Operational Standards and Guidelines for Biodiversity Management in Tropical and Subtropical Forest Plantations – How Widely Do They Cover an Ecological Framework?

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The development of standards and guidelines to secure sustainable forest management at different geographical scales has expanded greatly during the past fifteen years. Most of these efforts, however, have been formulated for natural forests only; those designed specifically for forest plantations are relatively few. The global forest plantation area is expanding rapidly, with obvious positive and negative impacts on biodiversity. We characterize the key concepts of biodiversity in tropical and subtropical forest plantations and present an analysis of how these elements are covered in the eight principal operational standards and guidelines for sustainable plantation forestry. We also examine the applicability of standards and guidelines in plantations established and managed under different initial settings. The results indicate that the standards and guidelines address certain key elements of biodiversity comprehensively, meanwhile others are ignored or receive only slight attention. There is also substantial variation between the sets in their nature (performance- vs. process-based), scope, congruity in concepts and hierarchy, and specificity. The standards and guidelines seldom take into account the varying initial settings for plantation establishment and the consequent variation in critical factors in biodiversity conservation and management. We recommend that standards and guidelines should be developed so as to pay more attention to the type and operating environment of plantations, to cover all key factors of biodiversity, and to consider building closer relationships between the social and ecological aspects of biodiversity.

Keywords afforestation, conservation, criteria and indicators, reforestation, sustainable forest management
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1 Introduction

The quest for sustainable forest management has led to the development of standards and guidelines to secure the maintenance of biological, social and economic functions of forests. In this study, "standard" refers to a set of principle, criteria and indicator, or at least some combinations of these hierarchical levels that serve as a tool to promote sustainable forest management (SFM) (Lammerts van Bueren and Blom 1997). "Guidelines" translate criteria and indicators (C&I) into practical guidance to meet the requirements of C&I (Lammerts van Bueren and Blom 1997).

During the past fifteen years, processes to develop standards and guidelines have mushroomed (Granholm et al. 1996, Castaneda et al. 2001, Rametsteiner and Simula 2003, CEPI 2004). The majority of such standards and guidelines have been formulated for the management of natural forests (Castaneda et al. 2001, CEPI 2004); those designed specifically for forest plantations are relatively few (ITTO 1993a, Guidelines Shell/WWF…1993, Principles for commercial… 1995, IUCN/WWF 2000a–b, Applegate and Raymond 2001, Poulsen and Applegate 2001, Forestry South Africa 2002, AFS 2003a–b, ABNT 2004, CertforChile 2004, FSC 2004, FAO 2005a, LEI 2005a–b). Forest plantations, however, are of increasing importance in wood production, particularly in the tropics and subtropics (FAO 2000). The global plantation estate has increased from 18 million ha in 1980 to 187 million ha in 2000 (Carle et al. 2002). About half of the plantation estate in 2000 is known to be in industrial use (Carle et al. 2002). The global share of plantations in the industrial roundwood supply was estimated at some 35% in 2000, and is expected to rise to 44% in 2020 (ABARE- Jaakko Pöyry 1999).

Forest plantations (a subgroup of planted forests, defined by FAO 2005c) are established for various purposes and under a great variety of initial settings. They form a continuum, from intensively managed "tree crops" to extensively managed "forests". Standards and guidelines, however, seldom distinguish among plantation types. The primary focus of this study is on intensively managed fast-growing tree plantations, which are a significant land use form and a source of industrial wood in many areas in the tropics and subtropics. The total area of these plantations is estimated at some 10 million ha, to which a further 0.8–1.2 million ha is being added each year (Cossalter and Pye-Smith 2003).

The ecological characteristics of all types of plantations – including species composition, stand profile and structure, age and size class distributions, organic matter and nutrient cycling – differ to a greater or lesser extent from those of natural forests (Evans and Turnbull 2004). In addition, plantation forestry usually operates on lands under varying degrees of human influence. In such conditions, the role of the plantation in the landscape and the ability of standards and guidelines to address landscape level processes become important issues in the conservation and management of biodiversity (Lamb 1998, Lindenmayer 2002, Lawes et al. 2004, Nasi et al. 2005).

The processes and initiatives to formulate standards can be divided into three broad groups: policy, operational and scientific (Lammerts van Bueren and Blom 1997). Categorization of the processes and/or standards is anything but clear, due to their various actors, multiple targets and continuous development.

The policy processes – also known as C&I processes (see e.g. Simula 2003) – have developed non-normative C&I to be used as a forest policy instrument and as a tool for reviewing, monitoring and reporting on the state of, and trends in forests. C&I operate mainly at the regional and/or international level, but policy processes have also given rise to C&I at the level of the forest management unit (FMU), such as the Pan-European Operational Level Guidelines for Sustainable Forest Management (PEOLG) of the Ministerial Conference on the Protection of Forests in Europe (MCPFE 1998), or the ATO/ITTO principles, criteria and indicators for the sustainable management of African natural tropical forests (ATO/ITTO 2003). The policy processes are summarized e.g. in Simula (2003).

Forest certification is a major instrument promoting SFM via market forces. Forest certification standards set out requirements against which certification assessment is made (Nussbaum and Simula 2005). They are normative, i.e. their requirements must be met in order that a certificate can be gained. The standards can be either process or performance-based and they operate at the FMU level. The principal forest certification schemes are presented e.g. by CEPI (2004).

Scientific processes are used to test and compare existing standards (Prabhu et al. 1996a, Lammerts van Bueren and Blom 1997). Parallel and supplementary to the development of standards, various guidelines have been developed to assist managers to design and undertake operations to meet the requirements of standards (see e.g. ITTO 1992, ITTO 1993a–b).

As the standards have been developed at one spatial scale, they are not necessarily relevant to another. The need for common C&I at the global level has been argued (Vähänen & Granholm 1996, IISD 2003), but the current trend is toward national and subnational level C&I rather that global ones. This development is especially distinctive among certification schemes (CEPI 2004).

The conservation and management of biodiversity is a central component of sustainable forest management and forms an axiomatic part of all standards and guidelines. There has been considerable debate over the effects of plantation forestry on biodiversity and the possibility of integrating biodiversity protection and intensive wood production (see e.g. Sawyer 1993, Allen et al. 1995, Rosoman 1995, Spellerberg and Sawyer 1995, Carrere and Lohmann 1996, Carrere 1999, Silver et al. 1999). The ability of standards and guidelines to address the characters of biodiversity relevant to plantation forestry is essential for sustainable plantation management. Previous studies analysing standards and/or guidelines for sustainable forest management have mainly focused on comparisons between forest certification schemes; they do not cover standards for tree plantations or focus on specific thematic areas, such as biodiversity (Meridian Institute 2002, World Bank/WWF 2003, Pokorny and Adams 2003, CEPI 2004, FERN 2004, Holvoet and Muys 2004).

Including biodiversity conservation and management in operational standards and guidelines is anything but straightforward, due to the multidimensional nature of biodiversity and the special characteristics of plantations. Standards and guidelines, however, are important tools in plantation establishment and management; it is estimated for example that over 8 million ha of plantations are managed under forest certification standards alone (FSC 2005, PEFC 2006; M. Edwards/The Australian Forestry Standard, personal communication). The figure is growing rapidly as new prominent plantation countries, such as China and India, enter the field (FAO 2005b).

The purpose of the present study is to determine (i) what the key elements of biodiversity in forest plantations in the tropics and subtropics are, and (ii) how current operational standards and guidelines for tropical and subtropical forest plantations cover them on three levels of biodiversity (those of the within-species, the species and the ecosystem). We also discuss the applicability of standards and guidelines in industrial fast-growing plantations established and managed under different initial settings.

2 Ecological Dimension of Biodiversity in the Plantation Context

Biodiversity is a process and a continuum of interacting properties (Kamppinen and Walls 1999). The conservation and sustainable use of biodiversity assume that certain key elements, such as the processes creating and maintaining biodiversity, as well as the basic factors acting in and maintaining suitable conditions for these processes, occur at the levels of the within-species, the species and the ecosystem. The ability of standards and guidelines to address these key elements at all levels of biodiversity is a precondition for successful conservation and management.

One approach to examining the ecological dimension of biodiversity in a plantation context is to characterise the concept of biodiversity in terms of central ecological factors and to study the effects of plantations on these factors. For this purpose, biodiversity was divided into two broad categories: i) three levels of biodiversity as adopted and used in the Convention on Biological Diversity (in its broad sense) (Table 1), and ii) key elements which are important for biodiversity at a given site/area (Table 2). The categorisation was further used as a basis for analysing the ecological coverage of standards and guidelines (see Section 3).

Table 1. Basic levels of biodiversity and examples of effects on them of plantation establishment and management.

	Levels of biodiversity		
	Within-species (genetic)	Species	Ecosystem
Concept of variation with determination	Genetic diversity: variation in the genetic composition of individuals within or among species.[a)]	Species richness: total number of species within a region[b)] Species diversity: abundance of species within a region[b)] Taxic diversity: taxonomic dispersion of species[b)] Functional diversity: richness of functional features and interrelations in an area[b)]	• Ecosystem diversity: in the broad sense, diversity of ecosystems, landscapes, bioregions and biomes. Most appropriately assessed as diversity of habitats and ecosystems on a local or regional basis.[c)]
Influence of plantation establishment and management	• Influences both cultivated species as well as native flora and fauna in the plantation area; • Gene pool of cultivated species manipulated by man (e.g. provenance selection); • Changes in the natural environment, such as fragmentation, affects processes maintaining genetic diversity of native flora and fauna (random genetic drift, selection, migration and mating).	• Strongly dependent on the initial conditions for plantations establishment; • Low diversity and richness in cultivated areas due to one or a few cultivated species; • Potential increase in species richness towards the end of the rotation due to recruitment of new species; • Low species abundance due to dominance of cultivated species; • Potential for high species richness and abundance in remaining native forest fragments between the plantation blocks.	• Highly dependent on initial conditions for plantation establishment, plantation design and layout; • May increase ecosystem diversity (e.g. afforestation of *Imperata* grasslands) or decrease it (e.g. conversion of native ecosystems into a plantation).

a) Namkoong et al. 1996
b) Bisby 1995
c) Heywood and Baste 1995

The Convention on Biological Diversity recognises three principal levels of biodiversity: ecosystems, species and genes (UNEP 1992, Heywood and Baste 1995). Variation among these levels can be described in terms of various concepts; in the case of species, for instance, these are richness, abundance and function (Table 1). In addition, there are complex sets of structural and functional relationships within and between the different levels (Heywood and Baste 1995).

The establishment and management of forest plantations affects all levels of biodiversity. The levels and some examples of these effects are shown in Table 1.

The current understanding of the generation, maintenance and loss of biodiversity (see e.g. Schulze and Mooney 1993, Barbault and Sastrapradja 1995, McNeely et al. 1995, Mooney et al. 1995, Stork et al. 1996, Tilman 2000) recognises certain factors as essential for biodiversity conservation and management. Globally accepted strategies for biodiversity management and conservation, such as the *ecosystem approach* (for description see CBD 2005a), are based on this current understanding and are applied for instance in the conservation and management of forest biodiversity (for examples of applications see e.g. CBD 2005b).

Some characteristics of the key elements are emphasised in the establishment and management of forest plantations. These elements were chosen as important factors in plantation context, and are presented – together with the effect of plantations on them – in Table 2.

These key elements represent different aspects of the interacting properties of biodiversity. They can be observed as processes (human-induced or natural, e.g. threat of extinction or invasions), as factors acting in the processes (e.g. keystone species or functional groups) or as impacts/outcomes of the process (e.g. habitat degradation). The occurrence of factors and impacts/outcomes indicates past or present occurrence of the processes.

The presence of the key elements is expressed by indicators (Table 2). In this context, the term 'indicator' is used broadly; it may be an input, process or output parameter (Lammerts van Bueren and Blom 1997). It is likewise in the nature of the indicators – as in that of the key elements – that they are highly inter-connected and interdependent. This is illustrated by the following example (indicators in italics): an *endemic species* may also be a *keystone species*, and may become a *threatened species*, due to competition by *invasive species* or *change in the quality of habitats*, which in turn cause changes in ecosystem processes, such as *nutrient cycle* and *water quality*.

Some characteristics of the key elements are emphasised in the establishment and management of forest plantations. The key elements are also unavoidably affected by plantation activities (Table 2).

3 Ecological Coverage of Standards and Guidelines

The ability of standards and guidelines to address the three basic levels and the key elements of biodiversity is essential for biodiversity conservation and management. In the following an analysis is presented of the extent to which the standards and guidelines cover the levels and the key elements of biodiversity shown in Tables 1 and 2. It is emphasised that the purpose of the analysis is not to rank standards and guidelines in order of superiority; this would be meaningless due to the varying nature of the sets. In addition, the analysis focuses on only a single aspect (i.e. biodiversity) of sustainable plantation management.

3.1 Methods

We screened the principal standards and guidelines for sustainable forest management and selected for the analysis those sets which fulfilled the following criteria: (i) the standards and guidelines are targeted at forest plantations; (ii) they cover the tropics and/or subtropics (as defined in FAO 2000), where most new plantations are established; (iii) if the standards are part of a forest certification scheme, they are endorsed and the scheme is in use; and (iv) the guidelines are not restricted to a particular plantation type. Since the guidelines are often developed for very specific purposes/circumstances and thus address only a

Table 2. Key elements of biodiversity, their indicators and influence on them of plantation establishment and management.

Key element	Indicator	Characteristics in the plantation context and influence of plantation establishment and management
Habitat degradation	Loss, change in quality and fragmentation of habitats	• Strongly dependent on initial settings for plantation establishment, plantation design and management; • Loss of habitats due to their replacement by a plantation; • Potential decrease of fragmentation if plantation increases connectivity between forest remnants; • Potential indirect increase in degradation if land-use in adjacent areas is intensified.
Endemism (presence of restricted-range species)	Long-term persistence of endemics within the plantation boundaries/area of influence	• Restricted or local endemism of particular importance; • May indicate area generally rich in species[a)] and used as a criterion in the selection of areas; • Risk for loss or fragmentation of critical habitats, or disturbance of processes creating and maintaining suitable habitats.
Rare and threatened species	Long-term persistence of rare and threatened species within the plantation boundaries/ area of influence	• Increased risk of extinction if plantation replaces critical habitat types or increases fragmentation; • May indirectly increase pressure of hunting or collection in adjacent areas.
Invasions and introductions	Control of invasive and introduced species	• Majority of plantations in the tropics and subtropics established with exotics[b)]; • Potential source of invasive species; • Risk of disturbance of ecosystem processes; • Numerous examples of invasions, relatively little documentation from plantations[c)].
Interactions among organisms	Maintenance of keystone species and functional groups	• Crucial for the well-being of cultivated species and adjacent ecosystems, e.g. pollinators, mycorrhizas and termites; • Elimination of a harmful competitor, like *Imperata* spp., as a keystone species and promotion of forest regeneration.
Spatial and temporal variability of ecosystems	Imitation of effects of natural disturbances, maintenance of keystone ecosystems	• Modification of natural disturbance regimes; • Potential imitation of natural disturbances e.g. by maintaining the vegetation cover of different successional stages at the natural proportions; • Risk of loss of keystone ecosystems, if not identified and protected prior to plantation establishment; • Potential for designing and managing a plantation to buffer keystone ecosystems.

Key element	Indicator	Characteristics in the plantation context and influence of plantation establishment and management
Ecosystem processes	Maintenance of decomposition and nutrient cycling, maintenance of quality and quantity of water	• Alteration of natural flows of water in the plantation and adjacent ecosystems; • Effects of soil cultivation, burning, fertilisation and inputs of new plant compounds from exotics to decomposition.
Rehabilitation and restoration		• Fast-growing plantations; potential means for catalysing succession processes in degraded areas; • May create favourable conditions for rehabilitation/restoration of native ecosystems within the plantation area by stabilizing land use and/or providing technical and financial incentives.

[a] Hawksworth and Kalin-Arroyo 1995
[b] Evans and Turnbull 2004
[c] Richardson 1998

Table 3. Standards and guidelines included in the analysis.

Standard/guidelines (Abbreviation)	Type	Reference
Guidelines Shell/WWF Tree Plantation Review (SH)	Guidelines	Guidelines Shell/WWF… 1993
ITTO guidelines for the establishment and sustainable management of planted tropical forests (IP)	Guidelines	ITTO 1993a
Linking C&I to a code of practice for industrial tropical tree plantations, CIFOR (CI)	Scientific	Applegate and Raymond 2001[b], Poulsen and Applegate 2001
The Australian Forestry Standard (AFS)[a]	Forest certification	AFS 2003a, 2003b[b]
Sistema Brazileiro de Certificação Florestal, CERFLOR – Forest Management – Principles, Criteria and Indicators for Planted Forests (CE)	Forest certification	ABNT 2004
Sistema de Certificación de Manejo Forestal Sustentable, CERTFOR – Standards (CT)	Forest certification	CertforChile 2004
Forest Stewardship Council Principles and Criteria for Forest Stewardship (FSC)	Forest certification	FSC 2004
Lembaga Ekolabel Indonesia – Sustainable plantation forest management (SPFM) system (LEI)	Forest certification	LEI 2005a, 2005b[b]

[a] Applicable to all forest types for wood production. Informative supplement (AFS 2003b) to guide application of the standard in medium and large-scale plantations.
[b] Supplements to the standards. Included in the analysis.

limited range of issues in plantation establishment and management, we selected only general guidelines for the analysis as indicated in the fourth criterion. The sets of standards and guidelines selected are shown in Table 3.

Two main approaches were applied in the analysis. First, the relevant elements from each standard or guidelines were assigned to the categories listed in Section 2 above, regardless of their number or of how well they address the primary objectives of the category. In this context "element" refers to a principle, criteria or indicator of a standard or a recommendation of guidelines. This approach assumes that the set as a whole will cover the category if one element, even a weak one, is included. Secondly, the elements categorised were rated (scoring from 1 to 3) according to how well they address the primary objectives of the category. The rating was based on authors' judgement and the highest score was given if the element(s) covered all aspects of the category. The rating was carried out in two phases. In the first phase, the element was rated independent from the scores of other standards/guidelines in that category. In the second phase, the elements and their scores were compared within the category and the scores were adjusted (if found necessary). This assures consistency of rating. If a category included several elements of one set (as was the case with many sets), it was rated according to how well the elements, as an entity, address the primary objectives of the category. The second approach enables a qualitative comparison of the standards and guidelines.

This method of categorization means that a single given element can be assigned to several categories, if it covers multiple aspects of biodiversity. If the elements dealing with the same topic represented different hierarchical levels (for instance a principle and an indicator), the level applied was the most informative one.

Table 4. Coverage by standards and guidelines of levels of biodiversity as adopted and used in Convention of Biological Diversity (score: 1 good, 2 fair, 3 poor).

Initiative[a)]	Within-species	Species	Ecosystems
SH	2	2	2
IP	2	2	2
CI	2	1	1
AFS	1	1	1
CE	2	2	2
CT	2	2	2
FSC	1	2	1
LEI	2	2	2

[a)] Abbreviations, see Table 3

3.2 Results

The Australian Forestry Standard (AFS) and the *Forest Stewardship Council Principles and Criteria for Forest Stewardship* (FSC) were the only sets which explicitly addressed all three levels of biodiversity. The other sets implicitly assumed that biodiversity at all levels is conserved and maintained if the standards were followed. In practice, however, differences in the standards will result in variation in the maintenance of the levels of biodiversity. The coverage of the three biodiversity levels is summarised in Table 4.

The genetic level was explicitly addressed by the *ITTO guidelines for the establishment and sustainable management of planted tropical forests* (IP), AFS and FSC. Most of the sets implicitly covered the genetic diversity of either cultivated or uncultivated species. Both species types were mentioned only by the *Guidelines, Shell/WWF Tree Plantation Review* (SH) and the FSC. *Sistema Brazileiro de Certificação Florestal, CERFLOR* (CE) required a programme for continuous assessment of alternative genetic materials. The processes maintaining genetic diversity were implicitly and to a varying extent included in all sets except the IP, *Sistema de Certificación de Manejo Forestal Sustentable, CERTFOR* (CT), and *Lembaga Ekolabel Indonesia* (LEI).

The species level was explicitly addressed by all sets except for the SH and CE. The AFS mentions assessment of species abundance where applicable; otherwise the sets did not distinguish between species richness and abundance. None of the sets took taxic and functional diversity into account. The standards dealt primarily with the species diversity of forest ecosystems; potential other ecosystems within the plantation area were not brought out except by the AFS, which in its identification of biodiversity values included

Table 5. Coverage by standards and guidelines of key elements of conservation and management of biodiversity in tropical forest plantations (score: 1 good, 2 fair, 3 poor, no indication if not covered).

Initiative[a]	Key element (*indicator*)							
	Habitat degradation (*loss, change in quality and fragmentation of habitats*)	Endemism (*persistence of endemic species*)	Rare or threatened species (*persistence of rare or threatened species*)	Invasions and introductions (*control of invasive and introduced species*)	Interactions among organisms (*maintenance of keystone species and functional groups*)	Spatial and temporal variability of ecosystems (*imitation of effects of natural disturbances, maintenance of keystone ecosystems, other*)	Ecosystem processes (*maintenance of decomposition and nutrient cycling, maintenance of quality and quantity of water, other*)	Rehabilitation and restoration
SH	2		2	2		1	1	3
IP	2		2	2	3	2	2	3
CI	1		1			2	1	3
AFS	2	2	1	1		1	1	3
CE	2		1	1		2	1	2
CT	2		1	2		2	1	3
FSC	2		1	1		1	1	2
LEI	2		2			3	1	3

[a] Abbreviations, see Table 3

aquatic flora, fauna, and wetlands under the Ramsar Convention.

The ecosystem level was implicitly and to a varying extent covered by all sets. The IP, *Linking C&I to a code of practice for industrial tropical tree plantations, CIFOR* (CI), AFS and FSC dealt with the concept of ecosystem/habitat diversity directly, but differed in their scope.

The key elements of biodiversity were handled in different ways by the different sets of standards. The formulation of standards varied from specific and often process-based or hybrid standards, such as the AFS, to general ones, such as the FSC. However, the specificity of the standards did not necessarily indicate how well they capture the key elements. The results of the analysis are summarised in Table 5.

None of the sets took into account all dimensions of habitat degradation (loss, change in quality and fragmentation). The prevention of habitat loss was implicitly included in protection statements in all sets. They also considered the conversion of natural forests into plantations to be an inappropriate action, with the exception of the IP and AFS, which allowed conversion under special cases, and the CI and LEI, which did not refer to the issue. Changes in habitat quality were included directly in the AFS, CT, FSC and LEI, and indirectly in the CI. Furthermore, the AFS and FSC included requirements for the monitoring of conservation values, the CT and LEI required supervision of changes in protected areas, and the CE the monitoring of biological resources of natural ecosystems. The CI required monitoring of the conformity of forest management activities with a landscape level plan. Fragmentation was covered in detail by the CI. The SH, AFS, CT and FSC dealt with the issue but in a more general manner. Wildlife corridors were generally perceived as a measure mitigating the effects of fragmentation.

Endemism was taken into account only in the AFS, which refers to centres of endemism as areas posessing significant biodiversity value and needing to be protected.

The long-term persistence of rare or threatened species was included explicitly in statements on habitat protection. The CI, AFC, CE, CT and FSC had separate indicators/criteria dealing with the protection of rare and threatened species.

Invasions and introductions were covered to a varying degree of specificity by all sets except for the CI and LEI. Monitoring of the spread of introduced species was included in the AFS, CE and FSC, but controlling/eradication measures only in the AFS and FSC. The SH, IP and FSC recommended that native species be preferred as plantation species.

Interactions among organisms were implicitly included only in the IP, which dealt with trees only.

All sets took a relatively static approach toward the maintenance of spatial and temporal variability of ecosystems. In general, the establishment of protected areas was considered a sufficient measure to guarantee variability of ecosystems. Keystone ecosystems – which contribute to variability and help maintain other key elements over time – were included to a varying extent in the protected areas of all sets. None of the sets, however, addressed the maintenance of spatial and temporal variability of ecosystems directly by maintaining/creating natural disturbance regimes, for instance within protected areas. The AFS included a criterion for this issue, but it was limited to the management of natural forests only. To increase variability, the SH and FSC recommended modification of plantation structure in harvesting and the AFS a range of age classes at the regional scale.

All sets included technical measures, such as those related to site preparation and road construction, for soil and water protection. However, only the CI and AFS placed these measures in a context of ecosystem processes and indicated their importance in these processes.

Rehabilitation and/or restoration were dealt with directly by the CE, FSC and LEI. The CE and LEI included requirements for the restoration/rehabilitation of degraded protected areas. In the FSC, restoration was part of the management objectives of the plantation. The sets dealt primarily with the restoration of forest ecosystems; potential other ecosystems within the plantation area were not mentioned. In the CI, AFS and CT rehabilitation/restoration requirements covered only those areas – such as log landings or extraction tracks – where soil/vegetation has been damaged by plantation operations.

4 Discussion

The results of the analysis indicate that standards and guidelines cover some key elements of biodiversity comprehensively, while other elements are ignored or receive very little attention. The three levels of biodiversity were explicitly addressed by two sets only. Political processes, such as the MCPFE, the Montreal Process and the Tarapoto Proposal (see e.g. Granholm et al. 1996), form a basis for some trade initiatives, which is reflected in their overall structure. However, there are conspicuous differences between all standards and guidelines e.g. in the nature (process- vs. performance-based), congruity in concepts and hierarchy, and specificity – all of which are expected to affect their applicability and their ability to capture the key elements.

The analysis has limitations which should be taken into account in interpreting the results. Selection of different key elements would give different results on the coverage of the standard. However, the differences within and between the standards are expected to remain visible. The rating of the elements is based on expert judgement which is a commonly used method in many fields (Meyer and Booker 2001). It is, however, subjective in nature and the results may change through the time, assessors and type of the analysis. It is likely that repeated rating of the elements could lead to slightly different scores. Due to the great heterogeneity of the standards and guidelines the scoring should not be used for ranking the standards in order of superiority. Consequently, the potential slight variation in scoring due to the selected method is considered insignificant and is not expected to influence the overall coverage of each category. The nature of the standards also limits the feasible methods to simple and relatively robust. More sophisticated methods, such as multi-criteria analysis (Mendoza et al. 1996), were not considered suitable for the purposes of this study.

In reality, plantations are established and managed in various initial settings; the question consequently arises of how the heterogeneous standards take these variable settings into account. To answer this question, we present three common scenarios, with their variations, for the establishment of industrial-scale fast-growing plantations: reforestation, afforestation and conversion. Afforestation and reforestation are also included as eligible land use activities for reduction of greenhouse gases in the Kyoto Protocol, although the rules of the Clean Development Mechanism (CDM) largely prevent using industrial fast-growing plantations as carbon sinks under the Protocol (UNFCCC 2005, 2006). We also discuss critical factors for biodiversity conservation and management, and how they are addressed by the standards and guidelines under each scenario.

A significant proportion of tropical and subtropical plantations have been established by "reforesting" degraded forest areas, where the remnants of original habitats, such as forest islands, riparian forests and wetlands, are still found (Evans and Turnbull 2004). The persistence of these remnants is usually attributed to their social, cultural or economic importance for the local community (Halladay and Gilmour 1995). Such conditions are commonly found in prominent plantation regions in Southeast Asia (e.g. Thailand, Malaysia and Indonesia) and South America (e.g. eastern Brazil).

Crucial to biodiversity conservation under such conditions is preventing further habitat degradation and securing the long-term viability of the remnants. At the landscape level, this would require an increase in connectivity between the remnants by plantation layout (i.e. reducing fragmentation) and securing the spatial and temporal continuity of different ecosystems. The remnants are often susceptible to degradation, due for instance to the edge effect, invasions, changes in hydrology or intensive exploitation; this requires mitigation measures at the local level, such as buffering or rehabilitation. Also needed, in order to guarantee the long-term viability of remnants, is the identification of keystone species and key functional groups and the ensuring of their persistence.

The overall approach and wording of most of the standards and guidelines suggest that they have been developed primarily for situations of reforestation, in areas where remnants of the original habitats are still found. In general, the standards and guidelines capture important factors, such as plantation design and layout in the landscape and protection of keystone ecosystems. However, there is substantial variation in the extent to which they deal with these factors, which increases the responsibility of plantation operators for protection of biodiversity.

Tree plantations have been successfully developed by "afforesting" marginal lands, such as *Imperata* grasslands of Southeast Asia, where native vegetation has been heavily degraded for decades (Turvey 1994, Otsamo 2000). These strongly human-induced areas have little or no original biodiversity left and limited use for agricultural or other purposes. In South Africa and parts of South America (e.g. the Rio de Plata region in southern Brazil, Uruguay and Argentina), "afforestation" has taken place in native grasslands. A majority of the South American Rio de Plata grassland, for instance, has been taken for rangelands and converted to agriculture since the 19th century; tree plantations have become an important land use form within the past decades (Soriano 1992). Unlike the *Imperata* grasslands, these native grasslands – if left undisturbed – harbour significant biodiversity values (Bilenca and Minarro 2004). The objectives for biodiversity management and conservation are thus significantly different in these two cases of grassland afforestation.

In reforestation of degraded lands the primary purpose of biodiversity management is to restore the structure and functions of native ecosystems or rehabilitate their elements in the set aside areas. A prerequisite for successful restoration is the treatment of the factors which have led to degradation (Lamb and Gilmour 2003). At the landscape level, design and layout of plantation and protected areas should support restoration targets and ensure the spatial and temporal continuity of ecosystems. Identification and reintroduction of keystone species and functional groups is pivotal for restoring ecosystem functions. Heavily degraded areas may be susceptible to invasions, particularly of pioneer species.

The standards and guidelines pay surprisingly little attention to restoration/rehabilitation of degraded ecosystems. Important aspects in restoration/rehabilitation, such as objectives, processes, techniques and interactions among organisms were omitted. It is worth noting that the sets pay attention to plantation design and layout, which is an important component in *forest landscape restoration* (ITTO and IUCN 2005).

However, these criteria are not designed to contribute to landscape restoration *per se*, but rather to prevent further degradation of ecosystems by plantation operations.

From the ecological point of view, the afforestation of native undisturbed grasslands and the conversion of intact or degraded primary forests present similar challenges to plantation management. The latter is still a rather common though controversial activity especially in Southeast Asia (Sunderlin and Resosudarmo 1996, Rudel et al. 2000). In both cases the elements of the original biodiversity may still be abundant and plantation development requires identification and protection of these elements. This brings into picture new elements of biodiversity, such as endemism and threatened species or habitats, which may have regional or even global importance. In general, the critical factors focus on maintaining the integrity of ecosystems and integrating the plantation into the landscape by minimising the negative impact. This would require, among other measures, the prevention of loss, of changes in quality and of ecosystem fragmentation, the maintenance of key interactions among organisms, and the securing of natural disturbance regimes.

Majority of standards and guidelines consider the replacement of natural forest by plantation as an inappropriate action, unless the forest is so severely degraded that its survival is in doubt. Surprisingly, a majority of the standards do not take a position on the conversion of other types of native ecosystems, such as grasslands or wetlands. The revision of some standards to include all valuable ecosystems, not only forests, is currently being debated (FSC 2005).

In some cases plantations are established in areas where virtually no original biodiversity values are left due to high population density and the intensive use of land, e.g. for agriculture, over centuries. Such situations are common in temperate regions, but are also found in the tropics and subtropics, for example in Java and Southern China respectively. Under such conditions the cost-benefit ratio of conventional measures of biodiversity management, such as protection and/or restoration activities, may be low. In this situation, a better outcome could be gained by implementing conservation/restoration measures in other areas, where the biodiversity value is high. The current standards and guidelines do not include an option for *biodiversity offsets* (see e.g. ten Kate et al. 2004), which – in some cases – would increase flexibility and yield better "net benefits" to biodiversity.

5 Conclusions

The special characteristics of forest plantations render necessary the differentiation of standards and guidelines between plantations and natural forests. In addition, as we have seen, there is considerable variation in plantation types and in the initial settings for their establishment, and consequently in the objectives and critical factors in biodiversity conservation and management. This creates a need for the development of standards and guidelines to meet the specific requirements of different circumstances. Currently, these circumstances are only partially covered by the principal operative standards and guidelines for tropical and subtropical forest plantations.

A trend toward the development of local/region-specific standards is found in the management of natural forests, where the variety of operating environments is even greater than in the case of plantations. Although standards and guidelines are designed to be applied at an operational level, they need to be strongly linked to the elements which generate and maintain biodiversity in a landscape context.

Operative standards and guidelines are mainly used by forest managers and certification bodies. The extent to which they adopt biodiversity standards and guidelines as an instrument assisting plantation management depends primarily on whether the objective of biodiversity management is in accordance with the other objectives of plantation management, and whether the standards and guidelines fulfil certain important attributes, such as relevance, clarity and applicability (see e.g. Prabhu et al. 1996b).

Current standards and guidelines (both for plantations and natural forests) treat ecological and social (as well as cultural) aspects of sustainable forest management independently. However, both aspects are intricately interlinked and play a considerable role in biodiversity conservation and management. Future research is needed to examine these relationships in a plantation context and to modify standards and guidelines accordingly. Further efforts are also needed to resolve conceptual discrepancies between the different sets.

To conclude: standards and guidelines (whether for biodiversity or for other aspects of sustainable plantation management) should not be considered as cast-iron measures of sustainability or instructions for achieving it. They should be seen as evolving tools in an adaptive management system, with the ultimate aim of sustainable plantation management.

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