management: Protected Areas Act	Points out the need for 'ecological viability and representivity of South Africa's biological diversity'. NEMPAA also provides for the classification of protected areas	List types of areas that can be declared as protected under this Act. All provisions for specially protected forest areas, forest nature reserves and forest wilderness areas, as declared under Section 8 of the NFA, are maintained

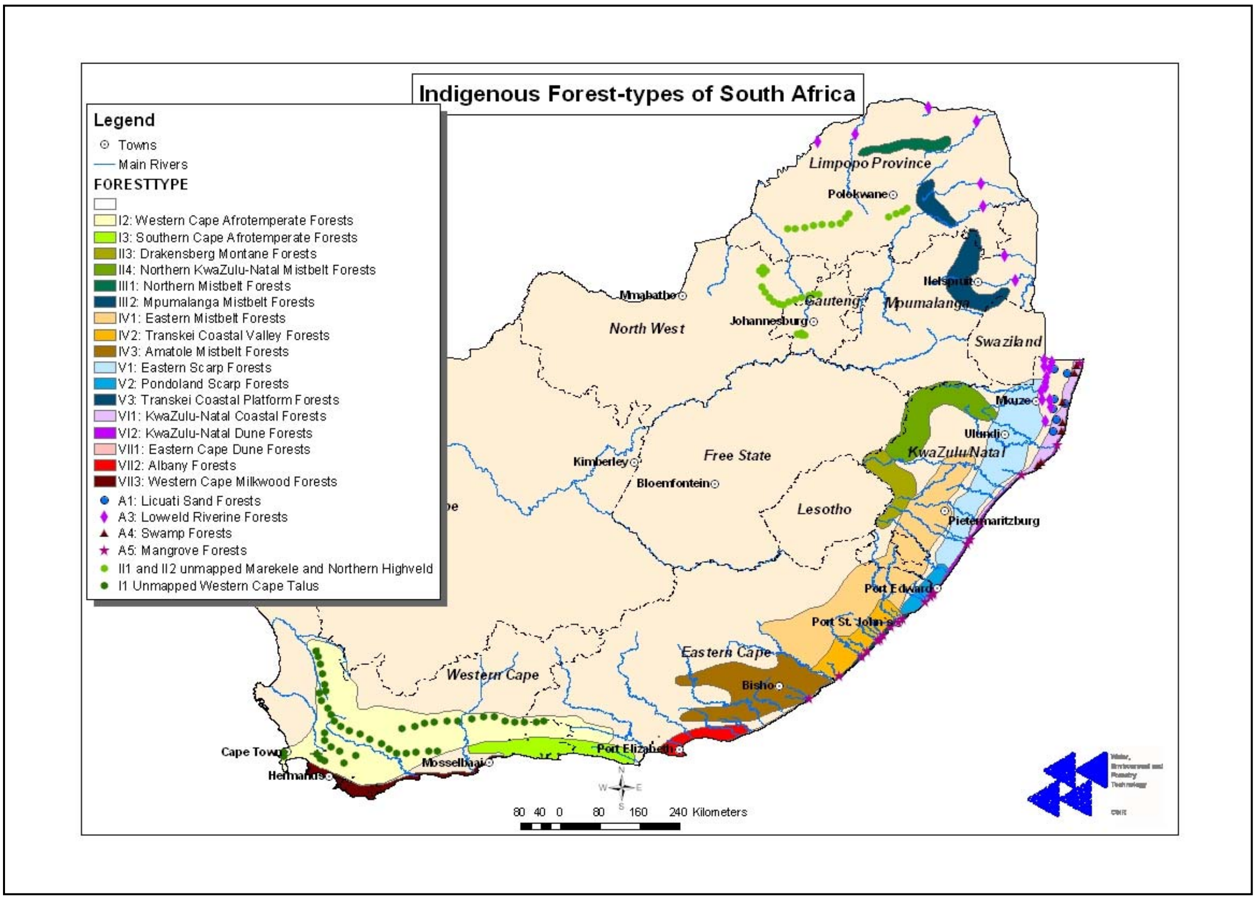
1.2 Forest types

Indigenous forest can be found from the Soutpansberg Mountains in the far north to the Cape Fold Mountains in the south. They occur as fragmented patches of varying size, on the eastern and southern seaboard and along the south and southeast facing slopes of the Escarpment. The tremendous spatial variation in climate, altitude, latitude and topography across this region has resulted in a diversity of forest types. Forests typically occur in the moist areas of the country, but specialised forest types are also found fringing rivers or within protected valleys in more arid areas.

To effectively monitor, evaluate and protect forests, the types of forests must be clearly defined, and their distributions accurately mapped. Early classifications of forest have been primarily subjective, but all have agreed on a major division of South African forest into inland temperate Afromontane forest and coast subtropical Indian Ocean types (Midgley et al. 1997). These are associated with two main phytochoria: the Afromontane archipelago and the Tongoland-Pondoland regional centres of endemism. The small area of sand forests in South Africa has also been recognised as distinctly different from other South African forest types, containing species that indicate their origin from Zanzibar-Inhambane region.

The first objective classification, of South Africa's indigenous forests, was completed by Von Maltitz et al. in 2003. The focus of this classification was based primarily on biogeography-and floristic similarities, using over 4 500 plot based woody vegetation samples from 427 forest sites. Formalised classification and statistical ordination was used to delimit the major forest types. The results are presented in Figure 1.

Figure 1: Distribution of indigenous forest types of South Africa



Source: Von Maltitz et al. 2003.

In the conservation planning analysis, forest types were used as the prime biodiversity element for target setting. In other words, forest types are used as surrogates for all forest biodiversity, the assumption being made that if representative samples (forest types) are conserved, then all biodiversity occurring in each forest type will also be conserved.

For some forest types this assumption has been questioned. Where forest types have high beta (or habitat diversity), representative sampling may require analysis of sub-types with in each forest type. Differences within a forest type can usually be attributed to variations in topography, altitude, and microclimate or soil type. It is evident that, for some forest types, certain species may only occur within specific habitats of the forest type. Because of this, it has been argued that here is a need for further refinement of the national forest types into sub-types that will be more representative of all forest biodiversity. However, it may be some years before this level of forest classification is available and until then, forest types will be used as approximate biodiversity surrogate for conservation planning and target setting.

1.3 Biodiversity value of South Africa's forests

South African forests are very ancient and have been fragmented for at least 20 million years. Shrinking and expansions reflect changes in glacial and inter-glacial periods. In this respect, our forest has special evolutionary significance. Fossil pollen has been used as indicators of past climatic conditions.

Although South African forests show stronger affinities with Afro-tropical forests, their position in relation to the Equator qualifies them as occurring within the temperate forested region. Recent research has shown that South African forest have the highest biodiversity of any temperate forested region in the world (Silander 2000).

What is also not always realised is the national biodiversity significance of South African forests. They are between three and seven times richer in tree species than other forested areas of the Southern Hemisphere, even though these forests cover a much larger area (see Figure 2). Furthermore, when it comes to the richness of genera and families of trees, South African forests are unparalleled (Cowling 2002; Silander 2001).

If the number of species occurring within each of South Africa's six biomes are considered relative to the total area covered by each biome, then the forest biome contains the highest density of species by far (3 000 species in approximately 5 052 km^2, as opposed to the next highest, fynbos with 7 500 species on 76 744 km^2).

Conservation International has added the Maputaland-Pondoland region, stretching from southern Mozambique to shores of Algoa Bay, to its list of global biodiversity hotspots. Global hot spots are areas harbouring at least 1 500 endemic plant species within their borders and which have lost much of their natural habitat as a result of human impacts. This new hotspot encompasses most of our forest biodiversity and certainly the majority of the most threatened forest types in South Africa.

The global and national importance of South Africa's forests place a heavy responsibility on the South African government to ensure their long-term conservation. To this end, there is an urgent need for the planning and implementation of a representative network of forest protected areas. This needs to be driven by defensible conservation targets for each forest type, which are scaled according to inherent diversity patterns and the threats that each forest type faces. The plan should also target the ecological and evolutionary processes that maintain forest biodiversity

What are the conservation implications of this? Firstly, we need to recognise and communicate widely that our forests are globally significant and treat them accordingly. We have already lost large areas of forest and many of our forest types are under-represented in strict conservation areas relative to national conservation targets. This needs to be rectified by identification of priority areas for inclusion within a strict protected area network.

1.4 Utilisation vs. protection

Since 1994, the Department of Water Affairs and Forestry has undergone significant changes and restructuring. This has affected the management, ownership and protected area status of South African indigenous forest (DWAF 1999).

In theory all forests are protected under the National Forests Act, but in practice considerable legal and illegal exploitation is occurring. Currently the conservation status of much indigenous forest is uncertain (Castley & Kerley 1996; Lawes et al. 2001)

Many of the forests are to be found in the poorer rural areas of the country where they play an important part in the local economy, livelihoods and culture of the people. In many respects, southern Africa's forest and woodlands are regarded as the poor people's safety net, providing as much as 35% of rural households' income (Lawes et al. 2004)

With increased urbanisation in recent years, the (often illegal) commercial utilisation of forest products (particularly for medicinal use, firewood and building material) has increased, placing many areas under threat of complete deforestation. Herein lies the central dilemma facing managers of these forests: they have important biodiversity significance (Midgley et al. 1997; Silander 2001) but are heavily utilised and valued by the country's people. In addition, with a highly fragmented and patchy distribution across the country, they do not form a cohesive, contiguous biome within which this diversity can easily be conserved or managed (Lawes et al. 2004).

Prior to 1994, the main management objective was protection, and consumptive use of those forests under state control was virtually prohibited. Following the passing of the National Forests Act in 1998, the emphasis has shifted to allow managed access and utilisation of forests. This has been given an institutional framework, through DWAF's Participatory Forest Management directorate). The NFA allows communities that live near or around state forests to utilise these forests without the need for a licence. It allows for the removal of products such as 'firewood, mushrooms, herbs, plants etc.' This exception is subject to certain restriction such as 'no live wood may be removed, and a person may collect only as much can be carried between sunrise and sunset' (DWAF 2005). Conservationist argues that the non-licensing extraction of forest products by local communities, while laudable in its intentions, will be very difficult to regulate and control.

Concerns have also been raised that policies advocating the devolution of state control of indigenous forests will effectively lead to open access and increased levels of non-sustainable use and associated biodiversity loss (Lawes et al. 2001; Obiri et al. 2002). This concern is expressed within the context of increasing loss of power of traditional authorities , and diminished capacity of the state to regulate the use and abuse of forests (DWAF 2003). Some forest ecologists also question the ability to estimate sustainable harvest levels in the absence of a good understanding of forest regeneration processes (Obiri et al. 2002; RM Cowling, pers. comm.).

1.5 Forest protected areas and IUCN categories

Currently, a number of categories of protected areas include forests. These include areas that have been declared as protected areas under municipal, provincial and national legislation (these are discussed in further detail below). None of these bits of legislation refer specifically to the international IUCN[5] protected area categories.

Section 8 of the NFA permits the Minister to declare a state forest (or part of it), and to declare it to be a protected area in one of the following categories:

- forest nature reserve
- forest wilderness area
- any other type of protected area recognised in international law or practice.

It has always been presumed in DWAF that 'any other type' referred primarily to the IUCN protected area categorisation. However, alternative and often conflicting protected area classification systems have led to confusion and further delays in implementing conservation action. Within DWAF, a management classification system has been used in some areas (notably in the Knysna region). While this has similarities with the IUCN protected area system, it is essentially a forest management classification system and not a protected area classification system *per se*.

Recent legislation and policy promoting bioregional approaches to conservation are likely to have a major impart on protected area planning in South Africa (DEAT 2001, NEMPAA and NEMBA). NEMPAA provides definitions for six types of protected areas. (While there are similarities with the IUCN protected area classification system, there are also confusing differences). The Act fails to describe guidelines and criteria that are needed to facilitate appropriate protected area category selection (Berliner 2002).

At the national level there is an urgent need to reconcile the different forms of protected area categorisation systems. DWAF has expressed a need to reconcile the DWAF management categories with the IUCN protected area categories and those designated by the NFA. This has also

[5] The World Conservation Union (formerly the International Union for Conservation of Nature and Natural Resources).

lead to the concerns around issues of relevance, applicability, procedure and harmonisation with other South African protected area processes (for example, NEMPAA).

The advantages of applying an internationally standardised protected area category system are numerous. Importantly, this will provide a common currency for global forest conservation indicators and regional monitoring programmes like the criteria and indicator monitoring and the Forest Stewardship Council (FSC) certification programmes

At the international level, the need for improved guidelines on applying IUCN protected area categories has been called. Recommendation 5.9 of the 5th IUCN World Parks Congress held in Durban calls for clarity on the process by which protected area management categories are assigned.

Section 8.4 looks at how an objective system was developed for classifying forest patches into IUCN protected area categories.

1.6 Participatory forest management and protected areas

The indigenous forest resource base is the smallest, most fragmented biome, making it arguably one of the most vulnerable. In spite of its small area, the forest biome is widely used and provides highly-valued resources, both from a livelihoods and a commercial forestry perspective (Lawes et al. 2001; Lawes et al. 2004).

Recent southern African trends in forest management policy have focused on the devolution of forest tenure and management from state authorities to local communities (DWAF 1997). People living around forests in rural areas are now being provided with opportunities to manage and benefit from indigenous forests. In South Africa this approach has been driven by the need to promote greater participation by citizens who had been disadvantaged by apartheid (DWAF 1997), while internationally, this approach has arisen out of increased recognition of traditional user rights and the need for equitable benefit sharing of sustainable harvesting of resources.

Participatory forest management (PFM) is being promoted by DWAF as both a mechanism to help conserve forests and to simultaneously provide local community benefits. PFM is therefore no small undertaking and will require careful planning. While its implementation can no longer wait for improved information, the use of adaptive management along with comprehensive monitoring and evaluation would seem to be the wise approach.

The products of systematic conservation planning needs to inform and support the appropriate implementation of PFM, in particular the identification of forests with high livelihood values and that have a high conservation value. These forests can be considered as ‘hotspot areas’ urgently in need of conservation action.

1.7 An indicator-based modelling approach

The use of indicators has become particularly important in monitoring progress towards sustainable development. Indicators are bits of information that summarise the characteristics of systems or highlight what is happening in a system. Indicators simplify complex phenomena, and make it possible to gauge the general status of a system. In particular, indicators make it easier to communicate about complex multi-criteria concepts like ‘sustainable development’. They translate the concept of sustainable development into numerical terms, descriptive measures, and action-oriented signs and signals. When a collection of indicators is combined mathematically (or aggregated), the resulting number is called an index.

Many of the indicators which have been developed (irreplaceability, threat, livelihood value, vulnerability to edge effects, poverty, population density, accessibility and habitat transformation of surrounding forest buffer areas) represent scaled values often derived from multiple data sources.

For example, the indicators of threats to forest were modelled using population pressure, agricultural suitability, forest accessibility, proximity to urban development and agricultural land potential.

Rule-based expert system modelling was used to automate the process of calculating multiple indicators for each forest patch. An indicator-based modelling approach forms the basis of the conservation planning decision support system.

1.8 Using expert systems with GIS

Expert systems are considered a branch of artificial intelligence (Waterman 1986). They rely on rule-based modelling to represent the decision-making algorithms of specialists. Typically, they consist of a knowledge or rule base, a database, and an inference engine.

Typically the development process involves a number of stages, including understanding the problem (conceptualisation), interviews with experts (knowledge acquisition), distillation of expert information into sets of heuristics (knowledge representation), and model testing, refining and calibration (validation).

Rules are coded or programmed using commercially-available expert system shells. They have been successfully used in natural resource management decision support for a number of years. (See, for example, Starfield & Bleloch 1983; Starfield & Louw 1986; Coulson et al. 1987; Noble 1987; Berliner 1990). More recently, expert systems are being used as intelligent interfaces to relational databases and geographical information systems, providing powerful and integrated spatial decision support information. (See, for example, Twery et al. 1991; Kalogirou 2002; Thomas 2002; Filis et al. 2003).

The use of expert systems as intelligent interfaces to GIS is a novel approach to the multi-criteria decision problems associated with systematic conservation planning. The approach has the potential to integrate two alternative approaches to conservation planning (as discussed by Cowling et al. 2003a), namely expert-based opinion and systematic computer optimisation algorithms (both essentially used to identifying priority areas for conservation planning).

Both the expert and the algorithm approach have pros and cons. The systematic approach can provide a region-wide perspective and the simultaneous assessment of large number of planning units. This is particularly important, given the large number of forest patches. The expert-driven approach allows for the incorporation of expert knowledge on biodiversity persistence and pragmatic management and implementation issues.

2 What is systematic conservation planning?

The selection of protected areas in the world has been influenced to a large extent by political, economic and aesthetic factors, rather than on trying to achieve biodiversity representivity. This has resulted in protected area systems that are under-representative of many elements of biodiversity. Moreover, most protected area systems have not taken into account the conservation of important ecological processes and long term persistence in their design.

The prime aim of systematic conservation planning is the establishment of a protected area network that is representative of the biodiversity of a country or a region. However, successful implementation will only be possible if the planning incorporates social-economic considerations. Resources for conservation are often limited, and conservation may be competing with other forms of land use. This is particularly relevant to forest conservation planning in developing countries like South Africa which are characterised by high levels of rural poverty, and where rural communities may rely directly on natural resources for their survival.

There is a general need to develop conservation landscapes that allow the maintenance of biodiversity whilst minimising impacts on the livelihoods of local people (Driver et al. 2003). To achieve this, Margules and Pressey (2000) have identified a number of broad steps to systematic conservation planning. These include:

- compile data on the biodiversity of the planning region
- identify conservation goals for the planning region
- review existing conservation areas
- select additional conservation areas
- implement conservation actions
- maintain the required values of conservation areas.

More specifically, systematic conservation planning identifies priority areas for biodiversity conservation, taking into account vulnerabilities and threats, patterns of biodiversity distribution (the principle of representation), and the ecological and evolutionary processes that sustain them (the principle of persistence).

Recent trends in conservation planning are: a) increased emphasis on the need for the efficiency and optimisation of protected area networks within the socio-economic and political context and, b) recognition of the important of maintaining habitat connectivity and ecological corridors.

In addition, the science of systematic conservation planning also needs to consider the design of nature reserves, deciding what kinds of buffer zones should surround protected areas, and how to establish corridors to link protected areas and allow organisms to move from one area to another. As in other areas of conservation biology, designing nature reserves is a 'crisis science', with a sense of urgency over the need to stem the loss of species caused by increased human population growth and associated land use pressures.

Pressey (1999) has identified five key characteristics of systematic conservation planning:

- **Data-driven**. Systematic approaches typically require integration of different datasets. These are often represented as a matrix of 'features' and 'areas or planning units'. The features can be species, vegetation types, or any other natural entities of interest.
- **Goal-directed**. The areas selected by systematic techniques reflect the explicit goals of the exercise. These goals are expressed as quantitative targets for each of the natural features being considered (for example, at least three occurrences of a species or at least 1 200ha of a forest type).
- **Efficient**. A key characteristic of systematic approaches is their efficiency. They are designed to achieve conservation goals with a minimum of cost, measured by factors such as number or total extent of conservation areas, acquisition cost, or opportunity costs for other uses.
- **Explicit, transparent and repeatable**. The results of systematic selection analyses can be explained in terms of data, goals and the selection rules. This will facilitate forest conservation managers to make decisions about sustainability, that can be defensible in terms of the persistence of biodiversity, rather than just short term economic gains or political expediency.
- **Flexible**. Systematic approaches allow for alternative scenario options for achieving multiple goals.

For further discussion on systematic conservation planning see Driver et al. 2003 and Cowling 1999. For a review of conservation planning issues specific to forests, see Berliner & Benn (2003).

3 Overview of approach and methods

3.1 Extent of natural forest

Accurate mapping of the extent of forest biome of South Africa has proved to be difficult, primarily for the following reasons.

- There is spectral image confusion which makes distinguishing forest from non-forest difficult (in particular with thicket and woodland).
- Methodologies used to map forests differ. Different scales and resolutions can make comparisons difficult (in particular between satellite imagery and aerial photography).
- The data is 'dirty'. Datasets include duplicate, shadow and sliver polygons.

Because no complete standard national forest cover data set was available at the time of analysis, a combination of a number of different datasets was used (Benn 2004). The NFI (National Forest Inventory) data set was used as the prime source. To address the gaps in this data, additional sources were used. These included data from KwaZulu-Natal Wildlife (provided by Dr P Goodman) and Mpumalanga Parks Board (provided by Mr Lotter). Data for the azonal forest types were obtained by using the recently completed national vegetation map (Mucina & Rutherford 2004).

Using a combination of different datasets, the indigenous forest cover estimated for South Africa was an area of 505 284ha (Benn 2004). Subsequent analysis found this to be a slight overestimation, that had included a number of duplicate and sliver polygons. After data cleaning, the total area was recalculated as 486 713ha. The amount of each forest type has also been calculated (see Table 2). Results have been compared with the National Land Cover estimates and the NFI data.

Table 2: Comparison of different national forest cover estimates

Forest type	Total area (ha)		
	This study[6]	NLC[7]	NFI[8]
Albany	22 046.37	11 932	
Amatole Mistbelt	64 221.09	48 445	
Drakensberg Montane	1 926.39	2 634	
Eastern Cape Dune	10 940.58	931	
Eastern Mistbelt	41 841.86	51 307	
Eastern Scarp	33 750.17	21 223	
KwaZulu-Natal Coastal	21 089.11	26 330	
KwaZulu-Natal Dune	12 395.89	24 865	
Licuati Sand	24 275.67	46 240	
Lowveld Riverine	11 401.28	8 443	
Mangrove	2 392.70	14 677	
Mpumalanga Mistbelt	32 772.36	46 249	
Northern KwaZulu-Natal Mistbelt	5 323.42	8 443	

[6] Berliner & Benn (2004), revised after data cleaning by Geoterraimage 2005. Data source: NFI data plus improved mapping from KZN and Mpumalanga provinces, and new national vegetation map (for zonal forests).

[7] Thompson (1999) National Land Cover, classified satellite imagery.

[8] DWAF (2003). National Forest Inventory based on NLC plus additional satellite imagery and aerial photography commissioned by DWAF for parts of country.

Forest type	Total area (ha)		
	This study[6]	NLC[7]	NFI[8]
Northern Mistbelt	19 203.65	14 677	
Pondoland Scarp	12 337.00	17 014	
Southern Cape Afrotemperate	68 563.35	77 521	
Swamp	3 021.71		
Transkei Coastal Platform	61 484.01	24 411	
Transkei Coastal Valley*		14 768	
Transkei Mistbelt	30 249.84		
Western Cape Afrotemperate	4 731.06	486	
Western Cape Milkwood	2 499.74		
Total	**492 699.76**	**538 630**	**534 407**

* Transkei Coastal Valley was considered part of Transkei Coastal forest for this study.

3.2 Planning units

The choice of appropriate planning units is critical to systematic conservation planning, as they represent the units of selection for prioritisation. A range of different planning units can be used. These include regular grid squares (for example, Rebelo & Siegfried 1992), broad habitat units (for example, Cowling et. al. 1999), land systems (Pressey & Taffs 2001) [9] and habitat remnants (Von Hase et al. 2003).

The first phase of this study used individual forest patches as planning units. This represented the most practical planning units, for two reasons. Firstly, it enabled the use of existing datasets (as used in the National Forest Inventory or NFI data).

A second phase of analysis was conducted using forest clusters and sixteen degree grid squares as planning units (see Section 8 for further details). Irreplaceability values have been calculated for forest patches, forest clusters and sixteen degree squares (SDS) with forests.

A total of 16 185 forest patches were evaluated, of which only 5 856 were larger than 10ha, and just over 800 larger than 100ha. Table 3 provides the size distribution of forest patches.

Table 3: Size distribution of forest patches, and the area contributed by patches in each size range

Patch size (ha)	Number of patches
0–10	10 322
10–25	2 866
25–50	1 347
50–100	804
100–250	543
250–500	243
500–1 000	33

Clustering reduced the number of planning units to 3 296. Although most clusters (92%) cover areas of less than 1 000ha, 13 are larger than 10 000ha and six are larger than 20 000ha.

Clusters were prioritised and sorted according to size, connectivity and irreplaceability. Marxan was used to calculated cluster irreplaceability (see Section 3.10 of this document).

[9] Land systems were used by Pressey & Taffs (2001) as planning units that acted as surrogates for the pattern of biodiversity across western New South Wales (Australia).

3.3 Forest clusters and connectivity

The forest biome is inherently fragmented, occurring as chains of 'habitat islands' embedded within a range of different vegetation types, including grasslands, fynbos, woodlands, bushveld, and succulent thicket. Increased land use pressures (urbanisation, agriculture and forestry plantations) have greatly exacerbated the fragmentation and isolation of indigenous forest patches.

Preserving the connectivity between remaining remnants of natural habitat and protected areas has been generally neglected in the design of reserves. Given the high degree of fragmentation, maintenance of habitat connectivity is considered to be a critical consideration for the long-term persistence of forest biodiversity.

In recent years, there has been a growing realisation that the conservation of ecological process requires a broader landscape approach integrating different forms of land use with conservation. In this respect, the need to plan for ecological connectivity is particularly important.

To ensure long term persistence, many species require dispersal and colonisation between habitat fragments and between meta-populations. Genetically isolated meta-populations may not be viable in the long term. Ecological connectivity allows for dispersal of individuals and genetic material between otherwise isolated sites.

The aim of the grouping of forests into relatively contiguous 'forest clusters' was to:

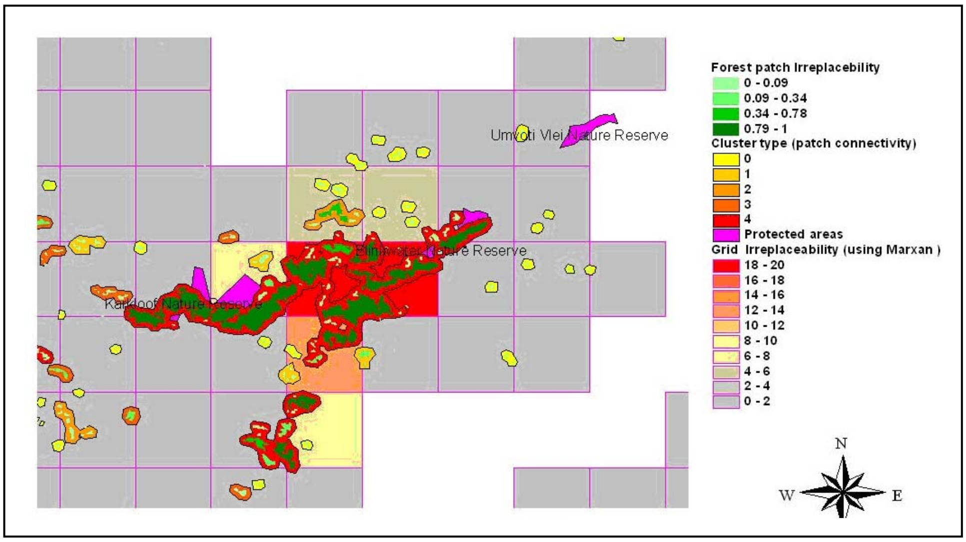
- address the problem of inconsistent forest patch delineation inherent in the original NFI data
- enable the identification of large semi-contiguous forest clusters for priority conservation action (forest clusters become a higher level planning unit for prioritisation)
- identify levels of connectedness (between forest patches)
- assist with identifying ecological corridors between forest patches and forest clusters.

A GIS rule-based modelling approach was used to derive cluster a connectivity index ('cluster type'). To do this we considered the following variables:

- the distance between patches
- level of habitat transformation in the intra-patch matrix
- alignment with river corridors.

Patches were considered as part of the same cluster provided distance between patches was less than 1 000m (that is, intersecting 500m patch buffers). Details of this analysis are given in Section 8. Figure 2 provides an example of the results of cluster analysis showing the cluster types, and irreplaceability of sixteen degree square grids.

Figure 2: Forest clusters in the Karkloof area of KwaZulu-Natal[10]



3.4 Forests and ecological networks

Ecological network are regarded as coherent systems of natural and/or semi-natural landscape elements, configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources (Bennett & Wit 2001). Ecological networks are an important component of reserve network design, bioregional planning and eco-region based conservation.

Ecological networks are characterised by five key elements (Bennett & Wit 2001), namely:

- a focus on conserving biodiversity at the ecosystem, landscape or regional scale
- an emphasis on maintaining or strengthening ecological coherence, primarily through providing for ecological interconnectivity
- ensuring that critical areas are buffered from the effects of potentially damaging external activities, including climate change
- where appropriate, restoring degraded ecosystems
- promoting complementarities between land uses and biodiversity conservation objectives, and particularly by exploiting the potential biodiversity value of associated semi-natural landscapes.

Ecological networks can be considered at a variety of spatial scales, such as a watershed, a mountain range or a natural community. In many of the cases where the initiative is part of government policy or planning, the region may be delineated by a sub-national administrative unit such as a municipal district.

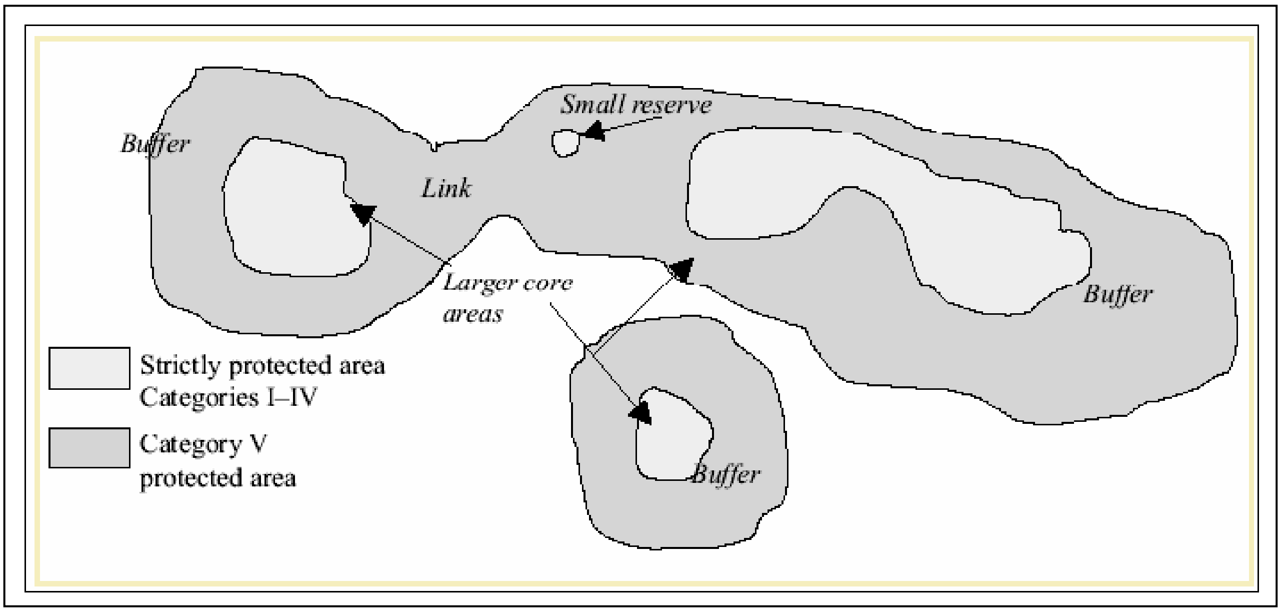
An important tool to in ecological network planning is the use of zoning. Zoning is a term used by conservation planners to denote the division of land into logical units for management. At its most basic, a zoning system includes a highly protected core area surrounded by a buffer zone. The core area – such as strict reserve or no-take area – protects critical habitat and species. The buffer zone

[10] Cluster type is an index of the degree of patch connectivity. Type 4 is red, the highest. Connectivity between clusters is indicated by the distance between patches, matrix transformation, and river length running through a cluster. Grid colours refer to different levels of cluster irreplaceability using Marxan. Red grids are 100% irreplaceable. Blank areas are outside of the planning domain.

may allow a broader range of uses, but is intended to insulate the core from threats to its conservation status.

The use of internationally standard protected area management categories in particularly Unesco[11] biosphere reserves and those developed by IUCN (protected area management categories) provide useful zoning frameworks. Figure 3 provides an example of how forest patches can be linked through a matrix of different kinds of protected areas

Figure 3: Hypothetical example of ecological corridors that connect forest patches, using IUCN management categories[12]

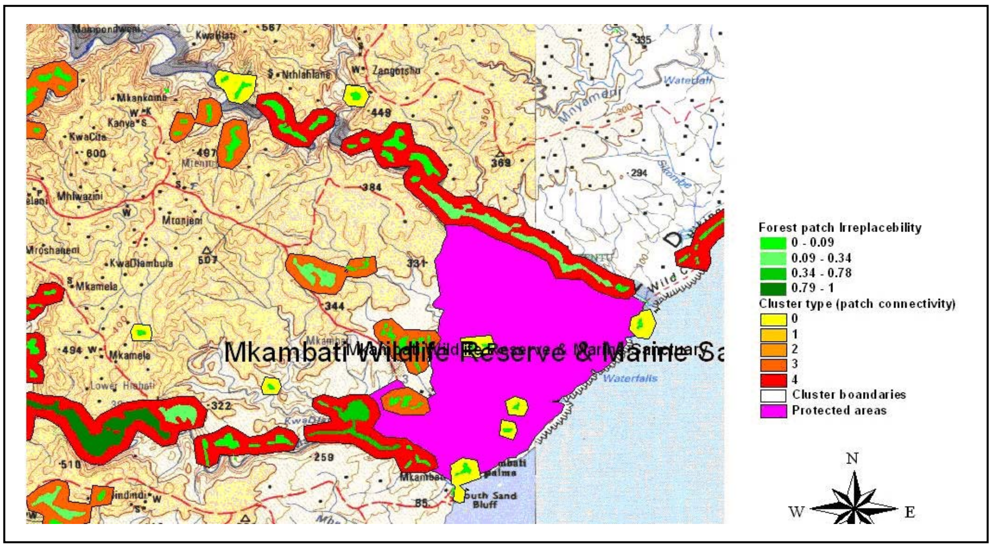


Forest clusters can play an important role in identifying linkages with existing protected areas and valuable habitat outside of protected areas. Figure 4 shows an example of ecological corridors along rivers connecting forest patches to reserve area.

[11] United Nations Educational, Scientific and Cultural Organization.

[12] Different kinds of protected areas, with core areas strictly protected and multiple-use protected areas in buffer zones.

Figure 4: Potential ecological corridors connecting forest patches and forest clusters, showing the importance of forest clusters in identifying linkages with existing protected areas[13]



3.5 Threat analysis

Threat analysis is an important component of systematic conservation planning. Forests in South Africa have a long history of non-sustainable utilisation, being one of the first biomes to undergo heavy exploitation with the colonisation of the Cape.

Most of the destruction of forest took place at the hands of European settlers in the period 1860–1940. Overall, it is estimated that the forested area of South Africa declined by approximately 40% between 1800 and 2000, while this value may be closer to 65% for coastal forest belt forest in KwaZulu-Natal (Lawes 2002).

Currently, forest are under threat from a number of land-use pressures, including coastal development, mining, agriculture and over harvesting for subsistence or illegal commercial use (in particularly for medicinal plants).

Coastal forests are currently under particular threat from coastal development, over-harvesting, and dune mining. In the past, coastal forests were extensively cleared for sugar cane cultivation. This is particularly alarming given that, of the various forest types, coastal forest tend to have the highest species diversity, as well as most of the forest-dependent endemic species.

Non-sustainable substance harvesting is on the increase. Fuelwood, building materials, and medicinal plants are in demand. Forests under particular pressure include areas in the former Transkei, Eastern Cape (DWAF 2003), and Limpopo.

Little quantitative data exits on the conservation status and condition of forests. The most intensive assessments date back to the early 1990s (Cooper 1985; Cooper & Swart 1992). More recent work in KwaZulu-Natal and has provided better and more up-to-date data for this province (Goodman 2000).

The few studies that are available, together with a lot of anecdotal accounts, suggest that, for many areas, the forest biome is currently under siege. Inventories undertaken by DWAF (DWAF 1999) revealed that uncontrolled and often illegal harvesting of a variety of forest products such as lathes, poles and fuelwood, but especially medicinal products, is widespread in former homeland areas and is placing increasing strain on some forest patches and certain forest species (DWAF 2003). In

[13] In this case, Mkambati Nature Reserve on the Wild Coast, Eastern Cape.

addition, increased demands for dune mining, urban and holiday cottage development are also placing increased pressure on many coastal forests.

Because of the absence of any quantitative assessment of forest impacts, a modelling approach was used to quantify threats to each forest patch. This study represents the first threat analysis of its kind to be conducted for indigenous forest in South Africa.

Table 4 provides a brief description of the key threats to forest biodiversity and how they were modelled to derive indicators. Four distinct kinds of threat/land use pressures were modelled. Indicators were derived using a rule-based scoring system. Rules were used to describe the hypothetical relationships between the triggers and modifiers of drivers of threat.

Table 4: Threats considered, data used and indicators derived

Threat	Spatial data used	Indicators
Unsustainable harvesting of subsistence forest products	• National census 2001 data (population density, wood use and poverty). • Accessibility to forest resources modelled using topography, road access, road penetration (from GIS intersections).	• Subsistence Resource Use Pressure Index (SRUPI) also used for forest livelihood value. • Accessibility index. • Population density, poverty and wood use index (in surrounding 5km buffer index).
Threats associated with surrounding land transformation	• Agricultural Research Council (ARC) land capability spatial data used to derive extrapolations of 'arability' (suitability to commercial cropping & plantations). • Modified using degree of existing land transformation (National Land Cover data 2000) surrounding forests, and population density in 5km buffer areas around forest.	• % arability index (of forest buffer area). • Threat of agricultural transformation index.
Urban expansion	• Coastal forest types. • Forests 15km from an urban area.	• Threat of urban expansion.
Mining	• DWAF data on forested areas that are currently being mined or proposed for mining.	• Threat of mining (scores depending on the value of the mineral may be included later).

The threats posed by uncontrolled fires and invasive aliens were excluded from the analysis because of the absence of national data coverage and the difficulties associated with modelling them. While important in some cases, they are not considered as major threat factors to the forest biome.

Highly aggregated results of the threat modelling are presented in Table 5, showing the proportion of each forest type under high threat.

Table 5: Percentages of patches that scored a 'high threat rating index', averaged for each forest type

Forest type	Number of forest patches with 'high' threat index	Total area with 'high' threat rating (ha)	Total area of each forest type (ha)	% of total forest type under 'high threat'
Eastern Cape Dune	130	10 941	10 941	100
KwaZulu-Natal Dune	219	11 838	12 398	95
Mangrove	32	2 905	3 054	95
Western Cape Milkwood	117	2 227	2 500	89
Albany Coastal	300	20 511	23 143	89
Transkei Coastal	2 854	49 058	61 490	80
KwaZulu-Natal Coastal	652	12 133	21 092	58
Swamp	14	943	3 022	31
Eastern Mistbelt	176	3 557	42 162	8
Pondoland Scarp	20	290	12 441	2
Lowveld Riverine	5	135	11 705	1
Licuati Sand	16	272	24 276	1

Forest type	Number of forest patches with 'high' threat index	Total area with 'high' threat rating (ha)	Total area of each forest type (ha)	% of total forest type under 'high threat'
Southern Cape Afrotemperate	7	441	77 534.9	1
Amatole Mistbelt	9	324	64 424	1
Northern Mistbelt	11	91	19 349	0
Eastern Scarp	3	49	33 765	0
Transkei Mistbelt	1	1	30 859	0

A compounded forest clusters threat raring was extrapolated by using proportional averaging of the forest patch threat ratings for each cluster.

3.6 Fragmentation, isolation and edge effects

Most forest types in South Africa have been fragmented throughout much of their evolutionary history by repeated and severe climate changes in the Quaternary (Eeley et al. 1999). However, selective logging of these forests from 1870 to 1944, the spread of agriculture, and lately the encroachment of commercial plantation forestry, have all exacerbated the dissection and fragmentation of the natural forested landscape (Lawes et al. 2000).

Increased forest fragmentation and isolation of remnant forests by non-favourable forms of land use (in particular, agriculture, urbanisation and plantation forestry) pose a potential long-term threat to forest biodiversity. Transformation of natural habitat of the inter-patch matrix leads to increased negative edge effects and decrease in ecological connectivity between patches (Swart & Lawes 1995; Laurance 2000; Wethered & Lawes 2003).

One of the most important consequences of forest fragmentation is a dramatic increase in the amount of habitat edge. Mounting evidence reveals that the abrupt, artificial edges created by forest fragmentation negatively affect many forest species and ecological processes. Increased fragmentation and exposure of forest edges to transformed matrix habitat can have numerous direct and indirect effects on forest biodiversity. Studies have confirmed the influence of changing forest edges to temperature, moisture and light gradients. The degree to which these changes penetrate into the forest, and the impacts on forest biodiversity are variable, often depending on a number of factors, for example the impacts (desiccation and vulnerability to fire) of clear-felling of plantations on forest edges that are north-facing will be more severe than forest edges that are south-facing (Murcia 1995).[14]

Important impacts, often not easy to measure, include disruption of ecological process important to forest, such as changes in geo-hydrology, wind flow patterns, fire regimes, seed dispersal, pollination and nutrient cycling (Laurance 2000).

Recent research indicates that small fragments have very different ecosystem characteristics from larger areas of forest, containing more light-loving species, more trees with wind- or water-dispersed seeds or fruits, and relatively few under-storey species. The smaller fragments also have a greater density of tree falls, a more irregular canopy, more weedy species and unusually abundant vines – lianas. Thus, they preserve only a highly-biased subset of the original flora and fauna which is adapted to these conditions. Reproduction rates are sometimes so low for some species in the most fragmented landscapes that their populations depend on immigration of other populations from areas with more extensive forest cover. Conservation strategies therefore need to ensure the preservation and restoration of large, continuous forest habitats in each region (FAO 2003).

[14] In the Southern Hemisphere.

Plantations pose (a much underplayed), potential long term threat to forest biodiversity. They are responsible for fragmentation and isolation of many forest patches in South Africa. Many valuable forest patches have become virtual islands in landscapes heavily transformed by hundreds of hectares of exotic plantations. Plantations were found to have negative effects on forest bird species richness in Eastern Mistbelt forests, mostly because plantations are of low-quality dispersal routes, and as such act to select or filter out certain species from the forest patches (Wethered & Lawes 2003).

Many forest patches are partially surrounded by transformed habitat. Plantations contribute a significant proportion to this (refer to Table 3). For some forest types, plantations contribute close to, or over, one third of this transformation.

Table 6: Average percentages of overall habitat transformation and percentage of plantations in 5km forest patch buffer areas for forest types*

Forest type	Transformation %	Plantations %
Albany Coastal	61	7
Amatole Mistbelt	58	20
Drakensberg Montane	59	34
Eastern Mistbelt	57	27
Eastern Scarp	62	21
KwaZulu-Natal Coastal	64	29
KwaZulu-Natal Dune	56	17
Licuati Sand Average	69	26
Lowveld Riverine	57	4
Mangrove Average	60	3
Mpumalanga Mistbelt	57	30
Northern KwaZulu-Natal Mistbelt	63	28
Northern Mistbelt	69	29
Pondoland Scarp	60	18
Southern Cape Afrotemperate	56	21
Swamp	64	30
Transkei Coastal Platform	57	11
Transkei Mistbelt	61	22
Western Cape Afrotemperate	57	17
Western Cape Milkwood	55	0
Grand average	**60**	**22**

* Using 2000 National Land Cover data.

To account for the differential vulnerabilities of forest to threats, a forest edge index was calculated. The amount of edge exposure of a forest patch to influences from the outside matrix is largely dependent on the size and shape of the patch. The length of the perimeter relative to the total area of the patch is a useful indicator of shape and edge exposure.

An index of the degree of patch edge exposure was derived using the following steps.

a) Mathematically, a circle represents the minimal amount of perimeter edge to area. A formula was derived such that the shape index will be zero for a circle,[15] and any deviation from a circular shape would give a value of greater than 1. The formula that meets these requirements is :

$$SI = P/ (2 (A \pi)^{0.5})$$

[15] Laurance (1990) adopted a similar approach but used a slightly different mathematical formula.

b) Because we need to combine indices to obtain relative ratings, the shape index values derived from the above formula were then scaled into 1–0 rating based on the following scaling formula:

$$1 - (\text{Highest SI} - \text{actual SI})/\text{highest SI}$$

c) Using the above scaling, a forest that is very narrow and indented will have a scaled shape index that approaches 1, while a forest patch that is close to circular in shape will have a scaled shape index that approaches 0 (see Table 7).

Table 7: Shape indices of four sampled forest patches*

Patch shape	Forest patch shape index (scaled from 0–1)	Patch shape	Forest patch shape index (scaled from 0–1)
	1		0.34
	0.5		0.1

* The higher the shape index, the more vulnerable a forest patch is to outside influence

Forest patches with a high shape index (high perimeter-to-area ratio), and that occur in unfavourable matrices, are likely to be more vulnerable to edge effects than forest patches with a low shape index (low perimeter-to-area ratio). The ‘favourability’ of a matrix was assumed to be a function of the level of habitat transformation. Forest patches occurring in highly-transformed matrices and with a high shape index were considered the most vulnerable to edge effects.

Table 8: Vulnerability rating of forest patches to edge effects using shape index and level of transformation in 5km forest buffer areas*

Shape index	Transformation %		
	>50	30–50	<30
0–0.3	Medium	Low	Low
0.3–0.6	High	Medium	Low
> 0.6	High	High	Medium

3.7 Global climate change and protected area planning

Forests are often highly sensitive to climate, judging by the past distribution of forest types during periods with different climates and by the vegetation bands on mountains. While the Intergovernmental Panel on Climate Change (IPCC) and associated national research programmes are generating valuable new information, forecasts of the potential impact of climate change on forests remain somewhat speculative. Some contend that the most significant threats are drying trends, changes in rainfall patterns, changes in fire regimes and changes in seasonality, which would in turn lead to changes in species distribution and composition. Others suggest that forests may be equally affected by the indirect effects of climate on soil properties or on reproduction. In the final analysis, the most important factor may well be the impact of climate change on human populations, affecting settlement and consumption patterns, which will then influence how forests are used. Nonetheless, the capacity of tree species to shift their ranges in response to climate change also depends on ecological factors, such as dispersal mechanisms.

Trees propagated by seeds that are scattered by the wind or carried by animals may disperse more easily than others. In addition, the changing ranges of animal species may affect those tree species that depend on them. A growing body of research has examined the possible effects of climate change on individual species and biotic communities. Research findings suggest that biological communities will shift in intricate and unexpected ways as the geographical distribution of species is altered individually rather than in community units. Populations located near the edge of a species' range, narrowly endemic species, and endangered species that exist only in protected areas or other limited habitats are especially vulnerable to regional vegetation shifts. Species already threatened by direct exploitation, habitat loss and habitat degradation are likely to be particularly susceptible to new threats

Strategies to mitigate impacts of climate change on forests include the following:

- selecting protected areas that include forest patches and clusters that span an altitudinal gradient
- protecting large areas of forest, where this is still possible
- maintaining or rebuilding connectivity between forest patches, clusters and adjacent protected areas
- protecting inter-patch matrix habitat and promoting reforestation
- protecting forest edges against structural damage, damage by fire and colonisation by invasive alien species by leaving a natural buffer zone of forest that could be managed to resemble a natural ecotone[16]
- softening the edges between matrices by diversifying and promoting less intensive types of land use, managing the use of fire, minimising the application of toxic chemicals, and controlling the introduction of plant species from outside the region.

3.8 Forest livelihood value and a subsistence use index

Indigenous forests provide important sources of natural resource products for many rural communities (Clark & Grundy 2004). The subsistence use of forests serves as important livelihoods safety net for many communities associated with forests (Shackleton & Shackleton 2004).

Subsistence products obtained from forests include: fuelwood (over 90% of households in some villages obtain fuelwood from forests); poles (for hut construction and fencing); edible plants (fruits, wild spinach, fungi and roots); carving (of household items or curios); honey; hunting (important source of protein in some areas), and grazing (forests are considered an important winter resource area in sourveld areas where surrounding areas provide poor winter fodder) (DWAF 2003).

Medicinal plants can be considered as important subsistence products to local communities, but also as (often illegally) harvested forest products that are sold at formal and informal markets across South Africa (Williams 2004).

The trade in plants for traditional medicines in South Africa is a multi-million rand hidden economy, largely operating from the main urban centres (Williams 2004). In 1997 there were an estimated 27 million consumers of traditional medicine and 100 000 practising traditional healers in

[16] A transitional zone between vegetation types.

the country. Medicinal plant species sourced from forests made up 49% of all species in the Durban markets (Mander 1998), while Williams (2004) found that 62% of all species (482 in number) traded at the Faraday Market in Johannesburg were forest or woodland species.

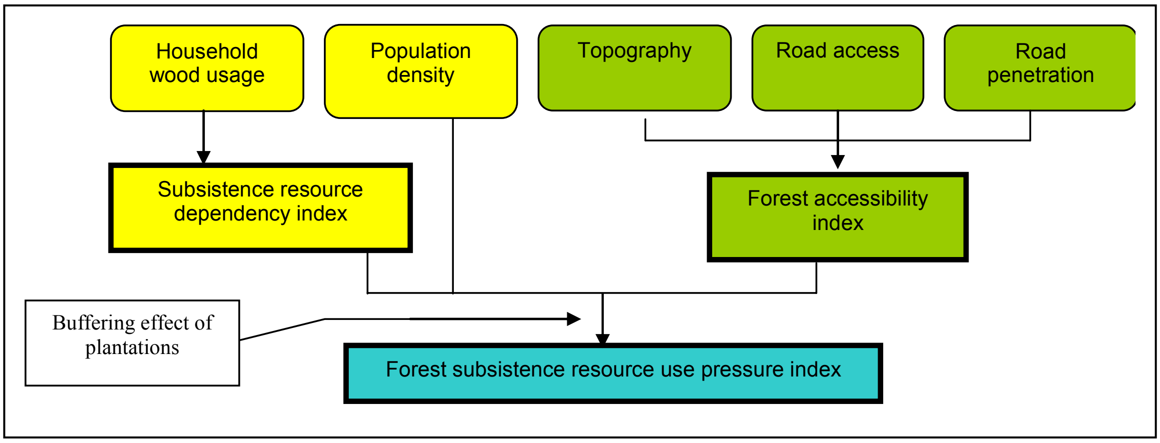
The harvesting and selling of medicinal plants may make a significant contribution to livelihoods of many rural households in parts of the country. Women, specifically, derive livelihoods from trading in forest and woodland products (Williams 2004).

The rates of use of subsistence forest products are difficult to determine, but Lawes et al. (2004) and Shackleton et al. 2001) believe they are increasing and, in some areas, use rates are already unsustainable. Support for this view can be seen in the increased numbers of medicinal plant gatherers, the increasing rarity or local extinction of some high-value species (such as *Ocotea bullata*, *Siphonochilus aethiopicus* and *Warburgia salutaris*), and the apparently increased demand for fuelwood by expanding rural populations (Shackleton et al. 2004).

Not all forests are equally utilised or important for rural livelihoods. Forests that are located away from rural populations, or that are geographical inaccessible (for example, those located in steep valleys) may only be lightly utilised, if at all. By contrast, forests located nears urban centres, or with high surrounding rural populations, are likely to be heavily utilised. The proximity to main or secondary roads, and the degree to which roads penetrate though forests, will also increase the accessibility of the forest resources to potential subsistence or commercial harvesting.

Because the degree of use of forest products is difficult to quantify directly, indicators of the degree of subsistence use of forests were modelled using a rule-based expert system. The model is illustrated conceptually in Figure 5.

Figure 5: Conceptual model used to derive an index of the Subsistence Resource Use Pressure of forest products[17]



Results of running the SRUPI model on forest patch data were in the form of classes of relative, scaled subjective ratings from 'very high' to 'very low'. Table 9 presents aggregated results by forest type.

Table 9: Percentages of each forest type with 'high' or 'very high' Subsistence Resource Use Pressure Index

Forest type	Total area (ha)	% 'high' or 'very high' SRUPI
Eastern Cape Dune	10 941	3.9
KwaZulu-Natal Coastal	21 092	3.6

[17] Yellow boxes represent data extrapolated from national Census 2001 data; green boxes represent data derived from GIS analysis of digitised topocadastal maps).

Forest type	Total area (ha)	% 'high' or 'very high' SRUPI
Transkei Coastal_Platform	61 490	3.2
Mangrove	3 054	3.1
Pondoland Scarp	12 441	2.3
Lowveld Riverine	11 705	1.6
KwaZulu-Natal Dune	12 398	0.9
Amatole Mistbelt	64 424	0.7
Southern Cape Afrotemperate	77 534.9	0.5
Eastern Mistbelt	42 162	0.5
Northern Mistbelt	19 349	0.5
Albany Coastal	23 143	0.3
Eastern Scarp	33 765	0.1
Transkei Mistbelt	30 859	0.1

3.9 Conservation targets

Targets are critical to the process of conservation planning. Conceptually, they represent the translation of the broad goals of representivity and persistence into more specific and quantitative targets. More importantly, targets provide the means of measuring the conservation value (or irreplaceability) of individual planning units.

An extensive consultative process aimed at obtaining input from a wide range of experts and stakeholders was used to identify targets for each pattern and process element used in this study. [18]

The following procedure was used to calculate forest type targets. A minimum base target value of 15% was used. This is based on the targets used by Pressey et al. (1997) and recommendations in Australian and New Zealand Environment and Conservation Council (ANZECC 1997).

This base target was then adjusted upwards depending on:

- species diversity of forest types (the species-area curve's z-value was used to adjust the base target, according to the method of Desmet & Cowling 2004)
- relative rarity of the forest type
- patch fragmentation
- historic reduction (since 1890)
- location within regions/centres of endemism.

Details of the mathematical calculation used are provided in Section 8.

Table 10: Summary of overall target values for each forest type[19]

Forest type	Rarity class	Fragmentation class	Historic reduction class	Overall target value (%)
Lowveld Riverine	High	Medium	Medium	100*
Swamp	High	Medium	Low	100*
Mangrove	High	Medium	High	100*
Licuati Sand	High	Medium	Medium	69
Western Cape Afrotemperate	High	High	Low	60
Southern Cape Afrotemperate	Low	Low	Low	49
Drakensberg Montane	High	High	Low	63.5

[18] This involved two expert workshops.

[19] * indicates targets set by expert opinion, due to absence of species data or, as in the case of swamp forest, extreme rarity that overrides other considerations.

Forest type	Rarity class	Fragmentation class	Historic reduction class	Overall target value (%)
Northern KwaZulu-Natal Mistbelt	High	High	Low	71.7
Northern Mistbelt	High	Medium	Low	59.5
Mpumalanga Mistbelt	Medium	Medium	Low	67
Eastern Mistbelt Forests	Medium	Medium	Medium	66.5
Transkei Mistbelt Forests	Medium	Medium	Medium	64.17
Amatole Mistbelt Forests	Low	Medium	Medium	62.12
Eastern Scarp Forests	Medium	Medium	Medium	61.61
Pondoland Scarp	High	Medium	High	66.61
Transkei Coastal Platform	Low	Medium	High	65.01

3.10 Irreplaceability analysis of patches using C-Plan

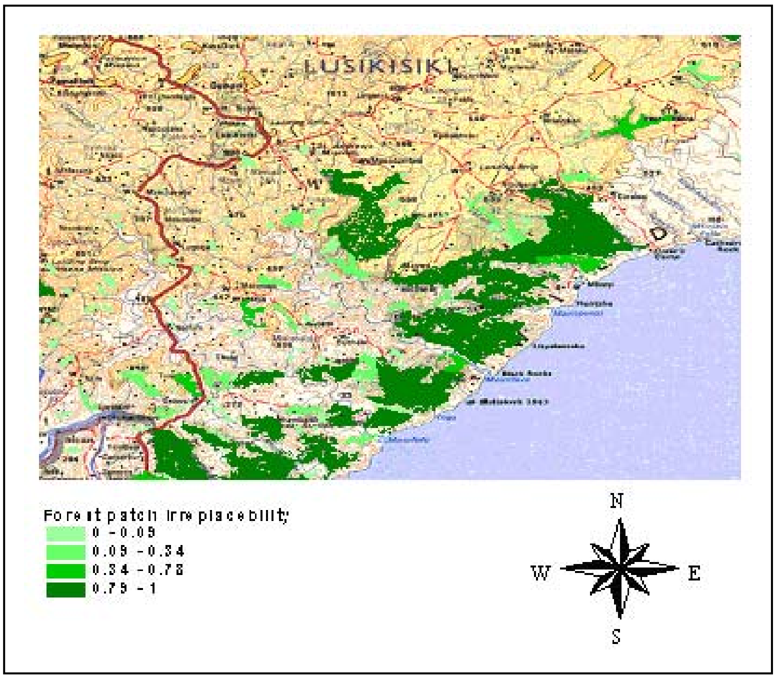
A map of irreplaceability depicts the options for achieving the defined set of conservation targets. Areas that are totally irreplaceable are non-negotiable, while areas with lower irreplaceability values allow for greater flexibility and patch choice. Simply stated, in this study the irreplaceability of an individual forest patch is the contribution of that patch to meeting the specific target set for the forest type. As targets are area-based, larger patches will tend to have higher irreplaceability values, due to the relatively greater contribution made to meeting targets.

C-Plan was used for forest patch irreplacability analysis. C-Plan is a conservation-planning computer decision support tool developed by the New South Wales National Parks and Wildlife Service (Anon 1999). It has been successfully used to calculate and map irreplaceability values in a number of local and international conservation planning studies. Notably, C-Plan has been extensively used for conservation planning of a reserve system for Australian forests (ANZECC 1997), and for the bioregional conservation planning of the CAPE, STEP and SKEP[20] programmes.

In addition to C-Plan calculating irreplaceability values, it also suggests a minimum set, which is a selected set of planning units that will enable targets to be achieved.

[20] Succulent Karoo Ecosystem Programme.

Figure 6: Forest patch irreplaceability analysis using C-Plan, for the Wild Coast region of Eastern Cape[21]



3.11 Irreplaceability analysis of forest clusters using Marxan

Marxan and CLUZ (its user-friendly interface for ARC View) are computer software programs developed specifically for conservation planning. They work by dividing the planning region into a series of planning units, listing the distribution of the conservation features found in the study area, setting targets for the amount of each feature to be included in the conservation landscape, and using computer software to identify the portfolio of units that best meet these targets.

Marxan differs from C-Plan in a number of ways. Importantly, it can promote the selection of planning units that incorporate ecological connectivity as well as socio-economic opportunity costs. Marxan's 'boundary costs' feature favours the selection of planning units which are grouped or connected. It makes conservation sense to minimise outside boundaries because planning units selected on this basis are more likely to function as linkages and corridors between protected areas. This is a particularly useful feature, given the importance of maintaining habitat connectivity in highly fragmented forests.

The cost of including a planning unit in a conservation portfolio may depend on a range of factors including size, financial value and the opportunity costs of preventing other land-use options. Marxan allows these data to be incorporated into the system, so any final conservation plans minimise these costs while still meeting the required conservation targets. We used the forest threat ratings as an index of relative opportunity costs of planning units.

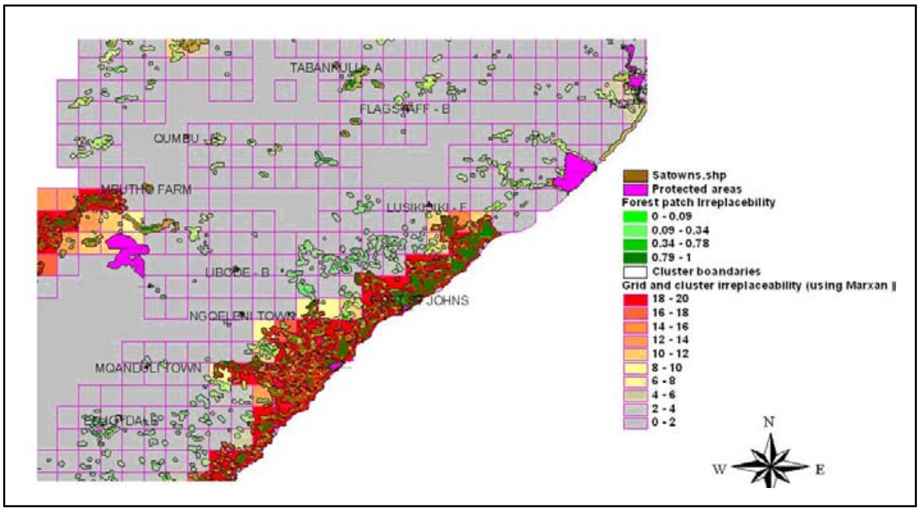
Marxan identifies near-optimal combinations of planning units that meet specified conservation targets. It does this by running the same analysis a set number of times and identifying the most efficient solution. Marxan also records the number of times that each unit is selected in each of the different runs. This number acts as an irreplaceability score, so that units that are selected in every run could be considered irreplaceable. CLUZ can display these scores and the resultant maps are valuable for conservation planning because they give a value for each unit, rather than showing a unit as either being part or not part of the most efficient solution. In Marxan irreplaceabilities are

[21] Darker shades of green represent higher irreplaceability.

expressed as a score out of 20, being the number of times the planning unit was selected out of 20 runs.

Marxan is able to consider a number of different kinds of planning units. We used forest clusters as the main planning unit along with sixteen degree squares for areas associated between the forest clusters. These areas were evaluated for their connectivity function between clusters. For further details on the methodology used, refer to Appendix 4.

Figure 7: Results of Marxan analysis for the Port St John area[22]



3.12 IUCN protected area classifications of forest patches

The advantages of applying internationally standardised protected area categories to forests are numerous. Importantly, this will provide a common currency for national and international forest conservation monitoring (Dudley & Stolton 2003).

These classifications would assist in assessments of progress towards meeting CBD obligations, national criteria and indicator monitoring, and Forestry Stewardship Council certification.[23]

The development of a semi-automated, computerised classification system was seen as a necessity, given the number of planning units. The number of criteria that could be included in the classification process was limited by the availability of national spatial datasets.[24]

We used a rule-based multi-criteria decision model to calculate suitability ratings for each of the six IUCN protected area categories for each forest patch. Five selection criteria were used to classify forests patches into protected area management classes:

- conservation value (as measured by irreplaceability)
- forest patch size
- livelihood value

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[22] This forest cluster is one of the largest and most important forest clusters. Red clusters and grids are 100% irreplaceable, that is, they were selected every time in 20 runs.

[23] It is likely that refinements of existing DWAF criteria and indicators regarding biodiversity conservation may need to include the area of forest under strict protection (Type 1 protected areas or IUCN categories I, II and III) and the extent of forest protected areas under IUCN multiple resource use-type management categories (V and VI).

[24] For example, additional data is required to classify areas qualifying for IUCN Category III that requires information on cultural-historical values of forests.

- land ownership[25]
- suitability for tourism
- threat rating.

An additional score was also calculated separately to determine the suitability for incorporation into biosphere reserves (larger multiple zone conservation areas with core and buffer areas). The following criteria were used:

- degree of transformation in forest 5km buffer areas
- whether a forest occurs in a centre of endemism
- the population density in the buffer area.

Results of this analysis for expressed as a suitability rating ranging from 'very low' to 'very high' for each protected area category for each forest patch. For further details refer to Section 8. The results of these evaluations appear in the Access FCP database (on the CD-ROM accompanying this report).

4 Results

Prioritisation is necessary to focus conservation action. There is no one single method of prioritising. We adopted a number of alternative approaches:

- prioritisation of forest patches based on irreplaceability (using C-Plan) and modelled threat
- priority livelihood value forest patches
- priority forest clusters (100% irreplaceable using Marxan).

4.1 Priority forest patches (using C-Plan)

Typically, conservation-planning units are prioritised in order to schedule conservation action. The assumption is that areas with a high irreplaceability and under high threat should receive priority attention. This is the classic approach to conservation planning adopted, for example, by Pressey et al. (1994) and Cowling et al. (1999a).

Using the FCP database and filtering for forest patches that are 100% irreplaceable, 111 forest patches were found to meet this criterion. Adding a second selection criterion to this filter – forest patches that scored a 'high' threat rating – 33 forest patches were identified. These are the so-called 'hot spot forest patches' which are listed in Table 8, along with associated information.

Forest patches that fell into Type 1 protected areas[26] were included in the C-Plan irreplaceability analysis. Irreplaceability values were calculated using both a 'clean slate' approach (by assuming no protected areas), and irreplaceabilities with current protected areas. The former was used as the standard unless otherwise stated.

The list of 'hot spot' forest patches listed in Table 12 are sorted so that forest patches that are unprotected are listed first (those requiring urgent conservation action). State forests are not considered as a special category of protected areas; however they may present the best opportunities for inclusion within a strict protected area network.

[25] An indirect method of approximating land ownership was developed using a rule-based model that analysed a compiled GIS coverage of protected areas falling under different authorities (including state forests). The assumption was that forests occurring outside of this were on private or communal land.

[26] Type 1 protected areas are national parks, provincial nature reserves and special forest nature reserves.

The 'low-hanging fruits' were identified, that is, forest patches that are in urgent need of conservation action, and have low opportunity costs .These include forests that are 'state forests', with a low SRUPI, and that are not under land claim. Priority forests that are under land claim or that have a high SRUPI require conservation actions that need close involvement with local communities, such as the approach advocated by the DWAF Participatory Forest Management directorate.

Priority forest patches listed as occurring 'partially within a protected area'; provide opportunities for expansion of existing protected areas.

Table 11: Priority Forest patches: 100% irreplaceable patches (using C-Plan), with high threat ratings[27]

Forest ID	Name or FMU	Forest type	Size (ha)	Protection status	Land claim	SRUP Index
1681	Mtunzini	KZN Dune	2 521	None	No	Medium
9426	Stanford forest	WC Milkwood	99	None	No	Low
9430	Stanford forest	WC Milkwood	80	None	No	Low
9435	Stanford forest	WC Milkwood	101	None	No	Low
14632	Langebosch (Langbos)	WC Milkwood	341	None	No	Low
14885	Langebosch (Langbos)	Albany Coastal	2 062	None	No	Low
15963	Mgwalana/ Begha Mouth	EC Dune	4 452	None	No	Medium
16103	Hamburg coast	EC Dune	1 400	None	No	Medium
16111	Kiwane Coastal Forest Reserve	EC Dune	598	None	No	Medium
6081	Hili/ Ntsubane	TK Coastal Platform	1 279	State forest	No	Low
6101	Ntsubane/Uzimpunzi	TK Coastal Platform	793	State forest	No	Low
8343	Mpame	TK Coastal Platform	538	State forest	No	High
9318	Mount Thesinger	TK Coastal Platform	548	State forest	No	High
9327	Mount Thesinger	TK Coastal Platform	1 390	State forest	No	High
9332	Ntlopeni/ Mkomanzi	TK Coastal Platform	632	State forest	No	Low
9333	Ntsubane/ Lotana	TK Coastal Platform	978	State forest	No	Low
9350	Mount Thesinger	TK Coastal Platform	583	State forest	No	Low
9984	Mngazana Mangrove	Mangrove	104	Partially state forest	No	
2109	Sokhulu	KZN Dune	3 800	Partially in Type 1 PA	No	Low
9979	Mhlatuze Richards Bay Game Reserve	Mangrove	975	Partially in Type 1 PA	No	Low
14890	Woody Cape NR	Albany Coastal	1 432	Partially in Type 1 PA	No	Low
2040	Dukuduku	KZN Coastal	1 069	Type 1 PA	Yes	high
9480	Mnbzwana swamp	Swamp	303	Type 1 PA	No	Low
9494	Eastern Shores Swamp	Swamp	406	Type 1 PA	No	Low
9967	Sokhulu	Mangrove	1 069	Type 1 PA	No	Low
9977	St Lucia Mangrove	Mangrove	177	Type 1 PA	No	Low
12326	Amatikulu	KZN Dune	576	Type 1 PA	No	Low
14889	Woody Cape NR	Albany Coastal	6 005	Type 1 PA	No	Low
16195	Mgwalana mouth to Begha Mouth dune	EC Dune	213	Type 1 PA	No	Medium
1671	Weza/ Ngele	Eastern Mistbelt	1 053	DWAF special NR	Yes	Medium
1676	Weza/ Ngele	Eastern Mistbelt	854	DWAF special NR	Yes	Medium

[27] Type 1 protected areas were included in analysis. Forests with no protection status occur on private or communal land. Note that some patches may span different land tenure types. FMU= forest management unit; WC = Western Cape; EC = Eastern Cape; TK = Transkei; PA = protected area; NR = nature reserve.

4.2 Priority livelihood value patches

Using the FCP data base all forests with a 'high' or 'very high' livelihood value (SRUPI score of >1.9), were selected. In total, 616 patches met these criteria. A second criterion, forest larger than 100 ha, was then applied, leaving 65 forests. Finally a third criterion, forest that had less than 10 % of their buffer area transformed by plantations, was used. (Plantations are thought to act as a buffer to indigenous forest harvesting). This left 21 priority livelihood forests, as presented in Table 12.

Table 12: Priority livelihood forests[28]

Forest ID	Name or FMU	Forest type	IR	Protection status	Population density	% poverty	Land claim
3030	Libode/ Nqadu	TK Mistbelt	1	state forest	0.75	69.89	yes
3810	Zingcuka/ Schwartzwald	Amatole Mistbelt	0.19	state forest	0.64	65.49	no
3826	Zingcuka/ Zilibokwe/ Heleby Forest	Amatole Mistbelt	0.26	partial state forest	0.74	62.34	no
5177	Gomo/ Tabankulu	Eastern Mistbelt	1	state forest	0.97	79.79	no
5185	Gomo/ Tabankulu	Eastern Mistbelt	0.97	state forest	1	77.92	no
5667	Amanzamnyama/ kumanzamnyama	Transkei Mistbelt	1	state forest	0.81	66.12	no
5668	Amanzamnyama/ kumanzamnyama	Transkei Mistbelt	1	state forest	0.83	66.92	no
6078	Bulembu/ Isibhorolo	Eastern Mistbelt	0.53	state forest	1.48	72.6	no
6486	Pagela/ Gxwaleni	TK Coastal Platform	1	state forest	1.36	54.96	no
8343	Mpame	TK Coastal Platform	1	state forest	1.34	55.27	no
9327	Mount Thesinger	TK Coastal Platform	1	state forest	1.03	71.03	no
9497	Eastern Shores Swamp	Swamp	1	none	3.17	18.57	no
11806	Richards Bay town forests	KZN Coastal	0.11	none	3.92	20.56	no
14907	Fort Grey (East London rural)	Amatole Mistbelt	0.42	none	3.52	69	no
14908	Fort Pato Nature Reserve (East London rural)	Amatole Mistbelt	0.84	Type 1 PA	3.16	50.66	no
14909	Mdantsane (East London rural)	Amatole Mistbelt	0.1	none	9.15	56.75	no
16207	Winterstrand/ Cove rock	EC Dune	0.03	none	2.77	59.38	no
16252	Silverdale (East London rural)	Amatole Mistbelt	0.76	none	1.28	82.92	no
16322	Amalinda commonage (East London rural)	Amatole Mistbelt	0.12	none	11.86	47.82	no
16380	Zikwaba (East London rural)	Amatole Mistbelt	0.15	none	1.44	84.2	no

The selected forests all have a high SRUPI. It is interesting to note that most forests occur in heavily populated areas. A few of these forests have low poverty ratings (for example Richard Bay town, with only a 20% poverty index). This is because the SRUPI used surrounding population wood-use dependency rather than poverty *per se*. The forests which require urgent interventions include community conservation initiatives (such as participatory forest management). Many of these forests have a high conservation value and are under little or no formal protection.

4.3 Priority forest clusters (using Marxan)

Irreplaceability analysis of forest clusters was conducted using Marxan (see Section 8.6 for further details). Two types of planning units were used: forest clusters and sixteen degree grid squares

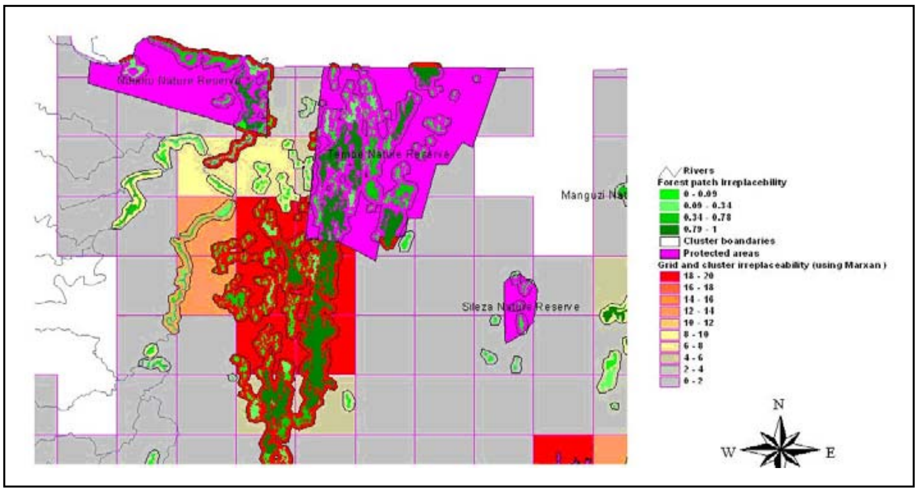
[28] Patches with a high SRUP index, larger than 100ha in size, and with less than 10% plantations in buffer areas. IR = irreplaceability (using C-plan). Population density is number of people/ha in 5km buffer; % poverty as measured by % of population in 5km buffer area earning less than R1 600/pm.

associated with forests. Analysis of grids is particularly useful to identify high conservation value areas with respect to maintaining connectivity between forest clusters.

Two types of irreplaceability were calculated – one with consideration of boundary costs, and one without. Using a boundary costs function tends to favour planning units that are connected or clumped. In most cases irreplaceability with boundary costs were used, unless otherwise stated.

In Figure 9 an example is provided of results of the Marxan analysis for the Ndumu-Tembe forest complex. The relationship between forest cluster inside and outside of existing protected areas is shown. The results of this analysis can be useful to identify areas for expansion of existing protect areas and corridors between valuable forest patches.

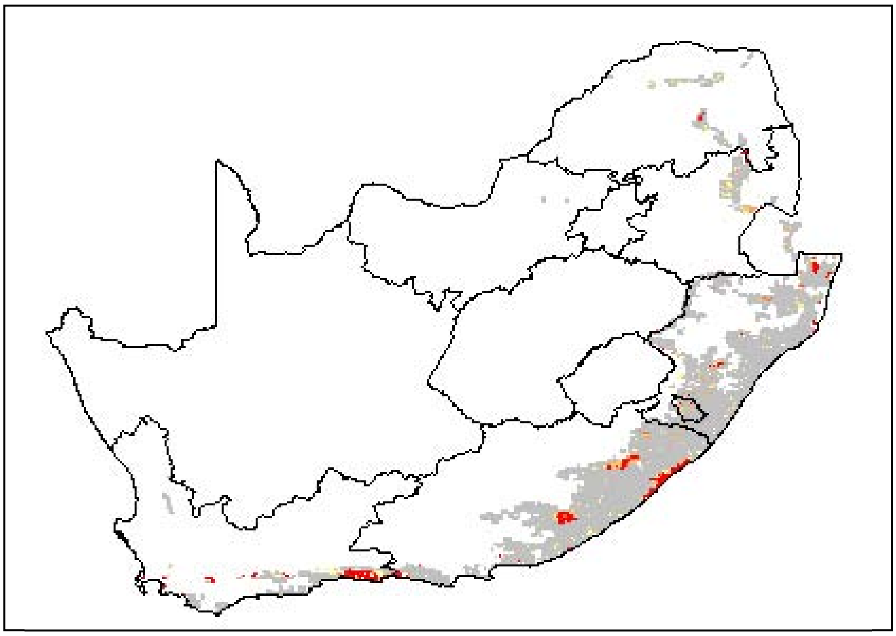
Figure 8: Ndumu-Tempe forest complex showing the types of planning units used in irreplaceability analysis[29]



A total of 3 016 forest clusters were identified. Of these, 63 were 100% irreplaceable. Figure 8 provides an overview of the important forest cluster areas across the country.

[29] Marxan calculated grid and cluster irreplaceability, while C-Plan was used for forest patch irreplaceability analysis. Grids (in red) have clusters of sand forests that are 100% irreplaceable (Note that existing Type 1 protected areas are excluded from the cluster irreplaceability analysis, but were included in the patch analysis). Red grids show recommend areas for extending the protected area network.

Figure 9: Planning domain for Marxan analysis[30]



The results of the Marxan analysis to identify priority clusters are presented in Section 8, sorted according to province and district. Criteria for selection of priority forest clusters include clusters with 100% irreplaceability (with boundary costs) or 100 % irreplaceability without boundary cost.

4.4 Priority clusters resilient to global climate change

Although not the focus of this analysis, the potential impacts of global climate change on forest biodiversity are important considerations in forest protected area planning.

Forests that span altitudinal gradients are though to be more resilient to the predicted effects of global climate change. Apart from altitudinal gradients, river corridors play an equally important role in this respect. River corridors travel down altitudinal gradients and are often the least transformed areas of a landscape (steep slopes are unsuitable for agriculture). This enables forest species to 'migrate' up river corridors, and as such river corridors act biodiversity repository areas, in highly transformed landscapes.

Priority forest clusters that are though to be resilient to climate change impacts were selected using the following criteria:

- Clusters need to be large (only Size Class 4 clusters).
- Clusters must be bisected by river corridors.
- The length of the river corridor going through the forest cluster must be as large as possible.
- Priority forest clusters should include as many different forest types as possible. This was accomplished by only selecting the top two clusters for each forest type.[31]

Results of this selection process are shown in Table 13.

[30] Priority forest cluster areas are shown in red (100% irreplaceable).

[31] Not all forest types were represented. For example, no large forest clusters with river bisection could be found for Western Cape Milkwood forest.

Table 13: Priority clusters for resilience to climate change[32]

Cluster ID	Forest type	% natural in matrix	River length (m)	Cluster name	Irreplaceability
2832	Albany	98	18 000	Unknown	1
2937	Albany	91	14 900	Unknown	0
2461	Amatole Mistbelt	88	70 700	Piri/Amatola	1
2370	Amatole Mistbelt	92	27 200	Id 2114	0.15
2737	Eastern Cape Dune	97	38 500	Unknown	1
2694	Eastern Cape Dune	92	9 300	Unknown	0
1069	Eastern Mistbelt	71	21 800	Unknown	1
1741	Eastern Mistbelt	97	13 300	Ngele	0.8
618	Eastern Scarp	96	31 800	Unknown	0.55
444	Eastern Scarp	97	10 400	Unknown	0.85
735	KwaZulu-Natal Coastal	82	30 100	Dukuduku	1
693	KwaZulu-Natal Coastal	73	12 900	Unknown	0.05
1030	KwaZulu-Natal Dune	96	21 600	Unknown	1
931	KwaZulu-Natal Dune	82	15 900	Mtunzini	0.8
477	Licuati Sand	85	63 500	Unknown	1
306	Licuati Sand	72	54 400	Unknown	1
1	Lowveld Riverine	100	67 800	Unknown	1
337	Lowveld Riverine	45	30 800	Unknown	0.65
103	Mpumalanga Mistbelt	93	48 300	Hebron	1
188	Mpumalanga Mistbelt	70	20 500	Unknown	0.7
68	Northern Mistbelt	85	11 900	Samangobos	1
72	Northern Mistbelt	84	9 700	Mmakgawa 1	0.4
2000	Pondoland Scarp	90	249 400	Nbanya	1
1874	Pondoland Scarp	91	36 400	Lutungulu 1	0.65
2882	Southern Cape Afrotemperate	78	258 300	Blue Lily's Bush	1
3018	Southern Cape Afrotemperate	60	31 100	Unknown	0.9
343	Swamp	91	19 500	Unknown	0.3
2377	Transkei Coastal Platform	87	24 600	Mpenvu	0.05
2284	Transkei Coastal Platform	95	11 800	Rebetshane	1
1966	Transkei Mistbelt	68	15 100	Id 333	1
2018	Transkei Mistbelt	64	11 300	Ludaka	1
2437	Western Cape Afrotemperate	100	25 700	Unknown	0.25
3111	Western Cape Afrotemperate	100	1 500	Unknown	0

4.5 Protected area gap analysis

A key output of systematic conservation planning is the design of an efficient and effective reserve network, representative of biodiversity pattern and process. One way of measuring the degree to which conservation targets are achieved is gap analysis. This is literally taken to mean assessment of the 'gaps', or target shortfalls within the protected area network. Because biodiversity is difficult to measure directly, habitat representivity in the form of forest types is used as a measure of biodiversity representivity.

Because South Africa already has a reserve network which protects areas of indigenous forest, it is necessary to assess the contribution that these protected areas make to attaining conservation targets

[32] These are: large clusters (Size Class 4) with river corridors, selected to represent as many forest types as possible. Cluster names (where known) and forest types are taken from the largest patch in cluster. Note that irreplaceability was not used as a selection criterion.

for each forest type. This process will show how well the current reserve network is doing in conserving a representative sample of forest biodiversity.

A common problem with assessment of reserve effectiveness is the question of what constitutes an effective protected area. We used SANBI's[33] classification system of Type 1 and Type 2 protected areas. Type 1 protected areas are reserves that have been declared under national legislation, and include national parks, provincial nature reserves wilderness areas and specially proclaimed state forests. Type 2 includes all other conservation areas (excluding state forest) such as private nature reserves, national heritage areas, community conservation areas, and municipal reserves. State forests are considered as a separate category altogether.

Gap analysis aimed to provide answers to four major questions.

- How much of each forest type is under some form of protection (Table 14)?
- How much forest is under strict protection, and what % of each forest type is still needed to achieve targets (Table 15)?
- For each forest type, what percentage of the 100% irreplaceable forests are in Type 1 protected areas (Table 16)?
- What is the provincial contribution to target achievement for each forest type (Table 17)?

How much of each forest type is under some form of protection?

Table 14: Protected area gap analysis: Percentages of forest types falling into some form of protection[34]

Forest type	Target %	Total area (ha)	% Type 1 PA	% Type 2 PA	% state forests	% area under some form of protection
Albany	35.00	22 046	34.8%	2.4%	0.0%	37.2%
Amatole Mistbelt	62.12	64 221	1.4%	1.0%	44.6%	47.0%
Drakensberg Montane	63.50	1 926	47.3%	0.0%	0.0%	47.3%
Eastern Cape Dune	48.46	10 941	8.3%	0.6%	0.0%	8.9%
Eastern Mistbelt	66.45	41 842	10.7%	0.8%	31.9%	43.4%
Eastern Scarp	61.61	33 750	25.8%	0.8%	9.3%	35.9%
KwaZulu-Natal Coastal	71.69	21089	61.3%	0.0%	0.0%	61.3%
KwaZulu-Natal Dune	69.20	12 396	22.7%	0.6%	13.0%	36.3%
Licuati Sand	69.27	24 276	42.2%	0.0%	0.0%	42.2%
Lowveld Riverine	100.00	11 401	67.9%	0.1%	0.0%	68.0%
Mangrove	100.00	2 393	73.9%	0.0%	0.6%	74.5%
Mpumalanga Mistbelt	66.99	32 772	47.2%	2.8%	0.0%	50.0%
Northern KwaZulu-Natal Mistbelt	71.74	5 323	14.9%	7.6%	0.0%	22.5%
Northern Mistbelt	59.56	19 204	3.6%	0.0%	63.9%	67.5%
Pondoland Scarp	66.61	12 284	10.4%	0.0%	33.0%	43.5%
Southern Cape Afrotemperate	49.08	74 848	6.9%	0.1%	49.4%	56.4%
Swamp	100.00	3 022	67.2%	0.0%	0.0%	67.2%
Transkei Coastal Platform	65.01	61 484	0.0%	0.0%	61.3%	61.3%
Transkei Mistbelt	64.17	30 250	0.0%	0.0%	57.5%	57.5%
Western Cape Afrotemperate	60.08	4 731	50.2%	0.0%	2.1%	52.4%
Western Cape Milkwood	55.76	2 500	2.0%	0.0%	0.0%	2.0%
Total		**492 700**				**44.4%**

[33] South African National Biodiversity Institute.

[34] Three types of protected areas were considered: Type 1 (national and provincial parks, wilderness areas and special forest protected areas), Type 2 (other forms of state protected areas, excluding state forests), and state forests.

Table 14 highlights forest types that currently are under low levels of protection. Forest types that have less than 30% of their area under some form of protection include, Eastern Cape Dune, Northern KwaZulu-Natal Mistbelt, and Western Cape Milkwood. Overall, 44% of the total area of indigenous forest is under some form of protection.

How much forest is under strict protection and what percentage of each forest type is still needed to achieve targets?

Table 15: Protected area target short falls for strict protected area categories (Type 1 protected areas)[35]

Forest type	Total area (ha)	Target %	Target area (ha)	% in Type 1 PA	Area required to meet target (ha)	Target shortfall (%)
Albany	22 046	35	7 716	34.8%	42	0.5%
Amatole Mistbelt	64 221	62	39 894	1.4%	39 002	97.8%
Drakensberg Montane	1 926	64	1 223	47.3%	312	25.5%
Eastern Cape Dune	10 941	48	5 302	8.3%	4 391	82.8%
Eastern Mistbelt	41 842	66	27 804	10.7%	23 337	83.9%
Eastern Scarp	33 750	62	20 793	25.8%	12 097	58.2%
KwaZulu-Natal Coastal	21 089	72	15 119	61.3%	2 193	14.5%
KwaZulu-Natal Dune	12 396	69	8 578	22.7%	5 760	67.2%
Licuati Sand	24 276	69	16 816	42.2%	6 572	39.1%
Lowveld Riverine	11 401	100	11 401	67.9%	3 660	32.1%
Mangrove	2 393	100	2 393	73.9%	623	26.1%
Mpumalanga Mistbelt	32 772	67	21 954	47.2%	6 484	29.5%
Northern KwaZulu-Natal Mistbelt	5 323	72	3 819	14.9%	3 028	79.3%
Northern Mistbelt	19 204	60	11 438	3.6%	10 741	93.9%
Pondoland Scarp	12 284	67	8 218	10.8%	6 883	83.8%
Southern Cape Afrotemperate	74 848	49	33 651	7.5%1	28 495	84.7%
Swamp	3 022	100	3 022	67.2%	990	32.8%
Transkei Coastal Platform	61 484	65	39 971	0.0%	39 971	100.0%
Transkei Mistbelt	30 250	64	19 411	0.0%	19 411	100.0%
Western Cape Afrotemperate	4 731	60	2 842	50.2%	466	16.4%
Western Cape Milkwood	2 500	56	1 394	2.0%	1 345	96.5%
Total	**492 700**			**17.6%**		

Currently around 17.6% of the total indigenous forest area falls within Type 1 protected areas. Two forest types are totally unrepresented within Type 1 protected areas. These are Transkei Coastal platform[36] and Transkei Mistbelt forests. Transkei Coastal forests are also under high threat, with 80% of the area of these forests classified as 'high threat'. Other forest types that are highly under-represented within Type 1 protected areas are Pondoland Scarp, Western Cape Milkwood and Eastern Cape Dune forests. Forest types that are better represented (>50%) within Type 1 protected areas include: KwaZulu Natal Coastal, Western Cape Afrotemperate and Mangrove forests.

Levels of strict protection (Type 1), relative to the conservation targets for each forest type are given in Table 15 as a 'target shortfall' (the percentage of target still outstanding). Only two forest types are reasonable close to meeting their conservation targets: Albany (0.5% outstanding) and KwaZulu-Natal Coastal (14.5% outstanding). Forest types with more than 70% of their target area outstanding include Amatole Mistbelt, Eastern Cape Dune, Eastern Mistbelt, Eastern Scarp,

[35] This assessment has not included the pending transfer of large parts of Knysna state forests to South African National Parks.

[36] There is some confusion regarding if Dwesa-Cebe nature reserve is formally legislated as a Type 1 or Type 2 protected area, we have considered it to be Type 2. (The reserve includes important Transkei Coastal forests).

Northern KwaZulu-Natal Mistbelt, Northern Mistbelt, Pondoland Scarp, Southern Cape Afrotemperate, Transkei Coastal Platform, Transkei Mistbelt and Western Cape Milkwood.

For each forest type, what percentage of the 100% irreplaceable forests are in Type 1 protected areas?

This question aims to establish how the current strict protected area network is doing with regard to protecting the 100% irreplaceable forests for each forest type. This helps to understand what forest types require urgent conservation action to protect valuable forest habitat.

Table 16 shows that, for a number of forest types very little, if any of the highly valuable forests are under strict protection (Type 1 protected areas). Forest types with less than 5% of 100% irreplaceable forests under strict protection include Amatole Mistbelt, Eastern Cape Dune, Northern Mistbelt, Pondoland Scarp, Transkei Coastal Platform, Transkei Mistbelt and Western Cape Milkwood.

Forest types that are better represented in Type 1 protected areas, with more of their 100% irreplaceable forested area under strict protection, include Drakensberg Montane, KwaZulu-Natal Coastal, Lowveld Riverine and Mangrove.

Table 16: Forest type area with 100% irreplaceability (IR=1) that occur in Type 1 protected areas

Forest type	Total area (ha)	% in Type 1 PA	Area with IR=1 (ha)	Area with IR=1 and in Type 1 PA (ha)	% of forest area with IR=1 and in Type 1 PA
Albany	22 046	34.8%	9 499	5 654	59.5%
Amatole Mistbelt	64 221	1.4%	11 013	0	0.0%
Drakensberg Montane	1 926	47.3%	469	328	70.0%
Eastern Cape Dune	10 941	8.3%	6 663	202	3.0%
Eastern Mistbelt	41 842	10.7%	7 525	1198	15.9%
Eastern Scarp	33 750	25.8%	11 036	4 524	41.0%
KwaZulu-Natal Coastal	21 089	61.3%	7 550	7 390	97.9%
KwaZulu-Natal Dune	12 396	22.7%	6 896	1 324	19.2%
Licuati Sand	24 276	42.2%	6 918	2 891	41.8%
Lowveld Riverine	11 401	67.9%	5 857	5 466	93.3%
Mangrove	2 393	73.9%	2 326	1 702	73.2%
Mpumalanga Mistbelt	32 772	47.2%	7 393	5 037	68.1%
Northern KwaZulu-Natal Mistbelt	5 323	14.9%	1 604	663	41.3%
Northern Mistbelt	19 204	3.6%	5 543	14	0.3%
Pondoland Scarp	12337	10.8%	4 285	0	0.0%
Southern Cape Afrotemperate[37]	68 563	7.5%	5 597	0	0.0%
Swamp	3 022	67.2%	2 091	1 456	69.6%
Transkei Coastal Platform	61 484	0.0%	10 181	0	0.0%
Transkei Mistbelt	30 250	0.0%	5 500	0	0.0%
Western Cape Afrotemperate	4 731	50.2%	2 250	1 533	68.1%
Western Cape Milkwood	2 500	2.0%	621	0	0.0%
Totals	**492 699**		**12 0816**	**39 380**	**32.6%**

What is the provincial contribution to target achievement for each forest type?

Most forest types occur in one or two provinces, with the exception of Lowveld riverine forest which occurs in three. In such cases it need to be established what the relative contribution of each province is in achieving the forest type conservation targets. What is the distribution of forest types

[37] The pending inclusion of large parts of the Knysna forest in a national park will change these figures significantly.

across the provinces and what has each province achieved with regard to (strict) protection of representative samples of forest types occurring within the province? Answers to these questions are provided in Table 17 and Table 18.

Table 17: Provincial contribution to target achievement for each forest type considered

Forest type	Province	% of total area in province	National target (%)	Provincial target (ha)	Area in Type 1 PA (ha)	% provincial target achieved	% contribution to national target	% of provincial forest area to protect to achieve target
Albany	EC	100	35	7 716	7 674	99%	99%	0.2%
Amatole Mistbelt	EC	100	62.12	39 894	892	2%	2%	60.7%
Drakensberg Montane	KZN	100%	63.5	1 223	911	74%	74%	16.2%
EC Dune	EC	100	48.46	5 302	910	17%	17%	40.1%
Eastern Mistbelt	EC	32	66.45	8 984	0	0%	0%	66.5%
Eastern Mistbelt	KZN	68	66.45	18 820	4 467	24%	16%	50.7%
Eastern Scarp	KZN	100	61.61	20 793	8 697	42%	42%	35.8%
KZN Coastal	KZN	100	71.69	15 119	12 925	85%	85%	10.4%
KZN Dune	KZN	100	69.2	8 578	2 818	33%	33%	46.5%
Licuati Sand	KZN	94	69.27	15 797	8 773	56%	52%	30.8%
Licuati Sand	LP	6	69.27	1 019	1 471	144%	9%	0.0%
Lowveld Riverine	KZN	65	100	7 393	4 506	61%	40%	39.1%
Lowveld Riverine	MP	0	100	53	24	46%	0%	54.3%
Lowveld Riverine	LP	35	100	3 955	3212	81%	28%	18.8%
Mangrove	EC	4	100	104	0	0%	0%	100.0%
Mangrove	KZN	96	100	2 289	1 769	77%	74%	22.7%
Mpumalanga Mistbelt	MP	100	66.99	21 888	15 429	70%	70%	19.8%
Mpumalanga Mistbelt	LP	0	66.99	66	41	63%	0%	25.1%
Northern KZN Mistbelt	KZN	89	71.74	3 411	787	23%	21%	55.2%
Northern KZN Mistbelt	MP	11	71.74	408	5	1%	0%	70.9%
Northern Mistbelt	LP	100	59.56	11 438	697	6%	6%	55.9%
Pondoland Scarp	EC	71	66.61	5 819	32	1%	0%	66.2%
Pondoland Scarp	KZN	29	66.61	2 363	1 249	53%	15%	31.4%
Southern Cape Afrotemperate	EC	27	49.08	9 247	1 408	15%	4%	41.6%
Southern Cape Afrotemperate	WC	73	49.08	24 404	3 748	15%	11%	41.5%
Swamp	KZN	100	100	3 022	2 032	67%	67%	32.8%
Western Cape Afrotemperate	EC	4	60.08	102	0	0%	0%	60.1%
Western Cape Afrotemperate	WC	96	60.08	2 740	2 377	87%	84%	8.0%
Western Cape Milkwood	WC	100	55.76	1 394	49	4%	4%	53.8%

Table 18: Distribution of forest types across provinces and percentages under Type 1 protection[38]

Province	Forest type	Total area in province (ha)	Area in Type 1 PA (ha)	% in Type 1 PA
Eastern Cape	Albany	22 046.37	7 673.85	34.81%
	Amatole Mistbelt	64 221.09	891.64	1.39%
	Eastern Cape Dune	10 940.58	910.47	8.32%
	Eastern Mistbelt	13 519.61	0.00	0.00%
	Mangrove	103.86	0.00	0.00%
	Pondoland Scarp	8 735.95	32.05	0.37%
	Southern Cape Afrotemperate	18 839.83	1 408.41	7.48%
	Transkei Coastal Platform	61 484.01	0.00	0.00%
	Transkei Mistbelt	29 668.28	0.00	0.00%
	Western Cape Afrotemperate	169.68	0.00	0.00%
	Total	**229 729**	**10916**	**4.75%**
		(46%)		
KwaZulu-Natal	Drakensberg Montane	1 926.39	911.07	47.29%
	Eastern Mistbelt	28 322.26	4 467.11	15.77%
	Eastern Scarp	33 750.17	8 696.58	25.77%
	Kwazulu-Natal Coastal	21 089.11	12 925.43	61.29%
	Kwazulu-Natal Dune	12 395.89	2 817.73	22.73%
	Licuati Sand	22 805.09	8 773.35	38.47%
	Lowveld Riverine	7 392.99	4 505.62	60.94%
	Mangrove	2 288.84	1 769.25	77.30%
	Northern Kwazulu-Natal Mistbelt	4 754.07	786.60	16.55%
	Pondoland Scarp	3 547.94	1 249.50	35.22%
	Swamp	3 021.71	2 032.05	67.25%
	Transkei Mistbelt	581.56	0.00	0.00%
	Total	**141 294**	**48 934**	**34.6%**
		(29%)		
Mpumalanga	Lowveld Riverine	52.82	24.13	45.67%
	Mpumalanga Mistbelt	32 673.50	15 428.61	47.22%
	Northern Kwazulu-Natal Mistbelt	569.35	4.75	0.83%
	Total	**33 296**	**15 457**	**46.4%**
		(7%)		
Limpopo	Licuati Sand	1 471	1 471	100.0%
	Lowveld Riverine	3 955	3 212	81.2%
	Mpumalanga Mistbelt	99	41	41.9%
	Northern Mistbelt	19 204	697	3.6%
	Total	**24 729**	**5 421**	**21.9%**
		(5%)		
Western Cape	Southern Cape Afrotemperate	56 009.12	3 747.89	6.69%
	Western Cape Afrotemperate	4 561.38	2 376.65	52.10%
	Western Cape Milkwood	2 499.74	49.24	1.97%
	Total	**63 070.24**	**6 174**	**10.9%**
		(13%)		

The Eastern Cape has the largest share of the national forest estate with 46% occurring in this province. KwaZulu-Natal has the second most with 29%, the Western Cape has 13%, Mpumalanga 7%, and Limpopo only 5%. Very small amounts of forested area also occur in Gauteng and North

[38] Percentages in brackets at end of each section are % of total forest estate occurring within each province

West, but unfortunately no data was available for this analysis. Overall, Mpumalanga and KwaZulu-Natal have the highest levels of strict protection at 46.4% and 34.6% respectively. The Eastern Cape has the lowest levels of protection with only 4.75% under Type 1 protection.

4.6 Endangered ecosystem status of forest types

The listing of threatened ecosystems is potentially a powerful tool to focus conservation action, helping to prevent further loss of already fragmented and degraded ecosystems (Driver, et al. 2003). Because these listings can have important legal, socio-economic and ecological implications, it is important that the methods used are scientifically defensible.

In South Africa, the motivation to list endangered ecosystems is partly attributed to Section 52 of NEMBA.[39] This piece of progressive legislation reflects the general trend in conservation biology from species-based conservation to ecosystem and landscape-scale conservation planning (Simberloff 1997; Knight 1998; Cowling 1999; Margules & Pressey 2000). This Act does not specify how threatened ecosystems should be identified.

Rouget et al. (2004) provided the first classification of South African ecosystems into endangered status classes. All 441 vegetation types represented in the SANBI 2004 vegetation map for South Africa, Lesotho and Swaziland were assessed. Unfortunately, this study represented forests only at the level of forests groups, and not types. This, and the fact that the classification system relied heavily on habitat loss (transformation) as a selection criterion, means the designations for forest ecosystems are not very useful. No reliable data exists for determining levels of historic habitat loss for forest types. This should therefore not be used as a main criterion for assessing the ecosystem status of forests.

An alternative approach to forest endangerment classification has been put forward by Berliner (in prep.). Multi-criteria assessment was used to aggregate the contribution of a number of selection criteria into an ecosystem endangerment score. The criteria used included:

- threat rating (modelled)
- rarity
- approximated historic reduction of forest type
- endemicity of forest types (to South Africa)
- potential to achieve target
- protected area target shortfall.

The suggested endangerment categories derived form the multi-criteria assessments are presented in Table 19.

Table 19: Suggested IUCN endangerment categories for forest types

Forest type	Endangerment category
Western Cape Milkwood	Critically Endangered
Mangrove	Critically Endangered
Pondoland Scarp	Critically Endangered
Transkei Coastal Platform	Critically Endangered
KwaZulu-Natal Dune	Critically Endangered

[39] NEMBA, Section 52(1)(a): 'The Minister may, by notice in the Gazette, publish a national list of ecosystems that are threatened and in need of protection. (b) An MEC for environmental affairs in a province may, by notice in the Gazette, publish a provincial list of ecosystems in the province that are threatened and in need of protection.

Forest type	Endangerment category
Lowveld Riverine	Critically Endangered
KwaZulu-Natal Coastal	Endangered
Licuati Sand	Endangered
Eastern Mistbelt	Endangered
Swamp	Endangered
Transkei Mistbelt	Vulnerable
Western Cape Afrotemperate	Vulnerable
Eastern Scarp	Vulnerable
Albany	Vulnerable
Northern KwaZulu-Natal Mistbelt	Vulnerable
Amatole Mistbelt	Near Threatened
Northern Mistbelt	Near Threatened
Drakensberg Montane	Near Threatened
Eastern Cape Dune	Near Threatened
Mpumalanga Mistbelt	Near Threatened
Southern Cape Afrotemperate	Low Concern

5 Way forward and recommendations

Development of a forest biome conservation implementation strategy and action plan

Systematic conservation planning provides the framework for creating a representative reserve network, but requires a strategic action plan to ensure implementation of the findings. Consideration of the opportunities and constrains to implementation need to be incorporated within this overall strategy and action plan. There is a need for integrated, multi-sectoral planning as is done in a Strategic Environmental Assessment. This needs to be done on a regional or sub regional basis.

Ongoing refinement of systematic conservation planning decision support tools

The decision support tools developed in this project need further refinement, and importantly need to be explicitly integrated with the DWAF National Forest Inventory system and the Sustainable Forest Management Criteria and Indicators monitoring programme.

Because modelling is an iterative procedure, the accuracy and reliability can only be improved through successive adaptive use, review and refinement. Ground-truthing of key variables (for example, forest condition, forest use and forest accessibility as predicted from the threat model and subsistence resource use pressure index). This would be essential for model calibration and improved reliability. This can be done using a set of case studies in different forest types. Rapid appraisal and evaluation techniques would need to be developed (it is envisaged that this could be conducted as part of an overall PFM intervention programme).

Specific areas of research that are required to improve the FCP decision support system include:

- refinement of forest type classification into sub-types
- development of a comprehensive database on cultural and historical sites
- providing a complete list of forest names, and agree on a naming convention for forest clusters
- doing research into modelling the impacts of global climate change and identifying resilient clusters
- identifying ecological corridors between clusters and links with other important habitats
- incorporating species data into the conservation planning model

- doing provincial gap analysis – providing a scorecard for levels of protection of forest types by province.

Refinement and maintenance of a database of indigenous forest indicators

Currently, the indicator data is available in an Access database, and in GIS shape files. The databases will require regular updates and maintenance and curatorship. This information should also be made accessible to the relevant decision-makers from a centralised location.

Development of a Forest Conservation Planning website

The FCP Access database and map book can be converted to a web-based product.

Case study analysis of selected priority forests

The validation of key socio economic indicators should involve staff engaged with participatory forest management implementation planning and management. Case study analysis will allow improvements in systematic planning of conservation and sustainable development and poverty alleviation. The use of rapid rural appraisal techniques and livelihoods evaluations would be of particular importance.

Maintaining connectivity and ecological corridors through integration with regional and municipal spatial development frameworks and bioregional planning initiatives

Preserving the connectivity between remaining remnants of natural habitat and protected areas has been generally neglected in the design of reserves. Given the high degree of fragmentation, maintenance of habitat connectivity is considered to be a critical consideration for the long-term persistence of forest biodiversity. In recent years, there has been a growing realisation that the conservation of ecological process requires a broader landscape approach integrating different forms of land use with conservation.

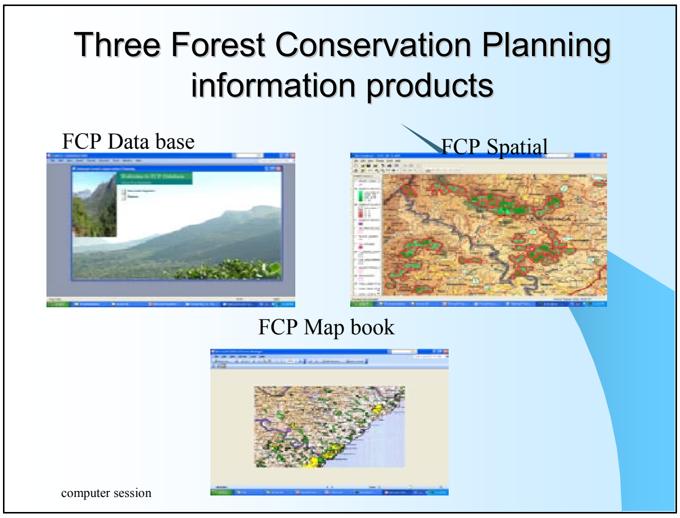
Capacity building

There is an urgent need for capacity building and training for effecting the implementation of systematic conservation planning. In particularly the use of the conservation planning tools discussed and provided in this report

6 Appendix 1: The Forest Conservation Planning CD-ROM: An overview

The FCP CD-ROM is an information package accompanying this report. It consists of three main information modules (see diagram below). In addition, the CD contains an additional resource folder that includes PowerPoint slides (course work on forest conservation planning), instructions on how to use the products, and additional reference documents, including a protected area planning legal review.

Figure 10: Three Forest Conservation Planning information products



FCP database

Runs in: Access

Objective: Provides user-friendly interactive (search and criteria filtering) of records of forest patch and forest clusters data and indicators.

Requires: Access 2000 or more recent versions (part of MS Office professional package).

FCP spatial (shape files)

Run in: Arc Explorer, using the project file FCP.aep (preset attribute settings).

Objective: Provides spatially referenced data on irreplaceability, threat, livelihood value of forest clusters and patches as well as other associated attribute data.

Requires: ARC Explorer software (freeware, provided with on the CD-ROM as a self-installing program).

FCP CD-ROM map book

Runs in: Any JPG viewer.

Objective: Easy reference for location of forest patches with a backdrop of 1:250 000 topographical maps (arranged by province and district). Highly irreplaceable forest patches are highlighted and labelled with the unique patch ID number. Look-up tables are provided to search for patch indicators.

Instructions: Self-explanatory, but for further details, see accompanying CD-ROM.

7 Appendix 2: Glossary of terminology

Accessibility index	Index of accessibility of forests patch to resource users. Index calculated from topographic position, road access to forests, and penetration of roads inside forest patch and presence of plantations/woodlots. Index from –5 (highly inaccessible) to +5 (highly accessible)
Arability	Arability index is a simplified index of the agricultural land potential of the forest buffer area (%)
Biodiversity elements	In systematic conservation planning these are the features that are targeted for conservation representivity within a protected area network. Forest types were the prime element in this study
Biosphere reserve	Suitability rating for multi-zoned protected area including and around forest patch
Boundary costs	Used in the Marxan conservation planning software to penalise the selection of non-contiguous planning units. Promotes the selection of connected planning units
Centre endemism	Centres of endemism: a high concentration of plant taxa with very restricted distribution (endemics)
Cluster area	Total area covered by forest cluster, includes both forest area and the 500m buffer area around forest (forest cluster matrix)
Cluster irreplaceability	Irreplaceability of clusters without consideration of boundary costs. Derived using Marxan that selects planning units based on target achievement and threat cost only. See ‘irreplaceability’
Cluster irreplaceability with connectivity	Irreplaceability value of clusters, calculated using Marxan, to include boundary costs of planning units along with target achievement and threat/costs. This emphasises the need for ‘connectivity’ between planning units and ‘compactness’ of the selected protected area network
Cluster livelihood	The compounded livelihood value for a cluster, obtained by proportion averaging (by area) of each forest patch’s livelihood value within a cluster. See ’Livelihood value’
Cluster size	Cluster class (1 to 4) based on size of forested area in cluster (0=< 25 ha; 1=25–50 ha; 2=50–200;3=200–500; 4=>500ha)
Cluster threat	The compounded threat value for a cluster, obtained by proportion averaging (by area) of each forest patch's threat rating within a cluster. See ‘Threat rating’
Cluster type	A relative (1 to 4 rating) index of the average degree of connectivity between patches within a forest cluster. Determined by matrix transformation and presence of river in cluster
Cluster name	Because forest clusters are a construct of this project, there are no official names. However, some names have been allocated using the principle of adopting the name of the largest patch occurring within a cluster. Many patches, and hence clusters, names have not been recorded.
C-Plan	Computer program designed to calculate irreplaceability values of planning units. It was used in this project to give forest patches irreplaceability ratings. Originally developed by the New South Wales National Parks and Wildlife Service (Anon 1999), C-Plan has been successfully used to calculate and map irreplaceability values in a number of local and international conservation planning studies
Cultural-historical	Cultural and historical data associated with forests (in complete data)
Forest (fpatchid)	Forest patch identification number. A unique identification number for each forest patch
Forest clusters	Forest patches classified into clusters based on inter-patch distance (patches within 1000m apart are considered part of same cluster)
Forest patches	Original digitised satellite imagery delineation of forest patches from National Forest Inventory data. Mostly consist of contiguous forest patches, but in some cases patches may have been split up by roads, management units or land ownership
Forest group	Forest types are grouped into seven forest groups
Irreplaceability (forest patch)	A map of irreplaceability depicts the options for achieving the defined set of conservation targets. Areas that are totally irreplaceable are non-negotiable, while areas with lower irreplaceability values allow for greater flexibility and patch choice. Simply stated, in this study the irreplaceability of an individual forest patch is the contribution of that patch to meeting the specific target set for the forest type
IUCN Ia	Suitability rating for strict nature reserve (managed mainly for science)
IUCN Ib	Suitability rating for wilderness area (managed mainly for wilderness protection)
IUCN II	Suitability rating for national park (managed mainly for ecosystem protection and recreation)
IUCN III	Suitability rating for natural monument (managed for conservation of specific natural features)
IUCN IV	Suitability rating for habitat/species management area (managed mainly for conservation through management intervention)
IUCN V	Suitability rating for protected landscape/seascape (managed mainly for landscape /seascape conservation and recreation)

IUCN VI	Suitability rating for managed resource protected area (managed mainly for the sustainable use of natural ecosystems)
Land claim	Land claim pending or lodged for forest patch
Land ownership	Forest patch land ownership/tenure category. The following were used: a) State land (including state forests, excluding protected areas)), Private and communal land; Level 2 protected area (all formal PA categories, excluding state forests). No complete dataset data was available – data was derived from extrapolation of multiple datasets
Livelihood value	An index of the importance of the forest patch to provide subsistence products. Calculated using rule-based modelling of population density around forest, wood use/ poverty, accessibility index and presence of plantations/ woodlots
Magisterial	Magisterial district
Marxan	Marxan (and CLUZ , its user-friendly interface for ARC View) are pieces of computer software developed specifically for conservation planning. Marxan differs from C-Plan in a number of ways; importantly it can incorporate connectivity (boundary costs) and socio-economic cost (or opportunity and threat-related costs) into the selection process
Main road access	Main road access to within 5km of forest
Mining	Presence of mining or application to do mining within a forest patch
Mining threat	The threat to a forest patch from mining. Rated according to demand for the mineral
Name	Common name used for forest patch (may be same for more than one patch)
Natural (%)	Percentage of area in 5km buffer that is still natural (untransformed), using National Land Cover data
Pairrepl	Irreplaceability calculation taking into account the current protected area coverage in relation to targets
Planning unit	In systematic conservation planning, the planning unit is the area unit used in irreplaceability analysis. It may contain any number of biodiversity elements, each with a conservation target. The FCP used three types of planning unit's sixteen degree grid squares, forest clusters and forest patches
Plantations (%)	% of 5km buffer that has been transformed by plantations (degree to which a forest patch is surrounded by exotic plantations)
Pop density	Extrapolated population density – people per ha in 5km buffer zone
Poverty (%)	Extrapolated % of employable population in 5km buffer area earning less than R1 601/year
Priority rating (papriority_rating)	Conservation priority rating of the forest patches using irreplaceability and threat. Irreplaceability used is PA irreplaceability that includes protected areas in the selection units (1 is highest, 4 is lowest).
Priority rating	Conservation priority rating of the forest patch using irreplaceability and threat (1 is highest, 4 is lowest), assuming no PA coverage
Regendsm	Regions of floristic endemism: higher geographical classification of centres of endemism
Road access	Road access to within 5km of forest (good/bad)
Road penetration	ratio of road surface area inside forest to forest patch area
Scaled shape index (forest patch)	SI or Shape Index is the length of the perimeter relative to the total area of the patch. Provides an index of the amount of forest edge exposed to the surrounding matrix. It is derived by applying a mathematical formula that gives a value of a shape relative to a circle. Scaled as a 0 (circle) to 1(highest edge exposure for narrow or segmented forests)
Size	Flat surface area covered by forest patch (in hectares)
SRUPI	Subsistence Resource Use Pressure Index. Composite index predicting the relative degree of subsistence use of forests, classified into five classes (from very high to very low)
SRUP_rating	Subsistence Resource Use Pressure Index. Composite index predicting the relative degree of subsistence use of forests, classified into five classes (from very high to very low)
Targets	In conservation planning, targets are set for biodiversity elements (forest types). The percentage of (extant) forest type required for long term biodiversity persistence. Calculated using species-area curve relationships, adjusted for rarity and fragmentation
Threat mining	Threat of mining transformed into a 1 to 5 index rating
Threat rating	Overall forest patch threat rating (five classes: from very high to very low). Used rule base model to combine individual threats of subsistence over-harvesting (SRUPI), agriculture, mining and urban development.
Threat transformation	Threat of agricultural and urban land transformation to forest patch
Threat urbanexpan	Threat of urban expansion into forested area. Approximated by distance from urban areas, with coastal areas

	being particularly sensitive
Transformation (%)	Percentage of land cover area in 5km buffer that has been transformed from its natural state
Type 1 PA	Type 1 protected areas are statutory protected areas including national parks, provincial nature reserves, world heritage sites, and special forest nature reserves and wilderness areas declared under the NFA
Type 2 PA	Type 2 protected areas include municipal nature reserves, private nature reserves, national monuments, natural source use areas and community conservation areas (but exclude state forests)
Urban expansion	Forest patches occurring within 15km of an urban area (yes/no index)
Vulnerability to edge effect	Potential impacts that activities surrounding the forest have on the forest. It is a function of the perimeter exposure, relative to the total area (accounted for by the scaled shape index) and the level of transformation of the surrounding 5km forest patch buffer
Wood use	Density of households that rely on wood as main source of energy in the 5km forest buffer
Xy_coord	XY longitude and latitude , GPS[40] readings

[40] Global Positioning System.

8 Appendix 3: Technical details

8.1 Introduction

This section provides additional technical details of the methods and data used in the Forest Conservation Plan. This section is made up of a number of specialist reports from the core technical team of the project. They include Derek Berliner (responsible for project management and conceptual development of the project, as well as indicator development and rule-based expert system modelling, gap analysis and classification of endangered ecosystem status), two GIS specialists, Grant Benn of GISCO, and Dr Mathieu Rouget of SANBI. Mr Benn was largely responsible for the compilation of the original forest patch layer, the C-Plan analysis of forest patches, as well as the development of forest type targets. Dr Rouget did the GIS analysis for identifying forest clusters and cluster types. He also was responsible for conducting the Marxan analysis that assigned irreplaceability ratings to clusters, and to grid square planning units.

8.2 Overview of datasets used (DD Berliner)

Threat-related data

A number of datasets were used to determine threats. These include National Land Cover data giving indications of the degree and type of transformation around forests. National Land Capability data was used to model the threat of agricultural expansion into forests.

GIS analysis of forest cover relative to urban areas indicated by the National Land Cover database was used to estimate the threat of urban expansion. This involved identifying those forests which occur within 15km of an existing urban area. A similar approach was used to determine road accessibility to each forest using a publicly available GIS roads database. The accessibility within each forest (road penetration) was estimated using an index of total road length inside a forest expressed as a proportion of the forest area.

Descriptive data describing forests threatened by mining and land claims was used to identify forests threatened by these land-use practices. This was not possible for all the areas described in the mining and land claims databases, as only those forests where corresponding names are available in the forest patch data set could be assigned values for these threats.

Table 20: Data used in threat models

Type	Description of procedure	Original data source	Data headings
Urban expansion	Forest patches occurring within 15km of an urban area (yes/no index)	Spatial overlays with National Land cover data (Thompson 1999)	URBAN EXPAN
Arability (threat of agricultural land transformation from subsistence or commercial agriculture)	Using land capability data. Percentages of each class falling into a 1km buffer area around each forest patch. Worked into a overall % arability (proportion of land in Class (I, II , II and IV) expressed as a % of land in class (V, VI, VII)	Land Capability Data (Schoeman et al. 2000)	ARABILITY (%)
Mining in forests	Matching known areas with existing or pending threat of mining (Yes/no index)	DWAF authority	MINING
Road access within 5km of forest (forest accessibility)	Using GIS analysis proximity of forest patch to national road (good/bad index of roads 1km from forest)	GIS analysis of national roads spatial data base	ROAD ACCESS
Main road access within 5km of forest	Proximity of forest patch to national road (good/bad)	GIS analysis of national roads spatial data base	MAIN ROAD ACCESS

Type	Description of procedure	Original data source	Data headings
Road penetration inside forest	Using GIS analysis, ratio of area of forest to length of roads inside forest patch.	Analysis of national roads spatial data base, with forest patches	ROAD PENETRATION
Land claims	Matching forest patches to land claims in forest areas	Department of land Affairs and DWAF data sources	Yes/no index

Note that the threat of non-sustainable substance resource use is currently under model development, as is an estimation of the cumulative threat index for each forest.

Socio-economic data

Socio-economic analysis of the area surrounding each forest was conducted using 5km buffer areas surrounding each of the 21 227 forest patches. National 2001 census data (Statistics SA) was used to approximate population densities, poverty indices and numbers of households using wood for each 5km forest buffer zone.

Because the lowest resolution of national census data is aggregated at 'enumerator area' (EA) level, proportions of EAs that overlapped with forest buffer areas were used to estimate approximate populations within each forest buffer area. This approach requires the assumptions to be made that population density, poverty and fuel wood dependence are evenly distributed through out each EA. (See Figure 11).

An index of poverty was derived by calculating the number of income earners (and unemployed) earning less than R1 600 per annum as a proportion of total. (R1 600 per annum as a poverty level was also used by the Institute of Natural Resources in its forestry and poverty study (INR 2003).

Figure 11: Forest patch analysis using enumerator areas [41]

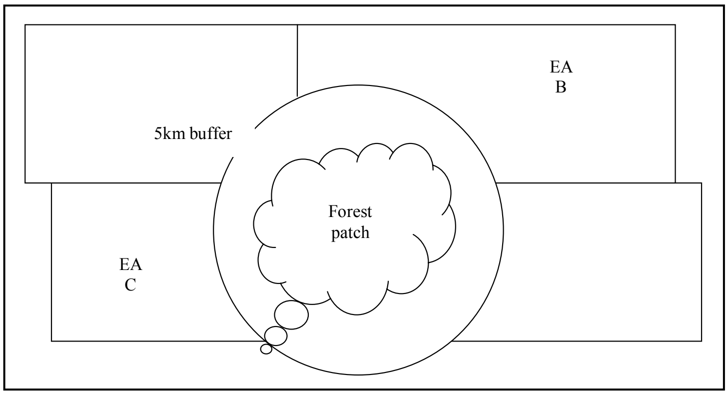


Table 21: Socio-economic data

Type (and units)	Description of procedure	Original data source	Data headings
Extrapolated population number in 5km forest patch buffers (People per forest patch buffer)	Extrapolated population number in overlap of EA data with 5km forest patch buffers	National 2001 EA census data, overlaid with forest patch data (using GIS mapping)	POP NO
Population density for 5km buffer areas (People per ha of the buffers)	Approximated population densities surrounding forest patches, using population number in forest patch buffer areas	National 2001 census data GIS modelling to calculate area of forest buffers.	POPULATION DENSITY IN BUFFER (people/ha)

[41] Using GIS, analysis is conducted on a 5km buffer zone around each forest patch. The degree of overlap with each EA (enumerator area), the spatial units used for the national census data, is used to mathematically approximate averages (the principle of proportional representation) inherited from each EA. (This includes population numbers, poverty levels and number of households using wood as main source of fuel).

Type (and units)	Description of procedure	Original data source	Data headings
Poverty index of populations associated with forest patches (% approximated population earning below R1 600 per annum)	Proportion of population earning below R1 600 per annum expressed as a percentage of total approximated population inside forest patch buffer	National 2001 census data (income brackets for each sub-place)	% POVERT
Numbers of households using wood as main source of fuel in forest buffers (Number of household using wood per buffer)	Number of household dependent on wood for energy associated with each forest patch	GIS extrapolation of National 2001 census data	WOOD_USSE NO.
Density of household using wood as main fuel source in buffers (Number of house holds per hectare of buffer)	Number of households using wood as main fuel source, divided by the area covered by forest buffers	GIS analysis of forest patch buffers	WOOD _USE

Biodiversity-related data

Table 22: Biodiversity-related datasets

Type	Description of procedure	Original data source	Data headings
Distribution and size of forest patches by forest type	Spatial analysis of forest patch, allocation of unique number, and size and distribution	Various DWAF, CSIR & provincial data (based on land cover data (Thompson 1999) plus finer scale local mapping)	FOREST (Patch id) AREA (HA) FOREST_ TYPE
Forest shape	Ratio of perimeter length to area of forest patch	As above	RATIO AREA: PERMITER
Irreplaceability ('conservation value')	Irreplaceability value calculated using C-Plan with specific target values	Various biodiversity datasets obtained from national forest classification and provincial authorities	IRREPLAC
Forest patch relative to centres and regions of endemism	Overlay of forest patch distributions with Van Wyk & Smith's (2001) centres and regions of endemism	Forest patch distribution data overlays with maps of centres and regions of endemism (Van Wyk & Smith 2001)	REGION OF ENDIMISM CENTER OF ENDEMISM
Forest patch ecotones	Percentage of area of 1km buffer around forest with natural vegetation	Land cover data (Thompson 1999)	% NATURAL VEG. IN 1KM BUFFER
Index of agricultural land transformation around forest patch	Percentage of area of 5km buffer transformed, excluding plantations	Land cover data (Thompson 1999)	% TRANSFORMATIO N IN 5
Degree to which forest patch is surrounded by exotic plantations	Percentage of area of 5km buffer with exotic plantations	Land cover data (Thompson 1999)	% PLANTATIONS

Topographic data

Table 23: Topographic data with reference to position on landscape

Type	Description of procedure	Original data source	Data headings
Forest patch position on landscape	GIS analysis of predominant land form where forest patch is located. Average percentage slope	GIS digital terrain data	PERC SLOPE

8.3 Modelling threat to forests (DD Berliner)

Introduction

Expert system rule-based modelling was used to derive composite indices of threat, as well as the subsistence use and livelihood value of for each forest patch. This section describes the process and rules used.

The four most important threat factors that impact on forest biodiversity were modelled using an indicator and scoring and weighting approach. Table 24 describes these threats along with the spatial indicators used to track them. Expert knowledge was used to derive rules that enable relative magnitude of threats to be approximated. The expert system CORVID was used to model forest patch threats. These models are available form the author on request.

Table 24: Threat indicators

Threat	Spatial indictors/surrogates used	Scoring rules (or reference table)
Unsustainable harvesting of subsistence forest products [SRUPI]	Poverty index, Population density around forest. Accessibility to forest resources (topography, road access to and within forest)	SRUPI value from 1 to 5
Threats associated with surrounding land transformation [Threat Transform]	Arability of surrounding forest land implying (suitability to commercial cropping & plantations) Degree of existing transformation	Score from 1–5 determined by arability % and % transformation
Urban expansion [Threat urbanexp]	Coastal forest types. Forests 15km of an urban area.	If within 15km of urban area = 2 If coastal and within 15km of urban area = 5
Mining [Threat mining]	Currently being mined or proposed	Yes = 5 No = 0

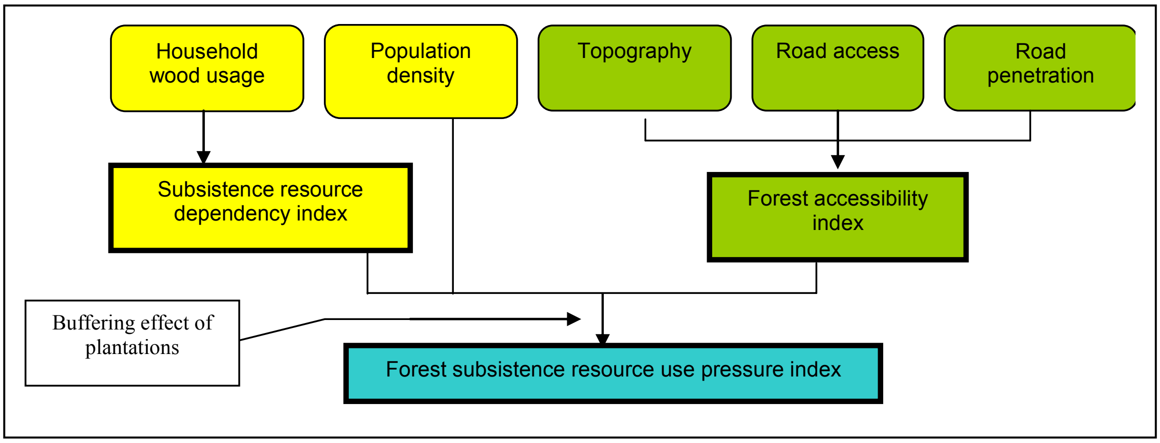
Subsistence resources use (SRUP Index)

A Subsistence Resource Use Pressure Index was derived using rule-based modelling. This section describes the process and assumptions.

Indigenous forest provides important sources of natural resource products for communities that live close to them. The degree of use of these forest products is difficult to determine directly. However, an indirect approximation of the degree of subsistence use of forests has been done using the following assumptions:

- Household wood use is used as an indicator of subsistence resource dependence for a specific population.
- Higher population densities living close to forests will make higher demands on forests products.
- The degree of use of a forest is modified by its proximity and accessibility of the forest to neighbouring communities.
- Accessibility to forest resources is determined by the topographical position of a forest, road access and road penetration inside the forest.

Conceptual approach[42]



Rules use to score forest accessibility

Accessibility to forest products by potential subsistence resource users is dependent on the ease of access to the forest. This can be modelled by considering its predominant topographical position within a landscape, road access to the forest and road penetration inside the forest. Forest patches that are pronominally situated at the bottom of valleys being less accessible than those on flat area, with forest on mountain slopes being intermediate. Road access to the forest was scored as good or bad depending on presence on national road within 5km of a forest. Road penetration within a forest was rated as 'none', 'poor', 'medium' or 'good' depending on the ratio of total length of roads within a forest to total forest area. These three variables are combined using expert system rules, to give an overall forest resource accessibility index from –5 (highly inaccessible) to + 5 (highly accusable).

The values used to score accessibility are given in Table 25. These values are used in the expert system rules to assign the accessibility index. For example If road access to the forest is 'good' and the forest is situated on a 'flat', and road penetration within the forest is 'good' then accessibility index is +5

Table 25: Values used to score forest accessibility

Average slope %	Road access		Road penetration in forest			
	Bad	**Good →**	**None**	**Poor**	**Medium**	**Good**
>25	–5		–3	1	2	3
10–25	–4		–2	2	3	4
<10	–2		–1	3	4	5

Rules used to score SRUPI

An index of subsistence resource dependency of populations living within 5km forest buffer areas was derived using national census data on household energy use and population density. We were particularly interested in the number of households in buffer area that depended on wood as main source of fuel. Population density was used to modify the wood usage. Its inclusion was based on the general assumption that the higher the population density, the higher the demand on surrounding resources.

[42] Yellow boxes represent data extrapolated from national Census 2001 data; green boxes represent data derived from GIS analysis of digitised topocadastal maps).

National census 2001 collected information on both population number and the energy use of households. (This included uses for cooking, heating and lighting, with possible sources being electricity, gas, paraffin, coal, solar, wood and 'other'.)

We aggregated this information by taking the highest number of households that depended primarily on wood within each use type. The enumerator area data was transformed into extrapolated values for each forest buffer area using a proportional averaging approach (as described in the introduction).

The application of wood usage as an indicator of subsistence resource dependency is based on the assumption that areas which have a large number of households that use wood as a main source of energy are also likely to have a high dependency on other primary subsistence resources products such as medicinal plants, wood for building materials and natural foods, hunting, grazing etc. These resources are not necessary extracted from forest; however, when forest resources are accessible, relatively higher use of these forest can be expected in areas with a higher wood dependence.

We considered using a poverty index as an accessory indicator of subsistence resource dependency, based on the assumption that poverty is associated with high subsistence resource dependence. However the measurement of poverty is complex, as are its cause and effects. We derived an index of poverty based on the number of individuals earning below R1 600 per annum. This figure showed a low but insignificant correlation with wood use. It was felt that wood usage represented a more direct measure of subsistence resource dependency. It is for this reason that poverty indices were not used.

The number of households that use wood as main source of energy was calculated from the national census 2001 energy use dataset. Section H28 of the national census questionnaire was used (see Box 1).

Box 1: Section H-28 of the national census (2000) questionnaire

ENERGY/FUEL

(H-28)

What type of energy/fuel does this household MAINLY use for cooking, for heating and for lighting? Write one code in each box.

1 = Electricity
2 = Gas
3 = Paraffin
4 = Wood
5 = Coal
6 = Candles
7 = Animal dung
8 = Solar
9 = Other (specify)

Note:
- Wood (4), coal (5) and animal dung (7) cannot be used for lighting
- Candles (6) cannot be used for cooking or heating

Cooking	**Heating**	**Lighting**

Note that data refers to number of households per unit area of each 5km forest buffer area. Table 26 shows the scoring (value from 1 to 5) for wood use per hectare.

Table 26: Scores used for wood usage (number household per ha)

Wood use (number of households per ha)	Frequency (number of forest buffers)	Rating	Score
0–0.1	14 140	Very low	1
0.1–0.2	5 991	Low	2
0.2–0.3	948	Medium	3
0.3–0.4	116	High	4
0.4–0.5	25	Very High	5
0.5–0.6	6	Very high	5

Wood use (number of households per ha)	Frequency (number of forest buffers)	Rating	Score
>0.6	1	Very high	5

Population densities within forest 5 km buffer areas varied from zero to over 60 people per ha. We scored population density using a 1 to 5 rating as described in Table 27.

Table 27: Scoring population densities of the 5km forest buffer areas

People/ha	Frequency (number of forest buffers)	Rating	Score
0–1	14 964	Very low	1
1–10	4 023	Low	2
10–20	92	Medium	3
20–30	31	High	4
>30	388	Very high	5

Modifying effects on SRUPI

Plantations and woodlots adjacent or near forest patches are known to have a buffering effect on subsistence use of forests. While plantations and woodlots do not provide all subsistence products commonly used from forest (such as medicinal plants or bark), they do provide an important source of firewood and building materials. Forest surrounded by plantations (no spatial data is available on woodlots) will be less vulnerable to subsistence over-use, while forest surrounded by transformed areas other than plantations are likely to be more vulnerable to subsistence over-harvesting. The rationale underlying this conclusion is that these forests will be the only source of subsistence products in a highly transformed landscape.

Table 28: Buffering effect of plantations around forest patches (Plantation buffering)

% Plantations in buffer	Modifying score to SRUPI
<30 %	0
30–70 %	–1
>70 %	–2

Forest patches surrounded by highly transformed land (excluding plantations) will be the only source of firewood and other subsistence products for adjacent communities, hence increasing the pressure on these forest. Modifying scores to SRUPI are given in Table 29.

Other potential modifying effects that were considered but have not been included in the threats model include modification in subsistence use pressure resulting from the availability of alternative resource within the buffer area. For example forest surrounded by woodlands would provide a higher buffering effect compared to forest surrounded by grasslands.

The following formula was used to derive a score for the subsistence resource use pressure on each forest. (Values represent scores for forest buffered area)

Subsistence Resource Use Pressure Index = ((1.5*(density of household wood use score)) + (population density score) + (accessibility index score))/3 + (plantation buffering)

Note that the first two variables have score values from 1 to 5, while the accessibility index score range from –5 to +5. The highest possible SRUPI score is 5. Then wood use has been multiplied by 1.5 to give additional weighting, as it is perceived to be the overriding factor in determining subsistence resource dependency.

Table 29: SRUPI score ratings used

SRUPI	Rating
<1	Very low
1–2	Low
2–3	Medium
3–4	High
4–5	Very high

Threats relating to surrounding land transformation (agriculture and plantations)

Conceptual approach

While conversion of indigenous forest to cultivated lands is prohibited under the National Forests Act, significant loss has occurred in the past and according to anecdotal evidence is still occurring (particularly as a result of coastal housing and resort development and clearing for grazing and crop growing in communal areas).

Apart from direct threat of habitat loss, the long-term persistence of forest biodiversity is significantly threatened by incompatible surrounding land use. Transformation of land surrounding forest leads to increased forest fragmentation and isolation and the associated risk of biodiversity loss as predicted by island bio-geographic theory. Reduced gene flow, changes in geo-hydrology and destruction of forest ecotones are just some of the impacts associated with land transformation.

Changes in surrounding land use can have significant impacts on natural disturbance regimes such as wind and fire. Regular, cool burns are important to maintain forest ecotones. Absence of fire for long periods or very hot fires will impact negatively on forest margins.

The following assumptions were used.

a) Forest surrounded by land with a high arability index were more likely to experience future impacts associated with to land transformation. The surrounding population densities modify the level of this threat.
b) Forest already surrounded by high levels of transformed vegetation were considered to be more vulnerable to threats associated with unnatural forest margins, fragmentation, changes in geo-hydrology and increased human pressure.

Two spatially linked datasets were used to quantify this threat. Firstly, the National Land Cover data (Thompson 1999) was used to derive an index of transformation within each forest buffer area (based on the proportion of natural to transformed vegetation). Secondly, the National Department of Agriculture's Land Capability Data was used to derive an index of arability. Using the seven land capability classes, the first four classes describe level of arability, while the last four describe land that is considered unsuitable for cultivation (without extensive inputs). We calculated an arability index for each forest buffer based on the proportion of arable classes to non-arable classes and expressed this as 'percentage arability'

Scoring rules used

The scoring in Table 29 reflects the threat of impacts associated with the existing degree of land transformation and the risk of future land transformation (as based on land arability). Low arability limits future transformation impacts, however in cases where transformation is already high, threat value increase rapidly with increases in arability.

Table 30: Scores used for current and future threat associated with surrounding land transformation

a) For high surrounding population densities (more than 8 people/ha)

% arability	% transformation in forest buffer		
	0–35	35–70	>70
0–35	1	2	3
35–70	2	3	4
>70	2	4	5

b) For low surrounding population densities (less than 8 people/ha)

% arability	% Transformation in forest buffer		
	0–35	35–70	>70
0–35	1	1	2
35–70	1	2	3
>70	2	3	4

Threats associated with urban expansion

This threat has resulted in significant direct loss of forests, particularly in coastal areas of South Africa that are situated near urban development nodes. Lack of mainstreaming biodiversity issues into regional and municipal planning along with ineffective enforcement of environmental regulations are the root causes of this.

In quantifying this threat we made use of the following assumptions:

a) Forest occurring within 15km of an urban area were at risk.
b) Coastal forest types faced a higher risk. (In the past, most cases of forest clearing for urban expansion and resort development have occurred within coastal forest types.)

Scoring rules used

1. If forest patch occurs within 15km of an urban area, score 2.
2. If forest patch occurs within 15km of urban area and is one of the coastal forest types, score 5, otherwise score zero.

Threats associated with mining in forest areas

Dune mining has become a significant threat in some forested areas. Long-term assessment of this risk would entail modelling the incidence of valuable mineral resource under natural forest areas. However, this is beyond the scope of this project. Current mining threat to forest is focused primarily on dune mining in certain coastal forest. Areas currently facing this threat are specifically listed.

Scoring rules used

Forests that are currently being mined for heavy minerals or where known proposals have been put forward are give a threat score of 5.

Aggregation of threats

The threat rating represents the probable level of threat a forest is likely to face currently or within the next few years. Because the dynamics of threats affecting forests are very different from each other, obtaining a single overall index of threat is conceptually problematic. Despite this deriving an aggregated threat index is essential for selecting priority areas for conservation action.

Because threats are external forces acting on a forest, the level of impact on a forest is dependent on the inherent vulnerability of the forest type, the stress factors, duration and extent of threat and threshold levels of tolerance to the threat factors. A number of modification factors could have been included for some threats, but this would cause the overall model to be more complex.

Forest are rated into three threat categories: 'high', 'medium' and 'low'. A number of rules have been used to combine threats into one of these three categories. The rules rely on two assumptions. Firstly, each of the four threats considered has a certain threshold level where the threat will result in a forest receiving a 'high' threat rating. This logic is captures in the rule-based model shown in Box 2.

Box 2: Expert system rules used to aggregate multiple threats

IF [SRUPI] > =4
OR [Threat Transform] >=4
OR [Threat urbanexp] = 5
OR [Threat mining] = 5
THEN [forest threat rating] = 'high'

For forest patches with intermediate levels of threat, a combined average is used:

IF [SRUPI] <4
OR [Threat Transform] <4
OR [Threat urbanexp] < 5
OR [Threat mining] < 5
AND [combined average threat] > = 2.5
THEN [forest threat rating] = 'medium'

For forest with low threat levels the following rule is used;

IF [SRUPI] <4
OR [Threat Transform] <4
OR [Threat urbanexp] < 5
OR [Threat mining] < 5
AND [combined average threat] < = 2.5
THEN [forest threat rating] = 'low'

8.4 Systematic conservation planning and IUCN protected area categorisation (DD Berliner)

This is an extract from a paper presented by the author at the Knowledge Marketplace Discussion World Conservation Forum 3rd IUCN World Conservation Congress, Bangkok, Thailand, 18–20 November 2004. It provides much of the background thinking that went into the IUCN protected area category expert system model as used to derive the ratings represented in the FCP database.

Recommendation 5.9 of the 5th IUCN World Parks Congress held in Durban in 2003 calls for clarity on the process by which protected area management categories are assigned. This discussion looks at possible criteria and indicators (in particular those developed for systematic conservation planning) to facilitate IUCN protected area categorisation. The approach is illustrated using a case study for classifying South African forests into IUCN protected area management categories.

The discussion revolves around what principles criteria and indicators should or could be used to develop an objective and systematic approach to IUCN protected area classification systems.

Problem statement

The IUCN protected area categories were originally developed predominantly as a statistical tool. In the absence of any other international framework, the IUCN categories have been used in ways that their original architects did not foresee.

Increasingly, *systematic conservation planning* is being used as a planning framework to establish representative systems of protected areas,[43] It is suggested that the systematic conservation planning approach can provide the basis of a more objective and systematic approach to improving guidelines for classification of protected areas into IUCN protected area management categories.

The purpose of the IUCN protected area management categories system is to provide an internationally recognised conceptual and practical framework for planning, management and monitoring of protected areas.[44]

The use of a range of different kinds of protected area categories within the IUCN system should ideally be used to minimise trade-off costs and promote win-win situations. However, existing IUCN guidelines (1994) do not provide a sufficient rational and framework to effect optimal designation.

It is suggested that protected area category designations need to be more closely aligned with systematic conservation planning and bioregional priority setting goals. The attainment of conservation targets may require that a range of different kinds of protected areas be used, areas that provide optimal benefits to a range of different stakeholders. Calls for improved IUCN protected area guidelines were made in the recommendations of the Fifth IUCN World Parks Congress in Durban in 2003.

To improve on existing IUCN protected area guidelines, it is suggested that a multi-criteria decision making framework be used, with sets of principles criteria and indicators directly linked to systematic planning procedures.

Suggested principles and criteria

a) Conservation value

Principle	Conservation value is an important consideration for determining protected area category.
Criterion	IUCN classes I to III should have a high conservation value.
Indicator	Irreplaceability value as calculated using C-Plan for set targets.

b) Reserve size

Principle	Establishment of reserves for small patches may not be cost-effective. Size is also critical for the persistence of large-scale ecosystem processes. Small patches may require active intervention.
Criteria	Conservation of representative samples of forest ecosystems processes will require relatively large contiguous management units. Small patches may be critical as connectivity corridors.
Indicator	Size of forest patch in hectares.

[43] See, for example, Margules & Pressey 2000 and Davey 1998.

[44] From Recommendations of the fifth IUCN World Parks Congress, Durban 2003.

c) Traditional use of area/Livelihood value/land restitution

Principle	Achievement of conservation targets with minimum socio-economic costs.
Criterion	Consideration of opportunity costs involved for strict protection categories.
Indicator	Index of forest patch livelihood value as derived from SRUPI.

d) Land ownership/tenure/governance

Principle	Achievement of conservation targets with minimum socio-economic costs.
Criterion	Certain forms of land ownership will be more suited to certain form of conservation management than others (for example, state land more suitable to establishment of strict protection, communal land, for multiple use areas).
Indicator	Land ownership/tenure (state land, private or communal)

e) Commercial potential (tourism/hunting etc.)

Principle	Tourism is an important form of non-consumptive use and an important aspect of some protected area categories (for example, national park).
Criterion	Areas far from tourism routes or nodes or that are inaccessible (without road access) will be less suitable for tourism**.**
Indicator	Accessibility and road access to forests.

f) Land transformation

Principle	Forest surrounded by land that is untransformed will be better suited to a multiple zoned conservation area with the forest patch forming part of a larger protected area:
Criterion	Surrounding land use and degree of transformation of natural vegetation.
Indicator	Percentage transformation in transformed land in 5km buffer area around forest.

h) Bioregional importance (Centre of endemism)

Principle	Centres of endemism are areas with high conservation value. Forest and other vegetation types around the forest are likely to contain more endemic species than areas outside of theses centres.
Criterion	Areas surrounding forest within centre of endemism are likely to be of a high conservation value, with endemic species or species with limited distributions.
Indicator	Does forest patch fall into a centre of endemism (yes/no).

i) Surrounding population density and poverty levels

Principle	Forest patches surrounded by high population densities will be less suited to creation of strict protected areas or extended areas beyond the forest.
Criterion	Highly populated areas surrounding forest will be less suited to the creation of extended conservation areas.
Indicator	Population density in the 5km forest buffer area, as calculated using proportional averaging from enumerator area national census data.

Selection criteria used to classify South African forest patches into IUCN protected area categories

The forest biome makes up less than 0.4% of the surface area of South Africa. They are highly fragmented with over 20 000 forest patches. These are embedded within a wide range of ecological habitats, and socio-economic contexts. Many high conservation value forests are associated with poor rural communities.

Deriving PA selection criteria

Table 31 derives criteria and indicators using the IUCN 1994 PA category guidelines.

Table 31: Selection criteria and indicators used to classify forest patches based on 1994 IUCN PA category guidelines[45]

IUCN category	Criteria (based on 1994 IUCN guidelines)	Suggested indicators
Ia: *Strict nature reserve:* managed mainly for science	• The area should be large enough to ensure the integrity of the reserve • The area should be significantly free of direct human intervention • The area should *not* require substantial management interventions or habitat manipulation to maintain biodiversity (refer to Category IV)	• High conservation value (irreplaceability) • Size of forest patch • Surrounding land transformation • Road access/ accessibility • No consumptive use (low forest livelihoods value) • State-owned land
Ib: *Wilderness area:* managed mainly for wilderness protection	• The area should possess a high natural quality, with minimal human disturbance • The area should contain significant biogeographic feature(s) of scientific, educational, scenic or historic value • The area should be able to offer solitude/ wilderness experience. • Non-motorised travel within area, no roads. • The area should be of sufficient size.	• High conservation value (irreplaceability) • Surrounding land transformation • Road access/ accessibility/road penetration • Forest patch size • No consumptive use (low livelihoods value)
II: *National park:* managed mainly for ecosystem protection and recreation	• The area should contain a representative sample of major natural regions or features of *both* scientific and tourist significance • The area should be large enough to contain one or more entire ecosystems not materially altered by current human occupation or exploitation • *Usually o*wnership and management by the highest competent authority of the nation	• High conservation value (irreplaceability) • Accessibility for tourism • Size • Threat rating • Land ownership/tenure • Low or no consumptive use (low livelihoods value)
III: *Natural monument:* for conservation of specific natural features	• The area should contain one or more natural features of outstanding significance • Sites of national or local heritage significance	• High to medium conservation value • High cultural historical values • Size
IV: *Habitat/ species management area:* managed mainly for conservation through management intervention	• The area should be critical for the survival of one or more species/ habitats/ ecosystems of national, regional or global importance • Habitat protection/manipulation is essential intervention necessary • The size of the area should depend on the habitat requirements of the species to be protected	• Medium to high conservation value (irreplaceability) • Livelihoods value (some form of consumptive use may be necessary for simulating 'natural' disturbance regime in some forests)

[45] . Note: Only indicators with available spatial data with national coverage or modelled indices were used.

IUCN category	Criteria (based on 1994 IUCN guidelines)	Suggested indicators
V: *Protected landscape/ seascape:* managed mainly for landscape/ seascape conservation and recreation	• The area should possess a landscape of high scenic quality, with diverse associated habitats, flora and fauna along with manifestations of unique or traditional land-use patterns • The area should provide opportunities for public enjoyment through recreation and tourism within its normal lifestyle and economic activities • The area may be owned by a state authority, but is more likely to comprise a mosaic of private and state ownerships.	• High livelihood value of forest • Low conservation value • Surrounding land transformation • Accessibility for tourism and suitability of forest patch inclusion into larger conservation area • Land ownership
VI: *Managed resource protected area* managed mainly for the sustainable use of natural ecosystems	• The area should be at least *two-thirds* in a natural condition, although it may also contain limited areas of modified ecosystems (large commercial plantations would *not* be appropriate for inclusion) • The area should be large enough to absorb sustainable resource uses without detriment to its overall long-term natural values	• High livelihood value of forest • Land cover transformations • Size • Land ownership • Low irreplaceability

Deriving scores for indicator values for criteria

Scoring of criteria indicators is needed to conduct multi-criteria analysis. The following criteria were used.

Conservation value

Principle Conservation value is an important consideration for determining protected area category.

Criteria IUCN classes I to III should have a high conservation value.

Indicator Irreplaceability value as calculated using C-Plan for set targets.

Table 32: Irreplaceability value scores for IUCN PA categories

Irreplaceability	IUCN PA category						
	Ia Scientific reserve	***Ib Wilderness***	***II National park***	***III Natural monument***	***IV Habitat/ species management***	***V Protected landscape***	***VI Managed resource use area***
<+0.2	0	0	0	0	0	3	3
0.2–0.4	0	1	0	0	0	3	2
0.4–0.6	1	2	1	1	1	2	1
0.6–0.9	2	3	2	1	2	1	0
>0.9	3	3	3	1	2	0	0

Livelihood value

Principle Achievement of conservation targets with minimum socio-economic costs.

Criterion Consideration of opportunity costs involved for strict protection categories.

Indicator Index of forest patch livelihood value as derived from SRUPI.

Table 33: Forest patch livelihood values for IUCN PA categories

Livelihood value	IUCN PA category						
	Ia Scientific reserve	***Ib Wilderness***	***II National park***	***III Natural monument***	***IV Habitat/ species management***	***V Protected landscape***	***VI Managed resource use area***
V low (<1)	3	3	3	1	3	1	0

Livelihood value	IUCN PA category						
	Ia Scientific reserve	*Ib Wilderness*	*II National park*	*III Natural monument*	*IV Habitat/ species management*	*V Protected landscape*	*VI Managed resource use area*
Low (1–2)	1	1	2	1	3	1	1
Medium (2–3)	0	1	1	1	2	1	2
High (3–4)	0	0	0	1	1	1	3
Very high (4–5)	0	0	0	1	0	1	3

Land ownership

Principle Achievement of conservation targets with minimum socio-economic costs.

Criterion Certain forms of land ownership will be more suited to certain form of conservation management than others (for example, state land is more suitable to establishment of strict protection, communal land, for multiple use areas).

Indicator Land ownership/tenure (state land, private or communal).

Table 34: Land ownership values for IUCN PA categories

Land ownership	IUCN PA category						
	Ia Scientific reserve	*Ib Wilderness*	*II National park*	*III Natural monument*	*IV Habitat/ species management*	*V Protected landscape*	*VI Managed resource use area*
State	3	3	3	3	3	2	2
Private	0	1	0	1	1	3	0
Communal	0	1	1	1	1	2	3

Suitability for tourism

Principle Tourism is an important form of non-consumptive use and an important aspect of some protected area categories (for example, national park).

Criteria Areas far from tourism routes or nodes or that are inaccessible (without road access) will be less suitable for tourism.

Indicator Accessibility and road access to forests.

Table 35: Road access for tourism values for IUCN PA categories

Road access for tourism	IUCN PA category						
	Ia Scientific reserve	*Ib Wilderness*	*II National park*	*III Natural monument*	*IV Habitat/ species management*	*V Protected landscape*	*VI Managed resource use area*
Good	1	1	3	1	1	1	2
Bad	1	1	0	0	0	0	0

8.5 GIS analysis of forest patches using C-Plan (G Benn)

Identification of biodiversity elements for planning

Pattern elements

The taxonomic datasets used contain a number of fundamental flaws and biases, and assessments of surrogacy among taxonomic groups have not provided encouraging results. Higher levels in the biodiversity hierarchy (for example, species assemblages, habitats and landscapes) have often been used as surrogates, and have some advantages over the species-based approach. Higher order elements integrate ecological processes and ecosystem functions, and are often available for entire study areas. However, no surrogate is paramount, but rather a combination of surrogates representing elements from across the biodiversity hierarchy should be used.

Biodiversity elements are often categorised into pattern and process elements. Pattern elements are generally described by the spatial distribution of biological and ecological entities, for example, the distribution of vegetation types or species. The majority of conservation planning studies have focused on pattern elements. Process elements refer to ecological processes and ecosystem functions which operate within and among the levels of the biodiversity hierarchy and are critical for the maintenance of the pattern elements. The inclusion of pattern and processes elements in conservation planning is important if we are to ensure both the representation of biodiversity within a reserve network (pattern) and its long term retention in the face of the degradation of natural systems.

Species were ultimately dropped from the analyses, as they could not be assigned with any degree of confidence to specific forest patches. The faunal data was, without exception, only available at the quarter degree scale. We could have simply assigned a species presence in a patch if the patch occurred within the relevant quarter degree squares. However in most instances, a large number of patches overlapped with each quarter degree square. This would have resulted in the faunal species distributions being substantially over-estimated. In addition, the vegetation data only allowed for species data to be accurately assigned to 30 forest patches (less than 1%). These constraints were not deleterious to the development of the forest classification because, unlike this study, it was not dependent on the location of individual forest patches and the assignment of data to these patches. However, the exclusion of species data from this study is not seen as a major shortcoming because the forest type classification used as the primary pattern element was developed using floral data (and to a lesser degree faunal data) to identify the forest types. In other words, species distributional patterns are inherent and reflected in the forest types.

Process elements

A key requirement for the inclusion of process elements in conservation planning is the ability to spatially represent each process. The processes listed therefore have a very strong bias towards those that can be easily represented or analysed in an explicit spatial sense. Thus, the majority of the processes included allow for a process to be expressed through the size or spatial distribution of forest patches.

Planning domain and units

The planning domain was the entire region of South Africa within which indigenous forests occur. Within South Africa, forests are restricted to the Western Cape, Eastern Cape, KwaZulu-Natal, Mpumalanga and Limpopo provinces. In other words, forests are almost exclusively distributed along the southern and eastern extremities of the country, with little or no representation in the arid interior. The distribution of forests in South Africa is limited by water availability, with forests occurring primarily in summer rainfall areas with annual precipitation above 725mm and in winter rainfall areas above 525mm.

Some areas were not adequately covered in the NFI dataset, so in these areas forests were added from other data sources. These additional sources included forest datasets from KwaZulu-Natal Wildlife (P Goodman) and the Mpumalanga Parks Board (M Lotter). Furthermore, the NFI dataset did not adequately describe the azonal forest types, so for these forest types the patches defined in the new national vegetation map (Mucina & Rutherford 2004) were incorporated into the forest patch layer.

The final forest patch (planning unit) layer is made up of 20 556 patches covering an estimated area of 5 052.30 km^2. The majority of the patches by number (96%) are smaller than 1km^2 in size; however, these patches only represent 38% of the forest area. Of the area of forests in South Africa as described by the patch layer used in this study, Southern Cape Afrotemperate, Amatole Mistbelt and Transkei Coastal Platform forests cover the largest area (615km^2 to 775km^2). In contrast, Western Cape Milkwood, Drakensberg Montane, Swamp, Mangrove and Western Cape Afrotemperate forests are the rarest forest types covering between 19km^2 and 47km^2.

Table 36: Size distribution of forest patches, and the area contributed by patches (before data cleaning)

Size range (ha)	Number of patches	Area of patches (ha)
0–10	14 592	38 354.26
10–25	2 902	46 046.25
25–50	1 365	47 927.50
50–100	828	57 895.87
100–250	560	85 808.45
250–500	172	59 876.35
500–1 000	82	55 616.20
1 000–2 000	34	45 759.19
> 2 000	21	67 945.94

Setting targets for forest types

A consultative process aimed at obtaining input from a wide range of experts and stakeholders was used to identify targets for each pattern and process element used in this study. The first step involved the development of an initial method of determining targets by the core study group. These were then sent for review to an expert focus group for comment and adjustment. These targets were then presented at a workshop, during which the methods of setting targets were discussed and final adjustments made.

Recent research has shown the usefulness of species-area curves in helping to develop conservation targets. For example, Cowling et al. (1999b) used species-area curves to adjust the baseline target values for vegetation types in the Cape Floristic Region (CFR). This method involves analysing species-area curves to compare species turnover and relative species numbers for areas of similar size among ecoregional classification units. More recently, Desmet & Cowling (2004) showed how the power form of the species-area relationship can be used to set conservation targets using sample data.

The method they described involves calculating the slope (z-value) of the power form of the species-area curve. This can then be used to estimate the proportion of the area required to represent a given proportion of species:

$$S' = A'^{z}$$

The vegetation database used to derive the forest type classification was used here to determine the z-value for each forest type. This was done with the aid of EstimateS software (Colwell 1997) with the bootstrap estimator using the following equation:

$$z = (y_2 - y_1) / (x_2 - x_1)$$

where: y_2 = log(total number of species in a forest type)

y_1 = log(average number of species per sample)

x2 = log(total area of a forest type)

x_1 = log(average area of samples)

Desmet & Cowling (2004) found the bootstrap estimator provided the most consistent response across datasets to the under- or over-estimation of species number. The z-values were then ordered and the ratio between each type and the lowest value was determined. The type with the lowest z-value was assigned the base value of 15%, while the base value for the remaining types was determined by multiplying the z-value ratio for a type by 15%.

The 15% target was based on a study by Pressey et al. (1997), which aimed to identify a representative forest network for Australia.

The base values for the forest types were then also adjusted on the basis of four factors:

a) Relative rarity
b) Patch fragmentation
c) Historic reduction (since 1890)
d) Location within regions/centres of endemism.

a) Relative rarity

This was simply determined by the area covered by each forest type expressed as a percentage of the total forest area. On the basis of these values, each type was assigned into one of three rarity classes (high, medium or low) using a natural breaks classification procedure. Target values were then adjusted as follows:

High = +7.5%

Medium = +5.0%

Low = + 2.0%

b) Patch fragmentation

This was determined by first determining the mean patch size and mean nearest-neighbour (inter-patch) distance for each forest type. These two sets of values were separately grouped into three classes, namely high, medium and low. A matrix approach was then used to assign each type to a high, medium or low fragmentation category.

Table 37: Patch fragmentation matrix

		Mean patch size		
		Low	*Medium*	*High*
Mean inter-patch distance (nearest-neighbour)	*High*	High	High	Medium
	Medium	High	Medium	Low
	Low	Medium	Low	Low

This approach resulted in types with high inter-patch distances and low mean patch sizes being considered as more fragmented than types with low inter-patch distances and high mean patch sizes. Target values were then adjusted as follows:

High = +7.5%

Medium = +5.0%

Low = + 2.0%

The same method was used to adjust those process targets which required adjustment on the basis of forest type fragmentation.

c) Historic reduction (since 1890)

Expert opinion was used to assign each forest type into one of three reduction categories, namely high, medium and low. Mr I van der Merwe and Mr T Stehle provided the expert opinion in this instance. Target values were then adjusted as follows:

High = +7.5%

Medium = +5.0%

Low = + 2.0%

d) Location with regions/centres of endemism

A GIS layer describing the boundaries of the regions and centres of floral endemism as described by Van Wyk & Smith (2001) was obtained. The occurrence of each forest type within these regions was then determined by means of spatial overlays at the forest patch level. The targets for forest types which overlapped with these regions/centres were adjusted by +5%. The final target percentage for each forest type was therefore calculated as follows:

Final target = Base + Rarity + Fragmentation + Reduction + Endemism

Each forest type could have its target percentage area adjusted upwards by a minimum of 6% or a maximum of 27.5%.

Setting targets for processes

The only process which required explicit targets were:

- natural disturbance regime
- intra-forest seed and propagule dispersal
- pollination
- herbivory.

The base target for each of these was set to three of the largest extant patches and then adjusted on the basis of each type's fragmentation class, with low fragmentation requiring three patches, medium fragmentation requiring four and high fragmentation types needing six patches. The remaining processes did not require explicit targets:

- natural ecotonal/edge processes – this process was accounted for in the threat analysis by the percentage area of transformation and the percentage area under plantations indices
- connectivity (surrogate for linkage related processes)
- resilience against climate change
- foraging, roosting and breeding habitat for forest dependent fauna – this process was accounted for by the attainment of the pattern targets.

The species area curve analysis showed the lowest z-value for the Albany Coastal Forests, which was thus assigned the base target value of 15%. Mpumalanga Mistbelt forest showed the highest z-value and was assigned a base target value of approximately 50%. See Table 38 for a summary of the z-values, z-value ratios and calculated base target values.

Table 38: Species sample number, z-values, z-value ratios and resultant base target values for the 21 forest types[46]

Forest type	z-value	z-value ratio	Base target (%)	Sample size
Albany Coastal	0.059766	1	15.00	15
Mangrove	0.102355	1.712586	25.69	66
Eastern Cape Dune	0.113396	1.897325	28.46	21
Western Cape Milkwood	0.130539	2.184156	32.76	13
Swamp	0.142756	2.388563	35.83	114
Southern Cape Afrotemperate	0.151722	2.538588	38.08	255
Northern Mistbelt	0.157629	2.637423	39.56	144
Drakensberg Montane	0.165359	2.766758	41.50	103
Pondoland Scarp	0.165802	2.774169	41.61	69
Transkei Mistbelt	0.176003	2.944857	44.17	170
Transkei Coastal Scarp	0.179354	3.000918	45.01	150
Amatole Mistbelt	0.179795	3.008292	45.12	179
Licuati Sand	0.184344	3.084407	46.27	40
Eastern Mistbelt	0.185075	3.09665	46.45	243
Kwazulu-Natal Coastal	0.186034	3.11268	46.69	129
Kwazulu-Natal Dune	0.188046	3.146349	47.20	143
Northern Kwazulu-Natal Mistbelt	0.198191	3.316099	49.74	52
Mpumalanga Mistbelt	0.199186	3.332749	49.99	206
Lowveld Riverine	No species data	No species data	NA*	0
Western Cape Afrotemperate	No species data	No species data	38.08	0
Eastern Scarp	No species data	No species data	41.61	0

* Lowveld Riverine forest was assigned an overall target value of 70% (based on expert opinion).

Irreplaceability analysis

Using the calculated target values, C-Plan was used to assign irreplaceability values to individual forest patches. C-Plan, a conservation-planning computer decision support tool developed by the New South Wales National Parks and Wildlife Service (Anon 1999) has been successfully used to calculate and map irreplaceability values in a number of local and international conservation planning studies. Notably, C-Plan has been extensively used for conservation planning of a reserve system for Australian forests (ANZECC 1997).

A map of irreplaceability depicts the options for achieving the defined set of conservation targets. Areas that are totally irreplaceable are non-negotiable, while areas with lower irreplaceability values allow for greater flexibility and patch choice. Simply stated, in this study the irreplaceability of an individual forest patch is the contribution of that patch to meeting the specific target set for the forest type of that patch. As targets are area-based (including those for the processes), larger patches will have higher irreplaceability values due to their relatively greater contribution to meeting a set target.

Just considering forest types (that is, biodiversity pattern and not considering the included processes), approximately 2% of the forest patches were assigned irreplaceability index values of between 0.8 and 1 (Table 39), with 43 (0.21%) falling into the 100% irreplaceability class. However, this represents more than 40% of the available forest area being assigned an irreplaceability value greater than 0.8, with 15% being totally irreplaceable. These results indicate that, while very few patches can be considered highly irreplaceable, these patches represent a substantial proportion of the available forest area.

[46] Table sorted on the z-value.

Table 39: Irreplaceability statistics considering only forest types

Irreplaceability class	Number of patches (% of total patch number)	Area (km^2)	% of total forest area
1	43 (0.21)	757.89	15.00
0.8–0.99	340 (1.65)	1 333.98	26.40
0.6–0.8	144 (0.70)	265.08	5.25
0.4–0.6	174 (0.85)	248.62	4.92
0.2–0.4	415 (2.02)	424.39	8.40
0.0–0.2	19 440 (94.57)	2 022.35	40.03

Table 40: Irreplaceability statistics considering forest types and processes

Irreplaceability class	Number of patches (% of total patch number)	Area (km^2)	% of total forest area
1	113 (0.55)	1 272.42	25.18
0.8–0.99	278 (1.35)	855.53	16.93
0.6–0.8	143 (0.70)	262.04	5.19
0.4–0.6	171 (0.83)	226.50	4.48
0.2–0.4	413 (2.01)	416.64	8.25
0.0–0.2	19 438 (94.56)	2 019.18	39.97

The results for individual forest types (Table 38) mirror those for all patches irrespective of forest type (Tables 39 and 40). Again, the number of patches with irreplaceability values greater than 0.8 represent a small percentage of the total patch number, while the areas represent a substantial percentage of the available area of each forest type. A number of forest types actually show less than 1% of the number of patches having irreplaceability values between 0.8 and 1; these are Amatole Mistbelt, Eastern Scarp, Pondoland Scarp and Albany forests. Drakensberg Montane forests have the largest percentage of patches with irreplaceability values greater than 0.8 (18.66%). However, when considering the percentage of forest area assigned irreplaceability values greater than 0.8, Swamp (69.19%) and Mangrove (76.16%) forests have the highest percentages.

Reserve effectiveness

The existing reserves used in the analysis (national parks, provincial nature reserves and specially demarcated state forests) conserve approximately 17% of the total forest area in South Africa. Looking at the broad forest types, Southern Afrotemperate (7.4%) and Southern Mistbelt (6.7%) forest types are conserved by less then 10%, while at the other end of the spectrum the Azonal (48.0%) and Northern Coastal (47.0%) groups are currently being conserved by almost 50%.

Existing reserves only meet the conservation targets for two of the 21 forest types (Swamp and Mangrove forests) (Table 41). The remaining forest types are under-protected by between approximately 2% (Albany forest) and 65% (Transkei Coastal Platform forest). Eight forest types are under-protected by more than 50%, these include Western Cape Afrotemperate (50.55%), Northern KwaZulu-Natal Mistbelt (56.87%), Mpumalanga Mistbelt (52.41%), Transkei Mistbelt (64.17%), Amatole Mistbelt (60.74%), Pondoland Scarp (56.13%), Transkei Coastal Platform (65.01%) and Western Cape Milkwood forest (53.79). In addition, six forest types are under-protected by between 25% and 50%, namely Licuati Sand (27.07%), Southern Cape Afrotemperate (41.81%), Eastern Mistbelt (46.78%), Eastern Scarp (26.87%), KwaZulu-Natal Dune (46.47%) and Eastern Cape Dune forest (40.14%). In summary, 67% of the forest types are inadequately conserved by at least 25%, with almost 40% being under-protected by more than 50%.

Table 41: Contribution of existing protected areas to the attainment of conservation targets for forest types

Forest type	Area protected (km^2)	Percentage protected	Outstanding target (%)*
Lowveld Riverine	77.57	48.99	21.01
Swamp	20.35	67.25	–11.42*
Mangrove	21.63	70.74	–0.74*
Licuati Sand	102.62	42.20	27.07
Western Cape Afrotemperate	4.51	9.53	50.55
Southern Cape Afrotemperate	56.37	7.27	41.81
Drakensberg Montane	9.12	47.29	16.21
Northern KwaZulu-Natal Mistbelt	7.93	14.87	56.87
Northern Mistbelt	76.47	39.43	20.13
Mpumalanga Mistbelt	50.46	14.58	52.41
Eastern Mistbelt Forests	83.01	19.67	46.78
Transkei Mistbelt Forests	0.00	0.00	64.17
Amatole Mistbelt Forests	8.92	1.38	60.74
Eastern Scarp Forests	117.46	34.74	26.87
Pondoland Scarp	13.05	10.48	56.13
Transkei Coastal Platform	0.00	0.00	65.01
KwaZulu-Natal Coastal	129.46	61.29	10.40
KwaZulu-Natal Dune	28.22	22.73	46.47
Eastern Cape Dune	9.11	8.32	40.14
Albany	76.77	33.16	1.84
Western Cape Milkwood	0.49	1.97	53.79

* Note: negative values indicate forest types for which the currently protected area is greater than the conservation target

The extent to which existing protected areas affect the pattern of patch irreplaceability, considering their contribution to target attainment, is shown in Table 42. Overall, these results suggest that the current protected areas do not significantly alter the number and area of patches falling into the various irreplaceability classes. This is especially the case for the two highest irreplaceability classes, while the greatest degree of change only occurs in the number and area of patches in the lowest (0.0–0.2) irreplaceability class. Where the spatial pattern of irreplaceability is defined at the patch level, there are no substantial changes from the situation where existing protected areas are not considered. These results further highlight the inadequacy of the existing protected areas in meeting the conservation targets.

Table 42: Irreplaceability statistics considering forest types and processes, and including the contribution of existing protected areas to target attainment

Irreplaceability class	Number of patches (% of total patch number)	Area (km^2)	% of total forest area
1	105 (0.51)	1 218.82	24.12
0.8–0.99	266 (1.29)	725.18	14.35
0.6–0.8	133 (0.65)	245.19	4.85
0.4–0.6	161 (0.78)	188.25	3.73
0.2–0.4	393 (1.91)	354.18	7.01
0.0–0.2	19 498 (94.85)	2 320.68	45.93

A minimum set algorithm was used to select a set of patches which would be required to attain the forest type and process targets if none of the patches were already conserved by existing protected areas. The following rules were used in the algorithm:

- Select site with highest irreplaceability, if tied –
- Select site with largest area, if tied –

- Select next site.

The algorithm selected a set of 3 23 sites, with a total area of 4 19.84 km^2. The mean patch size for the selected set was 1.17km^2 with the largest selected site being 66.00km^2 in area. For a detailed summary of selected sites for each forest type see Table 43. Again, the selected patches represent in most instances a small percentage of the available patches, while at the same time covering the majority of the available forest area. Possible exceptions to this are Lowveld Riverine, Drakensberg Montane, Northern KwaZulu-Natal Misbelt and Western Cape Milkwood forests where the selected patches represent more than 50% of the available patches. The situation is particularly interesting for Drakensberg Montane forests where the minimum set algorithm selected 100% of the available patches. This indicates that all of the available patches of this forest type would need to be protected in some manner if the conservation target is to be attained.

Table 43: Number and area of patches selected by minimum set algorithm for analysis with none of the forest patches considered protected by the existing protected area network

Forest type	Number of patches selected (% of total patch number)	Area (km^2) of selected patches (% of total area)
Lowveld Riverine	59 (62.77)	152.25 (96.16)
Swamp	15 (41.67)	27.62 (91.26)
Mangrove	16 (36.36)	27.64 (90.39)
Licuati Sand	97 (27.25)	212.57 (87.42)
Western Cape Afrotemperate	69 (26.44)	38.30 (80.92)
Southern Cape Afrotemperate	219 (12.25)	639.76 (82.49)
Drakensberg Montane	134 (100)	19.29 (100)
Northern KwaZulu-Natal Mistbelt	153 (52.94)	47.16 (88.45)
Northern Mistbelt	81 (9.00)	165.87 (85.52)
Mpumalanga Mistbelt	210 (13.08)	289.31 (83.58)
Eastern Mistbelt Forests	483 (23.36)	367.54 (87.07)
Transkei Mistbelt Forests	670 (23.10)	279.50 (90.50)
Amatole Mistbelt Forests	241 (9.67)	494.42 (76.70)
Eastern Scarp Forests	75 (5.10)	208.77 (61.74)
Pondoland Scarp	79 (15.52)	98.45 (79.40)
Transkei Coastal Platform	710 (18.73)	530.06 (86.14)
KwaZulu-Natal Coastal	56 (7.09)	167.59 (79.34)
KwaZulu-Natal Dune	19 (7.95)	101.49 (81.75)
Eastern Cape Dune	12 (9.23)	78.87 (72.06)
Albany	20 (3.94)	149.58 (64.61)
Western Cape Milkwood	105 (70.47)	23.78 (95.11)

The same minimum set algorithm as that described above was used to select forest patches required, in addition to those forest areas already conserved, to meet the outstanding conservation targets. This analysis showed that an additional 976 patches would be required, representing an area of 2 391.98km^2 (in addition to the 893.52km^2 of forest already conserved). The mean patch size of the additional set was 2.39km^2, with the largest patch covering 66.0km^2 in area. This represents a reduction of 21.20% (873.05km^2) in the total area required to meet the conservation targets when comparing these statistics with those for the analysis where the current protected area network is not considered.

For a detailed summary of required patches for each forest type see Table 44. As expected, the algorithm did not select any additional areas for Swamp and Mangrove forests as the existing protected areas already account for the area required by the conservation targets. Nine of the forest types require less than 10 additional patches to attain conservation targets. These types include, Lowveld Riverine, Licuati Sand, Western Cape Afrotemperate, Drakensberg Montane, Northern Mistbelt, KwaZulu-Natal Coastal, KwaZulu-Natal Dune, Eastern Cape Dune and Albany forests. However, these patches still represent substantial areas of each forest type, with percentage areas selected for these nine types ranging between 15% and 60%. In contrast, four forest types require more than 100 additional patches representing more than 50% of the available area. These types include Eastern Mistbelt, Transkei Mistbelt, Amatole Mistbelt and Transkei Coastal Platform forests.

Table 44: Number and area of additional patches selected by minimum set algorithm for analysis considering the contribution of existing protected areas to meeting targets.

Forest type	Number of patches selected (% of total patch number)	Area (km^2) of selected patches (% of total area)
Lowveld Riverine	9 (9.57)	37.96 (23.97)
Swamp	0 (0.00)	0 (0.00)
Mangrove	0 (0.00)	0 (0.00)
Licuati Sand	5 (1.40)	66.99 (27.55)
Western Cape Afrotemperate	8 (3.07)	24.02 (50.75)
Southern Cape Afrotemperate	23 (1.29)	325.83 (42.01)
Drakensberg Montane	7 (5.22)	3.67 (19.03)
Northern KwaZulu-Natal Mistbelt	68 (23.53)	36.98 (69.36)
Northern Mistbelt	9 (1.00)	81.99 (42.28)
Mpumalanga Mistbelt	52 (3.24)	186.65 (53.92)
Eastern Mistbelt Forests	121 (5.85)	218.56 (51.78)
Transkei Mistbelt Forests	200 (6.89)	198.40 (64.24)
Amatole Mistbelt Forests	111 (4.45)	394.68 (61.23)
Eastern Scarp Forests	43 (2.92)	127.99 (37.83)
Pondoland Scarp	30 (5.89)	70.51 (56.87)
Transkei Coastal Platform	260 (6.86)	400.42 (65.07)
KwaZulu-Natal Coastal	6 (0.76)	32.79 (15.52)
KwaZulu-Natal Dune	3 (1.26)	67.94 (54.72)
Eastern Cape Dune	1 (0.77)	64.64 (59.06)
Albany	1 (0.20)	38.48 (16.62)
Western Cape Milkwood	19 (12.75)	13.57 (54.27)

8.6 GIS analysis of forest clusters (M Rouget)

Methodology

1. Combine forest patches from Derek Berliner with selected forest patches from vegetation map (Mucina & Rutherford 2004).
2. Convert to grid (100m resolution).
3. Calculate degree of connectivity by running focal average on a circle of 500m radius.
4. Consider patches to be connected if distance between patches is <500m and degree of connectivity >5 (arbitrary value): This resulted in 3 296 clusters/ isolated patches being identified.
5. Characterise clusters according to forested area, land use in the matrix and river length.
6. Derive four types of clusters and isolate single patches or small clusters based on rules (see Table 45).

7. Derive four classes of clusters depending on forested area (that is, each cluster is characterised by its type and its class), see Table 46.
8. Map forest clusters (see Table 47 and Figure 12).
9. Assign forest patch to cluster.
10 Projection used:

Projection	Albers
Datum	Sphere
CM	25
1st //	−33
2nd //	−24

Note: when suffix "_dd" is used, it means that the data is unprojected (decimal degrees).

Table 45: Cluster type based on % naturalness in the matrix and river length

Cluster type	Forested area	Matrix	Rivers	Description
0	<25ha	–	–	Isolated forest patches
1	>25ha	<50% natural	<1 500m	Forest cluster in unfriendly matrix
2	>25ha	<50% natural	>1 500m	Forest cluster in unfriendly matrix along river
3	>25ha	>50% natural	<1 500m	Forest cluster in natural matrix
4	>25ha	>50% natural	>1 500m	Forest cluster in natural matrix along river

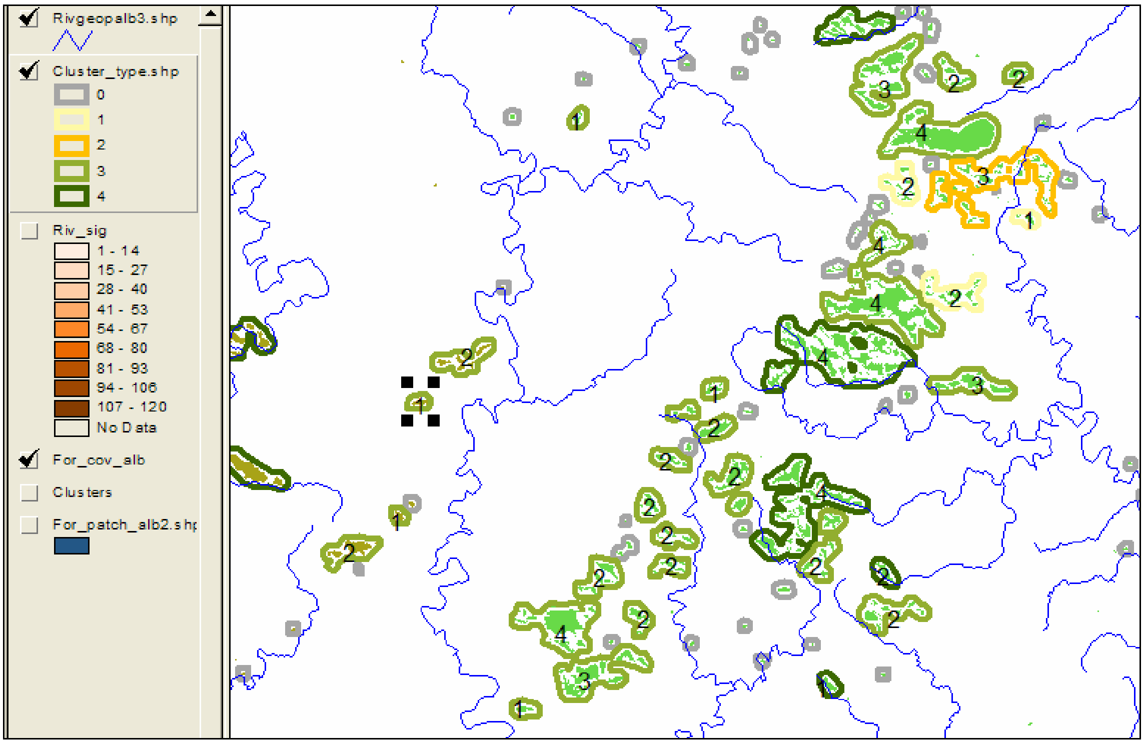
Table 46: Cluster class based on forested area

Cluster size	Forested area
0	< 25 ha
1	25 - 50 ha
2	50 - 200 ha
3	200 - 500 ha
4	> 500 ha

Table 47: Number of forest clusters in each type/class

		Size					
		0	**1**	**2**	**3**	**4**	**Grand Total**
Type	**0**	1 837					**1 837**
	1		52	39	2		**93**
	2		9	18	8	5	**40**
	3		394	375	85	45	**899**
	4		78	154	94	101	**427**
	Grand total	**1 837**	**533**	**586**	**189**	**151**	**3 296**

Figure 12: Cluster type and cluster size[47]



Data dictionary

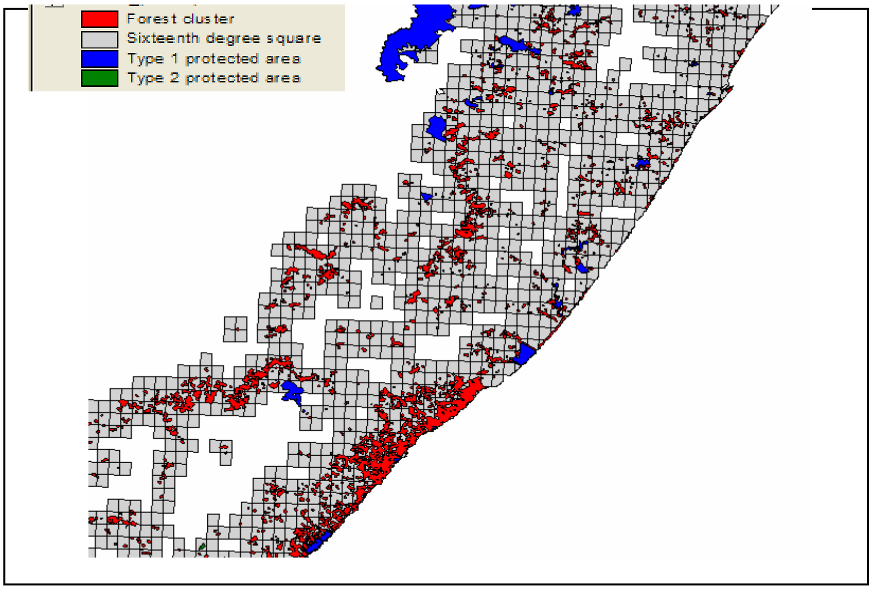
File name	Description	Attributes	Notes
Cluster_type	Shapefile of Forest clusters	Gridcode: unique ID Area_ha: cluster area (ha) For_ha: forested area (ha) Patch_no: number of patches Nat_pc: % natural in the matrix Riv_length: river length (m) Type: cluster type Size: cluster size	Albers projection
Cluster_type_dd	Shapefile of Forest clusters	Same as cluster_type	Unprojected
Clusters_stats	Clusters characteristics (Excel spreadsheet)	See various worksheets	Was used to derive forest type and class
Fpatch_cluster	Assign each forest patch to a cluster	Fpatchid: patch ID Cluster_id: cluster ID (same as gridcode	Only big patches could be linked (tiny patches are not linked to any cluster)

Marxan irreplaceability

I derived a layer of planning units consisting of forest clusters, protected areas and arbitrary grid squares (sixteenth degree squares – SDS) (Figure 13). Type 1 (statutory) protected areas were considered to contribute to target achievement.

[47] Cluster type is colour-coded and cluster size is indicated by the number. The most viable clusters are those of types 3 and 4, and class 4.

Figure 13: Planning unit layers derived



For each planning unit, the area of each forest type was recorded.

Marxan calculates irreplaceability on the basis of three factors:

a) target achievement (planning unit significantly contributing to targets are favoured)
b) planning unit cost (planning units of lower cost are favoured)
c) compactness (planning units connected to each other are favoured in the selection).

I use the same targets as for the forest plan.

The cost of planning unit was set as follows:

For forest clusters	cost = threat x 100 (ranges from 0 to 250);
For SDS	cost = 500
For protected areas	cost = 100

I derived two irreplaceabilities: one taking into account the first two factors (target achievement and planning unit cost), the other taking into account all factors (compactness included).

Figure 14: Irreplaceability based on target achievement and planning unit cost[48]

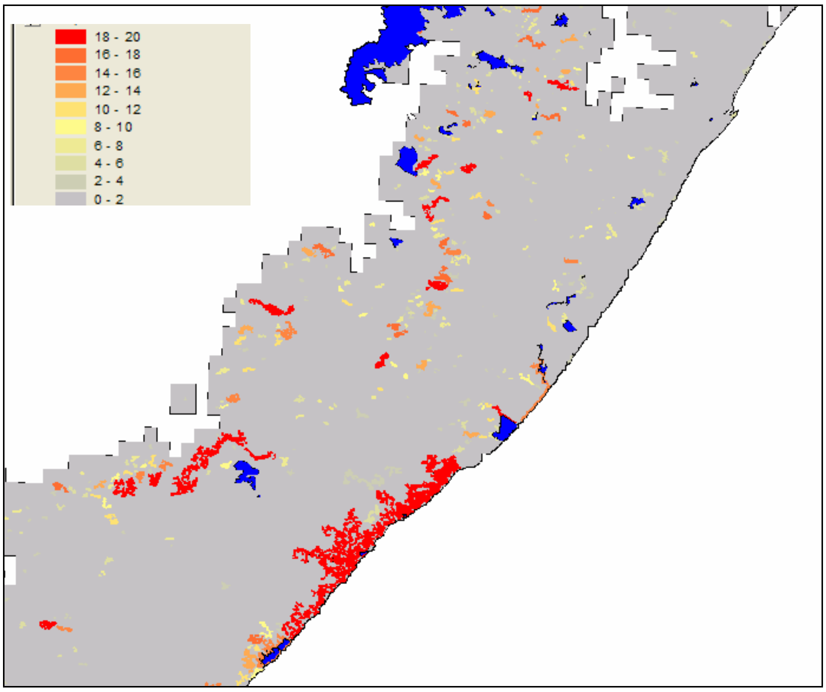
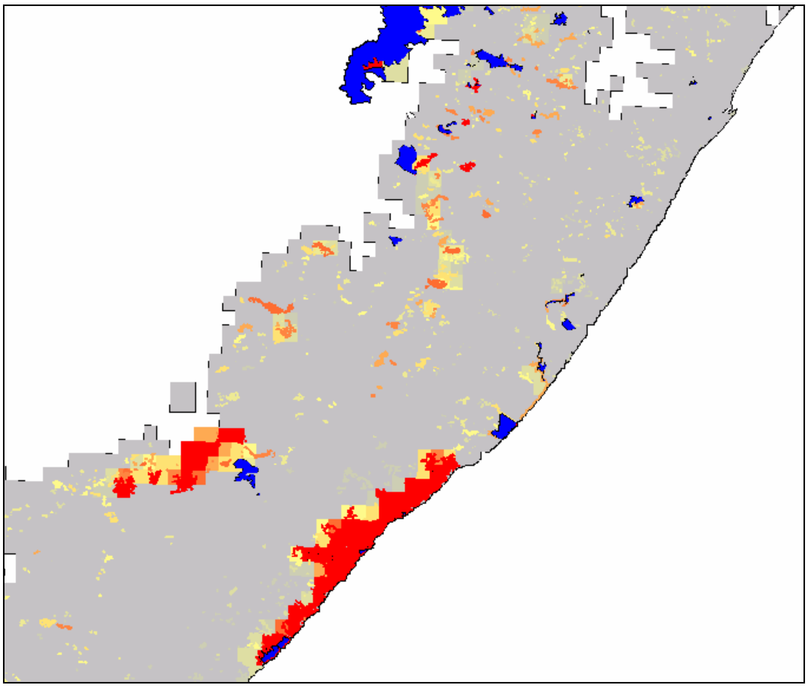


Figure 15: Irreplaceability based on target achievement, planning unit cost and compactness[49]



[48] The number relates to how often each planning unit was selected out of 20 runs. Planning units selected 20 times out of 20 are irreplaceable. See field imp_sum14 in the pu_cluz3 shapefile's attribute.

[49] See field imp_sum13 in the pu_cluz3 shape file's attribute.

Table 48: Derivation of irreplaceability

File name	Description	Attributes	Notes
Pu_cluz3.shp	Shapefile of Marxan irreplaceability	Pu_code2: unique code Sds_code: code for SDS Cluster_co: code for cluster Type_pu: type of planning unit Cost: cost value Status: available or conserved Imp_sum13: irreplaceability (Fig. 4) Imp_sum14: irreplaceability (Fig. 3)	Albers projection Use the legend cluz_20runs to display the irreplaceability correctly
Pu_cluz3_dd.shp	Shapefile of Marxan irreplaceability	Pu_code2: unique code Sds_code: code for SDS Cluster_co: code for cluster Type_pu: type of planning unit Cost: cost value Status: available or conserved Imp_sum13: irreplaceability (Fig. 4) Imp_sum14: irreplaceability (Fig. 3)	Same as pu_cluz3 but in decimal degrees.

8.7 Endangered ecosystem status of forest types (DD Berliner)

Introduction

The classification of ecosystems into endangered status categories, although not new, is currently receiving increased attention from conservation biologists (see for example Noss & Peters 1995; Noss 1996; 2000; Anderson et al. 1998; Ricketts et al. 1999; Rouget et al. 2004). In South Africa, the motivation to list endangered ecosystems is partly attributed to Section 52 of the National Environmental Management: Biodiversity Act.[50] This piece of progressive legislation reflects the general trend in conservation biology from species-based conservation to ecosystem and landscape-scale conservation planning. This progressive piece of legislation reflects the general trend in conservation biology from species-based conservation to ecosystem and landscape-scale conservation planning (Simberloff 1997; Knight 1998; Cowling 1999; Margules & Pressey 2000).

NEMBA does not specify how threatened ecosystems should be identified. Rouget et al. (2004) provide the first study to classify South African ecosystems into endangered status classes. All 441 vegetation types represented in the SANBI 2004 vegetation map for South Africa, Lesotho and Swaziland were assessed.

We have expanded on this study by considering a number of approaches to ecosystem evaluation, including ecological integrity assessment, (Karr 1992; Noss et al. 1999; Andreasen et al. 2001), ecological risk assessment (US Environmental Protection Agency 1998; Harwood 2000; Noss 2000), ecosystem threat/vulnerability assessment (Rouget et al. 2003; Wilson et al. in press), and target-based systematic conservation planning (Pressey et al. 2003; Cowling & Pressey 2003; Desmet & Cowling 2004).

While the methodology and criteria used to list threatened species is well-established, with accepted internationally best practice (see for example the IUCN red data lists such as the South African red data book for the listing of mammals – Friedman & Daly 2004), the listing of threatened ecosystems is relatively new concept, without the benefit of nationally standardised or internationally recognised best practice.

[50] Section 52(1)(a): The Minister may, by notice in the Gazette, publish a national list of ecosystems that are threatened and in need of protection. (b) An MEC for environmental affairs in a province may, by notice in the Gazette, publish a provincial list of ecosystems in the province that are threatened and in need of protection.

The listing of threatened ecosystems is a potentially powerful tool to focus conservation action, helping to prevent further loss of already fragmented and degraded ecosystems (Driver et al. 2004). Because these listings can have important legal, socio-economic and ecological implications, it is important that the methods used are scientifically defensible, making best use of available information.

Methods

Assessment criteria

Rarity

Rarity is the most commonly used criterion (Anderson et al. 1998).The emphasis on rarity is justifiable to the extent that small populations are generally more vulnerable to extinction. It is particularly important to consider whether a plant community is rare naturally, or as a result of human activities.

Transformation (extent of habitat decline)

Because some ecosystems are naturally rare, the extent of decline often may be preferable to rarity as a conservation criterion and is often closely associated with future risk (Noss 2000). However, the exclusive dependence on levels of habitat decline (levels of transformation) to classify endangered status of ecosystem, while elegant in its simplicity, raises a number of potential problems.

For certain ecosystems, determining historical habitat loss may confounded by the fact that certain disturbance regimes (in particularly grazing and fire), can result in alternative stable vegetation states (Walker & Noy-Meir 1982; Walker 1989). Examples of this abound, such as the stable limit cycles observed in the Serengeti between woodland and grassland (Sinclair 1979), different states of bush or shrub land encroachment (Scholes & Archer 1997, Walker 1989) and between forest and grassland or forest and fynbos (Geldenhuys 1994; Richardson et al. 1995; Midgley et al. 1997). Remotely sensed imagery is relatively successful in determining levels of permanent transformation (from natural habitat to cultivation or plantations), but is less successful in determining habitat loss due to habitat change or conversion from one state to another.

Habitat loss and conservation targets

Levels of habitat reduction, when considered in conjunction with conservation targets needed for long term persistence of species/ecosystems, is potentially a powerful method of determining the probability of long term persistence of an ecosystem.

Species-area relationships tend to be based only on botanical richness and, as such, can be misleading. In cases where an ecosystem may be critical for certain stages of various species life cycle such as seasonal feeding or breeding grounds (migratory herbivores, spawning fish etc.), the minimum area needed to sustain ecosystem processes will not be accurately reflected by floristic diversity. Mangrove forests are a good example of this. Importantly, as has been pointed out by Desmet and Cowling (2004), conservation targets derived from species-area relationships do not take in to account ecological processes.

Level of protection and conservation targets

The endangered status of ecosystems should reflect the current level of protection they receive. Rare ecosystems under threat and not well represented in a system of protected areas should receive a higher endangered status than if the same ecosystem was well represented within protected areas.

Ecosystems can only be assessed as being sufficiently protected if current levels of protection meet predefined conservation targets. Conservation target setting is a critical aspect of systematic conservation planning (Cowling 1999; Cowling & Pressey 2003; Pressey et al. 2003). Targets for South African forest types were set by Berliner & Benn (2004) using species-area relationships (as described by Desment & Cowling 2004), adjusted for rarity and level of habitat fragmentation.

This study uses conservation targets as criteria to assess the endangered status of forest types in two ways. Firstly, these are used to indicate the level of protected area target shortfall. Secondly, these are used to determine the potential of the remaining habitat to achieve the conservation target (that is, comparing what remains of a forest type to what is still needed to meet the conservation target).

Ecosystem threat/ vulnerability

Assessments concerned with ecological integrity should contain a mix of retrospective and prospective analyses (US Environmental Protection Agency 1998). We need to know the effects of past activities in order to forecast future impacts under alternative management scenarios. Noss and Peters (1995) used imminence of threat as one of four criteria to classify endangered USA ecosystems, while Williams & Araujo (2000) used risks of local threats combined with species occurrences and vulnerabilities to estimate probabilities of persistence of species.

Problems with assessment of threat include the inherent complexity involved with multivariate assessments. This is further compounded by the differential ecosystem resilience levels and hence moderating responses to disturbance and threats.

Numbers of rare and endangered species

Noss and Peters (1995) used the numbers of rare and endangered species as one of the criteria to score the endangered status of American ecosystems. This is undoubtedly a useful criterion but problems of data availability and accuracy abound. Lists of red data species and endemics for South Africa are available. However these are at the level of presence (not abundance) and at the scale of quarter degree squares. It would be difficult to assign species to any specific forest patch on the basis of quarter degree square data. In addition, species distribution data are notoriously problematic, with unavoidable survey biases relating to incomplete geographic coverage of the area being surveyed.

Biologically distinct ecosystems (endemicity)

Biologically distinct ecoregions are those with high levels of species richness, endemism and other outstanding biological qualities (Noss 2000). This study used expert judgment to consider biological uniqueness of forest types. Forest types that did not occur beyond the borders of South Africa were considered as ‘endemic forest types’ and were given higher scores.

A multicriteria approach to aggregating criteria scores

This study uses the Pressure- State- Response model to provide a framework for the selection of criteria used in multicriteria analysis (see Table 50). The multicriteria problem-solving approach has been successfully used to assist with spatially related environmental decision-making (see, for example, Carver 1991; Laaribi et al. 1996; Berliner & Macdonald 2005) and in conservation planning (Noss et al. 2002; Von Hase et al. 2003).

The following steps characterise multicriteria assessment (after Carver 1991):

- Identification of feasible or potential alternatives (variants or scenarios).
- Construction of criteria to take into consideration.

- Identification of indicators to evaluate the performance of each alternative with respect to every criterion.
- Selection of different weighting scenarios for indicators
- Scoring the performance of each indicator for each criterion
- Normalising indicator scores to common units (if necessary).
- Multiply by weightings, for each alternative weighting scenario.
- Aggregation of these evaluations to obtain the solution that globally offers the best evaluations.

The aggregated scores for criteria considered were expressed as a percentage of total possible score under a particular weighting scenario. The aggregated score was used to classify forest types into one of the five IUCN Red List categories as presented in Table 49.

Table 49: Ecosystem endangered status categories, and classification rules used[51]

IUCN Red List categories	Abbreviation	Classification rule aggregated score
Critically Endangered	CE	>=70%
Endangered	E	>=60%
Vulnerable	V	>=50%
Near Threatened	NT	>=40%
Least Concerned	LC	>=0%

A number of criteria weighting scenarios were considered. These are listed from 'A' to 'F' in Table 50. Criteria scores for each forests type were multiplied by weighting factors and then aggregated and expressed as an overall percentage of the total possible score.

The weighting scenarios used include the following:

a) All criteria considered equally.
b) Approximates the method used by Rouget et al. (2004), with emphasis placed on criterion F, (the potential still to achieve targets).
c) Approximates the classification used by Noss & Peters (1995) for classifying American ecosystems (although an additional criterion of 'numbers of rare and endangered species' were also in the American study).
d) Uses all criteria but gives low weightings to criteria D and E, and emphasises criterion F.
e) Emphasis on Criteria A and F, probably the most important two criteria, but other criteria contribute to a lesser degree

Note that the five endangered ecosystem categories used, follow the nomenclature as used for IUCN red data species

Results

Results of the multicriteria analysis are presented in Tables 50 and 51. Six alternative weighting scenarios were considered. In general there was a relatively high convergence of results between the different weighting scenarios. (Refer to Table 50 for standard deviations between different weighting scenarios.)

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[51] '>=' implies greater or equal to the given score, up to the next category above.

Table 50: Results of multicriteria analysis used to determine endangered ecosystem status of South African forest types[52]

Criteria	Weightings					
	A	B	C	D	E	F
A. Rarity	1	0	1	1	1	2
B. Threat	1	0	1	1	2	1
C. PA target shortfall	1	0	0	1	1	1
D. Endemism	1	0	0	0.5	0.5	0.5
E. Transformation	1	1	1	0.5	0.5	0.5
F. Potential to achieve target	1	2	0	2	2	2
Forest Type	**Status**					
Western Cape Milkwood	CE	NT	CE	CE	CE	CE
Swamp	VU	E	E	E	E	CE
Northern KwaZulu-Natal Mistbelt	E	LC	NT	VU	VU	E
Mangrove	E	CE	CE	CE	E	CE
KwaZulu-Natal Dune	E	CE	CE	E	CE	E
Lowveld Riverine	E	CE	E	CE	CE	CE
Pondoland Scarp	CE	CE	CE	CE	CE	CE
Drakensberg Montane	VU	LC	NT	VU	NT	VU
Eastern Cape Dune	VU	LC	NT	VU	VU	VU
Licuati Sand	E	CE	VU	CE	E	CE
Western Cape Afrotemperate	E	NT	VU	E	E	E
KwaZulu-Natal Coastal	E	CE	CE	E	E	E
Eastern Mistbelt	CE	E	E	E	E	E
Transkei Coastal Scarp	CE	CE	CE	CE	CE	E
Transkei Mistbelt	E	E	NT	E	E	E
Mpumalanga Mistbelt	VU	LC	LC	VU	NT	NT
Northern Mistbelt	VU	NT	LC	VU	NT	VU
Albany	VU	LC	E	NT	VU	NT
Amatole Mistbelt	VU	NT	NT	VU	VU	VU
Eastern Scarp	E	E	VU	VU	VU	VU
Southern Cape Afrotemperate	NT	LC	LC	LC	LC	LC
No. of CE forests	4	7	6	6	5	6
No. of E areas	9	2	3	5	7	6

Table 51: Deriving a single endangered ecosystem rating for forest types by classifying the mean of scores for each weighting scenario considered

Forest type	Criteria weighting scenarios and their aggregated scores						Mean	Standard deviation	Red list category
	A	B	C	D	E	F			
Western Cape Milkwood	83	47	87	82	84	84	78	14.0	CE
Mangrove	63	100	73	72	64	76	75	12.2	CE
Pondoland Scarp	80	73	73	73	71	71	74	2.9	CE
Transkei Coastal Platform	80	73	73	73	77	66	74	4.4	CE
KwaZulu-Natal Dune	67	73	87	68	73	67	73	6.9	CE
Lowveld Riverine	63	87	60	75	73	73	72	8.6	CE
KwaZulu-Natal Coastal	60	73	87	62	67	61	68	9.3	E

[52] Abbreviations of IUCN red list categories used: CE= Critically Endangered, E = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern).

Forest type	Criteria weighting scenarios and their aggregated scores						Mean	Standard deviation	Red list category
Licuati Sand	60	87	53	72	67	70	68	10.4	E
Eastern Mistbelt	70	60	60	67	69	63	65	4.0	E
Swamp	53	60	60	65	64	70	62	5.2	E
Transkei Mistbelt	67	60	47	63	60	60	59	6.2	VU
Western Cape Afrotemperate	60	47	53	60	60	63	57	5.5	VU
Eastern Scarp	60	60	47	57	54	54	55	4.5	VU
Albany	57	33	67	47	51	49	51	10.1	VU
Northern KwaZulu-Natal Mistbelt	60	33	40	57	51	60	50	10.2	VU
Amatole Mistbelt	57	47	27	57	54	51	49	10.4	NT
Northern Mistbelt	53	47	33	53	49	54	48	7.2	NT
Drakensberg Montane	53	33	47	50	46	57	48	7.5	NT
Eastern Cape Dune	57	20	47	50	51	51	46	12.0	NT
Mpumalanga Mistbelt	53	33	27	50	46	49	43	9.6	NT
Southern Cape Afrotemperate	40	20	20	33	31	31	29	7.2	LC

Discussion

The listing of threatened ecosystems is potentially a powerful tool in focusing conservation action. It can provide simplified yet clear message to conservation authorities regarding conservation priority ecosystems. The terminology used is intuitively understandable to administrators who may be unfamiliar with the terminology used in irreplaceability analysis. The results of ecosystem status analysis need to inform local and regional spatial development planning. The methodology used to determining ecosystem status needs to be scientifically defensible, reliable and repeatable over time.

The processes is by no means simple, ecosystem status and the probability of long term persistence are determined by multiple variables including both environmental and socio-economic factors. The probability of persistence is also likely to be contingent on internal properties of ecosystems, particularly inherent resilience to anthropogenic perturbations. Resilience is defined by Holling et al. (1995) as the amount of disturbance that an ecosystem can sustain before a change in system control or structure occurs. This definition tells us that different ecosystems may well respond differently to similar levels of disturbance. For example the distinction between fine grain and course grain forests, used to describe the different strategies of recruitment and gap replacement evident between Afrotemperate and Coastal forests, respectively (Midgley 1996:290).

8.8 Review of the National Forest Protected Area GIS Database (‘Forest Patch.shp’) (M Thompson)[53]

Review of the forest patch data integrity

The objective was to conduct an internal data quality assessment of the client-supplied Forest Patch (FP) database, ‘as-is’, with respect to the integrity of the spatial data and associated tabular attributes. The assessment is specifically confined to an assessment of the internal data quality, not attribute mapping, or modelling accuracy, or overall relevance.

The FP database contains 20 556 data records (that is, forest patch polygons), equivalent to 505 230.7ha, which are described in terms of ±20 attribute fields, which have been derived previously from a combination of internal and external data modelling procedures.

[53] Summarised from the original report by Mark Thompson (Geoterraimage 2005).

Ortho-photo evaluation of forest patch boundary accuracy

The objective of this component was to conduct an external data quality assessment of the 452 x *priority / non-priority* forest patches, based on a *qualitative* visual comparison of the mapped forest patch boundaries and areas of dense, closed canopy forest visible on suitable digital ortho-photography. As indicated in the terms of reference, the completeness of this spatial image comparison is dependent on the spatial coverage of digital ortho-photos supplied by DWAF. Suitable digital ortho-photos were supplied for approximately 60% of the 452 x *priority / non-priority* forest patches (that is, 269 *priority / non-priority* forest patches, representing 66% (or 60 286ha) of the total *priority / non-priority* polygons).

Boundary assessment procedures and coding

A visual assessment of forest patch boundary accuracy was completed by overlaying each priority / non-priority forest patch polygon over the comparable digital orthophotograph with the GIS, and comparing the mapped vector boundary to the extent of visible forest coverage. Accuracies were subjectively coded according to the following qualitative classes:

- **Good**: Good agreement between mapped vector and photo-determined forest extent in terms of polygon shape, size and location.
- **Medium**: Reasonable agreement between mapped vector and photo-determined forest extent in terms of either polygon shape, size *and/ or* location.
- **Poor**: Limited agreement between mapped vector and photo-determined forest extent in terms of either polygon shape, size *and/ or* location; or inclusion of non-forest vegetation covers such as plantation or scrub-forest (that is, north-facing low canopies).

Results of ortho-photo boundary mapping assessment

Subject to the fact that the assessment is both subjective and qualitative in approach and reporting, and that results are based on only ± 60% of all *priority/ non-priority* forest patches, the following conclusions can be made:

- 41.6% of polygon boundaries were classified as good (112 polygons = 41 914ha)
- 24.9% of polygon boundaries were classified as medium (67 polygons = 12 757ha)
- 33.5% (of polygon boundaries were classified as poor (90 polygons = 5 796ha).

Although the *number* of ‘poor’-rated polygons is higher than that of ‘medium’ polygons, the *actual area* of forest cover associated with this class is significantly smaller than either the medium or good categories. It thus appears that in general boundary mapping accuracies are lower for the smaller forest patches, and that for the majority of larger forest patches, boundary accuracies can be deemed acceptable. Interpretation of the above result in terms of original data sources shows that:

- 100% of the ‘good’ polygons were sourced from the ‘NFI’ dataset
- 25% of the ‘medium’-rated polygons were also sourced from the ‘NFI’ dataset, representing 84% of the total ‘medium’-rated forest patch area
- 29% of the ‘medium’-rated polygons were also sourced from the ‘old NFI’ dataset, representing 13% of the total ‘medium’-rated forest patch area
- 39% of the ‘poor’-rated polygons were also sourced from the ‘old NFI’dataset, representing 55% of the total ‘poor’-rated forest patch area
- 32% of the ‘poor’-rated polygons were sourced from the ‘UWP’ dataset, representing 11% of the total ‘poor’-rated forest patch area

- 5% of the ‘poor’-rated polygons were sourced from the ‘VegMap’ dataset, representing 20% of the total ‘poor’-rated forest patch area

In conclusion this would seem to indicate that the NFI and old NFI datasets are the most accurate in terms of spatial comparison to the reference ortho-photos, and that the UWP and VegMap datasets are the least accurate. Understanding of these results is however also dependent on understanding of source data characteristics, since it is to be expected, for example, that all Landsat-derived forest patch boundaries are likely to have a low spatial accuracy when compared to reference photography captured at a much more detailed scale. In many instances it appears that the cause of a ‘medium’ or ‘poor’ boundary accuracy rating (of what are assumed to be Landsat-derived boundaries due to vector-line characteristics), is a result of a geographical shift in the original source image data, rather than a boundary delineation error, which may be attributable to the accuracy of original satellite geo-referencing prior to forest mapping.

However, based on the overall assessment, it must be clearly stated that all such boundaries should be taken as geographical approximations of actual forest edge delineations and none should be seen as potential administrative or legal representations, since, at the scale of field survey, considerable local inaccuracies will still be found.

A file is supplied containing all screen-captured JPGs for each of the individual forest patch/ ortho-photo comparisons should DWAF wish to either re-evaluate these subjective accuracy assessments, or have access to a visual record of results.

Data integrity review conclusions

The identified data integrity problems associated with duplicate, mirror and slivers polygons, and the missing records do not constitute, collectively, a significant data integrity problem within the overall forest dataset. Apart from the missing data records associated with *externally modelled* forest indices (that is, threat and irreplaceability ratings etc.), the majority of errors can be corrected in-house by DWAF, using readily available reference data and using the flagged records as provided. DWAF will however have to make two key decisions on final forest patch data content prior to implementing such amendments and/ or modifications, namely:

a) Is forest data for Swaziland to be included in the final FP dataset? If so, this will require re-modelling of the THRTRATING”, “PARATING”, “SRUPRATING”, and, if applicable, IUCN and BIORESERVE attributes, with the assumption that all associated input variables required for these parameters are available for Swaziland. This cannot be confirmed within the scope of this data review process.

b) Correction of all duplicate and mirror polygons is a simple process. Correction of potential ‘sliver’ problems will require a decision confirming that all polygons below the 2ha size threshold will be *assumed* to be mapping errors and not actual forest patches. This cannot be easily validated for all potential sliver polygons due to the number of records (that is, > 7000) involved.

Final conclusion with reference to evaluated forest patch dataset

The evaluated dataset appears to have been compiled from a number of different input datasets, which may have been in turn derived from different reference data (that is, aerial photos and satellite images). This appears to have resulted in inconsistencies within the evaluated dataset in terms of accuracy and format of mapped forest patch boundaries, although the majority of such boundaries appear to be of an acceptable level of accuracy. The integration of different input datasets may be the reason for the large number of internal polygon integrity problems (that is, slivers, mirrors and duplicates), although the geographical area associated with such problem polygons is insignificant despite their number.

9 Appendix 4: Lists of priority forest clusters

The following forest clusters have been identified as priority forest areas for expansion of the forest protected area network. Only forested areas outside of Type 1 protected areas were considered. Some of the selected areas may already be under some form of protection (as Type 2 protected areas, state forests or private nature reserves).

9.1 Prioritisation method

All forest clusters that scored a 100% irreplaceability (using Marxan). Note that forest clusters that scored 100% irreplaceability for either of the two irreplaceability values considered (with boundary costs or without boundary costs). Analysis of irreplaceability values when with boundary costs are considered will give preference to the selection of planning units that are grouped or connected.

Notes

1. Some forest clusters fell across more than one magisterial district or province.
2. Names of clusters were derived, in most cases, from the largest patch occurring in the cluster. In many cases no names were available.
3. Clusters consist of patches with a 500m buffer area. Patches that are within 1 000m apart were considered as part of the same cluster. The cluster area includes the forest patches and the inter-patch cluster matrix. The forested area only consists of the forest patch area of the cluster.
4. The percentage natural habitat is an approximated index of how untransformed ('natural') the cluster buffer matrix is. It was calculate by proportional averaging of the percentages of untransformed habitat in each 5km buffer area.
5. The forest type of a cluster is extrapolated from the forest type of the largest patch in the cluster. (It is possible that clusters may contain more than one forest type.)
6. Cluster numbers with * indicate examples of where the clusters fall just outside of an existing protected area. These clusters would be ideal candidates for inclusion within existing, but expanded, protected areas.

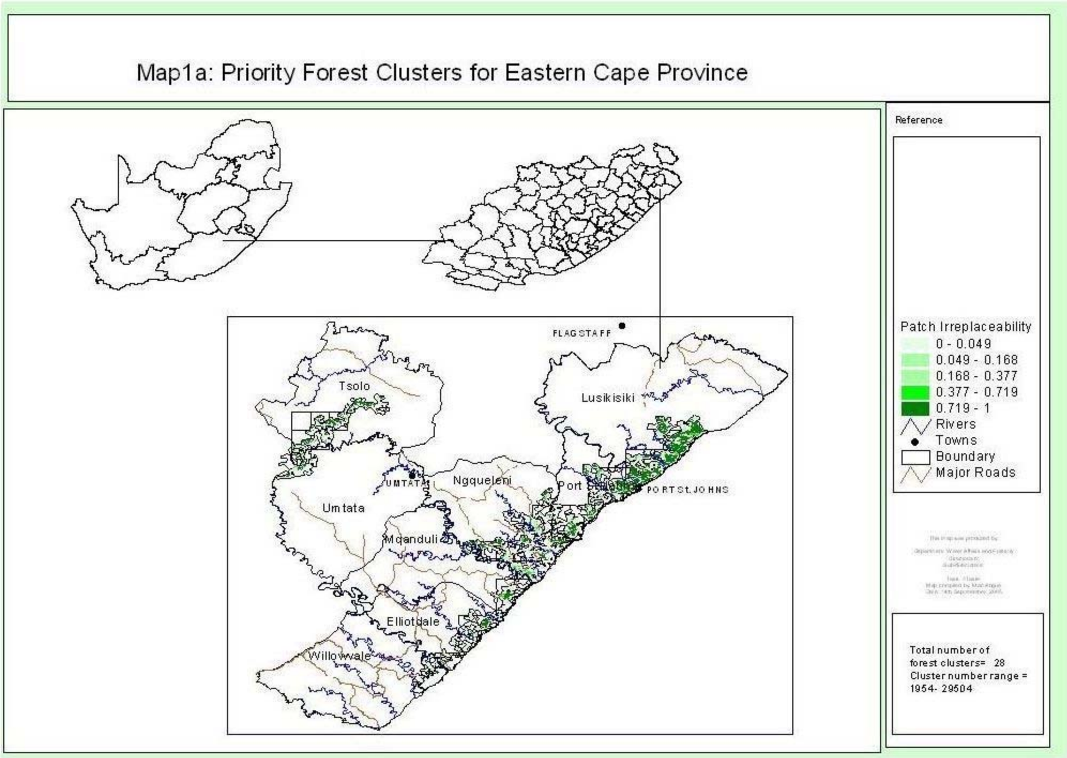
Table 52: List of priority forest clusters

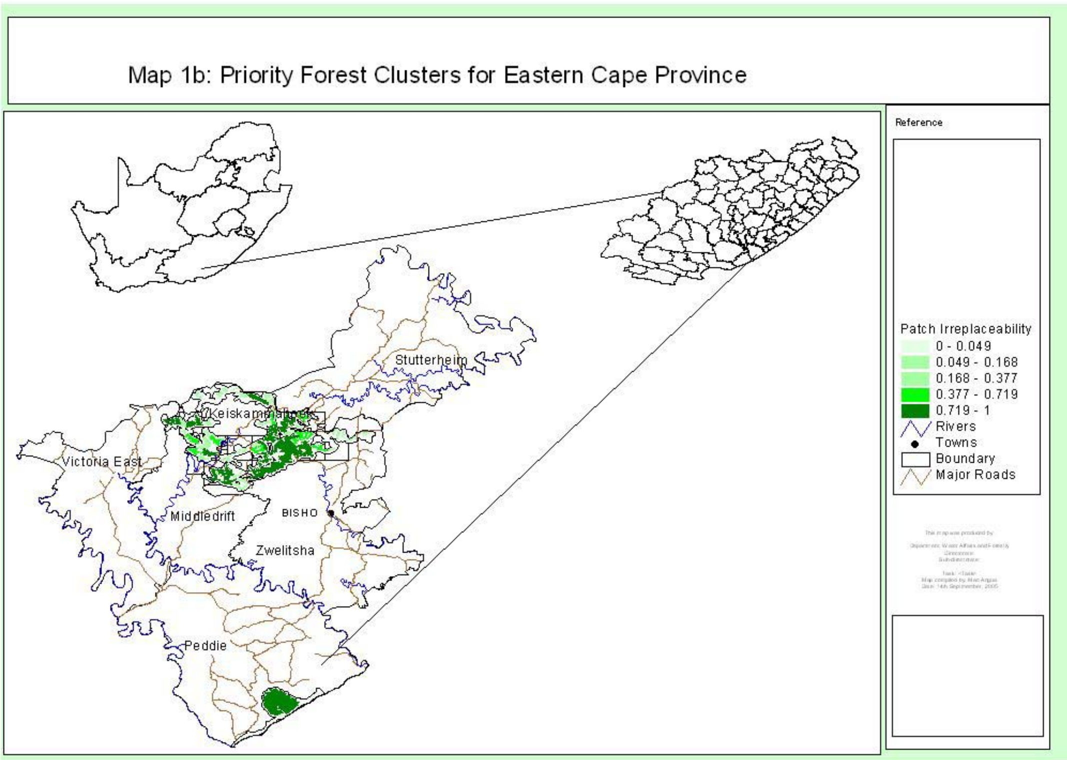
Province	Map	District	Cluster ID	Cluster name	Forest type (of largest patch)	Cluster forest area (ha)	% natural in matrix	No. of patches
LP	3a	Letaba/ Pietersburg	68	Grootbosch/ Samangobos	Northern Mistbelt	7 023	85	108
MP/LP	4b	Pelgrimsrus/ Mapulaneng/ Phalaborwa	103	Mariepskop to Onverwacht	MP Mistbelt	12 784	93	111
KZN	2a	Ingwavuma	306	Unknown	Licuati Sand	1 819	72	19
KZN	2a	Ingwavuma	307	Unknown	Lowveld Riverine	198	93	2
KZN	2a	Ingwavuma	308	Unknown	Licuati Sand	57	100	4
KZN	2a	Ingwavuma	310	Unknown	Licuati Sand	423	100	9
KZN	2a	Ingwavuma/ Ubombo (N)	311	Unknown	Licuati Sand	13 491	97	298
KZN	2a	Ingwavuma	312	Unknown	Swamp	314	91	8
KZN	2a	Ingwavuma	322	Unknown	KZN Dune	114	54	17
KZN	2a	Ingwavuma	338	Unknown	Licuati Sand	6	100	1
KZN	2a	Ingwavuma	345	Unknown	KZN Dune	55	100	1
MP	2c	Wakkerstroom	354	Mooibron	Northern KZN	177	100	3

Province	Map	District	Cluster ID	Cluster name	Forest type (of largest patch)	Cluster forest area (ha)	% natural in matrix	No. of patches
					Mistbelt			
MP	2c	Wakkerstroom	366	Unknown	Northern KZN Mistbelt	25	100	1
KZN/ MP	2c	Paulpietersburg/ Utrecht/ Piet Retief/ Wakkerstroom	373	Pongola bush	Northern KZN Mistbelt	983	100	6
KZN	2a	Ingwavuma	409	Unknown	KZN Coastal	155	71	1
KZN		Utrecht	413	Unknown	Northern KZN Mistbelt	119	100	7
KZN		Ubombo (KZ)	420	Unknown	KZN Coastal	34	82	3
KZN	2a	Ngotshe/ Ubombo (KZ)	444	Jozini	Eastern Scarp	3 552	97	7
KZN	2e	Ngotshe	536	Ntendeka	Eastern Scarp	3 446	94	33
KZN	2e	Ngotshe	563	Unknown	Northern KZN Mistbelt	141	54	5
KZN		Newcastle	593*	South of Ncadu Nature Reserve	Northern KZN Mistbelt	168	100	12
KZN		Newcastle	616	Unknown	Northern KZN Mistbelt	87	95	2
KZN	2b	Hlabisa/ Ubombo	617*	Nqutshini (falls outside St Lucia NP)	Licuati Sand	1910	84	2
KZN		Glencoe	670	Glencoe	Northern KZN Mistbelt	209	94	2
KZN	2b	Enseleni/ Hlabisa/ Lower Umfolozi	735	Dukuduku	KZN Coastal	12 445	82	162
KZN	2d	Lions River/ New Hanover/ Umvoti	1069*	Karkloof	Eastern Mistbelt	4 779	71	42
KZN		Richmond (N)	1354	Unknown	Eastern Mistbelt	1 151	69	17
EC		Umzimkulu/ Mount Currie	1498*	Nsikini	Eastern Mistbelt	1 172	85	42
EC		Umzimkulu	1569	Bencairnie Forest Reserve	Eastern Mistbelt	973	60	64
EC		Bizana/ Masixebeni/ Mt Ayliff/ Alfred	1741	Weza State Forest/ Ngele	Eastern Mistbelt	1 003	97	50
EC		Kwabhaca/ Mt. Frere	1768	Buffalo Nek Forest Station	Transkei Mistbelt	1 697	83	189
EC		Tabankulu	1868	Tabankulu /Kugomo	Eastern Mistbelt	1 074	100	43
EC	1a	Tsolo	1966	ID 333	Transkei Mistbelt	3 428	68	226
EC	1a	Bizana/ Lusikisiki/ Mqanduli/ Ngqeleni/ Umzimvubu/ Port St. Johns/ Xhora/ Elliotdale	2000	Port St Johns	Pondoland Scarp	35 083	90	1332
EC	1a	Engcobo/ Tsolo/ Umtata	2018	Ludaka	Transkei Mistbelt	2 443	64	194
EC	1a	Engcobo	2071	Ngxangxasana	Transkei Mistbelt	1 929	87	81
EC	1a	Lusikisiki	2106	Unknown	Transkei Coastal Platform	25	100	1
EC	1a	Umzimvubu/ Port St. Johns	2144	Gogogo	Transkei Coastal Platform	28	100	13
EC	1a	Ngqeleni	2157	Mpoza/ Maseko	Transkei Coastal Platform	23	100	1
EC	1a	Gatyana/ Willowvale/ Xhora/ Elliotdale	2284	Rebetshane	Transkei Coastal Platform	5 036	95	215
EC	1a	Xhora/ Elliotdale	2293	Unknown	Transkei Coastal Platform	22	89	2
WC		Clanwilliam	2344	Unknown	Western Cape Afrotemperate	499	100	25
EC	1b	Cathcart/ Keiskammahoek/ Middledrift/ Stutterheim/ Victoria East/ Alice/ Zwelitsha	2461	Pirie/ Amatola	Amatole Mistbelt	26 098	88	405

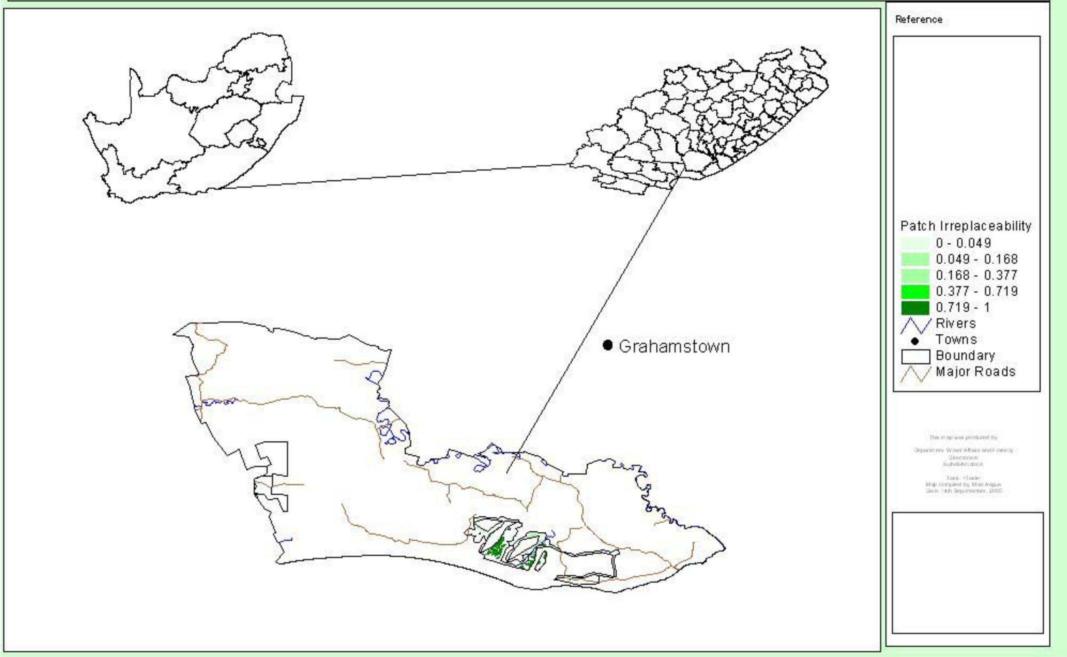
Province	Map	District	Cluster ID	Cluster name	Forest type (of largest patch)	Cluster forest area (ha)	% natural in matrix	No. of patches
EC	1b	Stutterheim	2535	Unknown	Amatole Mistbelt	31	74	5
EC	1b	Keiskammahoek	2562	Unknown	Amatole Mistbelt	31	73	2
EC		Oos-Londen/ East London	2672	Unknown	Eastern Cape Dune	602	89	18
EC	1b	Peddie	2737	Mgwalena mouth to Begha mouth	Eastern Cape Dune	5 185	97	32
EC	1c	Alexandria/ Kirkwood	2798	Unknown	Albany	120	95	7
EC	1c	Alexandria	2832	Alexandria	Albany	9 780	98	24
EC	1d	Humansdorp/ Joubertina/ George/ Knysna/ Uniondale	2882	Gouna/Blue Lily's Bush	Southern Cape Afrotemperate	49 625	78	801
WC	5	George	2930	Bergplaas	Southern Cape Afrotemperate	41	88	11
WC	5	George	2954	Unknown	Southern Cape Afrotemperate	284	100	6
EC	1d	Humansdorp	3117	Unknown	Southern Cape Afrotemperate	80	57	4
EC	1d	Humansdorp	3128	Witelsbos	Southern Cape Afrotemperate	88	57	9
EC	1d	Humansdorp	3134	Unknown	Southern Cape Afrotemperate	21	65	4
WC	5	Knysna	3165	Unknown	Southern Cape Afrotemperate	60	100	3
WC		Riversdal	3241	Stillbaai Melhout woud	Western Cape Milkwood	341	94	1

10 Appendix 5: Maps of priority forest clusters by province and district

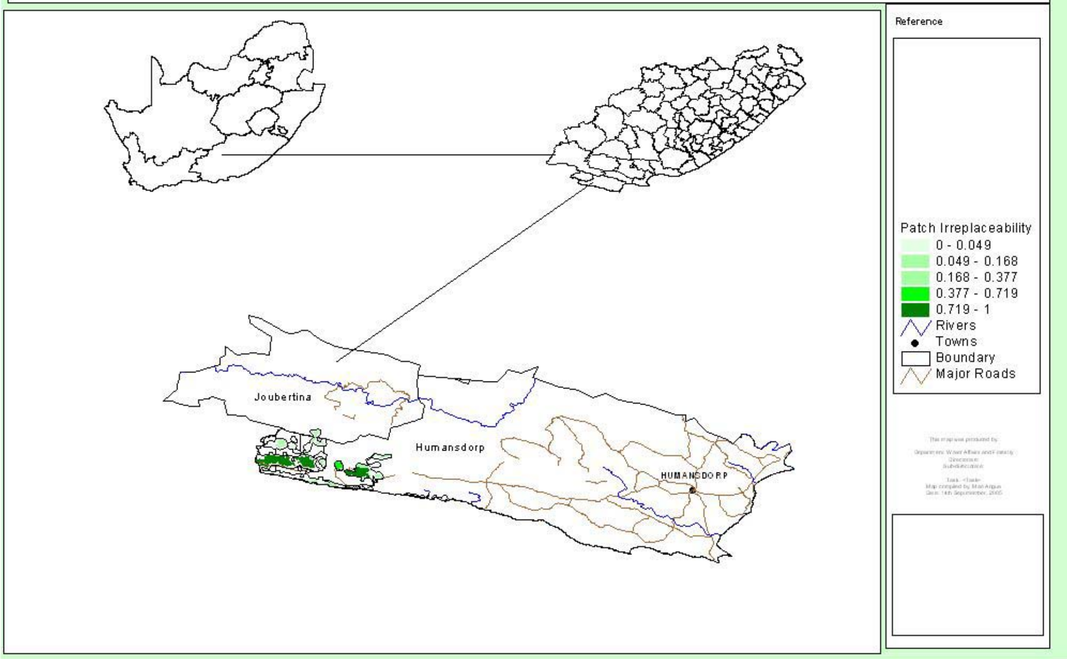


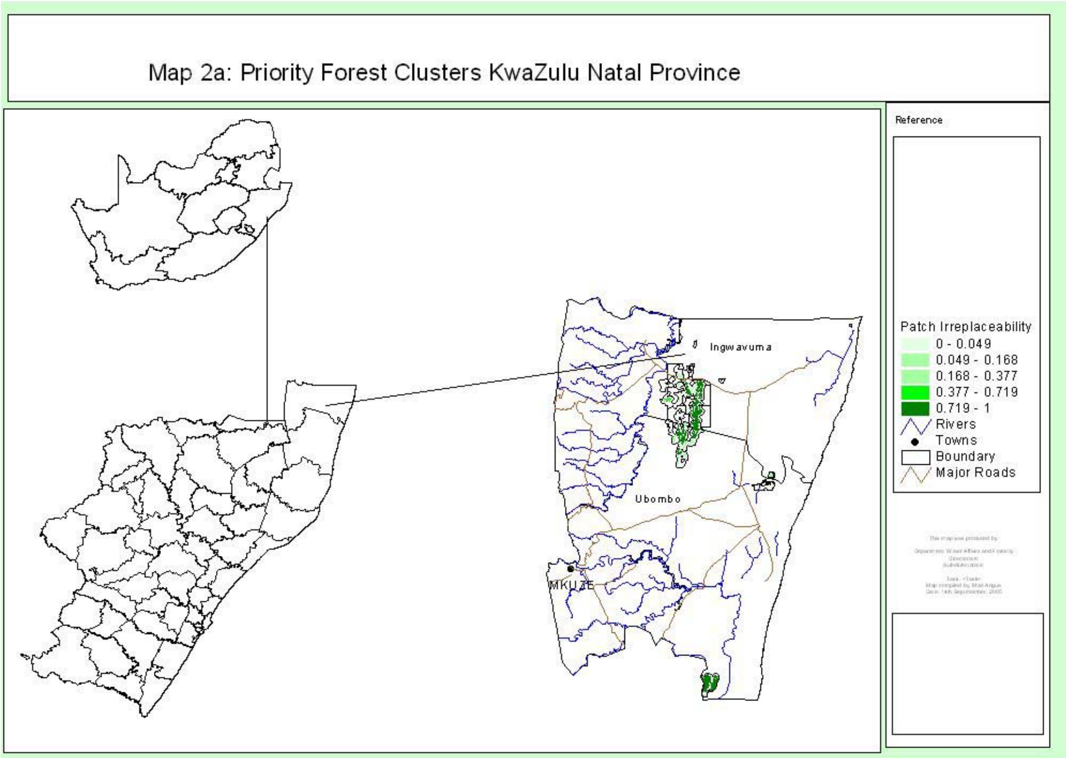


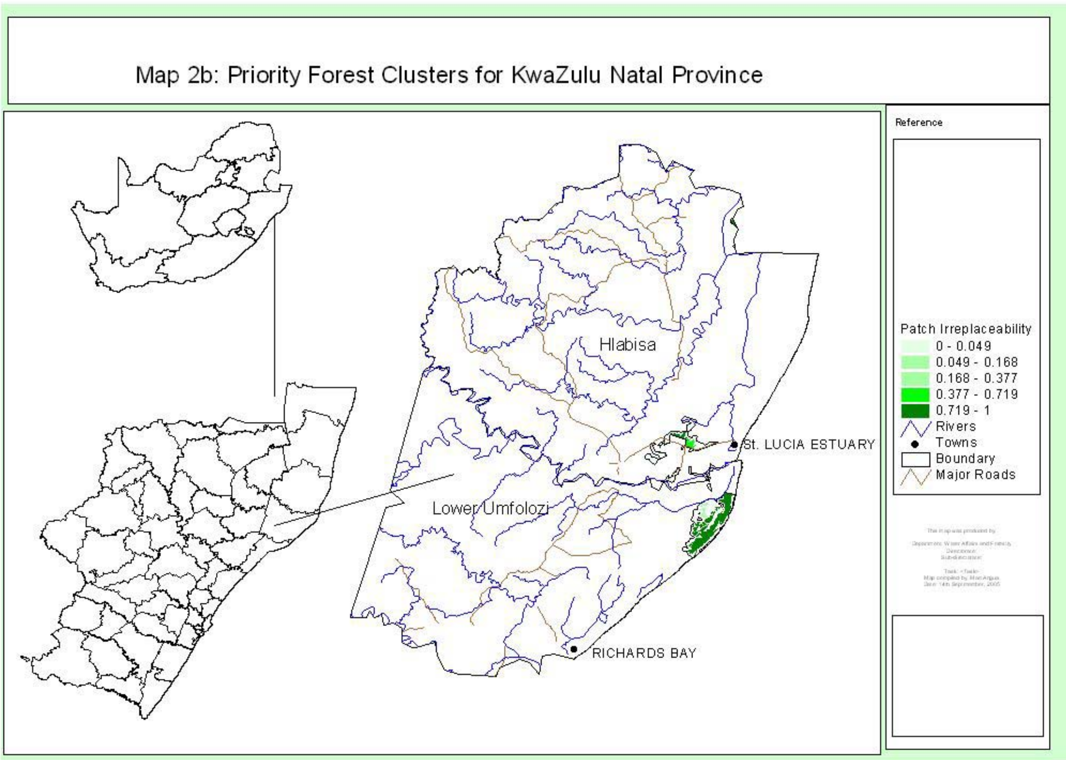
Map 1c: Priority Forest Clusters for Eastern Cape Province

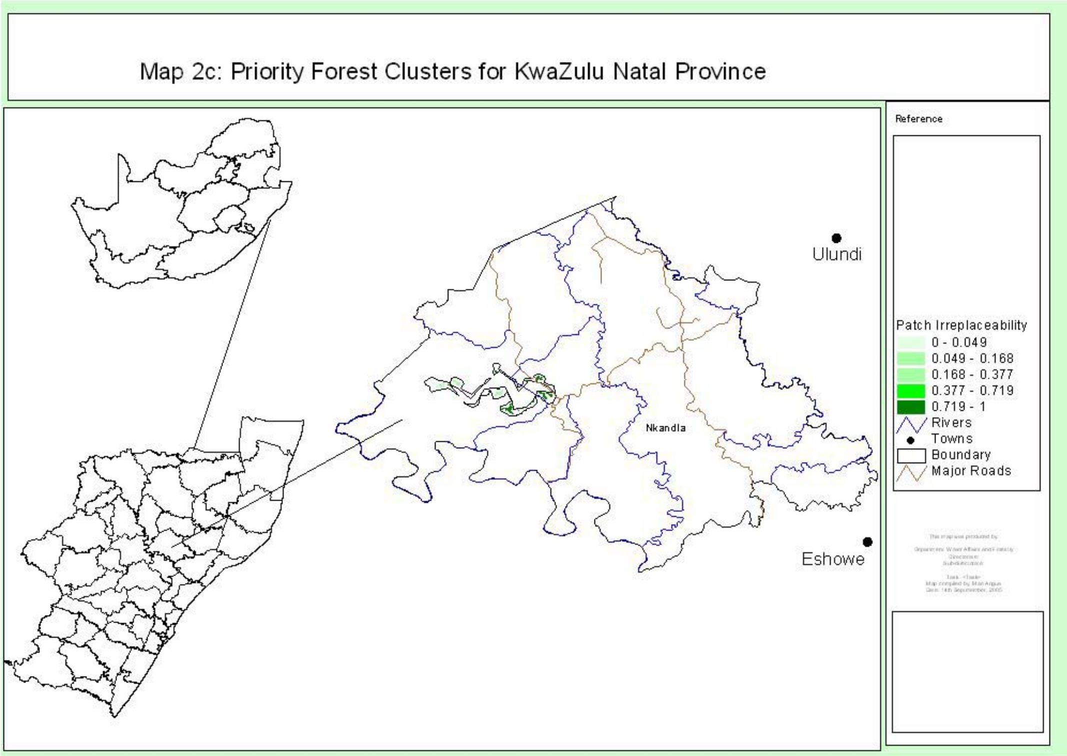


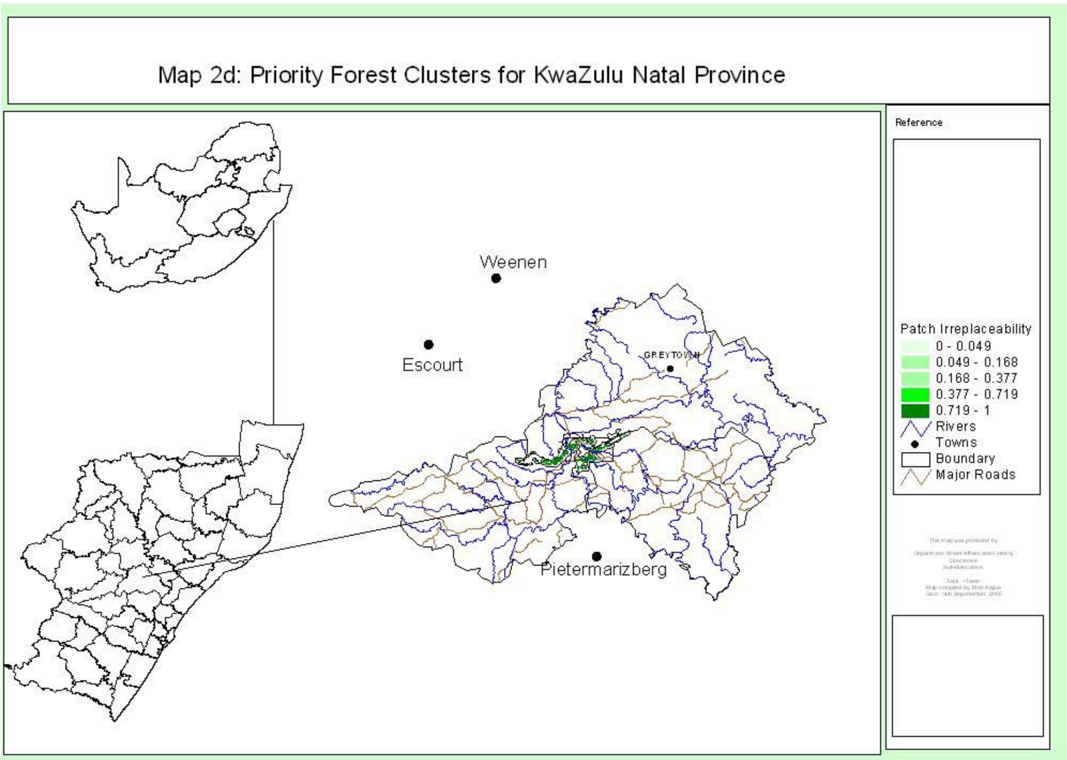
Map 1d: Priority Forest Clusters for Eastern Cape Province

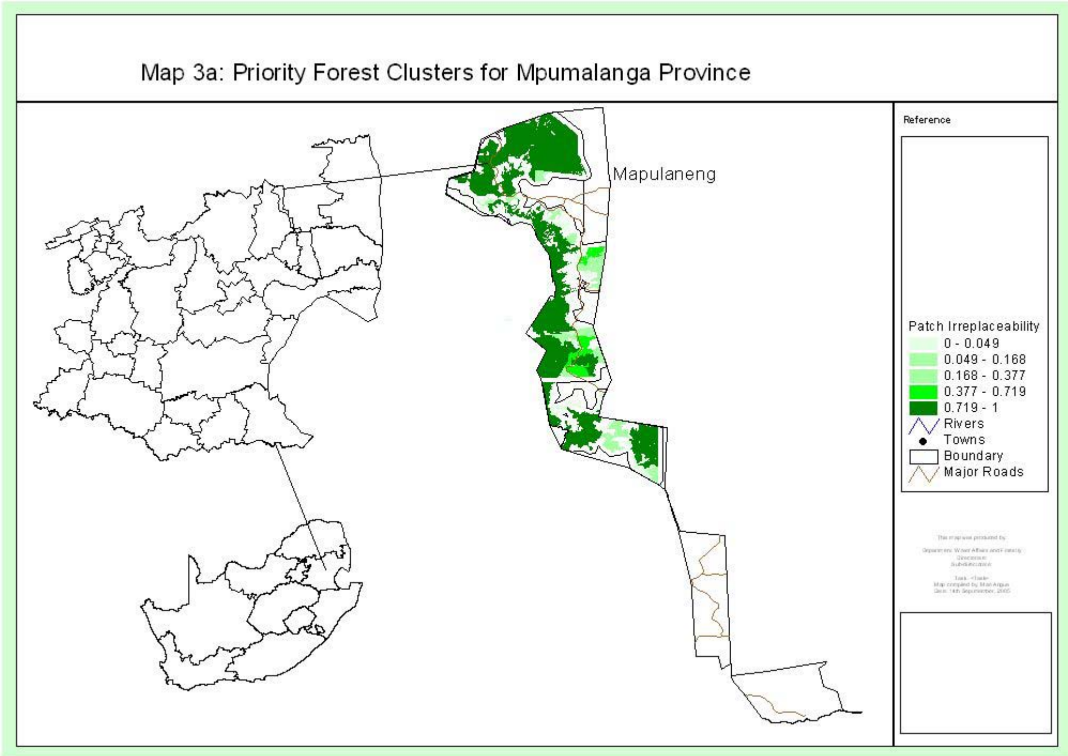



Map 2a: Priority Forest Clusters KwaZulu Natal Province
Reference
Patch Irreplaceability
0 - 0.049
0.049 - 0.168
0.168 - 0.377
0.377 - 0.719
0.719 - 1
Rivers
Towns
Boundary
Major Roads
Ingwavuma
Ubombo
MKUZE

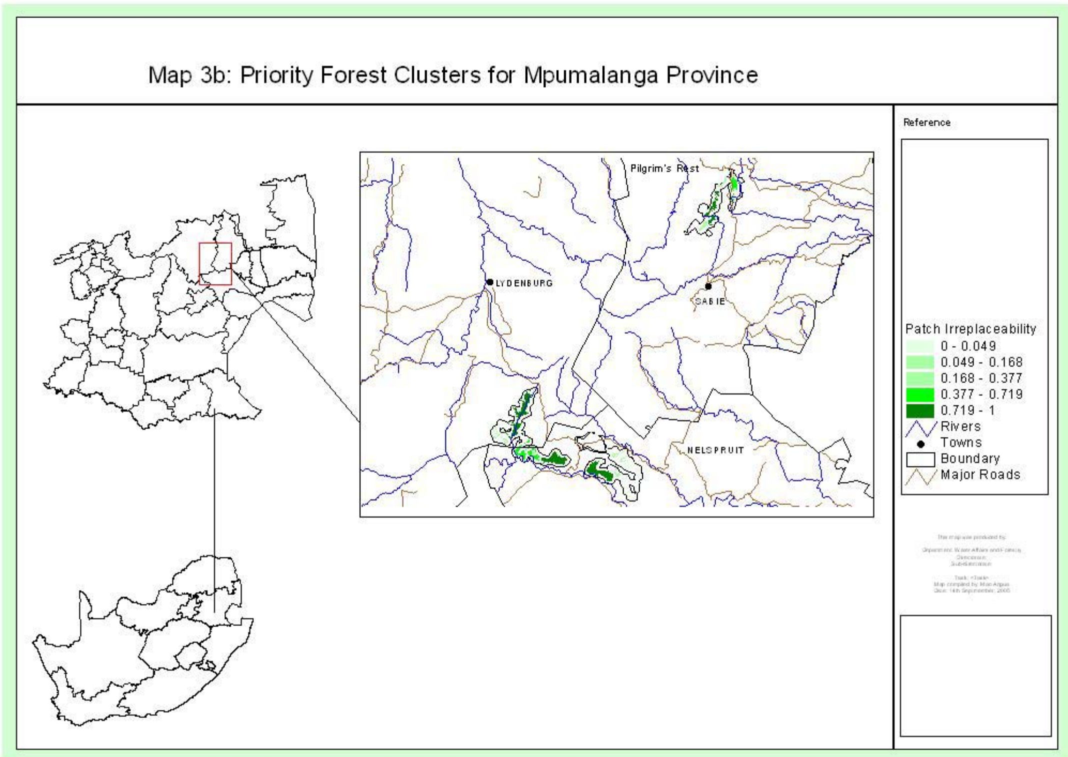

Map 2b: Priority Forest Clusters for KwaZulu Natal Province
Reference
Patch Irreplaceability
0 - 0.049
0.049 - 0.168
0.168 - 0.377
0.377 - 0.719
0.719 - 1
Rivers
Towns
Boundary
Major Roads
Hlabisa
St. LUCIA ESTUARY
Lower Umfolozi
RICHARDS BAY


Map 2c: Priority Forest Clusters for KwaZulu Natal Province
Ulundi
Nkandla
Eshowe
Reference
Patch Irreplaceability
0 - 0.049
0.049 - 0.168
0.168 - 0.377
0.377 - 0.719
0.719 - 1
Rivers
Towns
Boundary
Major Roads


Map 2d: Priority Forest Clusters for KwaZulu Natal Province
Weenen
Escourt
GREYTOWN
Pietermarizberg
Reference
Patch Irreplaceability
0 - 0.049
0.049 - 0.168
0.168 - 0.377
0.377 - 0.719
0.719 - 1
Rivers
Towns
Boundary
Major Roads

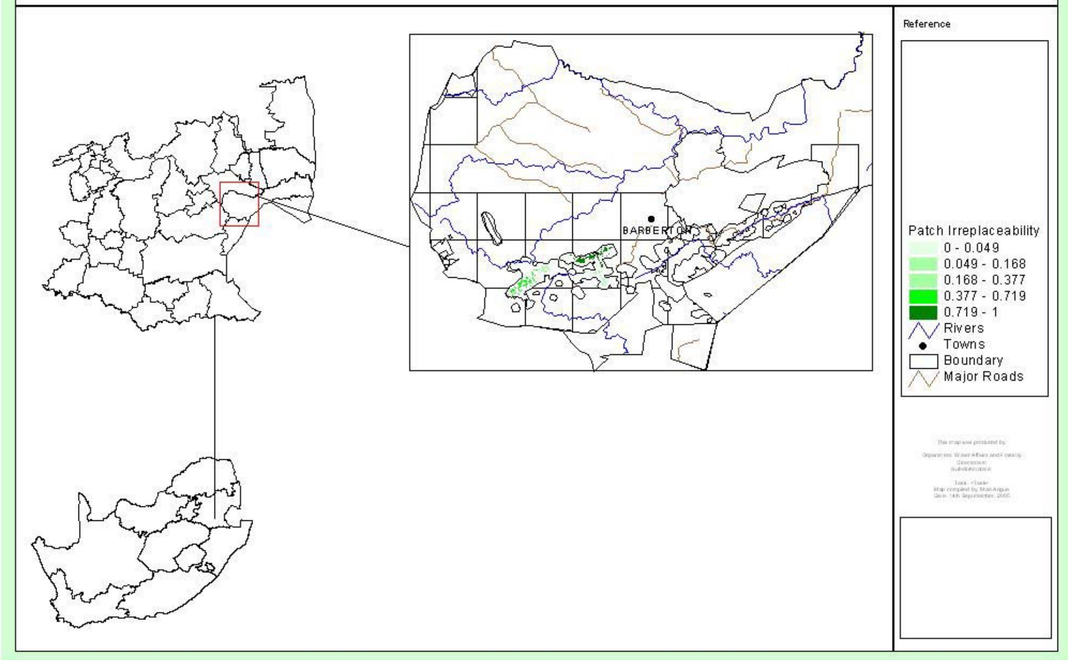


Map 3a: Priority Forest Clusters for Mpumalanga Province

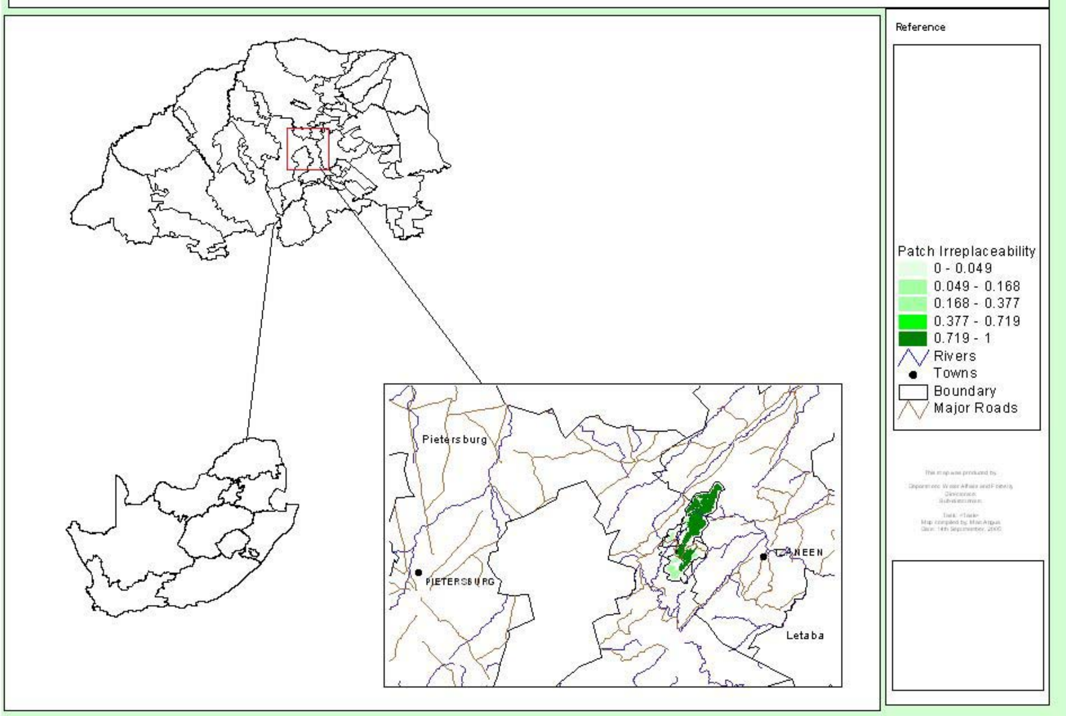


Map 3b: Priority Forest Clusters for Mpumalanga Province

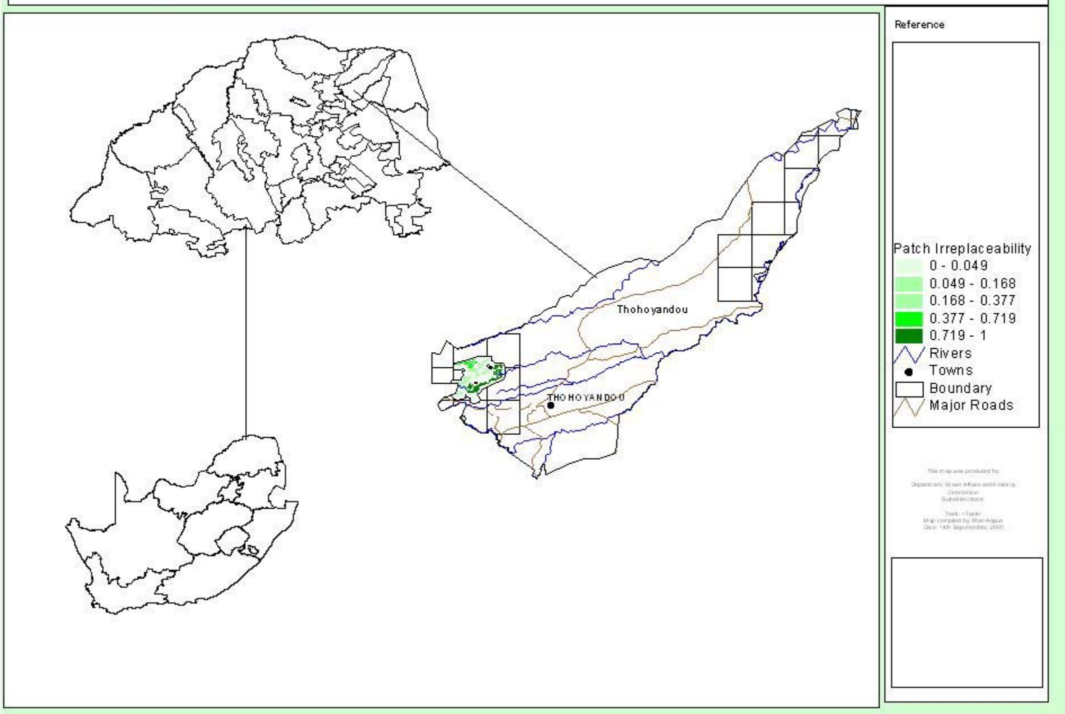
Map 3c: Priority Forest Clusters for Mpumalanga Province



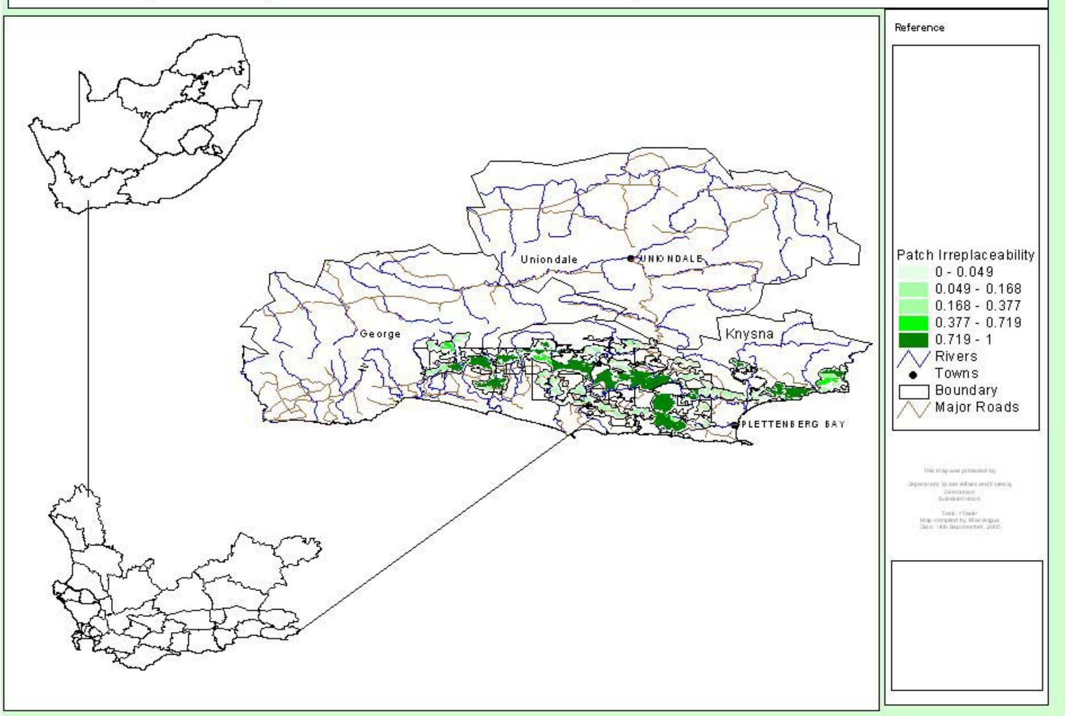
Map 4a: Priority Forest Clusters for Northern Province



Map 4b: Priority Forest Clusters for Northern Province



Map 5: Priority Forest Clusters for Western Cape Province



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