BIODIVERSITY CRITERIA AND INDICATORS FOR THE SUSTAINABLE MANAGEMENT OF INDUSTRIAL PLANTATIONS

by

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PREFACE

The research presented in this dissertation was conducted in the Forest Biodiversity Programme, as part of the requirements for the degree of Master of Science in the School of Environment and Development, at the University of Natal, Pietermaritzburg, from August 1998 to June1999, under the supervision of Professor Michael Lawes.

I hereby certify that the research reported in this dissertation is my own original and unaided work except where specific acknowledgement is given, and that no part of this dissertation has been submitted in any form for any degree or diploma to another University.

Signed

Elizabeth M. Linnett

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- All Mondi and Sappi participants of the workshop.

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ACRONYMS

ACT:	Amazon Co-operation Treaty
ATO:	African Timber Organisation
C&I's:	Criteria and Indicators
CIFOR:	Centre for International Forestry Research
DWAF:	Department of Water Affairs and Forestry
EMS:	Environmental Management System
FAO:	Food and Agricultural Organization
FMU:	Forest Management Unit
FSC:	Forest Stewardship Council
IPF:	Intergovernmental Panel on Forests
ISO:	International Organization for Standardisation
ITTO:	International Tropical Timber Organization
P,C&I:	Principles, Criteria and Indicators
SFM:	Sustainable Forest Management
UNCED:	United Nations Conference on Environment and Sustainable Development

EXECUTIVE SUMMARY

Introduction

Afforestation impacts on biodiversity through processes such as replacement of original habitat and habitat fragmentation. Commercial forestry also impacts on the processes that regulate biodiversity such as natural disturbance regimes, dispersal/migration, reproduction, regeneration/succession, trophic dynamics and local extinction. Therefore, one of the challenges in the sustainable development of forestry is the need to protect biological diversity in the rich ecosystems found in South Africa. The NFAP (1997) states that key facets of sustainable forest development include the protection of biodiversity, and stakeholder agreement on the criteria and indicators of sustainable forest management (SFM).

Aims of this study

The aims of this study are to:

- determine the impacts of industrial plantations on biodiversity;
- determine the role of biodiversity C&I's in SFM;
- develop a broad set of C&I's which may be used to assess the sustainability of industrial plantations, with particular reference to the maintenance of ecosystem integrity and thus biodiversity; and to
- rank indicators and verifiers according to criteria of practicality.

Criteria and indicators

Definition of criteria and indicators

Criteria and indicators (C&I's) can be defined as "tools which can be used to collect and organize information in a manner that is useful in conceptualizing, evaluating and implementing sustainable forest management," (Stork *et al.*, 1997). They measure progress towards SFM.

Box 1: Definition of Principle, Criterion, Indicator and Verifier (Lammerts van Bueren and Blom, 1997; Stork *et al.*, 1997)
A **principle** is defined as *"a fundamental truth or law used as a basis of reasoning or action".* Principles are explicit elements of a goal, e.g. sustainable forest management.
A **criterion** is a *"principle or standard that a thing is judged by".* A criterion can therefore be seen as a 'second order' principle, adding meaning and direction to the primary principle without being a performance measure in itself.
An **indicator** can be defined as *"any variable or component of the forest ecosystem or the relevant management system used to infer attributes of the sustainability of the resource and its utilisation."* Indicators provides verifiable measures of change in criteria over time.
A **verifier** is "*data or information that enhances the specificity or ease of assessment of an indicator."* Verifiers are the most scale sensitive and may vary from site to site. These are the tests used to provide specific details that reflect changes in the indicators under which each is identified.

Biodiversity criteria and indicators

Human interventions in forests inevitably affect biodiversity. Perry (1994) stated that there is a need for "forest-management techniques that reconcile commodity production with preservation of biodiversity". The degree to which biodiversity can be maintained within managed forests is still a matter of debate and requires more research. However, there is no intrinsic reason that a wide range of species cannot be maintained within forests that are also managed for products. "Disturbances are a healthy, diversifying force in nature as long as they are consistent with species adaptations: the disturbance associated with using forest products need be no different if we understand the needs of species and preserve the factors that protect system integrity "(Perry, 1994).

There are many approaches to the assessment of biodiversity. The species approach has been rejected in favour of more integrative measures of biodiversity. Changes in biodiversity can be assessed indirectly through assessment of the processes that generate and maintain biodiversity. Noss proposed a hierarchical approach from regional landscape level, to community-ecosystem, population-species, and the genetic level. This is the most holistic and comprehensive approach suggested to date. It would be very time-consuming to assess biodiversity at all these levels, but a shortcut is provided through the use of indicators. This concept of hierarchy was adopted as the framework for the implementation of C&I in the assessment of biodiversity at an FMU level.

Hierarchical framework

Criteria and indicators are arranged in a hierarchical framework of principles, criteria, indicators, and verifiers. The hierarchy should be both horizontally and vertically consistent. Criteria and indicators can also be applied at a hierarchy of levels. The landscape is the first level of the hierarchy followed by the habitat, community guild, species and genetic levels.

Role of criteria and indicators

C&I's are an adaptive management tool which can be used to assess progress towards the goal of sustainable development. There are no explicit universal standards as these are formulated at the FMU level within the applicable Environmental Management System to ensure local relevance. C&I's at the FMU-level fall within the national hierarchical framework. They are flexible and encourage monitoring to ensure continual improvement. At present, C&I's initiatives are voluntary and there is no accreditation process, but there is a reluctance on the part of industry to become involved. There is the belief that C&I's are part of existing environmental management systems. However, some of the problems associated with this process-based method of implementing C&I's are that it lacks independent auditing and enforcement. Systems that audit performance indicators such as FSC ensure that biodiversity conservation is not merely an ideal, but that steps are being taken to approach this goal. DWAF is currently adapting the international initiatives to derive a prescribed set for national application. If C&I's are to be incorporated in a certification system, then efforts should be made to include all relevant stakeholders in the process. The C&I's for local application should be developed by the forest managers in conjunction with certification bodies to ensure local relevance, participation and accountability.

How will these be implemented and at what scale?

The Department of Water Affairs and Forestry (DWAF) is working to develop relevant C&I's at a national level. However, South Africa lags behind the rest of the world in the development and implementation of C&I's at both the national and FMU level. Local-scale assessment is needed because it is the management decisions made in individual FMU's that determine the sustainability of forest management. The White Paper on Conservation and Sustainable Use of Biological Diversity (1997) recognizes the role of and the need for incentives which support the maintenance of biological diversity at the user level. C&I's at the forest management unit have been developed by organizations such as the Rainforest Alliance, the Soil Association, the African Timber Organization, and Lembaga Ekolabel Indonesia. The Centre for International Forestry Research (CIFOR) is currently undertaking a project to test C&I for SFM at FMU level. However, standards developed at regional and national level may not be fully compatible with standards used for the assessment of the quality of forest management at the level of the forest management unit. These sets of C&I's have been developed for application in logged tropical forests (not plantations) and therefore require modification before they can be applied in plantations found in temperate South Africa.

Difficulties in identifying biodiversity criteria and indicators

Defining sustainability

The term sustainability is used extensively, particularly in the forestry industry, even though there is still a great deal of uncertainty as to what sustainable forest management is. Sustainability relies on the spatial and temporal perspective of the observe and is a shifting target which changes through time. Sustainability of the plantation industry in South Africa will depend to some extent on the definition of sustainability and the description of the forestry management unit that is used.

Framework to support C&Is

Forestry legislation which emphasizes sustainability in South Africa is still being formulated. DWAF is currently developing a national framework for criteria and indicators, however, confusion exists over who should be developing C&Is and how the process should be implemented. The lack of a national framework to support and guide the development of C&Is at the FMU level, resulted in the selection of biodiversity criteria and indicators having to be based on the international initiatives which focus on natural forests.

It is important to remember that these indicators and verifiers are only suggestions and will need to be tested against the wider phenomena they are intended to represent or summarize so that they can be relied upon. This could result in modification, refinement, or even the abandoning of some indicators if they are found to be unreliable.

Appropriate scale of application and assessment

One of the difficulties of selecting C&Is for plantation forests is deciding on the scale of assessment. Environmental changes caused by plantations vary temporally and spatially. However, due to economic and time constraints, it would be impossible for plantation managers to assess plantation sustainability at the regional level. The plantation landscape is the effective FMU which should be used in the assessment of sustainability. This is the area directly under the control of the plantation manager.

Since the structure, composition and function of plantations at the FMU levels are dynamic in both space and time, identifying an appropriate scale of management at this level may be come a challenge to forestry managers. Since natural processes occur at many scales in the FMU, it is important to determine at which level the C&Is are applicable. In some cases the appropriate spatial scale for management may be the plantation stand, in others the plantation compartment or the ecosystem, habitat or niche of which the plantation forms a part.

Limits of acceptable change

It is impossible for forest managers to sustain everything and it is therefore, important to decide what is to be sustained in plantation forests. This requires a common understanding and vision of 'acceptable levels of change'. However, the conflict between scientists, decision-makers and forest managers on their perceptions of the levels of acceptable change is one of the major obstacles to implementation of the C&I process. A compromise will have to be reached, where thresholds are set at realistically attainable levels for forest managers, but which will also be acceptable to scientists and policy-makers. This could perhaps be achieved by making use of Bayesian Inference.

Evaluation of C&Is

One of the challenges of the C&I procedure is the process of evaluation. It is important that the practicality of C&I's be assessed in a clear and rational manner, and the reasons for acceptance or rejection be objectively determined. Expert voting alone will not be adequate for scientific and instructive evaluation, since it is based on a value judgement, preconception and assumptions rather than upon scientific principles. It is therefore, important that the C&I process links scientific evaluation with management perceptions during the evaluation process.

Process for identifying criteria and indicators

International C&I initiatives were examined to determine which indicators could be applied to management and conservation of biodiversity at an FMU level. Since UNCED, there have been three major international initiatives conducted on a governmental level towards the formulation of criteria and indicators to assess the sustainability of forest management at the national level: the Montreal Process, the Helsinki Process and the Tarapoto Proposals. Several NGOs have also begun initiatives to define SFM. The FSC has formulated principles and criteria applicable to tropical, boreal and temperate forests for the purpose of timber certification at the forest level. Indicators drawn from the international initiatives were combined with those suggested by Stork *et al.* (1997) for conservation of biodiversity at the FMU level. Boyle *et al.* (in press) later rejected many of these verifiers according to certain criteria of practicality. As these criteria of practicality are similar to mine, Boyle's smaller set of verifiers were then further investigated for application in FMUs in a temperate area such as South Africa.

The C&I's were presented to representatives from the forestry industry namely, Sappi and Mondi, for evaluation of their practicality and relevance. The participants were given a list of 11 attributes against which to score the C&I's. The results of the workshop can be summarized as follows:

Ranking of Indicator categories

The landscape category of indicators scored the highest average per verifier followed by the species richness / diversity category, the community guild category, and the habitat structure category. Participants discussed the usefulness of landscape-level indicators as integrative measures of processes and biodiversity at other levels. These indicators scored highly on the question of ease of assessment. The habitat structure category scored very low as the indicators were seen as impractical, time-consuming, and outside the scope of current plantation management activities. The participants felt that this would impose an extra work-burden on to the managers.

Ranking of questions

The verifiers scored highest on the issues of precision of definition, relevance, and relation to the assessment goal. They scored lowest on the issue of ease of assessment which incorporates analysis of data, difficulty and accessibility of data. Many of the proposed methods are easy to understand and to conduct, but are constrained by lack of data, limited personnel and financial considerations. However, most participants agreed as to their relevance to biodiversity conservation and the responsibility of the industrial forestry sector to ensure that biodiversity is not harmed irreparably.

Recommendations

Sustainable plantation management

- A clear definition and common understanding of sustainable plantation management is needed.
- Sustainable forest management requires both performance targets (C&I's) and a management process of continuous improvement (adaptive management) to achieve those targets. This involves:
    - participation of the major stakeholders;
    - clear environmental policy and demonstrated commitment to it;
    - allowing for uncertainties;
    - monitoring, learning and adaptation.

  An EMS is useful in guiding this process.
- Researchers and managers must continually interact when addressing the issues, choices, and consequences of management decisions.

Developing C&I's for the FMU

- Indicators at the FMU level should be compatible with those at the national level;
- The FMU should be clearly defined and described. This requires information regarding management plans, FMU boundaries, biodiversity including habitat types, historic and current areas of intervention, inventory data; contours, streamlines and other physical elements; and roads, settlements and other infrastructural elements;
- C&I's should be formulated in conjunction with forest managers to ensure local relevance and practicality;
- Development of C&I's should take into account the diverse nature of the plantation landscape. C&I's should be applicable in the plantation stands as well as in indigenous ecotypes;
- No single criterion or indicator is alone an indicator of sustainability. Individual criteria and indicators should be considered in the context of other criteria and indicators;
- Development of core indicators such as:
  "red flag" indicator - if this is not satisfied then neither is the criterion
  "green flag" indicator - if this is satisfied then so is the criterion,
  will enable rapid assessment of biodiversity;
- Monitoring programmes need to be instituted to assess the effectiveness of the C&I's in the assessment of biodiversity and its sustainability;
- C&I's need to be supported by long-term research to build up the database;
- C&I's can serve as performance indicators within a certification system such as FSC or tools to evaluate sustainability in a procedural system such as ISO 14000. A combination of performance and process standards will be most effective in achieving SFM.

Evaluation of C&I's

- Practicality of C&I's needs to be assessed in a clear and rational manner, and the reasons for acceptance or rejection objectively determined;
- Expert voting alone will not be adequate for scientific evaluation, since it is based

on a value judgement, preconception and assumptions rather than upon scientific principles;

- The evaluation process needs to link scientific evaluation with management perceptions;
- Field testing of proposed C&I's should occur within an adaptive management framework.

Implementation of C&I's

- The best approach to C&I at present appears to be a voluntary approach;
- A combination of performance and process standards is needed to make the transition to sustainable plantation management.

Conclusion

C&I's for sustainable forest management are one of the main achievements in the progress towards sustainable forest management in the 1990's. SFM involves many factors and uncertainties and is therefore a moving target. Criteria and indicators are appropriate in this context as they are not an end in themselves, but represent a dynamic and systematic tool to assess changes and trends in the status of biodiversity and condition of the natural environment. They serve as an "early warning" system and help identify gaps, threats and new opportunities for forest management. Regularly available information on the state of forests and forest management should contribute to better decision-making, and thus reduce the risk of unsustainable forest management policies and practices.

CHAPTER ONE: INTRODUCTION

Less than 0.5% of South Africa is covered by indigenous forests. These forests cannot supply the majority of South Africa's wood requirements due to their limited extent, slow growth and sensitivity to logging. Plantations of fast-growing trees are therefore needed to cater for the demand for wood products. Pines (*Pinus sp.*), gum trees (*Eucalyptus sp.*) and wattle (*Acacia sp.*) are the most popular genera for afforestation. In 1995 industrial plantations covered an estimated 1 487 000 hectares (1.2% of total area of South Africa) of which 47% was owned by four large private companies (DWAF, 1997b). KwaZulu-Natal contains the second largest area of plantation forest in South Africa (37%). Currently, afforestation is occurring at a rate of 10 000 to 12000 hectares per annum, with the greatest potential for further afforestation in KwaZulu-Natal and the Eastern Cape.

Afforestation has many environmental and social consequences, some of which can be mitigated (DWAF,1997b). The plantation forests of South Africa have transformed previously grassland areas and have created an entirely new environment. Therefore, one of the challenges in the sustainable development of forestry is "the need to protect biological diversity in the rich ecosystems found in South Africa" (DWAF, 1997b). The effects of afforestation on biodiversity is discussed in chapter 2. Whether exploitation of forest resources can be sustained will depend on social and environmental considerations such as: increased competition for water, ensuring higher economic benefits than can be derived from other potential users of the same resource, meaningful contribution to rural development, the protection of biodiversity and stakeholder agreement on the criteria and indicators of sustainable forest management (SFM) (NFAP, 1997).

1.1 Sustainable Forest Management

The White Paper on Sustainable Forest Development in South Africa (1996) requires that the industry not only be internally efficient and profitable, but also rational in its use of resources, equitable in its development, and environmentally sustainable. Sustainability relies on the spatial and temporal perspective of the observer and is a shifting target which changes through time. The degree to which the plantation industry in South Africa is sustainable will depend to some extent on the definition of sustainability, the description of the forest management unit (FMU) that is used, and the establishment of clear management goals and objectives. Ferguson (1996) suggests that "sustainable development (or sustainable forest management) might well be regarded as...a ritualistic symbol or icon of some desired, but ill-defined future". The National Forestry Action Programme (NFAP) defines sustainable forest management as "the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems" (DWAF, 1997b). However, the establishment of monoculture plantations will certainly destroy the ecosystem that it is replacing, so this definition should be modified to read "....and that minimizes damage to other ecosystems." It is therefore important to be able to distinguish between natural disturbance and disturbance caused through management actions. It is also essential to determine acceptable amounts of disturbance.

According to Nambiar and Brown (1997), plantation sustainability is most likely if there is maximum alignment between key interdependent variables that include:

- ecological capability of the site,
- intensity of management,
- soil, water and other environmental values,
- economic benefit and social goals.

Forest policies and management now recognize multiple functions of indigenous forests such as social, cultural and spiritual functions, maintenance and enhancement of biological diversity, as well as their health and vitality. Plantation estates need to be managed to ensure that there is a balance between production and environmental values. Plantation managers therefore need to know how management actions are impacting on biodiversity.

Internationally, progress towards the goal of sustainability is measured through the development and application of principles, criteria and indicators. Assessing SFM with the use of C&I's provides systematic and objective information about the state and trends of the forests and forest management practices (Granholm *et al.*, 1996). Although, SFM has been defined in the NFAP, there is still much confusion about its practical implementation. Nevertheless, there are increasing political pressures on scientists, managers and policy makers to provide criteria and indicators for assessing sustainability.

1.2 Criteria and Indicators

Criteria and indicators (C&I's) can be defined as "tools which can be used to collect and organize information in a manner that is useful in conceptualizing, evaluating and implementing sustainable forest management," (Stork *et al.*, 1997). They measure progress towards SFM. They can be arranged in a hierarchical framework. Lammerts van Bueren and Blom (1997), and Stork *et al.* (1997) list four hierarchical levels which include principles, criteria, indicators and verifiers (Box 1).

Box 1: Definition of Principle, Criterion, Indicator and Verifier (Lammerts van Bueren and Blom, 1997; Stork *et al.*, 1997)
A **principle** is defined as *"a fundamental truth or law used as a basis of reasoning or action".* Principles are explicit elements of a goal, e.g. sustainable forest management.
A **criterion** is a *"principle or standard that a thing is judged by".* A criterion can therefore be seen as a 'second order' principle, adding meaning and direction to the primary principle without being a performance measure in itself.
An **indicator** can be defined as *"any variable or component of the forest ecosystem or the relevant management system used to infer attributes of the sustainability of the resource and its utilization."* Indicators provides verifiable measures of change in criteria over time.
A **verifier** is "*data or information that enhances the specificity or ease of assessment of an indicator."* Verifiers are the most scale sensitive and may vary from site to site. These are the tests used to provide specific details that reflect changes in the indicators under which each is identified.

1.2.1 Value of C&I's

Criteria and indicators are not an end in themselves, but represent a dynamic and systematic tool to assess trends and changes in the condition of forests. They serve as an "early warning" system and help identify gaps, threats and new opportunities for forest management. Carefully selected indicators reduce the number of measurements required to show progress towards SFM and thus aggregate information in a comprehensive way. This simplifies the communication process between all interested parties.

C&I's can aid in the orientation of forest and environmental policies and research and guide forest practices towards sustainable forest management. They may also have an important role in directing the inventory of forest resources and the use of forest resources by using the data that is more relevant and more reliable (ISCI, 1996). C&I's for sustainable forest management are being developed to assess trends in the state of forests and forest management. They are considered as being a policy instrument to evaluate progress towards SFM. They have the potential to help the orientation of forest and environmental policies and research, and guide forest practices towards sustainable forest management which meets the expectations of society.

1.2.2 Scale of implementation

The development of C&I's which can be applied to the commercial plantation industry has not been well researched. While the Centre for International Forestry Research (CIFOR) are currently working towards developing international plantation C&I's, the South African government (DWAF) is working to develop relevant C&I's at a national level. However, South Africa lags behind the rest of the world in the development and implementation of C&I's at both the national and FMU level. Local-scale assessment is needed because it is the management decisions made in individual FMU's that determine the sustainability of forest management. The White Paper on Conservation and Sustainable Use of Biological Diversity (1997) recognizes the role of and the need for incentives which support the maintenance of biological diversity at the user level.

1.3 Aims

The aims of this thesis are as follows:

- To determine the impacts of industrial plantations on biodiversity;
- To determine the role of biodiversity C&I's in SFM;
- To develop a broad set of C&I's which may be used to assess the sustainability of industrial plantations, with particular reference to the maintenance of ecosystem integrity and thus biodiversity;
- To rank indicators and verifiers according to criteria of practicality.

The development of plantations threatens the sustainability of the natural environment. Although the concept of sustainability might not be attainable in the context of the plantation industry, it serves as an ideal towards which management can strive. C&I's are tools which can be used to assess biodiversity and therefore, progress towards sustainable forest management.

CHAPTER TWO: IMPACTS OF AFFORESTATION ON BIODIVERSITY

Biodiversity, short for biological diversity is "the variety and variability among living organisms and the ecological complexes in which they occur" (OTA, 1997). In addition, because "items are organized at many [biological] levels," biodiversity "encompasses different ecosystems, species, genes, and their relative abundance" (OTA, 1997). Conservation can be defined as the "wise use of our resources so that they will remain available for our use and enjoyment in the future" (Low and Rebelo, 1996). Conservation embraces any progress and development which increases human betterment, provided that the environment is not irretrievably damaged. The environmental context is very important in biodiversity conservation and it is because of this that conservation is so critically affected by how humans impact the environment. We thus need to ensure that urbanisation, agriculture, afforestation and other land-uses do not lead to irreversible losses of our rich biodiversity. Although not traded, biodiversity does have a value. Conservation of biodiversity is one of the "non-use values" of industrial plantations. Sometimes, people place a higher value on these "non-use values" than on any of the formally marketed goods and services (DWAF, 1997b). One of the challenges in the sustainable development of forestry is therefore "the need to protect biological diversity in the rich ecosystems found in South Africa" (DWAF, 1997b).

The supply of wood and wood products from afforested areas has prevented the over-exploitation and destruction of indigenous forests. However, the plantation forests of South Africa have transformed areas that were previously grassland areas and have created an entirely new environment. The main environmental impacts of industrial forestry revolve around the quantity and quality of water resources, soil, biodiversity, weed dispersal, atmosphere, and visual landscape (Kruger et al., 1995; Olbrich et al., 1997). The impacts of plantation forestry are poorly quantified in South Africa, other than in the case of water resources. Commercial forestry displaces many of the original species, and even though it does provide habitat for new species suited to arboreal habitats, biodiversity in plantations is lower than otherwise. Commercial forestry also impacts on the environmental processes that regulate biodiversity such as natural disturbance regimes, dispersal/migration, reproduction, regeneration/succession, trophic dynamics and local extinction. At the level of the forest estate, negative impacts are greater on the afforested land than on the adjoining un-afforested land, depending on the quality of the land management practised. Impacts on the un-afforested land include vegetation change and weed invasion arising from altered fire regimes. This is where management actions can have the greatest positive impact through protection of habitats (Lawes et al., 1998). The impacts of afforestation on biodiversity will be discussed in two categories, namely general impacts, and impacts on specific habitats.

2.1 General impacts on biodiversity

2.1.1 Habitat fragmentation

Afforestation results in habitat fragmentation. Wilcox and Murphy (1985) state that habitat fragmentation is "the most serious threat to biological diversity, and the primary cause of the present extinction crisis." Fragmentation reduces biodiversity through four major mechanisms:

2.1.1.a)Initial exclusion

One of the most rapid and obvious effects of fragmentation is elimination of species that occurred only in the portions of the landscape destroyed by development. Many rare species are endemics with very narrow distributions, occurring in only one or a few patches of suitable habitat (Meffe and Carroll, 1994; Armstrong *et al.*, 1996).

2.1.1.b)Isolation

The modified landscape (i.e. matrix) in which natural fragments exist is often inhospitable to many indigenous species, thus preventing normal movements and dispersal (Saunders *et al.*, 1991; Everard, 1993; Meffe and Carroll, 1994; and Armstrong *et al.*, 1996). Patches of indigenous vegetation in commercial timber plantations have been likened to habitat "islands" in an "inhospitable sea" i.e. the area planted with exotic timber trees (Everard, 1993; Armstrong *et al.*, 1996). The species richness and abundance of plants, birds and small mammals are much greater in indigenous habitat than in mature pine plantation. Ecological processes such as pollination and seed dispersal are not disrupted totally. The absence or scarcity or rodent and avian pollinators (Rebelo, 1987) and vertebrate-pollinated plants in mature pine plantations, however, may lead to disruption of vertebrate-mediated pollination in indigenous habitat patches isolated by these plantations. There may also be disruption of wind-mediated and insect-mediated pollination. Plantations act as wind-breaks and perhaps flight barriers to insects (Wood and Samways, 1991).

2.1.1.c)Island-area effect

Small fragments contain fewer habitats, support smaller populations of indigenous species that are more susceptible to extinction, and are less likely to intercept paths of dispersing individuals. In some cases, the dominant process determining change in species composition may be local extinction. For example, the loss of a particular type of vegetation might result in the local extinction of a dependent species and a more broad-scale extinction. When local populations become isolated, they face a higher probability of extinction (Meffe and Carroll, 1994). The following species are likely to be most vulnerable to local extinction following habitat fragmentation: rare species, species with large home ranges, species with limited powers of dispersal, species with low reproductive potential, species dependent on resources that are unpredictable in time or space, ground-nesting species, species of habitat interiors, and species exploited or persecuted by people (Meffe and Carroll, 1994).

2.1.1.d)Edge effects

Climatic influences and opportunistic predators and competitors from the disturbed landscape penetrate into fragments, reducing the core area of suitable habitat (Meffe and Carroll, 1994; Saunders *et al.*, 1991). Lovejoy *et al.* (1986) identified edge effects as the most important cause of ecological changes resulting from habitat fragmentation. Fragmentation of the landscape results in changes in the physical fluxes across the landscape. Alterations in fluxes of radiation, wind, and water can all have important effects on remnants of indigenous vegetation (Saunders *et al.*, 1991). Edge zones are usually drier and less shady than forest interiors, favouring shade-intolerant plants over typical mesic forest plants. Fragmentation has the greatest impact on relatively rare, forest interior, and understorey bird species and can result in an increased influence of generalist predators, competitors or brood parasites (Newmark, 1991; Thiollay, 1992).

In a study of a forest subject to human disturbance, Kruger and Lawes (1997) found generalist species at the forest edge and forest dependent species in the interior. Ozanne *et al.* (1997) conducted a study to determine the influence of edge effects on forest canopy invertebrates. They found that overall abundance dropped significantly near the edge. Species richness was also lower at the edge. The trophic structure of the arthropod community differed at the edge, which supported proportionately more generalist predators and fewer specialist predators than the core.

2.1.1.e)Changed ecological relations

Fragmentation not only alters species composition, but also the fundamental ecological processes that shape and govern ecological communities. The boreal forests in the northern hemisphere provide examples of the types of changes in processes that can occur. Competition for limited forest resources such as dead wood and nesting cavities can be critical to the maintenance of forest biodiversity. Unlike old-growth forests, cleared landscapes, silvicultural clear-cuts, second-growth forests, and conifer plantations do not contain large amounts of dead wood. This results in an increase in the abundance of aggressive cavity competitors (Fiedler and Subodh, 1992). Fragmented forests have increased levels of nest predation in and around forest openings and near forest edge (Fiedler and Subodh, 1992; Meffe and Carroll, 1994). The edge functions as an "ecological trap" as it attracts breeding organisms to nest near the edge where predation rates are highest. The proportion of bird nests parasitized is also strongly correlated with proximity to edges between forests and clearings (Fiedler and Subodh, 1992). Decomposition rates are suspected to be affected by forest fragments, with intact forests having higher decomposition rates than smaller forest islands. This may be due to a decrease in species composition and abundance of scavenging and dung-rolling beetles (Fiedler and Subodh, 1992).

2.1.2 Invasion of exotics

The development of plantation forestry in South Africa has involved the introduction of plant species from other continents. Many of these species have adapted well to their new environments here, and spread and grow unaided in landscapes adjoining the plantation. Fragmentation increases the rate of exotic species invasion, often through creation of disturbed habitats through which exotics travel rapidly (Meffe and Carroll, 1994). Important invasive species are pines (cluster, patula, radiata and slash pine), many wattle species and a variety of shrubs (e.g. *Chromolaena odorata, Lantana camara, Solanum mauritianum, and Rubus cuneifolius*). These invasive plants affect water resources and reduce natural biological diversity. Invasions result in losses of indigenous species, changes in community structure and function, and even alteration of the physical structure of the system (Drake *et al.*, 1989). Geldenhuys *et al.*, (1986) describe the impacts of alien invasion both on indigenous areas and on the plantations. The Working for Water Programme aims to eliminate and control these invasive plants.

2.1.3 Loss of biodiversity

The impact of plantations on the diversity of animals has not been well researched (Lawes *et al.*, 1997). Most research has focused on the avifauna (Armstrong et al., 1996), although some work has been done on mammals (Armstrong and van Hensbergen, 1996) and insects (Armstrong and van Hensbergen, 1997). Faunal assemblages in *Pinus spp.* plantations are depauperate in relation to those of the original habitat (Armstrong and van Hensbergen, 1995; Armstrong *et al.*, 1996). The pine bird assemblage consists largely of forest generalist species. Generalists may survive in small patches because they can also use resources in the surroundings. Nectarivorous species and hole-nesting forest insectivores are absent from pine plantations. Small mammal occurrence in pine habitat is dependent on the presence of sufficient indigenous undergrowth (Armstrong and van Hensbergen, 1995). Plant species richness is usually depressed and species composition changed within plantations. The effect tends to be strongest under dense canopies on acid sites (Lawes *et al.*, 1998). The impact of plantations on plant species diversity depends to a large extent on the amount, configuration, and management of the unplanted areas of an estate (Lawes *et al.*, 1998). Recovery of plant and animal assemblages after clear-felling may take many years (Armstrong and van Hensbergen, 1995).

2.1.4 *Regeneration*

Plantation stands have both positive and negative impacts on the regeneration process. Lübbe and Geldenhuys (1991) and Geldenhuys (1997) suggest that manipulation of commercial plantation stands may promote the natural succession process in a way that facilitates (1) the restoration of native forest biodiversity, (2) the control of understorey weeds in plantations, and (3) the growing of useful crops under tree canopies. Stands of plantation and invader trees can facilitate the establishment of a wide range of shade-tolerant species in their understoreys and contribute to expansion of the local distribution of these species (Geldenhuys, 1993). However, clear-felling negates this positive effect. Plantation stands also act as barriers to the dispersal of plant seeds across the landscape.

2.1.5 *Interference with natural disturbance regime*

Disturbance regimes are important to the extent that they influence probabilities of extinction and colonization, and thereby the patterns of biodiversity in the landscape. Disturbances create openings or "gaps" which most forest trees require for successful establishment and maturation. The presence of a species may be determined by presence of the right kind of gap providing the right kind of regeneration niche (Geldenhuys, 1989). Changes in the intensity, frequency or pattern of the disturbance regime may therefore affect biodiversity. Total diversity of indigenous species at the landscape level will be greatest when disturbance occurs at its historical frequency and in its historical pattern. Changes in the frequency, as well as the type of disturbance will mean that most native species will no longer be well adapted for recruitment or establishment (Hobbs and Huenneke, 1992). Fire suppression and control results in a change in successional dynamics of forests. In order to maintain biodiversity, it is important to retain both later successional stages and a mix of all successional types within a landscape, not to retain ecosystems as static and unchanging (Meffe and Carroll, 1994).

2.2 Impacts on specific habitats

Habitats most severely affected by afforestation include wetlands, grassland, fynbos and indigenous forests:

2.2.1 Wetlands

The exotic species of trees grown in plantations use large amounts of water and therefore plantations that are situated too close to wetlands and perennial streams, or in their catchments cause wetlands to dry up. This results in a loss of the ecological functioning of the wetlands such as water purification and water storage, and impacts on the flora and fauna that utilize wetlands. Birds such as the endangered wattled crane are dependent on wetlands for breeding.

2.2.2 Grasslands

The South African grassland biome has relatively many endemic species of birds, butterflies, grasshoppers and plants (Brown, 1962; Siegfried, 1992; Pringle *et al.*, 1994; Low and Rebello, 1996). Rare plants are often found in grasslands, especially in the escarpment area. These rare species are often endangered, comprising mainly endemic geophytes or dicotyledonous herbaceous plants. Grasslands also support a variety of animals, including threatened species such as oribis (*Ourebia ourebia*), Stanley bustards (*Neotis denhami*)and blue swallows (*Hirundo atrocaerulea*). The grassland biome also has an extremely high biodiversity, second only to the fynbos biome (Low & Rebello, 1996). Grassland has been largely transformed by human activity, and only 2% is in nature reserves (Siegfried, 1989). The species diversity of grassland birds and grasshoppers declines in afforested areas (Samways and Moore, 1991: Allan *et al.*, 1995). About 2.7% of the grassland biome is planted to commercial trees, but this area is increasing yearly and the impacts on biodiversity should therefore be considered (DWAF, 1995).

2.2.3 Fynbos

Fynbos contains many endemic species and is a “hotspot” in terms of biodiversity conservation. This invasion of alien trees from plantations into this unique habitat of the western Cape threatens the survival of these vulnerable endemic species.

2.2.4 *Indigenous forests*

Climate and fire have confined natural closed forests to a relatively small area which has been further reduced by human activities to about 400 000 ha (Fuggle, 1992). This is only about 0.2% of the country's land surface, making forest the smallest biome on the sub-continent. Of this, 300 000 ha occurs in protected areas. Geldenhuys and MacDevette (In: Huntley, 1989) estimate a total forest biome flora of 1285 species. This is about 5% of southern Africa's plant species in an area occupying less than 1% of the subcontinent. Very little is known regarding the maintenance of diversity in southern African forests. Geldenhuys and MacDevette (In: Huntley, 1989) generalize with reservation that undisturbed forest is richer than disturbed forest and that mature forest is richer than regrowth or seral forest.

When plantations next to indigenous forests are logged, trees may fall onto the forest margin and damage it. Once damaged, the forest margin can no longer protect the indigenous forest from fire. The forest margin is an important food source for many forest animals e.g. bushbucks (*Tragelaphus scriptus*)shelter in the forest, but feed mainly on the smaller plants in the forest margin. In addition, logging can destroy the diverse forest/grassland ecotone. It has been argued that disturbance on the forest margin could increase species diversity and habitat for ecotonal species, but this is usually due to an increase only in generalist species (Newmark, 1991; Thiollay, 1992; Kruger and Lawes, 1997).

2.2.5 *River catchments*

Trees use large amounts of water. Afforestation in water catchments thus reduces runoff and water availability for other uses.

2.3 Impacts of plantation forestry practices on biodiversity

The objective of intensive forest management is to maximize wood production with a consequent loss of habitat complexity. Large dead wood (i.e., trees, snags, logs) are absent, as are multiple canopy layers and tree species mixtures. Reserved areas are fragmented and isolated, and landscapes are simplified because of regular cutting patterns and the absence of old growth. Intensive forest management focuses on the least diverse middle, closed-canopy stage, aiming for rapid site capture by trees, then cutting down the forest before it enters the old-growth stage.

The clear-cutting approach imposes a landscape pattern that is totally different from the natural temperate deciduous and moist tropical forests which are gap-driven. Some of the potential impacts of forestry practices on biodiversity are listed in Table 1.

Table 1: Impacts of forestry practices on biodiversity

Forestry practices	**Impacts on biodiversity**
Planting	Plantation of monoculture and introduced tree species - uniformity, loss of biodiversity, invasion of aliens
Clear felling	Removal of dead/decaying wood - loss of dependent plant and animal species and loss of biodiversity
Draining	Lowering of water table - loss of wet forests and wetlands high in biodiversity
Weeding, cleaning, thinning	Removal of understorey, an important habitat for many animal species - loss of biodiversity
Pesticides and fertilizer application	Release of chemical pesticides - poisoning of non-target species Fertilizer applications - changes in plant communities
Heavy machinery use	Increased frequency of vehicle use - disturbance of wildlife

The Rio Convention proposes that at a national scale at least 10% of each vegetation type be set aside for pristine or near-pristine use. Biodiversity is protected to a certain degree by the setting aside of un-afforested land and demarcation of conservation areas within the estates. Only 70% of estates may be planted. This requirement has created 600 000 ha of unplanted land which has been set aside for the preservation of the environment.

2.4 South African policies relevant to biodiversity and sustainable forest management

South Africa is a signatory to the Convention on Biological Diversity and the Framework Convention on Climate Change. In addition, South Africa is a signatory to the Rome Statement on Forestry (March 1995) which aims to attain the objectives arising from UNCED in the shortest time possible, while pursuing a balanced approach between the environmental and the developmental functions of forests.

The following are national policies that are relevant to biodiversity conservation and sustainable forestry in South Africa:

- The White Paper on Sustainable Forest Development in South Africa (1996) and the National Forest Act (1998) commit the government to counter adverse affects of industrial forestry on water resources and biodiversity.
- The White Paper on Environmental Management Policy for South Africa (1997) and the National Environmental Management Act (1998) focus on people and their participation in environmental decision-making. The policy of integrated environmental management provides for a coherent set of planning and decision procedures where development is intended.
- Regulations in terms of the Environmental Conservation Act (1997) provide for environmental impact assessments where land-use change will involve a conversion from natural habitat to a new cover type. Introduction of new plant or animal species from elsewhere will also require environmental impact assessment.
- The White Paper on the Conservation and Sustainable Use of Biological Diversity (1997) identifies as a national priority the necessity to utilize biological resources sustainably and maintain diversity to serve the national interest. This embraces the necessity to restore degraded ecosystems, to control the spread of alien organisms and to integrate biodiversity considerations into land-use planning procedures and environmental assessments.

2.5 Conclusion

Afforestation replaces areas of indigenous grassland and occasionally forest. Many of the original species are displaced due to loss of habitat. Plantations do provide habitat for new species suited to arboreal habitats, but biodiversity in plantations is still lower than otherwise. Specialist species are threatened as they cannot adapt to this new habitat. Commercial forestry results in habitat fragmentation and thus impacts on the processes that regulate biodiversity such as natural disturbance regimes, dispersal/migration, reproduction, regeneration/succession, trophic dynamics and local extinction. Threats to biodiversity have been recognized, and international and national policies have been formulated in an attempt to promote sustainable utilization of biodiversity. This has resulted in much discussion regarding various approaches to measure and manage biodiversity sustainably. According to Wynberg (1998), implementation of the 1997 White Paper on Biodiversity is slow and caught up in bureaucratic procedures. Furthermore, the majority of South Africans still perceive government approaches to biodiversity to be antagonistic to their needs and to serve the interests of the privileged few. Due to the fact that impacts of plantation forestry on biodiversity in South Africa is not well measured, C&Is should be chosen from the viewpoint of potential impacts and not perceived impacts.

CHAPTER THREE:
FRAMEWORK AND ROLE OF CRITERIA AND INDICATORS IN SUSTAINABLE PLANTATION MANAGEMENT

CRITERIA AND INDICATOR FRAMEWORK

3.1 Definition of hierarchical framework

The hierarchy concept provides a useful framework for the formulation and implementation of C&I's. Van Bueren and Blom (1997) suggest the following definition of a hierarchical framework: "A hierarchical framework describes hierarchical levels (P, C & I) to facilitate the formulation of a set of parameters in a consistent and coherent way. It describes the function of each level as well as the common characteristics of the parameters appearing on a particular level." The framework helps to break down the goal of SFM into parameters that can be measured or assessed i.e. principles, criteria, indicators, and verifiers (Lammerts van Bueren & Blom, 1997).

Principles

The level of principles breaks down the goal into more specific components. A principle should be formulated as an implicit or explicit element in achieving the goal of SFM and should refer to a function of the forest ecosystem.

Criteria

Criteria are the parameters appearing on the first level below the level of principles. Criteria translate the principles into states, or dynamics of the ecosystem. They are easier to assess, or at least to link indicators to, than the abstract non-measurable principles. Criteria describe the desired state of the ecosystem.

Indicators

The level of indicators adds measurable elements. Indicators determine the conditions and requirements that should be met by forest management and their choice is therefore of crucial significance for the level of management quality that should be achieved.

Quantitative and Qualitative Indicators

Indicators can either be quantitative or qualitative. A quantitative indicator is expressed and assessed in terms of amount, numbers, volumes, percentages, etc. A qualitative indicator is expressed as a situation, object, or process, and is assessed in terms of whether it is satisfactory or not. Quantitative indicators are preferable because the qualitative indicators are often more ambiguous. However, for several criteria for SFM it is not yet possible to use quantitative indicators because the limited scientific knowledge is insufficient to establish quantitative norms. Quantitative indicators are meaningless without a reference value. Assessment of the quality of the forest ecosystem relies to a certain extent on best professional judgement. Therefore, both quantitative as well as qualitative indicators have to be used for the assessment of sustainability of forest management.

Pressure, state and response indicators

Pressure indicators measure the pressures that are exerted on resources and ecosystems. State indicators assess the state or condition of the resource or ecosystem as a result of the pressures. Response indicators are those in which a cause-and-effect relationship can be demonstrated between management actions and indicator response. Pressure indicators are easier to develop than state or response indicators, but provide much less valuable information. Response indicators are potentially the most valuable indicators, but are also the most difficult to develop and apply (Stork *et al.*, 1997). Figure 1 depicts the relationship between pressure and state and response indicators.

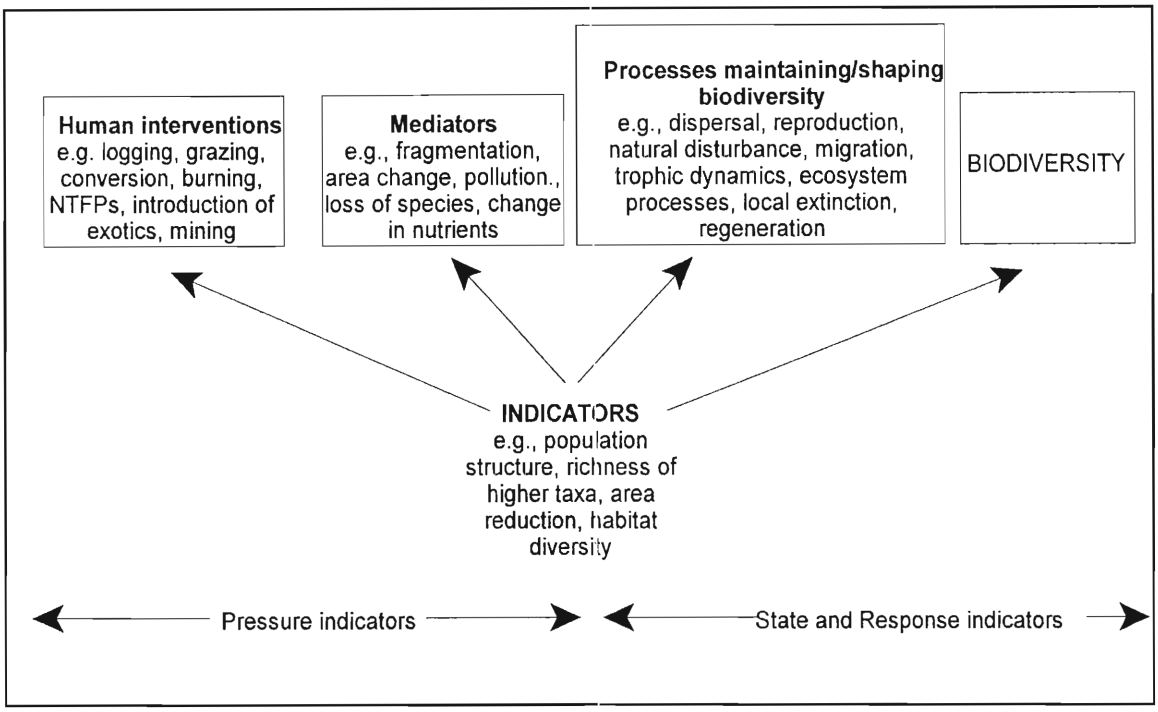


Figure 1: A conceptual model of the relationships between anthropogenic interventions under different forest management regimes, mediating processes, ecological processes which shape biodiversity, and biodiversity.
Source: Stork *et al.*, 1997

Verifiers

Verifiers describe the way indicators are measured in the field. They provide the source of information for the indicators and relate to the measurable elements of the indicators. The verification procedure clarifies the way that indicators are measured in the field and the way reference values are established.

Threshold values/tolerance levels/norms

Indicators need to be interpreted in the context of sustainable development in order to be meaningful. Measuring verifiers against a threshold provides a reference value for assessment of significance of a certain level of environmental quality or impact. The point where biodiversity is irreversibly harmed and development is no longer sustainable is known as the threshold limit. However, the processes which generate and maintain biodiversity are very complex and dynamic, and knowledge of the stress to which ecosystems can be subjected is limited. The complexity of the ecosystems and relatively limited scientific knowledge makes it therefore very difficult to determine thresholds. Formulation of threshold values must adhere to the precautionary principle in an adaptive management system. Knowledge available now should be used as extensively as possible and thresholds and target values should be set conservatively. Norms should be developed and adjusted as new scientific information and experiences become available (cf adaptive management). Assessment of forest ecosystem quality will rely to a certain extent on best professional judgement. Bayesian inference can be used to assist managers in estimating thresholds and/ or targets.

Bayesian inference

Bayesian inference is a statistical approach whereby all inferences about the parameters are made conditionally upon observed data. It can be used to estimate ecologically meaningful parameters and provides an explicit expression of the amount of uncertainty in these parameter estimates. It leads to testable predictions. Bayes theorem is used in decision analysis to estimate the consequences of a decision based on uncertainty and events. Predictions are modified when new data becomes available. Thus, Bayesian inference and decision theory provide a "quantitative framework and intelligible language in which to analyze and express adaptive management procedures" (Ellison, 1996).

Advantages of Bayesian statistics:

- Better use pre-existing data
- Stronger conclusions from large-scale experiments with few replicates
- Provides a framework for environmental management decisions
- Understandable by decision-makers when presented in clear language
- It is easier to compute than frequentist statistics
- Can assess relative probabilities of multiple hypotheses
- Easy to combine data from several studies

Disadvantages of Bayesian statistics:

- Complex, requires advanced statistical knowledge
- Many assumptions
- Assumptions are difficult to check
- Trades increased bias for reduced variance

Bayesian inference quantifies pre-existing beliefs which are continually updated in reaction to new data. This process fits in well with that of adaptive management. The major advantage of Bayesian inference is that provides testable predictions in conditions of uncertainty and lack of data.

3.2 Value of a hierarchical framework

The potential value of a hierarchical framework is that it among others:

- increases the chance of complete coverage of all the important aspects to be monitored or assessed;
- avoids redundancy; it limits the set of P,C&I to a minimum without superfluous parameters;
- shows a clear relationship between the parameter that is measured and compliance to the principle to which it refers. (Van Bueren and Blom, 1997).

3.3 Horizontal and vertical consistency

There is often inconsistency in use of terms, confusion of hierarchical levels, and inadequate formulation of parameters (P, C & I's). These irregularities are caused by insufficient clarification and understanding. Definitions of P ,C & I's are lacking or are too general. They may be too vague to give enough guidance for SFM. Inconsistency and a lack of coherence may result in insufficient coverage of the various aspects of SFM, overlap and redundancy of parameters and inadequate transparency. This results in confusion in the practical application of P, C & I's.

The hierarchy should be both horizontally and vertically consistent. A standard is horizontally consistent if parameters at one level do not have any overlap or duplication, while still covering all aspects of SFM. Vertical consistency refers to the relationship between parameters at adjacent levels. A standard is vertically consistent if the parameters are placed on the right hierarchical level, expressed in appropriate terms, and linked to appropriate parameters on the higher hierarchical level (Lammerts van Bueren & Blom, 1997). Figures 3 and 4 depict correctly and incorrectly formulated hierarchies respectively.

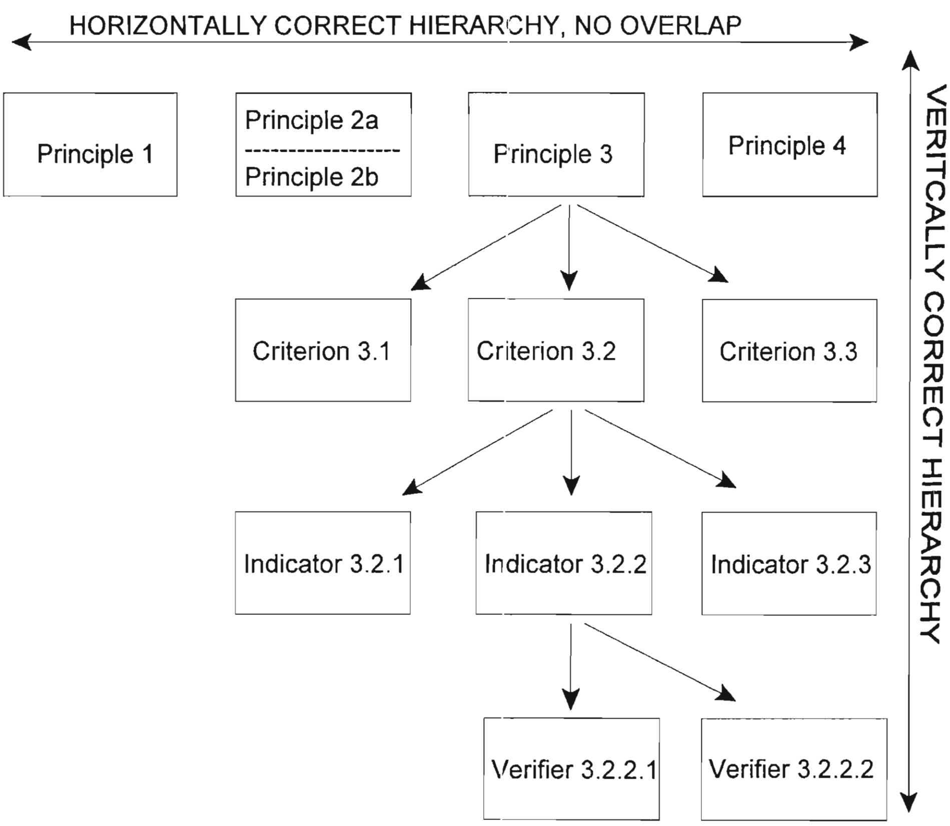
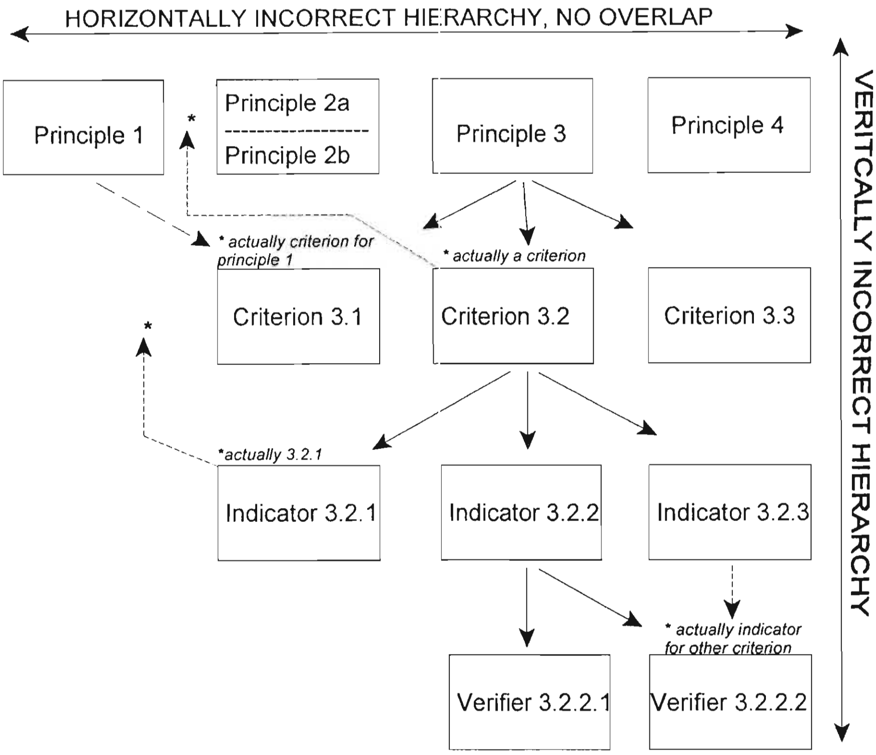


FIGURE 2: MODEL OF A HIERARCHICALLY CORRECT STANDARD FORTHE ELABORATION OF THE CONCEPT OF 'SUSTAINABLE FOREST MANAGEMENT', OR 'WELL-MANAGED FORESTS'
(Source: Lammerts von Bueren and Blom, 1997)



[*italic*] = how it should be

[roman] = as in hypothetical standard

FIGURE 3: HYPOTHETICAL EXAMPLE OF A HIERARCHICALLY INCORRECT STANDARD (Source: Lammerts van Bueren and Blom, 1997)

ROLE OF CRITERIA AND INDICATORS IN SUSTAINABLE PLANTATION MANAGEMENT

The public is becoming increasingly aware of commercial impacts on indigenous forests, notably asset-stripping of natural forests and loss of security of forest goods and services, especially biodiversity. There is also disillusionment with regulations, enforcement mechanisms and public subsidy as effective interventions. The Earth Summit, held in 1992, called for Sustainable Forest Management (SFM) by and for "civil society". It recognized the market as a way to deliver multiple forest goods and services, but noted that an evaluation of the market should include environmental and social costs. The NFAP states that sustainable resource use is best regulated by means of effects-based planning measures, as opposed to prescriptive measures. These planning processes are then supported by environmental management systems. The following sections discuss how C&I's can be applied within existing forestry environment management practices.

3.4 Guidelines for environmental management

Forestry companies in South Africa have voluntarily subscribed to best-practice guidelines for environmental management, the "Guidelines for environmental conservation management in commercial forests in South Africa" (Forestry Industry Environmental Committee, 1995). Forestry companies have developed self-assessment procedures to ensure application of the guidelines, incorporating them into their internal procedure manuals and instituting monitoring and evaluation procedures (Forestry White Paper, 1996). The guidelines advocate conducting environmental impact assessments, developing proper environmental management plans and undergoing regular environmental audits. They also provide recommendations for specific practices in silviculture, harvesting, road building, fire management, contract work as well as conservation.

Guidelines for specific actions may be established to complement standards. This is appropriate where a hierarchical framework is used to promote SFM and not specifically to assess the quality of forests and management. Guidelines should have a strong link to both criteria and indicators. Principles, criteria and indicators describe what should be accomplished and enables an assessment of whether this has been achieved. Guidelines indicate how one should implement the principles, criteria and indicators.

3.5 Standards and Environmental Management Systems (EMS)

C&I's do not promote explicit standards. Rather, C&I are based on standards relevant to the Environmental Management System (EMS) of the FMU in question within the national hierarchical framework. Standards are flexible and fit into a system of adaptive management. They are often incorporated into C&I's at the level of indicators. EMS standards should be complemented by C&I's to serve as an adequate tool for the assessment of the quality of forest and forest management. An EMS does not involve any assessment against external performance standards. The state of the ecosystem is not part of the assessment therefore it is uncertain to what degree EMS assessment can be indicative of the performance of the ecosystem.

Neither guidelines nor EMS are legally binding. Accreditation through statute and an independent authority with the resources to provide clear evaluation and certification of environmental management in forestry, could protect the interests of the forestry sector, as well as protecting the environment.

3.6 Labelling and certification

Labelling and certification programmes share two basic goals (Bass, 1996):

1. to improve the general standard of forest management, and/or market transition to sustainability; and
2. to generate market incentives for good forest management i.e. a price premium and/or market share for its products, by communicating good practice.

The African Timber Organization (ATO) has undertaken a 'Green Label Initiative'. The idea behind this was to offer the market a provenance certificate. Problems with eco-labelling include fraudulent claims, lack of regulation, and vagueness (Lathrop and Centner, 1998). These difficulties with public regulatory systems led to the development of private certification initiatives.

Certification demonstrates that a duly-identified product or service conforms to a specific standard. Certification is one of a number of means for the development of the international timber trade based on sustainable sources; it is an information-based instrument of trade and environmental policies which could, as a complementary instrument, make forest products trade contribute to the achievement of SFM (Bass, 1996).

Various certification schemes and programmes have been created at the international, national, state, and local levels, and by public and private sector organizations. They vary in scope and approach, and they use different principles and standards for evaluating the sustainability of forest management. Two types of standards appear in these approaches. Firstly, performance standards against which forest management is evaluated (Figure 4) and secondly, procedural standards, such as those used for the environmental management systems and developed by the International Standardization Organization (ISO).

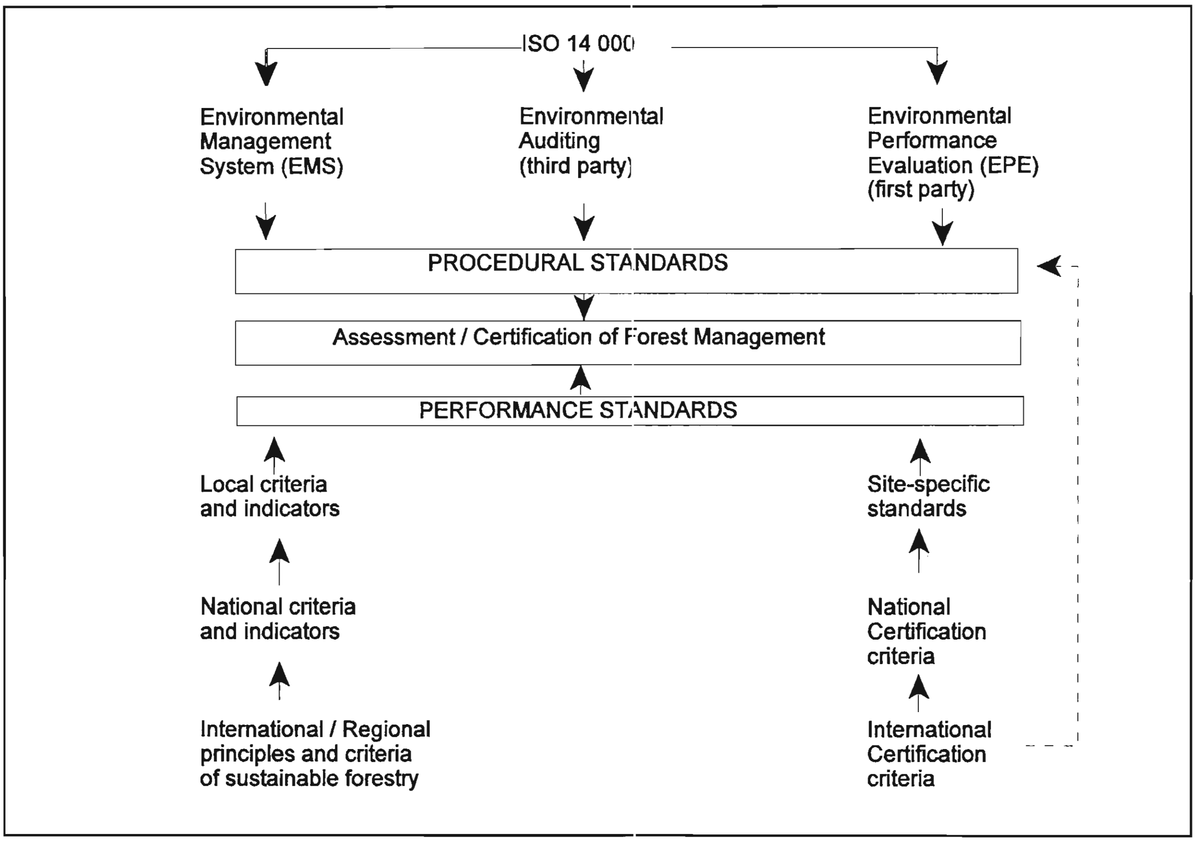


Figure 4: Procedural and Performance Standards in Certification of Forest Management.
Source: Baharuddin, H.G. and Simula, M. 1996.

Criteria and Indicators and Certification

It is difficult to distinguish between C&I's and certification as both address sustainable forest management, its characteristics and indicative measurements. There are many non-governmental and governmental initiatives to develop approaches and methods for measuring and evaluating forest management at the FMU level. Some of these seek to certify that the management of forests, is or will be, sustainable based on a predetermined set of standards. In these efforts, the terms "principles and criteria", "criteria and indicators", or "indicators" and/or "standards of performance" are used. This may result in confusion of concepts, terminology and processes.

C&I's for SFM are an instrument for describing and evaluating progress towards SFM. They assess changes and show trends over time in state or condition of forests and forest management. C&I's do not determine performance standards and/or acceptable levels for SFM. Certification, on the other hand, is designed to assess forest management practices / systems against the specific performance standards. Certification is currently applied only at the management unit level.

There is no internationally agreed framework which would ensure that the certification standards in use, or under development, would be in harmony with the C&I's for SFM approved in the various processes or their national level applications. However, there are similarities, to a great extent, in the concepts contained in both. It depends on the structure of the C&I's and the system of certification whether they both serve the process of achieving SFM. As they are both instruments, certification and C&I's are involved, although in a different way, with the enhancement of SFM. Both describe the elements that constitute SFM.

C&I's can only be linked to certification when specific performance standards, limits or thresholds are established for indicators. Development of sub-national C&I's, however, does not necessarily have to lead to certification: they can be used, for example, for strategic planning of the specific region. It should be noted that the "FMU" level has different meanings in different countries and regions in accordance with the overall situation of forests (e.g. homogeneity of ecological conditions), the ownership structure of forests, their management and the overall forestry administration in the concerned country. Certification should be based on forest management standards that are in accordance with internationally accepted principles and criteria, as well as with locally developed forest management standards. The International Standards Organization is enhancing the ISO 14000 standard for environmental management to incorporate provisions for forest management and forest products.

ISO14000

ISO 14001 is a new (late 1996) standard for Environmental Management Systems. It was based upon the ISO 9000 family of specifications. The key aspects of ISO14000 are that it is:

- voluntary;
- flexible and non-prescriptive;
- can use existing environmental programs and systems;
- pushes continual improvement;

- encourages cost saving by integrating environmental requirements;
- into the overall company systems (design, manufacturing, etc.); and
- can provide a substantial market advantage.

ISO 14001 requires the organization's top management to define an "Environmental Policy". The policy must include a commitment to both compliance with environmental laws and company policies, continual improvement and prevention of pollution. An Environmental Management System (EMS) must then be implemented in accordance with defined recognized standards. Specific measurable environmental goals, objectives and targets should be set based on the environmental policy and environmental impacts analysis. Specific programmes must then be developed to achieve these. EMS do not set specific requirements for environmental compliance nor do these standards establish requirements for specific levels of pollution prevention or performance. ISO 14000 combines both public regulatory and private certification approaches to eco-labeling. ISO 14020 sets out the general principles and goals for environmental labeling (Lathrop and Centner, 1998).

SAPPI has adopted ISO 14001 as its method of certification. SAPPI has developed an environmental policy and an EMS and undergoes external audits by a lead auditor and audit team. However, although one of the environmental goals is to conserve biodiversity, there are is no clear strategy or tools to measure progress towards attainment of this goal. Criteria and indicators can be used as a tool within ISO 14001 to enable organizations to monitor their environmental performance.

Forest Stewardship Council

The Forest Stewardship Council (FSC) is an international body which accredits certification organizations in order to guarantee the authenticity of their claims. The process of certification is initiated voluntarily by forest owners and managers. The FSC has established a worldwide standard of recognized and respected Principles of Forest Stewardship. These Principles and Criteria (P&C) apply to all tropical, temperate and boreal forests. More detailed standards may be prepared at national and local levels. The P&C are to be incorporated into the evaluation systems and standards of all certification organizations seeking accreditation by FSC.

MONDI has achieved certification by FSC and thus implements the FSC principles and criteria in the environmental management of its forest management units. However, these P&C's are developed at an international level and further C&I's need to be prepared for management at the FMU level. These C&I's will serve as tools to indicate progress towards biodiversity conservation and sustainable plantation management.

Challenges facing certification

Certain countries will not be able to meet performance standards as set by FSC due to factors such as weak policies, institutions, skills or traditional land management systems which do not lend themselves to assessment by certification systems. Quality of forest management can be addressed using three strategies, each mutually enforcing. The first two are: improving policy and law, and improving management systems. The third strategy of verification of the first two strategies and of performance, may only be financially justifiable in certain circumstances (Bass, 1997).

Comparison between ISO 14000, FSC and C&I's

While the FSC, C&I's and ISO 14000 all aim to improve environmental performance, they are very different in structure and operation. The former emphasizes forest performance standards while ISO 14000 provides management system standards. Other systems based on the management system approach are the Canadian Standards Association approach (designed for forestry) and the European Commission's Eco-Management Auditing System (EMAS) originally designed for industrial plants (Bass, 1997). Table 2 provides a summary comparison of FSC, ISO and C&I.

Table 2: Summary comparisons of FSC, ISO and C&I

(Source: Lawes (unpubl.), Bass, 1997, Lammerts van Bueren and Blom, 1997)

Issue	FSC	ISO 14001	C&I
Main protagonists	Environmental and some social NGOs; Buyers groups	Industry, especially large producers; Governments; WTO	Originally environmental NGOs; Governments; Some industry
Inherent values	"Value-laden"; Sustainable development-both environmental and social; Equity of application; Aspirations; no "lead-in"	"Value-neutral"; Modernist; EMS tool is enterprise-focused; Continuous improvement	"Value-laden" principles and criteria; Sustainable development paradigm; operates within EMS.
Purpose	Define good forest stewardship and accredit certifiers; 3rd party certification essential; Labels and chain of custody can be provided to market	Specify elements of management system to improve performance, 3rd party certification optional; certification permits general publicity, but no labels	Measure progress toward SFM at FMU level and state of the industry. Adaptive management tool. Reduce interpretations of exiting standards; National guidelines-accountability through hierarchical framework. No labels or publicity.
Standards	Performance standards based on global principles and criteria, encouraging compatible national standards; normative	Management system standard; No performance standards specified-but information document suggests options	No explicit standards; based on FMU-EMS relevant standards, but within national hierarchical framework. Flexible-adaptive management.
Governance	NGO; NGO/private members. Equal economic, social, environmental chambers with North/South balance	NGOs; Members are national standards bodies	NGOs/Gov?/private; International process adapted by National body-DWAF prescribed; Industry members subscribe to process, but mainly NGO motivated.
Accreditation	An international accreditation body itself	National accreditation bodies	No accreditation

SFM compatibility	Stresses high environmental and social performance-challenges the manager	Stresses management capacity and continuous improvement. Enterprise chooses performance standards; Socially difficult to integrate.	Stresses adaptive management; flexibility promotes continual improvement. Challenges manager. Environmental, production, and social criteria addressed.
Credibility with stakeholders	High with NGOs/buyers. Lower with some governments. Mandate problems; Risk of "monopoly"	High with intergovernmental bodies and industry; Low with NGOs/others; Narrow participation; No chain-of - custody reduces market potential.	High with NGOs and government bodies. Low with industry-seen as part of current EMS. Limited market potential.
Trade distortions	Standards may be considered too high; Social standards may be considered unwarranted	TBT recognizes ISO; ISO standards not considered unnecessary trade restrictions	No adverse effects-but can be used to verify achievement of standards and promote products

3.7 Management framework for implementing C&I's

Adaptive management

Adaptive management can be defined as "an approach used to guide ecological intervention in the face of uncertainty about the system" (Shea, 1998). It is a formal process for continually improving (resource) management policies and practices by learning from the outcomes of operational programmes. Thomas (1996) defines adaptive management as "a heuristic process coupling science and social values to promote the sustainable management of natural systems".

Ecosystems are very complex. Resource managers must often make decisions with incomplete information and an uncertainty of how ecosystems work (Haney and Power, 1996). They rely on two sources for guidance: personal experience gained through trial and error, and research results from scientific studies. These sources of knowledge are often insufficient when new objectives or field conditions arise. In such circumstances, managers must go beyond their base of reliable knowledge to decide what the best policies or practices may be. Scientific research may take a few years or may not be possible due to restricted budgets or other limitations. Therefore, managers are faced with the usually unacceptable option of no action or they must proceed by trial and error. Adaptive management enables forest managers to learn rapidly from the results of operational policies and practices as they are being implemented, and thus to keep pace with the rapidly changing demands of industrial and public clients. Despite published successes of adaptive management in other fields, it has seldom been applied rigorously to forestry issues.

Adaptive management requires:

- acknowledgment of uncertainty about what policy or practice is "best" for the particular management issue;
- thoughtful selection of the policies or practices to be applied;
- careful implementation of the plan of action;
- monitoring of key response indicators;
- analysis of the outcome considering the original objectives; and
- incorporation of the results into future decisions (Nyberg and Taylor, 1995).

Situations where adaptive management would be beneficial include harvesting techniques and silvicultural systems that provide alternatives to clear-cutting, methods for protecting riparian habitats and streams, landscape and stand-scale practices for maintaining biological diversity and sensitive wildlife values and watershed restoration techniques (Nyberg and Taylor, 1995). Adaptive management is especially important in circumstances where demands for change do not allow for intensive, process-level research, before starting widespread implementation of new approaches. This is especially true for implementation of C&I's for biodiversity conservation as threats of species extinctions do not allow time for extensive scientific research.

Challenges to implementation of adaptive management

There are numerous challenges to implementation of the adaptive management philosophy as a management strategy. Firstly, managers must be prepared to acknowledge publicly that they are uncertain about the results of some of their actions. Allowance must be made for results that critics may subsequently call "mistakes". Some of the options in any set being tested will unavoidably prove less successful than others, but these "mistakes" are essential to learning. Secondly, adaptive management requires more careful planning, implementation, and documentation than is often required for routine operations and therefore more staff and money will be required to implement it widely. The attention and funding required for effective monitoring programs, field layout, data storage, and data analysis are often in short supply. These extra costs may, however, be much lower than would be incurred in conducting scientific research on the same area. Also, the expected value of the new knowledge derived will often outweigh the costs (Nyberg and Taylor, 1995).

Education and training of managers and stakeholders both within and outside government will be needed for adaptive management to succeed. Partnerships between government, industry, and other interests must be formed. Scientific research will continue to be required to complement adaptive management, and will be particularly important for elucidating some of the functional aspects of forest ecosystems that may not be revealed by less intensive techniques.

3.8 Conclusion

Ecological systems are highly complex and the knowledge base challenged by high degree of uncertainty. Scientific research has not been able to provide decision-makers with predictive tools by which to measure impacts of afforestation on biodiversity. C&I's are an adaptive management tool which can be used to assess progress towards the goal of sustainable development. Bayesian inference is a statistical approach which is highly applicable in circumstances of uncertainty and lack of data. There are no explicit universal standards as these are formulated at the FMU level within the applicable Environmental Management System to ensure local relevance. C&I's at the FMU-level fall within the national hierarchical framework. They are flexible and encourage monitoring to ensure continual improvement. At present, C&I's initiatives are voluntary and there is no accreditation process. The agreement at a recent Forest Owners Association (FOA) environmental committee meeting that C&Is should be developed and used by the commercial forestry industry indicates that the industry is beginning to acknowledge the important role of C&Is for promoting and implementing sustainable forest management (Burden, pers. comm.) There is a reluctance on the part of industry to become involved in C&I's. Industry believes that C&I's are part of existing environmental management systems (EMS). However, one of the problems of implementing C&I's within a procedural framework such as ISO 14 000, is that while there is independent auditing of the system, there is no requirement for or enforcement of indicators which show progress towards the achievement of goals formulated in the EMS. Systems that audit performance indicators such as FSC ensure that biodiversity conservation is not merely an ideal, but that steps are being taken to approach this goal. DWAF is currently adapting the international initiatives to derive a prescribed set for national application. If C&I's are to be incorporated in a certification system, then efforts should be made to include all relevant stakeholders in the process. The C&I's for local application should be developed by the forest managers in conjunction with certification bodies to ensure local relevance, participation and accountability.

CHAPTER FOUR: CRITERIA AND INDICATORS FORMULATED THROUGH INTERNATIONAL INITIATIVES

International C&I initiatives were examined to determine which indicators could be applied to management and conservation of biodiversity at an FMU level. Since UNCED, there have been three major international initiatives conducted on a governmental level towards the formulation of criteria and indicators to assess the sustainability of forest management at the national level: the Montreal Process, the Helsinki Process and the Tarapoto Proposals. Several NGOs have also begun initiatives to define SFM. The FSC has formulated principles and criteria applicable to tropical, boreal and temperate forests for the purpose of timber certification at the forest level.

4.1 International C&I Initiatives

4.1.1 International Tropical Timber Organization (ITTO)

The International Tropical Timber Organization (ITTO) has a Year 2000 Objective which specifies that, by the year 2000, all tropical timber for export should be produced from sustainably managed forests. In 1992, ITTO published C&I's for the measurement of sustainable tropical forest management. Five criteria and 27 example indicators were prepared for use at the national level, and six criteria and 23 example indicators for use at the forest management unit level. All the indicators do not need to be measured to demonstrate SFM or the degree to which it has been achieved. This approach differs from other initiatives such as the Helsinki and Montreal processes which emphasise C&I's as a fully integrated and inseparable package. The ITTO Guidelines and Criteria, in common with C&I's in other initiatives, are not legally binding. Field testing of C&I's and their further development are the next essential steps that are or will soon be undertaken.

4.1.2 United Nations Conference on Environment and Development (UNCED)

Five documents produced at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992 are relevant to South African forestry. These are:

- the Forestry Principles, a non-legally binding authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests;
- the Convention on Biological Diversity, the objectives of which are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources:
- Agenda 21, a document presenting detailed work plans for sustainable development including goals, responsibilities and estimates for funding;
- the Rio Declaration, a statement of broad principles to guide national conduct on environmental protection and development; and
- the Framework Convention in Climate Change, which does not impact directly on forest policy, but which influences the forest sector as forests are recognized for their role in mitigating industrial carbon emissions.

4.1.3 Intergovernmental Panel on Forests (IPF)

After UNCED, the UN Commission on Sustainable Development established the Intergovernmental Panel on Forests (IPF) which first met in September 1995. Its purpose was to develop proposals to support the management, conservation and sustainable development of all kinds of forests consistent with the UNCED Statement of Forest Principles. Some of the main issues which were to be addressed are as follows:

- implementation of UNCED decisions related to forests at national and international levels;
- scientific research, forest assessment and development of criteria and indicators for sustainable forest management.

The IPF was dissolved in 1997 and the Intergovernmental Forum on Forests was formed. These international conventions and norms do not necessarily apply without change to the forest sector in South Africa. For example, many elements in the UNCED agreements relate to the conservation of moist tropical forests. Consequently, care will be needed in applying these norms to the development of policies in this country, while fully recognizing global obligations.

4.1.4 Helsinki process

The Helsinki Conference in 1993 advanced the "Forest Principles" of the UNCED with the aim of implementing them at regional and national levels. The follow-up led to the formulation of the pan-European criteria and indicators for sustainable forest management. This follow-up is referred to as the Helsinki Process. The six criteria and 27 quantitative indicators were adopted in 1994. Field testing in 1994-95 revealed that research needs are greatest in measuring biodiversity. In the 1996 Expert Level Meeting, the development of pan-European C&I's for SFM at sub-national and/or FMU levels, including an option to develop a set of general field level criteria applicable at a sub-national level, was discussed.

4.1.5 Montreal Process

The Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests, i.e. the Montreal Process was established in 1994. The sixth meeting of the Montreal Process in Santiago, February 1995, concluded with the Santiago Declaration in which 6+1 criteria and 67 indicators were endorsed as guidelines for use at the national level. The Montreal Process C&I's reflect the approach of managing the forests as ecosystems.

4.1.6 Tarapoto Proposal

The countries of the Amazon Co-operation Treaty (ACT) developed C&I's for the global, national and FMU levels after a workshop in Tarapoto, Peru in 1995. The outcome of the workshop was the adoption of 12 criteria and 77 indicators which are grouped into three categories: national level, management unit level and services at global level.

4.1.7 FAO/UNEP regional activities

The FAO/ITTO Expert Consultation on Harmonization on Criteria and Indicators for Sustainable Forest Management, which was held in Rome, February 1995, noted that arid and semi-arid areas of Africa and the Near East had not received attention under the international initiatives related to the identification of C&I's. FAO and UNEP jointly organised an Expert Meeting to discuss C&I's at the national level for Sub-Saharan, dry-zone African countries in Nairobi, Kenya in November, 1995. This meeting resulted in the development of 7 criteria and 47 indicators useful for assessment of forest resources at a national level.

FAO/UNEP undertook to hold Expert Meetings for the Mediterranean climate in North Africa and Near East countries, and for Central America.

4.2 Comparison of frameworks of C&I initiatives

The sets of criteria in the Helsinki, Montreal and Dry-Zone Africa are almost identical except that policy issues in the form of legal, institutional and economic elements necessary for sustainable forest management are presented under a separate (seventh) criterion in the Montreal and Dry-Zone Africa processes. In the Helsinki set these elements are covered indirectly by the descriptive, i.e. non-measurable policy instrument indicators under the concept areas of each criterion.

The ITTO and Tarapoto Proposal differ structurally from the other three initiatives. They have developed criteria and indicators also at the forest management unit level. In the ITTO initiative, many of the issues that are covered by national level criteria and indicators in other initiatives are included in the FMU level indicators. In the Tarapoto proposal the categorisation of the indicators is different from the other processes, however many of the same issues can be found among the indicators.

According to the FAO's review of ongoing initiatives, the criteria in all the initiatives include the following elements:

1. Extent of forest resources
2. Biological diversity
3. Health and vitality
4. Productive functions
5. Protective and environmental functions
6. Developmental and social needs
7. Legal policy and institutional framework appears in all initiatives, although in a different form.

The ITTO has developed guidelines addressing the issue of biodiversity, rather than including this as a criterion.

Similarities between the indicators relevant to biodiversity:

1. Area of forest cover
   -In Helsinki and Dry-Zone Africa, under the "forest resources" criterion
   -In Montreal and Tarapoto, under the two separate criteria dealing with "biodiversity" and "productivity/production functions".
2. Area damaged by biotic or abiotic agents
3. Extent of protected areas
4. Number of forest dependent/threatened species

The criteria in all the initiatives are similar in content, but the structure and wording varies. The quantitative indicator level has fewer similarities. However, while the initiatives use different definitions for the terms "criteria" and "indicators", the indicators are similar in terms of the elements that are recognized to be essential in order to identify and measure SFM.

In spite of many similarities, direct comparison of C&I's is not always feasible. Some aspects may not be covered or their focus diverges between the inputs and outcomes of forest management. This is due to the fact that C&I's are developed for different:

- geographic and/or ecological zones
- economic, ecological, social and cultural conditions
- levels and purposes.

Table 3: Comparison of C&I Initiatives Relevant to Biological Diversity at a National Level

Source: Intergovernmental Seminar on C&I's for Sustainable Forest Management, 1996, Helsinki.

[shaded box] Indicates indicators that are applicable at an FMU level.

ITTO	Helsinki	Montreal	Tarapoto	Dry-zone Africa
*ITTO has separate "Guidelines" addressing biodiversity	**Criterion 4:** Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems	**Criterion 1:** Conservation of biological diversity	**Criterion 4:** Conservation of forest cover and biological diversity	**Criterion 2:** Conservation and enhancement of biological diversity in forest ecosystems
	4.1. Changes in the area of natural and ancient semi-natural forest types	**1.1.a.** Extent of area by forest type relative to total forest area **1.1.b.** Extent of area by forest type and by age class or successional stage;	**4.a.** Area, by forest type, in categories of...	Ecosystem indicators **2.1.** Areas by types of vegetation (natural and man-made).
-Areas of protection forests&production forests within the permanent forest estate -The representativeness of the protected areas network at the current or planned reservation programme	...strictly protected forest reserves and forest protected by special management regime	**1.1.c.** Extent of area by forest type in protected area categories as defined by IUCN or other classification systems; **1.1.d.** Extent of area by forest type in protected areas defined by age class or successional stage;	...protected areas, in relation to total forest area **4.h.** Impact of activities in other sectors on the conservation of forest ecosystems (mining, ranching, energy, infrastructure, etc.)	**2.2.** Extent of protected areas
		1.1.e. Fragmentation of forest types		**2.3.** Fragmentation of forests
			4.f. Rate of conversion of forest cover to other uses	**2.4.** Area cleared annually of forest ecosystems containing endemic species

	4.2. Changes in the number & percentage of threatened species in relation to total number of forest species	**1.2.b.** The status of forest dependent species (threatened, rare, vulnerable, endangered or extinct) at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment **1.2.a.** The number of forest dependent species.	**4.b.** Measures for "in situ" conservation of species in danger of extinction	**2.6.** Number of forest dependent species at risk **2.7.** Resource exploitation systems used **2.10.** Population levels of key species across their range **2.5.** Number of forest dependent species
	4.3. Changes in the proportions of stands managed for the conservation and utilisation of forest genetic resources; differentiation between indigenous and introduced species	**1.3.a.** Number of forest dependent species that occupy a small portion of their former range **1.3.b.** Population levels of representative species from diverse habitats monitored across their range	**4.c.** Measures for the conservation of genetic resources	**2.8.** Average number of provenances **2.9.** Number of forest dependent species with reduced range **2.11.** Management of genetic resources
	4.4. Changes in the proportion of mixed stands			
	4.5. In relation to total area regenerated, proportions of annual area of natural regeneration		**4.e.** Rate of natural regeneration, species composition and survival	**3.2.** Percentages of forest ecosystems without regeneration

4.3 Development of a South African C&I Framework for FMU Application

Standards developed at regional and national level may not be fully compatible with standards used for the assessment of the quality of forest management at the level of the forest management unit. Differentiation and specific adaptation to conditions are necessary at the level of indicators and verifiers and to a lesser extent at the level of criteria. International C&I

initiatives were examined to determine which indicators could be applied to management and conservation of biodiversity at an FMU level (cf. Table 3). Indicators drawn from the international initiatives were then combined with those suggested by Stork *et al.* (1997) for conservation of biodiversity at an FMU level. Boyle *et al.* (in press)later eliminated many of these verifiers according to certain criteria of practicability. As these criteria are similar to mine, Boyle's smaller set of verifiers were then further investigated for application in FMUs in the temperate "tree-farm" environment that exists in South Africa.

CHAPTER FIVE: BIODIVERSITY ASSESSMENT AND TYPES OF BIODIVERSITY CRITERIA AND INDICATORS

The loss of biodiversity has resulted in increasing debate as to how best to preserve it. Measuring biodiversity is a complex problem and there are many difficulties in designing strategies that can be conducted in a reasonable amount of time and with a sensible investment in resources.

5.1 Approaches to the Assessment of Biodiversity

According to Perry (1994), there are three alternative approaches to the conservation of biodiversity:

1. A focus on individual species (fine-filter approach)
2. A focus on whole communities (coarse-filter approach)
3. A combination of fine- and coarse-filters (pluralistic approach).

Most conservation efforts to date have employed the fine-filter approach. The species category is useful in that it identifies entities for legal attention and assessment of the problem. Species can be counted and monitored over time. The public can also identify easier with the loss of a species than with the loss of a population or erosion of genetic diversity. However, the single species approach to conservation has been rejected by many biologists as a conservation strategy (Smith *et al.*1996). It has become clear that trying to save all species is tactically impossible when approached on a species-by-species basis. Moreover, the fine-filter is unlikely to be fine enough: the species that get the most attention are those that are easy to see and track (e.g. birds) or the "charismatic megavertebrates" - those animals that are particularly appealing or symbolic to humans (e.g. elephants). Many of the small species which play vital roles in ecosystem functioning could be ignored. The species category contains much hidden diversity in the form of local adaptations and genetic information. A species focus by itself also does not directly address the larger problem of habitat and ecosystem loss, which is the driving force in extinction. A focus on individual species also ignores the interconnections and interdependencies in the system as a whole and risks failure in the long run. A piecemeal, species-driven approach to conservation draws attention to only one part of biodiversity; a more comprehensive perspective must be taken (Meffe and Carroll, 1994).

The basic premise of the coarse-filter approach is that protecting species means protecting the structural and functional integrity of the system in which they are embedded. Rather than individual species, communities and landscapes are the focus of protection and restoration. However, this approach is not without problems. Species can be lost from communities that appear intact. It is therefore necessary to adopt a pluralistic approach (Noss, 1991) which is a combination of both fine- and coarse-filter approaches. Noss (1990) further argues for a hierarchical approach to conservation and monitoring, the four levels of the hierarchy being:

1. Regional landscape
2. Community-ecosystem
3. Population-species
4. Genetic

Hierarchy theory suggests that higher levels of organization incorporate and constrain the behaviour of lower levels (Noss, 1990). However, this does not suggest that monitoring and assessment be limited to higher levels. Lower levels in a hierarchy contain the details (for example, species identities and abundances) of interest to conservationists, and the mechanistic basis for many higher-order patterns. The hierarchy concept suggests that biodiversity be monitored at multiple levels of organization, and at multiple spatial and temporal scales:

5.1.1 Levels of organization

Biological diversity occurs at several hierarchical scales: genes, individuals, populations, species, communities, ecosystems and landscapes. At each of these levels, there are important relationships between biodiversity and ecosystem processes and between biodiversity and the ways in which ecosystems respond to disturbance. Another value of the hierarchy concept for assessing biodiversity is the recognition that effects of environmental stresses will be expressed in different ways at different levels of biological organization. Effects at one level can be expected to reverberate through other levels, often in predictable ways (Noss, 1990).

5.1.2 Spatial scale

The question of scale is very important in monitoring biodiversity and ecosystem management. Commercial forestry can have impacts at many scales ranging from the national and provincial level, the landscape and catchment level, and the forest management unit, to the stand level. The International Institute for Environment and Development (IIED) recommends that the implementation of sustainable development follow the principle of subsidiarity i.e. that decisions should be taken at the lowest possible levels. The White Paper on Conservation and Sustainable Use of Biological Diversity (1997) also recognizes the role of and the need for incentives which support the maintenance of biological diversity at the user level. Therefore, C&I's are best implemented at an FMU level. Even with the FMU, one needs to identify both the scale at which the perturbation or management operates and the smaller scale at which monitoring will detect changes before slowly responding variables are significantly altered.

5.1.3 Temporal scale

There are also temporal problems associated with the measurement and monitoring of biodiversity. In addition to the effects of growth time within the life of one organism, there is a major series of time effect. Many vegetation types depend upon periodic events, for example, fires, for their maintenance. Thus there is a changing verifier and a shifting baseline. Patterns become even more complex with verifiers that show hysteretic behaviour (relationships may change after a threshold has been passed), for example, when fresh water molluscs have been eliminated by bad water quality, a return of clean water may not be sufficient for rapid re-colonization.

The hierarchy proposal by Noss is the most thorough and effective strategy that has been proposed to date, but implementing it will require major effort and expense. A few semi-pluralistic shortcuts such as indicator species (so-called because they are considered to indicate the health of the entire system of interest) have been suggested. Biodiversity has been regarded as too broad and vague a concept to be applied to regulatory and management problems. However, this problem can be overcome if biodiversity is recognized as an end in itself, and if measurable indicators can be selected to assess the status of biodiversity over time (Noss, 1990). Diversity indices have been used in the past as quantitative criteria on which to enforce regulations on biodiversity. However, diversity indices lose information (such as species identity), are heavily dependent on sample size, and generally have fallen out of favour with the scientific community. Quantitative criteria are often preferred in the measurement of biodiversity even though qualitative changes in community structure are often the best indicators of ecological disruption (Noss, 1990). For example, when a natural landscape is fragmented, overall community diversity may stay the same or even increase, yet the integrity of the community has been compromised with an invasion of weedy species and local extinctions (Noss, 1983).

An integrative approach to the loss of biodiversity requires the use of ecological, demographic, morphological and molecular genetic information to ensure that the maximum amount of evolutionary information contained in populations existing within a region is preserved (Smith *et al.*,1996). Georgiadis and Blanford (1992) stated that "Instead of focusing on each species, we must conserve the processes that are defined by species' interactions within self-sustaining ecosystems". The process approach suggests that the changes in biodiversity may be assessed indirectly through assessment of the processes that maintain and generate biodiversity (Stork *et al.*,1997).

Franklin (1988) recognized three primary attributes of ecosystems namely, composition, structure, and function. These three attributes determine, and in fact, constitute, the biodiversity of an area. Composition is the identity and variety of elements, and includes species lists and measures of species diversity and genetic diversity. Structure is the physical organization or pattern of a system, ranging from habitat complexity within communities to the pattern of patches at a landscape scale. Function involves ecological and evolutionary processes, including gene flow, disturbances, and nutrient cycling. Franklin (1988) noted that the growing concern over compositional diversity has not been accompanied by an adequate awareness of structural and functional diversity. Indicators should point to the condition of each of these three attributes of ecosystems.

5.2 Methods of Assessing Biodiversity

5.2.1. Functional Guilds

The grouping of species into guilds aids in the assessment and prediction of the effects of natural and man-induced habitat modifications on faunal communities (Mannan *et al.*, 1984). The use of guilds for management purposes relies on the assumption that species in a guild respond similarly to environmental changes. For example, species of birds that forage and nest in the foliage of fir trees form a logical management unit or guild. Species in this guild should respond consistently (i.e., they should all increase or decrease in abundance) to a silvicultural treatment that alters the volume of canopy foliage (Mannan *et al.*, 1984). Guild analysis may be limited to the investigation of a taxonomic subset of the guild to address certain questions. There has been a proposal to differentiate between these two types of guilds, by referring to them as "true" (resource-based) community-guilds, and taxonomic assemblage-guilds. Selected guilds should be important to the structure and functioning of the ecosystems under consideration (Halffter, 1998).

One of the problems with the guild concept is that of scale, both in terms of guild definition and the severity of habitat alteration. The problem with guild definition is as follows: chosen species could be responding to habitat changes on a finer scale than is characterized by the chosen guilds. A finer scale, however, requires detailed information about the habitat requirements and would eventually have each species occupying its own guild which would eliminate the proposed benefits of management by the guild concept.

Guild members should respond consistently when habitat changes are severe. However, anthropogenic alterations in forest habitats are often subtle, and may result in only slight-to-moderate changes in percentage canopy cover, plant species' composition, or average size and spacing of trees. Members of the guilds examined by Mannan *et al.*, (1984) did not respond consistently to these types of changes. The lack of consistent responses to habitat alterations among species eliminates the possibility of predicting the responses of guild members by monitoring the abundance of a single "indicator" species. Mannan *et al.* (1984) caution that management should not rely solely on guild analyses to provide information of the impacts of perturbations in the forest environment.

Because guilds are based on known patterns of resource use, the guild structure of a community or ecosystem may provide a qualitative index of the trophic structure or food web within that system (Landres, 1983). Guild analysis has been used extensively in comparisons of community structure because of the direct relationship inferred between guilds and the functional roles performed within the community.

5.2.2 Indicator species

"Indicators are measurable surrogates for environmental end points such as biodiversity" (Noss, 1990). An indicator species (or group of species) has characteristics which "indicate" changes in biotic or abiotic conditions (Stork *et al.*, 1997). No single indicator will possess all of the desirable qualities and therefore, a set of complementary indicators is required (Noss, 1990). According to Munn (1998) and Halffter (1998) an indicator or indicator groups should:

- be sufficiently sensitive to provide an early warning of change;
- be distributed over a wide geographical area, or widely applicable;
- be capable of providing a continuous assessment over a wide range of stress;
- be relatively independent of sample size;
- be easy and cost-effective to measure, collect, assay, and / calculate;
- have sufficient information available about natural history and taxonomy;
- should provide information not only about intact community, but also for measuring reduction in biodiversity as a result of anthropogenic stress;
- be relevant to ecologically significant phenomena;
- be important to the structure and functioning of the ecosystem.

Landres *et al.*, (1988) and Stork *et al.*, (1997) discuss a number of difficulties with using indicator species to assess population trends of other species and to evaluate overall wildlife habitat quality, and noted that the ecological criteria used to select indicators are often ambiguous and fallible. Landres *et al.*, (1988) state that indicators should be used as part of a comprehensive strategy of risk analysis that focuses on key habitats (including corridors, mosaics, and other landscape structures) as well as species. This strategy could use monitoring indicators of compositional, structural, and functional biodiversity at multiple levels of organization. Indicator species must be chosen carefully in accord with local assessment goals.

Umbrella species are an example of indicator species. The reasoning behind umbrella species is that protecting sufficient habitat for umbrellas automatically protects species that require the same habitat, but less of it. The success of an indicator approach depends on how well the chosen species indicates the health of the rest of the system. Vertebrate species are the logical choice for umbrella species at a regional scale as they generally require large areas of habitat, but regional diversity depends on a balance between habitat types (e.g. successional stages) which requires more than one umbrella.

5.2.3 Taxic groups

Groups of species and / higher taxa can also be used to assess the biodiversity of an ecosystem or area (Boyle and Boontawee, 1995).

5.2.4 Species of Special Concern

Rare species

A species may be rare because of a highly restricted geographic range, high habitat specificity, small population size, or combinations of these characteristics. Different types of rarity make species vulnerable to different extinction processes. A locally abundant species that occurs only at one location is extremely vulnerable to local stochastic events or intentional habitat destruction. A broadly distributed species that exists at low population sizes might be more vulnerable to loss of genetic diversity and inbreeding (Meffe and Carroll, 1994).

Long-Lived Species

Long-lived species are characterized by delayed sexual maturity, low fecundity, reliance on high juvenile survivorship, and cessation of reproduction and protection of the adult phenotype when threatened. These life history characteristics mean that long-lived species have great difficulty responding to environmental changes that reduce their populations. These species are therefore, particularly vulnerable to extinction and their populations should be closely monitored and their habitats protected. Population decline might take years to observe and consequently, attention should be focused on population age structure and recruitment of juveniles into the population (Meffe and Carroll, 1994).

Keystone Species

A keystone species (or group if species) is one that makes an unusually strong contribution to community structure or processes (Meffe and Carroll, 1994). A keystone species may be a major predator, whose presence limits the abundance of prey; a unique food source; or a species that maintains critical ecosystem processes, such as nitrogen-fixing bacteria. Removal, addition, or change of population size of keystone species can have wide-ranging effects on other species, on processes and interactions, and even on land-forms. The removal of keystone species can make other members of the community vulnerable to extinction. While some individual taxa may function as keystone species, it is more common that sets of species will function in that regard. The goal of analyzing keystone species for any community is to determine membership in the minimal set of species that has disproportionate effects on the rest of the community and to focus conservation on these sets. Unfortunately, there are major gaps in our understanding of keystone species. There is only a basic knowledge of which sets of species are keystones in particular communities, and even less knowledge about the ecology of these species Meffe and Carroll, 1994; Stork *et al.*, 1997). There are several problems with the application of the keystone concept. Firstly, it is not rigorously defined. Secondly, there is a range in the strength of the keystone species' effects. Thirdly, a focus only on protection of keystone species could fail to protect other species or the system at large (Meffe and Carroll, 1994).

5.3 Monitoring biodiversity

Monitoring will be most effective when it is designed to test specific hypotheses that are relevant to policy and management questions. Monitoring is thus a necessary link in the "adaptive management" cycle that continuously refines management practices on the basis of data derived from monitoring. This data is analyzed with an emphasis on predicting impacts (Holling, 1978).

5.4 Conclusion

Noss proposed a hierarchy from regional landscape level, community-ecosystem, population-species, to the genetic level. This is the most holistic and comprehensive approach suggested to date. It would be very time-consuming to assess biodiversity at all these levels, but a possible shortcut is provided through the use of indicators. This concept of hierarchy was adopted as the framework for C&I use in assessment of biodiversity at an FMU level.

CHAPTER SIX: CRITERIA AND INDICATOR FRAMEWORK

PRINCIPLE:

The maintenance of ecosystem integrity and environmental capability

"Ecosystem integrity" is a more comprehensive phrase than the term "biodiversity". Unlike diversity, which can be expressed simply as the number of kinds of items, integrity refers to conditions under little or no influence from human actions; an ecosystem with high integrity reflects natural evolutionary and biogeographic processes. Ecosystem integrity is reflected in both the biotic elements and the processes that generate and maintain those elements, whereas diversity describes only the elements (Angermeier and Karr, 1994). Another distinction between integrity and diversity is that only integrity is directly associated with evolutionary context. Naturally evolved assemblages possess integrity, but random assemblages do not. Adding exotic species or genes from distant populations may increase local diversity, but it reduces integrity. Integrity goals allow for natural fluctuation in element composition. Loss of a particular element (e.g. species) or replacement by a regionally appropriate one need not indicate a loss of integrity unless the processes associated with the element's maintenance become impaired (Angermeier and Karr, 1994).

The environmental capability of a site is defined as bounded by (1) the inherent soil and biophysical constraints, (2) the responsiveness of the soil to management inputs, and (3) the genetic potential of the plantation species and their interaction with the environment of the site (Nambiar and Brown, 1997).

CRITERION:
The Maintenance and Enhancement of Biodiversity

This entails managing not only for the elements of biodiversity, but also for the processes that generate and maintain biodiversity such as speciation, migration, disturbance and predation. Indicators of processes fall into the categories of both "state" and "response" indicators and will therefore reflect the status and fate of biodiversity (Stork *et al.*, 1997). These indicators can be rapidly assessed by non-experts. Although time-series data may not be feasible, an approximation to a time-series can be achieved for example by using adjacent areas which have not been affected by management actions as benchmarks. As C&I assessment becomes operational, time-series data will be collected with repeated assessments of the same FMU.

Indicator 1: Landscape pattern and diversity is maintained

Rationale

Halffter (1998) argues that the consequences of human activities (community modification and fragmentation) are most evident at the landscape level. A landscape is an area composed of a mosaic of interacting ecosystems or patches (Forman and Gordon, 1986). Landscape patterns determine the variety, integrity and interconnectedness of habitats within a region. Both the resistance and the resilience of any given local ecosystem depend on the landscape and regional diversity within which it is embedded because landscape patterns influence factors such as the rate at which disturbances spread, the availability of colonizers to replenish losses, and movement and persistence of organisms. The movement and persistence of organisms is affected by habitat fragmentation as well as landscape connectivity. It has been suggested that because the survival of populations in a landscape depends on both the rate of local extinctions (in patches) and the rate of organism movement among patches, species in isolated patches should have a lower probability of persistence.

The best approach to protection and conservation is what we see in natural landscapes: complex patterns of hierarchically nested patches, which is effectively a fractal structure. Both the relative amounts of different types of habitat and the degree of interconnectedness (or conversely, fragmentation and isolation) are important at the landscape scale.

Landscape structure must be identified and quantified before interactions between landscape patterns and ecological processes can be understood (Turner, 1989). A series of heterogeneity characteristics such as patch size and shape, connections between them and ecotone extension best show their relationships to the diversity of species (Halffter, 1998). The proposed verifiers quantify changes in areal extent of vegetation types and fragmentation of the landscape.

Methods

Thresholds: Stork *et. al.* (1997) suggest critical values for all landscape pattern verifiers may be within ± 10% deviation from historical norms or values for "undisturbed" portions of the FMU. This threshold is arbitrarily chosen in order to provide a benchmark against which to assess change. Historical records of spatial change are not always available. Where these records are not available, according to Stork *et al.*(1997), the values can be compared against "undisturbed" portions of the FMU. This is very difficult to determine because even if these areas have not been subject to direct management interventions, they would not necessarily represent ecological integrity. It would also be incorrect to assume that the remaining patches of natural areas in the FMU are representative of the natural landscape pattern and diversity. However, this would have to be accepted as a starting point in a man-altered environment.

Spatial indices and other landscape-level measures of pattern can be developed in the office using maps of the FMU. Analogue maps can be used, but this is time-consuming. Sources of digital data, from air photos or satellite imagery are far more useful, and can be used with GIS and computer simulation models to project changes in diversity over time. Satellite remote sensing allows data to be collected rapidly and frequently over large areas and has a very high information content. Free, public-domain software is available for image analysis. In implementing landscape measures, the first step is to decide on the extent and pixel size of the area being considered. The choice of pixel size can affect the interpretation of the verifiers (Turner *et. al.*, 1989) and depends on the FMU size , the type of human interventions, the organisms which are known to be at risk in the area, and the natural pattern or fragmentation of the site.

In cases where a map is not available in a digitised form, the development of verifiers for contagion, dominance, fractal dimension and percolation index is not possible. In the case of limited expertise or maps not being available in digital forms, the minimum set of parameters to be measured includes:

- **Area**: Verifier 1.1.1
- **Patch structure**: Verifier 1.2.1, 1.2.2 and 1.2.3 can be easily measured by counting patches and determining the area of patches.
- **Connectivity**: Verifier 1.3.1 is based on a simple measure of distance between patches.

When digital maps are available, then the advantage of using verifiers 1.2.4,1.2.5,1.2.6 and 1.3.2 are that they provide a single metric of the entire map and thus are relatively direct to interpret (Gardner et al., 1987;O'Neill *et al.*, 1988).

VERIFIERS

I) AREA

Verifier 1.1.1: Areal extent of each vegetation type / habitat in the FMU (natural and man-made)

Rationale: A decrease in area of one or more habitats available may correlate with species decline (Wilson 1988; Saunders *et al.* 1991). The area of each vegetation type is basic information for most landscape-level analyses.

Verifier 1.1.2: Areal extent of protected biotopes/habitats

Rationale: The Rio Convention requires that 10% of each habitat be protected. Although 40% of plantation estates remain unplanted, special protection is not necessarily awarded to these areas. Certain ecosystems such as wetlands receive special protection in national legislation and management plans need to be in place to manage these ecosystems appropriately.

Verifier 1.1.3: Width of buffer strips between plantations and natural areas, and riparian zones

Rationale: Buffer strips between plantation stands and natural areas are essential to minimise impacts on these areas. Riparian areas are important as they perform many essential ecological functions. They act as corridors and islands. The plant and animal communities of riparian zones form an important interface between stream and terrestrial ecosystems, having elements of both systems. They are productive and soil moisture is high enough to support communities distinct from surrounding drier uplands. Riparian zones are biogeographically distinct with a larger number of species than the surrounding areas. They are also ecotonal, supporting species that are not common to upland or aquatic environments (Roberts & Carothers, 1982). At present, trees may not be planted closer than 30m from rivers, streams and wetlands. The Guidelines for Environmental Management recommend that trees not be planted closer than 50m from wetlands (Forestry Industry Environmental Committee,1995.). There should also be a buffer between plantation stands and natural areas. These recommendations can be tested by adaptive management.

II) FRAGMENTATION

Patch Structure Verifiers

Verifier 1.2.1.: Largest patch of each vegetation type

Rationale: The ecological characteristics of the landscape may be highly related to the characteristics of the largest patch. Information on maximum patch size may provide insight into long-term population viability because populations are unlikely to persist in landscapes where the largest patch is smaller than that species' home-range.

Verifier 1.2.2: Dominance

Rationale: This is a landscape metric of how common a single vegetation type may be over the landscape. It measures evenness, in contrast to richness, of patch structure. Its value indicates the degree to which species dependent on a single habitat can pervade the landscape.

Connectivity Verifiers

Verifier 1.3.1: Percolation index

Rationale: This measures the connectedness of a landscape from one edge to the other. The term derives from measures of the ability of water to percolate through the soil when the soil pores are connected. This index may be important for organisms who need to be able to move across the landscape using a single vegetation type (Gardner *et. al.*, 1987).

DISCUSSION

Boyle *et al.*, (in press) assessed the verifiers proposed by Stork *et al.* (1987) using the following criteria:

1. Ease of data collection and interpretation
2. Relevance to biodiversity
3. Responsive to change
4. Cross linkage to other indicators
5. Accountability

They concluded that many of the proposed verifiers for indicator 1 are partially duplicative. They are also difficult to assess. Four verifiers, namely 1.1.1, 1.2.2, 1.2.5 and 1.3.2 were considered to provide a broad range of information on landscape pattern, while being relatively easy to assess, and relevant to the conservation of biodiversity.

Indicator 2: Habitat diversity is maintained within critical limits

Rationale

The problems of habitat diversity and patterns of habitat patch configuration directly relate to habitat fragmentation and to the isolation of habitat patches in forest ecosystems (Whitcomb *et al.*, 1981). Development of patterns of habitat diversity according to specific criteria helps avoid the creation of widespread, monotypic timber stands, and the excessive fragmentation or isolation of habitat types, which may cause local extinction of species. Thomas et al., (1979) described habitat diversity as consisting of horizontal and vertical components. Horizontal components included the size, shape, composition, and relative spatial arrangement of habitat patches. These components are addressed at the landscape level. Vertical components included the number, relative density, composition, and absolute height of different vegetation layers. Spatial heterogeneity, complexity of habitat structure, as well as size of habitat, may correlate strongly with species richness (Bell *et al.*, 1991). MacArthur and MacArthur (1961 in James & Wamer, 1982) stated that bird diversity and foliage height diversity are linearly related. In their study they found that:

- The highest density of birds in forests occurs at high values of tree species richness and canopy height and intermediate values of tree density.

- The highest species richness per unit area occurs at intermediate values of tree species richness, canopy height, and tree density.
- The lowest density and species richness of birds occur in area of low tree species richness, low canopy height, and high density of small trees.

Methods:

Thresholds: Stork *et. al.* (1997) suggest a reasonable threshold might be ± ½ standard deviation of the spatial diversity observed in "undisturbed" patches of the same vegetation type in the FMU. Again, this merely provides a reference value which can be adjusted if it is found to be inadequate.

Short and Williamson (1986) describe a method of quantifying change in habitat structure based on the interpretation and ground-truthing of aerial photographs. The problem with this method is that it presumes the availability of aerial photographs. Relatively simple methods for quantifying habitat change are suggested below.

Issues

- Scale, both spatial and temporal, is a vital consideration in studies of organism/habitat structure interaction. Structure may vary in time due to succession or agents of disturbance e.g. fire which modify succession.
- The provision of suitable habitat for wildlife does not necessarily mean that population objectives will be met. Abiotic factors such as climate and biotic factors such as stochastic variations in population, competition and predation can have a major effect on wildlife apart from the influences of habitat.

VERIFIERS

Verifier 2.1.1: Vertical structure of the indigenous forest margins

Rationale: Felling of timber in the plantation stands may result in trees falling into the indigenous areas and damaging habitat structure, particularly of forest margins. As discussed in the introduction to habitat diversity, high structural complexity is important as it results in increased biodiversity.

Methods: Accurate measurements of canopy height and vertical stratification of the forest are difficult and costly to obtain. Canopy height may be estimated subjectively using broad height classes. A close correlation exists between stem diameter and height and therefore, dbh measurements can be used a surrogate, or regression equations parametrised and used for estimations of canopy height and frequencies of trees by height classes. A similar procedure may be used for estimations of crown diameters and their variability, while crown forms can be evaluated using Dawkins' five-point scale. Trees with broken stems or crowns should be scored as such. Various methods for greater quantification of forest vertical structure, usually involving the estimation of foliar biomass, are available and could be applied.

Verifier 2.1.2: Size class distributions

Rationale: An analysis of size class distributions is important to determine whether succession and regeneration is occurring in natural areas and to determine structural diversity between plantation stands.

Methods: The measurement of tree stem diameters at breast height is a basic operation of forest inventory and the use of data to develop frequency distributions of trees by classes of dbh is a basic tool of stand structural analysis. Simple statistical procedures, such as the x^2 test are sufficient for comparison among stands. Dbh should be taken at a minimum diameter of at least 10cm. All trees should be identified to species level if possible, to permit the analysis of the size-class distributions of species populations as well as their spatial distributions. Simple and easily calculated measures such as the variance/mean ratio (Greig-Smith, 1983) can be employed to determine the type of spatial distribution. It is important that both dead trees and lianas also be recorded and identified.

Verifier 2.2.1: Indigenous ecotone succession

Rationale: It is important to monitor succession or regeneration of natural ecotopes in the ecotonal areas where plantation forestry borders on natural habitats. For example, forest margins where plantation stands are close to, and affect natural regeneration, may regress. Good buffer zone policies are required here.

Verifier 2.3.1: Changes in habitat representation

Rationale: Wide habitat representation results in a high niche availability and therefore results in increased biodiversity.

Methods: A gradsect sampling method, wherein habitat type or physiognomy is measured at regular intervals across a gradient across potential change, can be used to determine changes in habitat representation over space and time. This may be used as a management tool to directly monitor the effect of plantation management techniques where relatively sensitive environments are encountered. For plants less than 1.5m in height, the relative abundance of different growth forms can be recorded in the standard plots using the Domin or Braun-Blanquet scales. Growth forms may include shrubs, vines, grasses, geophytes, ferns and other herbs. The abundance of woody and non-woody lianas and epiphytes can also be recorded.

Indicator 3: Community guild structures do not show significant changes in the representation of especially sensitive guilds, and pollinator and disperser guilds

Rationale

The grouping of species into guilds has been stated to aid in assessment and prediction of the effects of natural and man-induced habitat modifications on faunal communities (Mannan *et al.*, 1984). The use of guilds for management purposes relies on the assumption that species in a guild respond similarly to environmental changes. For example, species of birds that forage and nest in the foliage of fir trees form a logical management unit or guild. Species in this guild should respond consistently (i.e., they should all increase or decrease in abundance) to a silvicultural treatment that alters the volume of canopy foliage (Mannan *et al.*, 1984). Selected guilds should be important to the structure and functioning of the ecosystems under consideration (Halffter, 1998).

Because guilds are based on known patterns of resource use, the guild structure of a community or ecosystem may provide a qualitative index of the trophic structure or food web within that system (Landres, 1983). Guild analysis has been used extensively in comparisons of community structure because of the direct relationship inferred between guilds and the functional roles performed within the community.

Methods

Threshold

Critical values for verifiers may be similar as for habitat diversity, namely ± ½ standard deviation of the spatial diversity observed in "undisturbed" patches of the same vegetation type in the FMU.

Issues

General problems associated with the guild concept have already been discussed. The following are two of the main issues relating to the application of the concept:

- Scale is a problem, both in terms of guild definition and the severity of habitat alteration. The problem with guild definition is as follows: Chosen species could be responding to habitat changes on a finer scale than is characterised by the chosen guilds. A finer scale, however requires detailed information about the habitat requirements and would eventually have each species occupying its own guild which would eliminate the proposed benefits of management by the guild concept. Guild members should respond consistently when habitat changes are severe. However, anthropogenic alterations in forest habitats are often subtle, and may result in only slight-to-moderate changes in percentage canopy cover, plant species' composition, or average size and spacing of trees. Members of the guilds examined by Mannan *et al.*, (1984) did not respond consistently to these types of changes.
- The lack of consistent responses to habitat alterations among species eliminates the possibility of predicting the responses of guild members by monitoring the abundance of a single "indicator" species (Mannan *et al.*1984 and Block *et al.*, 1984). Block *et al.* (1984) also caution that investigators cannot infer the presence of other species in the guild based solely on the presence of guild-indicator species. Block *et al.* (1984) found it more economical and statistically less variable to monitor the population of the guild as a unit rather than to monitor the population of a single species. Management should not rely solely on guild analyses to provide information of the impacts of perturbations in the forest environment.

VERIFIERS

SENSITIVE GUILDS

Verifier 3.1.1: Change in composition of sensitive floral or faunal guilds

Rationale: Examples of sensitive guilds are those which are at the top of the food chain, such as raptors and other predators. For example, the raptor guild is important in rodent control in early plantation stand growth. Healthy raptor numbers may be a useful indicator of environmentally friendly plantation management procedures.

Issues: Low numbers or a decline in raptors does not necessarily imply poor plantation management. Like many verifiers, there are cause and effect problems. However, it is important to identify those guilds which would be most proximate to or respond closely to changes in management style or procedure.

ASSESSMENT OF FUNCTIONAL GUILDS

Rationale: It is speculated from limited data that isolation and fragmentation of ecotopes may cause the disruption of those biological processes that maintain biodiversity and ecosystem functioning, such as pollination, seed dispersal and nutrient cycling.

Methods: Changes in diversity of these functional groups relative to control sites, measured by simple passive methods may permit the effect of plantation management on biodiversity.

Verifier 3.2.1: The abundances of selected avian guilds

Rationale: Birds are relatively easy to detect through bird calls and visually. Many people are familiar with birds and can identify them.

Issues: Species in avian communities generally partition resources by specializing in diet, location and time of foraging, or nest-site requirements. From a management perspective, specialization means that species that use broadly similar resources may have different specific habitat requirements. Therefore, some guild members would respond differently to habitat modifications, especially those that are relatively subtle. Consistent intra-guild responses to a perturbation are likely to decrease as the number of species increase.

Methods: The selected guilds may be terrestrial consumers of insects or fallen fruits, specialised with respect to understorey microclimates. The abundance of these birds may be estimated by recording call frequencies in plots or along transects. Point-count stations should be laid out within the study plot 200m in a systematic or random manner. At least 20 counts are needed from each study plot. This can be accomplished in a morning starting soon after dawn. Between 3 and 10 minutes should be spent counting in each station. The observer can count up to an unlimited range or only within an arbitrary range, such as 25m from the observer. Two separate counts should be taken at each station. One in the first half of the season and the other in the second. Point counts are widely used for censussing songbirds, but are of little use for less detectable species. Point counts are more suitable than transects in patchy habitat, but less suitable in open habitat. Biases may be caused by counting the same bird twice, weather conditions and errors in detection (Sutherland, 1996).

Line transects are undertaken by observers moving along a fixed route and recording the birds they see on either side of the route. This is most suitable for large areas of continuous, open habitat. Transects may be random, have the length of one kilometre and be 250-500m apart. As in the point counts, the birds can be counted up to an unlimited distance or a single fixed distance. Transects are suited to large areas of homogeneous habitat, and are particularly useful where bird populations occur at low density. There are less likely to be errors in bird detection as the sample area increases linearly away from the line. However, identification can be difficult as the observer is continually on the move. The census may be biased if birds are missed, birds move before being detected, birds are counted twice, errors are made in distance judgement, or observations are not independent. (Sutherland, 1996).

Verifier 3.3.1: Diversity of pollinators, parasitoids, decomposers and seed predators

Rationale: Recent work on insects suggests they are highly susceptible to the adverse affects of ecotope fragmentation. Four functional groups of insects representing processes that are critical for the maintenance of ecosystems are particularly important: pollinators, seed predators, parasitoids and decomposers.

Methods: Sticky traps, usually yellow in colour, roughly 20cm by 20cm and covered in cling-wrap which coated with Formex and which may be impregnated with chemical attractant may be used for this.

Verifier: Decomposer guilds

Rationale: Soil organisms play an important role in controlling the decomposition of plant and animal materials, biogeochemical cycling, and the formation of soil structure (Turco *et al.*, 1994). Soil organisms indicate changes in the soil long before this can be accurately determined by measuring changes in organic matter. Macrofauna (e.g. ants, termites, earthworms, snails and slugs) have the greatest potential to directly affect the soil's functional properties (Linden *et al.*, 1994).

Method: Soil samples of known volume can be dug using a spade, or a corer where the soil is soft. The majority of earthworms and larger invertebrates can be removed while breaking the soil up by hand. Advantages, disadvantages and biases are discussed by Sutherland (1996) and Nordstrom and Rundgren (1972). There are many factors which must be taken into account. The distribution of organisms may be limited by environmental factors other than disturbance of habitat i.e. inadequate and unsuitable food supplies, inadequate soil moisture contents, unsuitable temperatures, incorrect lighting, unsuitable soil texture. pH and electrolyte concentrations and the presence of physical barriers to movement. Control plots are essential to prove the effects of plantations on presence or absence of soil invertebrates.

Verifier 3.4.1: The diversity of arthropods (Pitfall traps)

Rationale: It is possible to separate arthropods into broad functional categories such as spiders, predatory and non-predatory ants, centipedes etc.

Methods: Straight sided containers with preservative are sunk level with the surface of the ground. Enough traps should be set so as to ensure different micro-habitats are sampled. It is easiest to place pitfall traps in a line or cross, to aid relocation. Pitfall trapping is a cheap and easy method of catching very large numbers of invertebrates with minimum effort. However, catch rates vary with the nature of the surrounding vegetation as vegetation impedes invertebrate movement. This makes it difficult to compare between sites or at the same site over time. Catches are a product of both invertebrate density and activity. Pitfall traps tend to catch proportionately more large (>3mm long) invertebrates. Some species of ground beetle, once caught, emit pheromones that attract other individuals to the trap. (Sutherland,1996).

Indicator 4: The richness / diversity of selected groups shows no significant change

Rationale

It is important to monitor certain vulnerable species such as endemics and species which indicate significant human impacts.

Methods

Measuring total richness for by carrying out a complete census is only possible for plants and possibly some of the more conspicuous and philopatric mammals. Therefore, indicator groups can be very useful. Again, appropriate critical levels may be ±½ standard deviation of the spatial diversity observed in "undisturbed" patches of the spatial diversity observed in "undisturbed" patches of the same vegetation type in the FMU.

Issues

It is important to establish a sampling programme appropriate to the group of organisms that one wishes to use as an indicator group. A central problem for any sampling-based study is that of estimating to what degree the values obtained from sampling represent reality. The following criteria are important to consider when selecting indicator species:

- Important to the structure and functioning of the ecosystem
- Sufficient information available about natural history and taxonomy
- Easy to capture
- Should not put conservation of the group at risk
- Provide information not only about intact community, but also for measuring reduction in biodiversity as a result of causes such as reduction of area, degrees of disturbance, management or other anthropogenic disturbances.
- How quickly an asymptote for accumulation of species using the indicator group and capture methods required is reached (Halffter, 1998).

Murphy and Wilcox (1991) concluded in a study that vertebrates provide an adequate umbrella for invertebrates at most levels. However, butterflies have special habitat requirements and therefore consideration must be given to the protection and management of such habitat to provide for overall biological diversity.

VERIFIERS

MEASURES OF RICHNESS

Verifier 4.1.1: Number of endemic, specialised and dependent species, threatened, rare, or vulnerable in each habitat (grassland, wetland, forest)

Rationale: These are species that are most likely to become extinct and should therefore receive special protection.

Methods: Management plans must be in place and subject to meaningful monitoring and checklists of those taxa with special status should be updated on an annual basis to reflect changes in occupancy (i.e. management success or failure). Encourage lists for all management compartments or units as opposed to a single collated list for the estate.

Verifier 4.1.2: Population sizes / structure of selected faunal and floral taxa do not show significant change

Rationale: Certain taxa such as oribi, Karkloof blue butterfly, samango monkey, tree hyrax, grassland dependent bird species, wildflower species as well as forest tree species whose use may increase (i.e. population size decreases) with proximity of commercial operations.

Verifier 4.1.3: Soil invertebrates within plantation stands

Rationale: Acidosis of the soil may severely affect invertebrates that live in the soil e.g. invertebrates. The presence of earthworms in the soil is credited with indicating high soil quality. Earthworms contribute to several processes in soils through burrowing, faecal extraction, and their feeding and digestion processes (Lee, 1985).

Verifier 4.1.4: Numbers of invasive exotics and their abundance or increase in areal extent

Rationale: Exotics endanger the indigenous biodiversity and alter ecosystem vitality and health. Management of invasive exotics is vital for the sustainable management of a plantation estate. There are 36 invasive alien plants occurring in indigenous forest (Geldenhuys *et al.*, 1986). They are generally characterized by shade intolerance, propogule dispersal by birds and mammals, the accumulation of seed stores due to regular production of hard-coated seeds and the ability

to reproduce vegetatively. Only 8 of these were introduced as timber trees. *Acacia mearnsii* and *A. melanoxylon* are the only timber trees which have successfully invaded modified forest throughout the country. No alien animal has been able to naturalize in the indigenous forest. Alien tree species (e.g. pines and gums) used in local afforestation do well in South Africa because they are not attacked by the insect pests and plant diseases which affect the trees in their country of origin. The forest biome is resistant to alien invasion and has remarkable recovery potential following infrequent disturbance such as timber harvesting (Geldenhuys *et al.*, 1986). Most alien invasives in the forest establish themselves only in disturbed forest margins or large gaps in heavily exploited forest (Geldenhuys *et al.*, 1986). Frugivores are important in the dissemination of the seed of most alien invaders in forests. An understanding of the effect of changes in the food plants of bird and mammal dispersers in the reproduction of indigenous plants is necessary in order to control plant invaders in timber plantations.
Methods: Simple, ecological counting routines and / or measures of cover may be used.

INDICATOR 5: GENETIC DIVERSITY IS CONSERVED

Rationale

Genetic variation is a result of changing evolutionary histories and in itself is of value to the present and future individuals, populations, and species in which it occurs. It is a prerequisite for future evolution and biodiversity conservation programmes should provide opportunities for it (Eriksson *et al.*, 1993).

Methods

Smidt (1995) describes various methods of detecting genetic variation.

Conclusion

It is important to remember that these indicators and verifiers are only suggestions and will need to be tested against the wider phenomena they are intended to represent or summarize so that they can be relied upon. This could result in modification, refinement, or even the abandoning of some indicators if they are found to be unreliable. Due to time constraints, it was not possible to test these indicators and verifiers in the field, but expert voting was used as a first step in the testing process.

CHAPTER SEVEN: WORKSHOP ASSESSMENT OF PROPOSED C&I FRAMEWORK

A workshop was held with plantation managers and environmental managers from Mondi and Sappi. The proposed hierarchical framework (Table 4) was presented to the participants for discussion and comment as to its relevance and practicality.

Table 4: Proposed Hierarchical Framework for the FMU	
Principle: The maintenance of ecosystem integrity and environmental capability.	
Criterion: To maintain and enhance biodiversity	
Indicators	**Verifiers**
1. Landscape pattern is maintained	1.1.1. Areal extent of each veg. type (natural and man-made)
	1.1.2. Protection of biotopes/habitats
	1.1.3. Width of buffer strips
	1.2.1. Largest patch of each veg type
	1.2.1. Dominance
	1.3.1. Percolation index
2. Changes in habitat structure within critical limits	2.1.1. Vertical structure
	2.1.2. Size class distributions
	2.2.1. Indigenous ecotone succession
	2.3.1. Changes in habitat representation
3. Community guild structures do not show significant changes	3.1.1. Change in composition of sensitive floral/faunal guilds
	3.2.1. The abundance of avian guilds
	3.3.1. Diversity of pollinators, parasitoids, decomposers and seed predators
	3.4.1. Pitfall traps
4. The richness/ diversity show no significant changes	4.1.1. Number of endemic, specialised & dependent species, threatened, rare, vulnerable or extinct in each habitat (grassland, wetland, forest)
	4.1.2. Population sizes/structure
	4.1.3. Soil invertebrates within plantation stands
	4.1.4. Numbers and abundance of invasive exotics

7.1 Attributes used to evaluate C&I's

Eleven attributes were selected (Prabhu *et al.*, 1996) and formulated as questions to enable the participants to rate the usefulness of the C&I's. The attributes are as follows:

1. *Easy to detect, record and interpret:*
   It is important that indicators and verifiers are selected that result in minimal additional costs. Verifiers that are easy to detect, record and interpret are more cost-effective than others.
   a. Difficulty: How easy would it be to collect this data?
   b. Analysis: How easy would it be to analyse the data?
   c. Accessibility: How accessible is this data? Is it already collected?
2. *Relevance:*
   All C&I's should be relevant to biodiversity conservation within SFM.
3. *Unambiguously related to the assessment goal:*
   Each verifier must be directly linked to its indicator, each indicator to a criterion, and each criterion to a principle.
4. *Precisely defined:*
   The wording for the definition of the verifier should be simple and unambiguous.
5. *Diagnostically specific:*
   Verifiers should provide measurement information that allows a direct assessment of an indicator.
6. *Reliability:*
   The techniques or methods necessary to ascertain the information specified by the indicator must be sufficiently reliable, as indicated by replicability.
7. *Sensitivity:*
   The verifier must be sensitive to stress on ecological systems. A verifier / indicator is most useful when it provides meaningful information over a wide range of changes in the system.
8. *Provides a summary or integrative measure:*
   How much information does the verifier provide about the system?

9. *Accountability:*

   Do users feel accountability for monitoring the verifier?

Answer codes were provided which enabled the participants to rank each verifier on a scale of 1-5 where 1 represents the negative extreme i.e. very difficult / very bad and 5 represents the positive extreme i.e. very easy / very good.

7.2 Results and discussion of workshop

7.2.1 Ranking of indicator categories

The landscape category of verifiers scored the highest average scores (Table 5). The benefit of landscape-level assessment as a summary measure of biodiversity was mentioned. Most of these verifiers can easily be measured in the office using analogue or digital data. However, concerns were raised as to the expense of remote sensing. Mondi already has a mapping unit called ECDB. The species richness / diversity category was ranked second with an average per verifier of 35. The community guild category was ranked third of the four categories with an average per verifier of 33. The habitat diversity category scored the lowest with an average per verifier of 30. This is probably due to the fact that the participants felt that the assessment of habitat structure does not fit in with their routine forestry inventory practices and would add to their workload. The methods were also felt to be too time-consuming. They said that the hiring of contractors to do the work on behalf of the foresters would alleviate this problem, but would result in additional expense. There were also comments that habitat structure assessment was not relevant in the "tree-farm" environment that exists in South Africa.

Table 5: Ranking of indicator categories

Ranking	V. Groups	Ave. Totals	Ave./ Ver.
1	Landscape	434.33	36.19
2	Species	426.5	35.54
3	Community	406.25	33.86
4	Habitat	362	30.17

7.2.2 Ranking of questions

For each question, the scores given to each verifier by each evaluator were summed and were then added together to produce the total. This was then divided by the number of verifiers (18) to obtain the average score per verifier for that question. The verifiers scored highest on the questions relating to precision of definition, relevance, and relation to the assessment goal. They scored lowest on the issue of ease of assessment which incorporates analysis of data, difficulty and accessibility of data (Table 6).

Table 6: Ranking of questions

Ranking	Questions	Totals	Averages
1	Q4: Precisely defined ?	759	42.17
2	Q2: Relevance ?	740	41.11
3	Q3: Unambiguously related to the assessment goal ?	731	40.61
4	Q7: Sensitivity ?:	718	39.89
5	Q5: Diagnostically specific ?	707	39.28
6	Q8: Provides a summary or integrative measure ?	694	38.56
7	Q9: Accountability ?	693	38.5
8	Q6: Reliability ?	691	38.39
9	Q1b: Analysis ?:	586	32.56
10	Q1a: Difficulty ?:	570	31.67
11	Q1c: Accessibility ?	496	27.56

7.2.3 Ranking of verifiers (Figure 5 and Table 7)

Verifier 1.1.1: Areal extent of each vegetation type / habitat in the FMU (natural and man-made)

This verifier obtained the highest average score of 40. All questions scored above an average of 3. The information is quickly and easily obtainable.

Verifier 4.1.4: Numbers of invasive exotics and their abundance or increase in areal extent

This verifier was ranked second with an average score of 39. Everyone involved in commercial forestry is aware of the need to control invasive exotics. The Working for Water programme has also assisted in educating people about the threats posed by invasive exotics.

Verifier 1.2.1: Largest patch of each vegetation type

This verifier was ranked third with an average score of 38. All questions scored above an average of 3. The verifier scored high as this information is accessible as it is easily measured from maps.

Verifier 4.1.1: Number of endemic, specialised, and dependent species, threatened, rare, or vulnerable in each habitat (grassland, wetland, forest)

This verifier was ranked fourth with an average score of 37.92. All questions obtained an average score of 3.

Verifier 1.1.3: Width of buffer strip between plantations and natural areas, and riparian zones

This verifier was ranked fifth with an average score of 37.5. There is already great awareness in the forestry industry as to the importance of riparian areas and much research has been done on the subject. The questions that scored the lowest were questions 1b and 1c relating to accessibility and analysis of the data. However, the information can easily be obtained by measuring the buffers on the maps. The analysis probably scored low due to the difficulty of determining the minimum width of the buffer zones.

Verifier 1.1.2: Areal extent of protected biotopes / habitats

This verifier was ranked sixth with an average score of 36. However, it is actually a subset of verifier 1.1.1. and therefore merely needs to be applied to the data obtained in 1.1.1. Research is needed to provide improved scientific measures of adequacy / representativeness of conservation areas.

Verifier 3.1.1: Change in composition of sensitive floral and faunal guilds

This verifier was ranked seventh with an average score of 35. Questions 1a, 1b and 1c relating to ease of assessment obtained the lowest scores.

Verifier 4.1.2: Population sizes / structure of selected faunal and floral taxa do not show significant change

This verifier was ranked eighth with an average score of 35. Question 1c obtained the lowest score.

Verifier 3.2.1: The abundances of selected avian guilds

This verifier was ranked ninth with an average score of 34. Most of the questions received a moderate score of 3.

Verifier 3.3.1: Diversity of pollinators, parasite guilds, decomposers, and seed predators

This verifier was ranked tenth with an average score of 33. Questions 1a, 1b and 1c obtained the lowest scores.

Verifier 1.2.2: Dominance

This verifier was ranked eleventh with an average score of 32. Question 1b relating to analysis of the data scored the lowest. There was some confusion as to what dominance is, its value and how it is measured. However, analysis can easily be done using software available free on the internet if the data is in digital format.

Verifier 1.3.1: Percolation index

This verifier was ranked twelfth with an average score of 32. Questions 1a, 1b, 1c relating to ease of assessment and question 9 regarding accountability scored the lowest. As in the previous verifier, assessment is easily done through readily available software. Regarding accountability, there was probably reluctance due to the fact that participants did not realize that responsibility for monitoring this does not extend past the boundaries of the estate. Perhaps, the participants did not realize the need and value for migration corridors.

Verifier 3.4.1: The diversity of arthropods (Pitfall traps)

This verifier was ranked thirteenth with an average score of 32. Question 1c relating to accessibility of data obtained the lowest score.

Verifier 2.2.1: Indigenous ecotone succession

This verifier was ranked fourteenth with an average score of 32. Again, questions 1a, 1b and 1c received low scores. This verifier is redundant as the issue of buffer zones is already addressed at the landscape level, and verifier 2.1.2 includes size-class measurements in natural areas as well as in plantation stands.

Verifier 2.3.1: Changes in habitat representation

This verifier was ranked fifteenth with an average score of 31. Again, questions 1a, 1b, and 1c scored the lowest.

Verifier 4.1.3: Soil invertebrates within plantation stands

This verifier was ranked sixteenth with an average score of 29. This verifier can be evaluated under community guilds.

Verifier 2.1.2*:* Size class distributions

This verifier was ranked second last (seventeenth) with an average score of 28. All the questions scored low ratings. While, measurements in plantations stands are standard practice, assessment of natural areas would add to the workload of managers and would be too time-consuming.

Verifier 2.1.1: Vertical structure of indigenous forest margins

This verifier was ranked last (eighteenth) with an average score of 28. Questions 1a, 1b and 1c regarding ease of assessment of data scored lowest. Natural areas are not incorporated into assessment procedures and therefore, this information is not collected as part of routine forestry inventory practices. The methods mentioned are not difficult and do not require much expertise, but they are time-consuming.

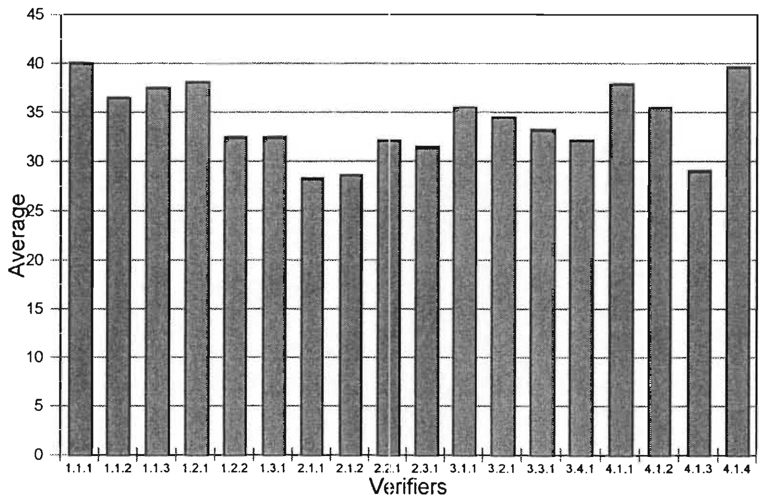


Figure 5: Average scores of biodiversity verifiers

Table 7: Ranking of Biodiversity Verifiers		
Ranking	**Verifiers**	**Averages**
1	1.1.1 Areal extent of each vegetation type (natural and man-made)	40.08
2	4.1.4 Numbers and abundance of invasive exotics	39.67
3	1.2.1 Largest patch of each vegetation type	38.08
4	4.1.1 Number of endemic, specialized & dependent species, threatened, rare, vulnerable or extinct in each habitat (grassland, wetland, forest)	37.92
5	1.1.3 Width of buffer strips	37.5
6	1.1.2 Protection of biotopes/habitats	36.5
7	3.1.1 Change in composition of sensitive floral/faunal guilds	35.5
8	4.1.2 Population sizes/structure	35.5
9	3.2.1 The abundance of avian guilds	34.5
10	3.3.1 Diversity of pollinators, parasitoids, decomposers & seed predators	33.25
11	1.2.2 Dominance	32.5
12	1.3.1 Percolation index	32.5
13	3.4.1 Pitfall traps	32.17
14	2.2.1 Indigenous ecotone succession	32.17
15	2.3.1 Changes in habitat representation	31.5
16	4.1.3 Soil invertebrates within plantation stands	29.08
17	2.1.2 Size class distributions	28.67
18	2.1.1 Vertical structure	28.33

7.3 Conclusion

It is important that the practicality of C&I's be assessed in a clear and rational manner, and the reasons for acceptance or rejection be objectively determined. Expert voting was used to give an indication of the practicality of the C&I's. However, expert voting alone will not be adequate for scientific evaluation, since it is based on a value judgement, preconception and assumptions rather than upon scientific principles. It is therefore, important that the C&I process links scientific evaluation with management perceptions during the evaluation process.

The landscape level in the hierarchy was seen as the most practical level at which to assess impacts of afforestation and plantation management actions on biodiversity. The habitat level was voted the most unpractical level at which to implement C&I's. It is important to remember that C&I's need not be implemented at all levels of the hierarchy. The plantation manger should decide on the appropriate level/s at the FMU level based on available scientific evidence. This is only a preliminary set of indicators and verifiers, and field testing and further evaluation should be conducted beginning with the most highly rated indicators and verifiers.

CHAPTER EIGHT: RECOMMENDATIONS AND CONCLUSION

The NFAP (1997) states that key facets of sustainable forest development include the protection of biodiversity, and stakeholder agreement on the criteria and indicators of sustainable forest management (SFM) (NFAP, 1997). Criteria and indicators (C&I's) can be defined as "tools which can be used to collect and organize information in a manner that is useful in conceptualizing, evaluating and implementing sustainable forest management," (Stork *et al.*, 1997). C&I's measure progress towards SFM. The following recommendations have been formulated to assist researchers and decision-makers involved in the criteria and indicator process.

8.1 Sustainable Plantation Management

- A clear definition and common understanding of sustainable plantation management is needed.
- Sustainable forest management requires both performance targets (C&I's) and a management process of continuous improvement (adaptive management) to achieve those targets. This involves:
    - participation of the major stakeholders;
    - clear environmental policy and demonstrated commitment to it;
    - allowing for uncertainties;
    - monitoring, learning and adaptation.

An EMS is useful in guiding this process.

- Researchers and managers must continually interact when addressing the issues, choices, and consequences of management decisions.

8.2 Developing C&I's for the FMU

- Indicators at the FMU level should be compatible with those at the national level;
- The FMU should be clearly defined and described. This requires information regarding management plans, FMU boundaries, biodiversity including habitat types, historic and current areas of intervention, inventory data; contours, streamlines and other physical elements; and roads, settlements and other

infrastructural elements;

- C&I's should be formulated in conjunction with forest managers to ensure local relevance and practicality;
- Development of C&I's should take into account the diverse nature of the plantation landscape. C&I's should be applicable in the plantation stands as well as in indigenous ecotypes;
- No single criterion or indicator is alone an indicator of sustainability. Individual criteria and indicators should be considered in the context of other criteria and indicators;
- Development of core indicators such as:
  "red flag" indicator - if this is not satisfied then neither is the criterion
  "green flag" indicator - if this is satisfied then so is the criterion,
  will enable rapid assessment of biodiversity;
- Monitoring programmes need to be instituted to assess the effectiveness of the C&I's in the assessment of biodiversity and its sustainability;
- C&I's need to be supported by long-term research to build up the database;
- C&I's can serve as performance indicators within a certification system such as FSC or tools to evaluate sustainability in a procedural system such as ISO 14000. A combination of performance and process standards will be most effective in achieving SFM.

8.3 Evaluation of C&I's

- Practicality of C&I's needs to be assessed in a clear and rational manner, and the reasons for acceptance or rejection objectively determined;
- Expert voting alone will not be adequate for scientific evaluation, since it is based on a value judgement, preconception and assumptions rather than upon scientific principles;
- The evaluation process needs to link scientific evaluation with management perceptions;
- Field testing of proposed C&I's should occur within an adaptive management framework.

8.4 Implementation of C&I's

- The best approach to C&I at present appears to be a voluntary approach;
- A combination of performance and process standards is needed to make the transition to sustainable plantation management.

The development of C&I's is one of the main achievements in the progress towards sustainable forest management in the 1990's. SFM involves many factors and uncertainties and is therefore a moving target. Criteria and indicators are appropriate in this context as they are not an end in themselves, but represent a dynamic and systematic tool to assess changes and trends in the status of biodiversity and condition of the natural environment. They serve as an "early warning" system and help identify gaps, threats and new opportunities for forest management. Regularly available information on the state of forests and forest management should contribute to better decision-making, and thus reduce the risk of unsustainable forest management policies and practices.

APPENDIX 1: Taxonomic Indicators

INDICATORS	ADVANTAGES	DISADVANTAGES
Vertebrates		
	Integrate effects of envir. stresses	Long-lived+therefore
		Low rates pop. incr.
		Long generation
		Low habitat
Birds		
	Easy to identify	
	Established systematics	
	Well-known biology	
	High in food chain	
	Long life-span: integrate effects of envir.	Long life-span:
	Mobility: monitoring possible over a	Mobility:Indiv. differ
	Utilize amateur interest	Pop. sizes buffered
	Surveillance data avail.	Buffering ability at
	Public interest-admin&political links	
Invertebrates		
	Generality of distribution	
	Trophic versatility	
	Specialism within generality&versatility	
	Rapid response to perturbation	
	Taxonomic tractability	Dev. of taxonomic
	Choice of species	
	Almost every habitat	
	Abundant	
	Easily sampled	
	Nb in ecol. functioning	
Tiger Beetle Family		
	Stabilized taxonomy	
	Well-known biology	
	Easily observed (50 hrs on 1 site)	
	World-wide distribution, range of habitats	
	Each species specialized within narrow	
	Patterns sp. richness correlate with other	
	Spp. of economic NB	
Orthoptera (grasshoppers)		
Samways and Moore, 1991	Conspicuous	Not present year-
	High numbers	Different species
	Important primary consumers	
	Generators of nutrients	
	Associated with grassland	
	Negatively affected by pines	

Odonata (butterflies)		
Samways *et al.*, 1996a; Wood	*C. tessellatus* and *A.leucosticta* are	Adults and larvae
	Habitat req. known - shade and running	
	Important flagship species	
	Many threatened species	
Others		
Carabidae, Coleoptera, Formicidae, Collembola, Pyrrhocidae are good indicators of grassland		

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