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# Comparing the biodiversity impacts of timber and other building materials



# Comparing the biodiversity impacts of timber and other building materials

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by

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# Publication: Comparing the biodiversity impacts of timber and other building materials

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# Table of abbreviations

Australian Building Codes Board
Australian Collaborative Land Use Mapping Program
Australian Land Use and Management
Building Code of Australia
Environment Protection and Biodiversity Conservation
Global warming potential
Interim Biogeographic Regionalisation for Australia
Intergovernmental Panel on Climate Change
World Conservation Union
Life cycle assessment
Life cycle inventory analysis
Life cycle impact assessment
National Forest Inventory
National Land and Water Resources Audit
Ozone depletion
Vegetation Assets, States and Transitions

# Executive summary

The sustainability requirements of building codes in Australia and other countries are becoming increasingly stringent. To date, legislated requirements in Australia have largely been restricted to the operational energy used in buildings and water use efficiency. However, it is likely that the Building Code of Australia (BCA) will address other environmental concerns in the future and that life cycle assessment (LCA) methodologies will play a prominent role in shaping regulations applying to Australian buildings (DEH 2006).

This report explores means of including the biodiversity impact of land use, such as forestry, agriculture, mining, and industrial and urban development, in life cycle assessments of buildings, building materials and other products. It aims to provide a framework for dialogue between the different professions involved in this process: ecologists, LCA practitioners, government, design professionals and industry. It examines:

- key concepts and terms
- Life Cycle Assessment processes
- Issues in incorporating land use impacts on biodiversity into LCA.

#### Key terms and concepts

#### Land use

The term 'land use' generally refers to the purpose to which land is committed. It includes the function the land is put to, the practices pursued in achieving that function and the products produced by the land use. 'Land management practice' is the approach taken to achieve a given land use outcome. For the purposes of LCA, land categories should be defined according to land management practices, as it is land management practices that cause environmental impacts, not the purpose of land use per se or the type of products produced. In this report, any use of the term 'land use' implies the use of the land under particular land management practices.

Within the LCA literature, a distinction is often made between 'land use' in 'mancontrolled cultures' and the 'extraction of biotic resources' from the 'natural environment' (Lindeijer et al. 2002). The two activities are then often assessed in different ways. This makes meaningful comparison of the relative impacts of different products and processes difficult. Clearly, as shown in Figure E1, there is a gradient of land management categories, rather than a distinct boundary, between those highly modified by human activities and those not substantively modified by such activities. The system boundary of any LCA examining the impacts of land use on biodiversity should include all forms of land management that contribute significant inputs to the processes or products under investigation.



A national park where human interventions in ecosystem processes are minimal.

A *Eucalyptus nitens* plantation in Tasmania with a 20–30 year rotation.

An industrial plant where human interventions in ecosystem processes are continuous.

#### Figure E1: Examples of different land uses and management practices

#### Biodiversity

The United Nations Convention on Biological Diversity (UN 1992) defines biological diversity (biodiversity) as:

the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

There are two widely accepted reasons for conserving biodiversity: to maintain the intrinsic value of biodiversity, and to meet the current and future needs and wants of humanity (DEST 1996; SCBD/UNEP 2000). Biodiversity underpins human wellbeing through the provision of ecological services.

Land use is one of many threats to biodiversity caused by human activity. Direct impacts of human land management practices may include the removal and ongoing repression of indigenous species, introduction of alien species, fragmentation of remnant vegetation and land/soil degradation. Other threats to biodiversity, which are also often associated with land use, include the release of toxins, nutrients and greenhouse gases into the environment, and the alteration of fire regimes.

#### Products and resources

Natural resources are used to produce products that meet human needs. Natural resources can be categorised in a number of different ways: biotic or abiotic, renewable or non-renewable, or of a flow, fund or deposit type (Heijungs et al. 1997; Lindeijer et al. 2002). Although not synonymous, there is a high degree of association between biotic, renewable, and fund and flow type resources and between abiotic, non-renewable and deposit type resources.

Biodiversity at the species and genetic level can be viewed as a resource required for the production of biomass. In this sense, species and genetic biodiversity can be viewed as information rather than physical material. This information can theoretically be used without depletion but, if lost, through the extinction of species or genes, it cannot be replaced.

Ecosystems differ from biodiversity at the species and genetic levels, as ecosystems represent an interaction between organisms and the environment in which they live (Abercrombie et al. 1992). Ecosystems are dynamic and can theoretically re-establish themselves, assuming appropriate species and genes are maintained elsewhere. However, with the loss of all examples of any given ecosystem there is a high risk of permanent loss of species and genetic diversity. Accordingly, it is arguable that an ecosystem, like a species or gene, should be viewed as a non-renewable or deposit resource.

Land itself can be viewed as a resource and an input into LCA and biodiversity can be viewed as a quality of the land on which it resides. The land resource is diminished with any reduction in the 'quality' of land and in this sense land should be viewed as a non-renewable or deposit resource. The degradation of land with relatively scarce qualities may be regarded as being more damaging than degradation of land with relatively common qualities.

#### Life Cycle Assessment

LCA studies the environmental aspects and potential impacts of a product throughout its life (i.e. cradle-to-grave) from raw material acquisition through to production, use and disposal. LCA differs from other approaches to environmental assessment, as it is a relative approach based on a functional unit. A functional unit is a quantified measure of the function of the product (e.g. 100 m<sup>2</sup> of floor covering or a 200 m<sup>2</sup> house) that may comprise different products produced utilising different processes, which in turn may require different inputs and produce different outputs.

The first phase in an LCA is to define the goal and scope of the study. The second phase, life cycle inventory analysis (LCI), entails data collection, data validation and the process of relating data to functional units. The third phase, life cycle impact assessment (LCIA), aims to quantify the importance of the environmental interventions quantified in the LCI output and aggregate these into a small number of indicators (in some cases one). The final phase is interpretation where LCA practitioners evaluate the study, draw conclusions and make recommendations, taking into account both quantitative results produced by the LCI and LCIA, and qualitative issues. Issues such as the sensitivity of results to assumptions, the effects of value choices and data quality may be addressed.

#### Limitation of LCAs

Although LCA is a powerful tool for comparing the environmental impacts of different products and processes, it has inherent limitations. LCAs incorporate trade-offs between the practicality of data capture and processing, and the certainty and meaningfulness of conclusions. LCAs never represent complete assessments of all environmental issues and value judgements are difficult to avoid in all phases of LCA.

LCIA typically excludes spatial and temporal information. However, the manner in which issues of space and time are dealt with can substantially affect the conclusions of an LCA. This is particularly pertinent when the impacts of renewable and non-renewable resources are being compared in an LCA, as their relative impacts are highly dependent on temporal and spatial scales.

#### Incorporating land use impacts on biodiversity into LCA

#### Land management categories

At the LCI level, it is theoretically possible to include separate entries for each of the elemental activities that comprise a land management practice. However, the allocation of areas to land management categories is an alternative and more practical approach (Lindeijer et al. 2002). Land management categories utilised in LCA should represent areas that have similar impacts on biodiversity.

There are a number of issues surrounding the allocation of areas to land management categories that must be considered including land tenure versus land management practice; notional land use versus actual land use; accounting for past land use; and the available land data. Existing land management frameworks exist. The hierarchical nature of the Australian Land Use and Management (ALUM) classification framework makes it a highly suitable base from which to develop more detailed classifications of the Australian land mass based on land management practices.

#### Allocating inputs to land management categories

In most cases, raw materials used to produce a functional unit will have been sourced from a number of potentially very different land management zones. Land management impacts on biodiversity must be allocated to each of these materials. In some instances, data on the origins of materials are likely to be severely limited making the process of allocating inputs to land management categories difficult.

The quantification of yield of outputs per unit of land is central to any LCA incorporating land use, as it is required to estimate the area of land required to produce a functional unit. However, yields can fluctuate over time and space. For the purposes of the LCA, it will likely be necessary to assume that outputs per unit of time are fixed within each land management zone over time.

#### Measuring biodiversity

Substantial effort has been devoted to the development of surrogate indicators of biodiversity in Australia to enable monitoring of biodiversity through time and to assess performance against publicly agreed and legislated biodiversity conservation priorities. Biodiversity indicators have been developed for application across a range of

spatial scales, from national to local. For example, indicators at the IBRA bioregion scale (DEWHA 2007g) include:

- The percentage of threatened ecosystems and other ecological communities identified across bioregions
- bioregions of high relictual fauna value
- relative importance of bioregions to threatened bird taxa
- total number of threatened species by subregion as per State and Territory listings (Sattler and Creighton 2002)

However, new or modified indicators may be required if land use impacts on biodiversity are to be meaningfully and practically assessed within an LCA framework. Ideally such indicators would be developed using expertise and data assembled for other biodiversity reporting purposes.

#### Transformation, occupation and relaxation

One means of assessing land use impacts on biodiversity is to distinguish between transformation, occupation and relaxation (renaturalisation) processes, where transformation is the change from one land use to another, occupation is the use of an area of land for certain human-controlled purpose after transformation, and renaturalisation is based on abandonment or regeneration of an area of land.



#### Figure E2: Transformation, occupation and relaxation on a given area of land.

The threat that a land use poses to the ongoing existence of biodiversity is highly dependent on the place in which that land use occurs. Many land uses have an impact on biodiversity disproportionate to the surface area they occupy because they require the same environmental attributes as particular ecological communities and/or species. It is arguable that transformation and occupation impacts are only important if they result in a permanent depletion of biodiversity or increase the risk of a permanent depletion of biodiversity. However, the manner in which land use impacts on biodiversity are judged should be aligned with national biodiversity conservation priorities and/or the views of a broad range of stakeholders rather than the value systems of individual LCA practitioners.

The incorporation of transformation, occupation and relaxation models into an LCA framework is not straightforward. If such models are to be utilised in LCA a reference state must be defined, from which the magnitude of land use impacts on biodiversity can be assessed. However, there are both theoretical difficulties in defining an appropriate reference state and practical difficulties in measuring divergence from any current—let alone past or future—reference state.

#### Accounting for occupation and transformation impacts

#### Occupation impacts

Although there are a number of different ways in which the occupation impact of a land use can be viewed, we propose that it should be viewed as the 'opportunity cost' of not allowing renaturalisation to occur (See Figure E3). The occupation impacts of land use on biodiversity can be considered a function of the units of land used, the

conservation status and/or irreplaceability of the ecosystems, species and genes affected by it, and the current renaturalisation potential.

An easily implemented approach to incorporating land use impact on biodiversity into LCA would be to use an indicator or combination of indicators, of the conservation status and/or irreplaceability of biodiversity within broad ecosystem-based zones and exploit generic indicators of renaturalisation potential for land management categories. Existing Australian frameworks include the Interim Biogeographic Regionalisation for Australia (IBRA) (Environment Australia 2000; DEWHA 2007g) and the Vegetation Assets, States and Transitions (VAST) frameworks.

For example, the VAST framework could be used as a generic indicator of the renaturalisation potential of land management zones and the percentage of threatened ecosystems within IBRA bioregions could be adopted as a measure of the conservation status of biodiversity where land use occurs. In this case, the output of the LCI would record the area required per functional unit by VAST class and IBRA bioregion, grouped by the percentage of threatened ecosystems (Table E1).

e	grouped by the percentage of threatened ecceptioner							
Land management	Vast class of land	Percentag bioregion	e of threa	tened ecos	systems wi	thin IBRA		
zone	category	0-20	20-40	40-60	60-80	80-100		
	Type VI							
	Type V							
А, В	Type IV					10		
C, D, E	Type III	40	20	10				
	Type II							
	Туре І							
	Type 0							

Table E1: Meters squared required per functional unit by the VAST class of land management zones and IBRA bioregions in which land use occurs, grouped by the percentage of threatened ecosystems.

Alternatively, instead of using a previously developed categorical indicator of renaturalisation potential, a series of quantitative indicators could be developed. The identification of specific indicators would need to be undertaken by technical experts utilising experience gained in the development and application of biodiversity indicators for other purposes.

In addition to, or instead of, examining impacts of land use at a landscape scale, land use impacts on individual ecological communities, species and other 'special values' should be assessed if the true impacts of different land uses are to be meaningfully compared.

#### Transformation impacts

We propose that transformation impacts should be judged according to the extent to which transformation results in a permanent depletion in renaturalisation potential, and the conservation status and/or irreplaceability of biodiversity impacted upon. For the sake of consistency, accounting for transformation impacts on biodiversity should be undertaken using a similar framework used to assess occupation impacts.

In the case of the extraction of non-renewable resources, transformation impacts can be relatively easily attributed to functional units. However, in the case of renewable resources, attributing transformation impacts to individual functional units causes substantial methodological difficulties. Theoretically, transformation impacts should be attributed to all subsequent resources produced as a result of the transformation process. In the case of renewable resources, assuming sustainable production, this could amount to an infinite number of functional units, because production is only limited by time.



Figure E3: Accounting for transformation impacts

We propose that contemporary transformation impacts be allocated to products produced in a land management zone according to current production levels across the entire land management zone and that transformation impacts associated with non-renewable and renewable resources be dealt with separately in the LCIA and interpretation phases of LCA. However, this approach would leave the LCA practitioner without a direct means of assessing the relative transformation impacts of renewable and non-renewable resources. One means of addressing this issue may be to assess the extent to which renaturalisation potential declines per year as a result of occupation for the production of renewable resources.

#### Global-scale LCAs

The goal and scope of individual LCAs will determine the extent to which land use impacts at a global scale need to be incorporated. It may be necessary to revert to general assumptions about the impacts of imported products in some instances.

#### Conclusion

Any approach to incorporating land use impacts on biodiversity into LCA should account for both the reversibility of impacts and the conservation status or irreplaceability of the biodiversity affected. The incorporation of these factors into LCA could utilise composite and/or elemental biodiversity indicators. In any case, the approach should be practical to implement and produce meaningful and easily interpretable results. To this end, it is likely that it will be necessary to make assumptions about the generic impact of land management categories on biodiversity and utilise contemporary data to limit speculation about past and future impacts. Both occupation and transformation land use impacts should be examined in LCAs as they both represent important impacts on biodiversity.

This report provides a framework for dialogue between ecologists, LCA practitioners, government and industry by identifying and discussing specific issues associated with the incorporation of land use impacts on biodiversity into LCA. It is clear that there are substantial impediments to the incorporation of these impacts into LCA in Australia as there is no universally agreed upon LCA method or suite of suitable biodiversity indicators. Furthermore, there is substantial variation in the scale at which relevant data is available.

Despite the many difficulties, by utilising experience gained in the development of biodiversity indicators for other purposes it should be possible to develop a meaningful and practical means of incorporating land use related impacts of building materials on biodiversity into Australian LCAs.

# 1. Introduction

The sustainability requirements of building codes in Australia and other countries are becoming increasingly stringent. To date, legislated requirements in Australia have largely been restricted to issues relating to the operational energy used in buildings and water use efficiency. However, it is likely that the Building Code of Australia (BCA) will address other environmental concerns in the future and that Life Cycle Assessment (LCA) methodologies will play a prominent role in shaping regulations applying to Australian buildings (DEH 2006).

This report explores means in which the biodiversity impact of land uses, such as forestry, agriculture, mining, and industrial and urban development, can be included in LCAs of buildings, building materials and other products. It aims to provide a framework for dialogue between the different professions involved in this process: ecologists, LCA practitioners, government, design professionals and industry.

# 2. Building regulations and voluntary schemes

## 2.1 Regulatory trends in Australia

The Building Code of Australia (BCA) aims to achieve and maintain acceptable standards of structural sufficiency, safety, health, amenity and, more recently, sustainability in Australian buildings (ABCB 2007). The Building Code of Australia is produced and maintained by the Australian Building Codes Board (ABCB) and has been given the status of building regulations by all states and territories.

The Federal Government's recent introduction, through the Building Code of Australia, of increased energy efficiency requirements for all buildings is indicative of a new focus on sustainability. Sustainability amendments at the state level have also been incorporated into the building code or enforced parallel to it. For example in Victoria, rainwater tanks, water efficient appliances/fixtures and/or solar hot water are requirements in all new homes.

To date, sustainability requirements within the BCA have been restricted to measures aimed at energy and water use. However, the Department of the Environment and Heritage recently commissioned a study to provide information to the ABCB on measures for improving the environmental sustainability of building materials (DEH 2006). The study used an LCA method and the resulting report examined a wide suite of potential indicators of environmental impact, including the area of land used for the production of building materials.

## 2.2 Trends in other countries

Sustainability requirements of building codes in other countries are also becoming more stringent. For example, a review of the New Zealand building code is in progress to ensure the NZ Building Code meets the requirements, purpose and principles of the new *NZ Building Act 2004* such as building safety, health, wellbeing and sustainable development (DBH 2004; DBH 2007). The most recent discussion document relating to this review considers the possibility of assessing the resources used by buildings through the carbon dioxide ( $CO_2$ ) emissions associated with their construction, operation, maintenance and demolition (DBH 2007). That is, a whole-of-life LCA approach with respect to carbon dioxide emissions may be included in their regulations.

# 2.3 Voluntary schemes

In addition to regulatory requirements, a large number of voluntary 'ecolabels' and environmental rating schemes and guides have been developed in recent years (Appendix 1). These schemes have been developed by a diverse range of groups and many are based on LCA methodologies. As with the BCA, most of these schemes currently limit their focus to environmental issues associated with building sites or the ongoing operation of buildings, such as water use, energy efficiency, toxicity and waste management. Most do not attempt to explicitly quantify the impacts of building materials on the environment in general or on biodiversity in particular. However, the possibility of including biodiversity metrics has been investigated by the developers of some of these schemes (e.g. NABERS; Vale et al. 2001) and it is likely that the range of environmental issues addressed by these schemes will increase with time.

# 3. Definition of key terms

## 3.1 Land use and land management practices

'Land use' refers to the purpose to which land is committed, such as food production, timber production, ore extraction, manufacturing, housing, recreation and/or biodiversity conservation. It includes the function the land is put to, the practices pursued in achieving that function and the products produced by the land use. A 'land management practice' is an approach taken to achieve a given land use outcome (e.g. farm cultivation practices, forest harvesting practices, etc) (BRS 2006b; Lesslie et al. 2006). For the purposes of LCA, land categories should be defined according to land management practices, as it is land management practices that cause environmental impacts, not the purpose of land use per se or the type of products produced. In this report, any use of the term 'land use' implies the use of the land under particular land management practices.

#### 3.1.1 Land use and the 'human' and 'natural environment'

Within the LCA literature, a distinction is often made between 'land use' in 'mancontrolled cultures' and the 'extraction of biotic resources' from the 'natural environment' (Lindeijer et al. 2002). Furthermore the environmental impact of resources extracted from 'man-controlled cultures' and the 'natural environment' are often assessed in different ways, making meaningful comparison of the relative impacts of different products and processes difficult. This approach effectively divides the Earth's surface into two land categories-natural and human environments-and requires an arbitrary boundary (i.e. the LCA system boundary) to be drawn between them. However, few if any, environments are unaffected by either human activities or natural processes. For example, the presence of an introduced species in a national park does not exclude the national park or introduced species from the natural environment, nor does the presence of a threatened species in an urban environment exclude that species or the 'urban environment' from the 'natural environment'. Clearly there is a gradient of land management categories, rather than a distinct boundary, between those highly modified by human activities and those not substantively modified by such activities (Figure 1). The system boundary of any LCA examining the impacts of land use on biodiversity should include all forms of land management that contribute significant inputs to the processes or products under investigation.



**a.** The Cradle Mountain–Lake St Clair National Park, Tasmania, where human interventions in ecosystem processes are minimal.



**b.** Multiple use forests, where human interventions in ecosystem processes may be intense but infrequent (e.g. 85–100 years). A recently clear-felled coupe and a regrowth forest are depicted.



**c.** A *Eucalyptus nitens* plantation in Tasmania with a 20–30 year rotation.



**d.** An intensive agricultural system where human interventions in ecosystem processes occur many times annually.



**e.** An industrial plant where human interventions in ecosystem processes are continuous.

Figure 1: Examples of different land uses and management practices

## 3.2 Biodiversity

The United Nations Convention on Biological Diversity (UN 1992) defines biological diversity (biodiversity) as:

the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Comparable definitions are adopted in the 2006 Australian State of the Environment Report (Beeton et al. 2006):

variability among living organisms from all sources (including terrestrial, marine and other ecosystems and ecological complexes of which they are part), which includes diversity within species and between species and diversity of ecosystems.

and the National Forest Policy Statement (Australian Government 1995):

a concept encompassing the diversity of indigenous species and communities occurring in a given region. Also called 'biodiversity', it includes 'genetic diversity', which reflects the diversity within each species; 'species diversity', which is the variety of species; and 'ecosystem diversity', which is the diversity of different communities formed by living organisms and the relations between them.

Biological diversity is the variety of all life forms – the plants, animals and micro-organisms – the genes they constitute, and the ecosystems they inhabit.

#### 3.2.1 Why is biodiversity important?

There are two widely accepted reasons for conserving biodiversity: to maintain the intrinsic value of biodiversity, and to meet the current and future needs and wants of humanity (i.e. to maintain human wellbeing) (DEST 1996; SCBD/UNEP 2000). Biodiversity underpins human wellbeing through the provision of ecological services such as the:

- provision of food, fuel and fibre
- provision of shelter and building materials
- purification of air and water
- detoxification and decomposition of wastes
- stabilisation and moderation of the Earth's climate
- moderation of floods, droughts, temperature extremes and the forces of wind
- generation and renewal of soil fertility, including nutrient cycling
- pollination of plants, including many crops
- control of pests and diseases
- maintenance of genetic resources as key inputs to crop varieties and livestock breeds, medicines and other products
- cultural and aesthetic benefits
- ability to adapt to change.

#### 3.2.2 Threats to biodiversity

Land use is one of many threats to biodiversity caused by human activity. Direct impacts of human land management practices may include the removal and ongoing repression of indigenous species, introduction of alien species, fragmentation of remnant vegetation and land/soil degradation, resulting in the permanent loss of environmental attributes required for the maintenance of indigenous biodiversity on that site. Other threats to biodiversity, which are also often associated with land use, include the release of toxins, nutrients and greenhouse gases into the environment, and the alteration of fire regimes (DEST 1996; Sattler and Creighton 2002).

## 3.3 Natural resources

Natural resources can be categorised in a number of different ways: biotic or abiotic, renewable or non-renewable, or of a flow, fund or deposit type (Heijungs et al. 1997; Lindeijer et al. 2002). Although not synonymous, there is a high degree of association between biotic, renewable, and fund and flow type resources, just as there is a large correspondence between abiotic, non-renewable and deposit type resources (Table 1). The use and extraction of natural resources are accounted for on the input side of life cycle assessments. Although the outputs of processes (e.g. toxic waste, nutrients, greenhouse gases etc) can also impact on natural resources (Figure 2), discussion of these impacts is beyond the scope of this report.

#### 3.3.1 Biodiversity as a resource

Along with abiotic matter (e.g. carbon, nitrogen, oxygen, and mineral ions), solar radiation, and a suitable climatic regime, biodiversity at the species and genetic level can be viewed as a resource required for the production of biomass. In this sense species and genetic biodiversity can be viewed as information rather than physical material (i.e. biomass). This information can theoretically be used without depletion (i.e. it can be viewed as a renewable or flow resource) but, if lost through the extinction of species or genes, it cannot be replaced (i.e. it can also be viewed as a non-renewable or deposit resource). However, biodiversity differs from most abiotic deposit resources (such as mineral ores) because the place in which these 'resources' reside does not necessarily remain fixed through time.

Ecosystems differ from biodiversity at the species and genetic levels, as ecosystems represent an interaction between organisms and the environment in which they live (Abercrombie et al. 1992). Ecosystems are dynamic systems that can theoretically reestablish themselves if lost, assuming appropriate species and genes are maintained elsewhere (i.e. ecosystems can be viewed as conditionally renewable or fund resources). However, with the loss of all examples of any given ecosystem (or any given developmental state of an ecosystem) there is a high risk of permanent loss of species and genetic diversity. Accordingly, it is arguable that an ecosystem, like a species or gene, should be viewed as a non-renewable or deposit resource.

Table	1:	Natural	resource	categories
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Biotic/ abiotic	<b>Biotic resources</b> are derived from living things (e.g. timber, food etc) (Heijungs et al. 1997).	<b>Abiotic resources</b> are derived from non-living things (e.g. mineral ores) (Heijungs et al. 1997).
Renewable/ non- renewable	<b>Renewable resources</b> can return to their previous stock levels after exploitation by natural processes of growth or replenishment (UN 2006).	Non-renewable resources cannot be regenerated after exploitation (e.g. mineral ores) (UN 2006).
	<b>Conditionally renewable</b> <b>resources</b> are natural resources whose exploitation eventually reaches a level beyond which regeneration will become impossible (UN 2006).	
Flow/ fund/ deposit type	<b>Flow type resources</b> have a limited availability at any given time but are non-depletable (e.g. solar radiation, wind and flowing fresh water supplied by precipitation) (Heijungs et al. 1997; Lindeijer et al. 2002).	Deposit or stock type resources do not regenerate and can only be depleted with use (e.g. mineral ores and fossil fuels) (Heijungs et al. 1997; Lindeijer et al. 2002).
	Fund type resources possess the capability of regeneration but are temporarily or locally depletable (e.g. peat, nutrients from soil minerals, ground water and lakes) (Heijungs et al. 1997; Lindeijer et al. 2002).	



Figure 2: Natural resources and their transformation for human use

#### 3.3.2 Land as a resource

Land itself can be viewed as a resource and an input into LCA. It is argued by Heijungs et al. (1997) that surface area can be treated as a flow resource in a similar way to solar radiation:

Land 'resource'  $(m^2 \text{ year}) = \text{surface area } (m^2) \times \text{time } (\text{years})$ 

Solar energy (kWh) = solar radiation (kW) x time (hours)

However, the land resource is also a function of the soil, climatic and geomorphic qualities of the land in question. Biodiversity can also be viewed as a quality of the land on which it resides:

Land 'resource' =  $(\Sigma 'quality'_i \times surface area_i) \times time$ 

The land resource is diminished with any reduction in the 'quality' of land (e.g. that caused by land degradation or the irreversible loss of biodiversity) and in this sense land should be viewed as a non-renewable or deposit resource. However, the land resource can be judged to be of very different value depending on the criteria used to measure quality (e.g. agricultural productivity compared with biodiversity value).

The land surface area available for specific land uses is finite and in some cases relatively scarce (e.g. land suitable for irrigated agriculture or land with the environmental attributes required by an ecological community).

Degradation of land with relatively scarce qualities may be regarded as being more damaging than degradation of land with relatively common qualities.

# 4. Life cycle assessment

LCA studies the environmental aspects and potential impacts of a product throughout its life (i.e. cradle-to-grave) from raw material acquisition through to production, use and disposal. It involves:

- compiling an inventory of relevant inputs and outputs of a product system
- evaluating the potential environmental impacts associated with those inputs and outputs
- interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study (AS/NZS ISO 14040 1998; ISO 14040 2006).

LCA was developed as a space- and time-independent environmental assessment method for industrial products (Milà i Canals et al. 2007) which focused on abiotic resource depletion and waste product toxicity. However the method has evolved with time and many LCAs now examine a wider range of environmental impacts (e.g. those associated with land use) (DEH 2006). This has presented LCA practitioners with philosophical challenges and added complexity to LCA methodologies.

LCA differs from other approaches to environmental assessment, such as environmental impact assessment and risk assessment, as it is a relative approach based on a functional unit (ISO 14044 2006). A functional unit is a quantified measure of the function of the product in question. For example, the functional unit of an LCA may be 100 m<sup>2</sup> of floor covering, a window frame, a house frame or a 200 m<sup>2</sup> house. A functional unit may be comprised of different products produced utilising different processes, which in turn may require different inputs and produce different outputs. LCA is designed to allow comparison of the relative environmental impacts of these different products and processes.

## 4.1 Definition of Goal and Scope

The first phase in an LCA is to define the goal and scope of the study. This phase should outline the reasons for the LCA study, the intended use of its results, and the

system and data categories to be examined. Furthermore, it should determine such things as the geographic extent, time horizon and data requirements of the study (i.e. it should define the system boundary) (ISO 14044 2006).

# 4.2 Life cycle inventory analysis

Life cycle inventory analysis (LCI) entails data collection, data validation and the process of relating data to functional units (ISO 14044 2006). The output of an LCI is a list of environmental interventions expressed per functional unit (e.g. kg of  $CO_2$  emitted per house frame). Data for LCIs might be obtained from private sources (e.g. the main producers of products and their suppliers), government agencies (e.g. land management and conservation bodies), scientific and other literature, and/or existing LCI databases.

An important aspect of LCI is the allocation of outputs and inputs to human-controlled processes (and their associated environmental burdens) to functional units (ISO 14044 2006). In the case of processes that produce more than one output (e.g. sawmilling that produces appearance-grade timber, structural-grade timber and wood chips, the refining of ores that yield multiple types of metal, the use of cropland for the production of different grains etc), it is necessary to determine the allocation of environmental burdens of each process to each product. For recyclable materials (e.g. wood, steel etc), environmental burdens associated with the extraction and processing of raw materials must also be allocated among primary and recycled materials (Heijungs et al. 1997; Hertwich et al. 2002).

### 4.3 Life cycle impact assessment

Life cycle impact assessments (LCIAs) aim to quantify the importance of the environmental interventions quantified in the LCI output and aggregate these into a small number of indicators (in some cases one) (Hertwich et al. 2002). This initially requires the selection of 'impact categories', 'category indicators' and 'characterisation models' (defined below). LCIA then comprises two mandatory elements (classification and characterisation) and four optional elements (normalisation, grouping, weighting and data quality analysis; ISO 14044 2006).

There are two general approaches to categorising life cycle impacts in LCIA—a midpoint approach and an endpoint approach (Bare and Gloria 2005). The outputs of a midpoint approach (midpoint indicators, e.g. global warming potential) are readily understood and their scientific basis well established (e.g. the global warming potential, that is radiative forcing, of different gases such as methane and carbon dioxide are quantifiable). In contrast the outputs of an endpoint approach (or damage assessment) often have high levels of uncertainty attached to them, but are expressed in terms of impacts on valued items rather than environmental themes. For example, if taking an endpoint approach, an LCA practitioner may endeavour to quantify the changes in storm frequency or habitat destruction caused by the emission of greenhouse gases rather than simply quantifying their global warming potential.

#### 4.3.1 Mandatory elements of LCIA

#### 4.3.1.1 Selection of impact categories

Impact categories are groups of environmental issues to which LCI results may be assigned (e.g. global warming). The impact categories selected should represent a comprehensive set of environmental issues related to the product system under consideration and take into consideration the goal and scope of the study (ISO 14044 2006)

#### 4.3.1.2 Selection of category indicators

A category indicator is a 'quantifiable representation of an impact category (ISO 14044 2006)' (e.g. kg of  $CO_2$  equivalents). Category indicators can be selected

anywhere along the environmental mechanism between the LCI results and the category endpoints (ISO 14044 2006).

#### 4.3.1.3 Selection of characterisation models

Characterisation models mathematically describe 'the relationship between the LCI results, category indicators and, in some cases, category endpoint(s)' (ISO 14044 2006). They are used to derive 'characterisation factors', which are applied to convert LCI results to the common unit of each category indicator (ISO 14044 2006). They should be based on reproducible empirical observation and/or an identifiable environmental mechanism (i.e. they should be scientifically justifiable; ISO 14044 2006). For example, Intergovernmental Panel on Climate Change (IPCC) characterisation models could be adopted to describe the relationship between emissions of greenhouse gases (i.e. the LCI results) and global warming (i.e. the impact category). The 2007 IPCC report outlines the global warming potential (i.e. characterisation factors) of a large number of greenhouse gases over 20-year, 100-year and 500-year time frames (Solomon et al. 2007).

#### 4.3.1.4 Classification

Classification is the process of assigning LCI results to appropriate impact categories (Hertwich et al. 2002). For example, carbon dioxide ( $CO_2$ ), CFC-11 ( $CCI_3F$ ) and carbon tetrachloride ( $CCI_4$ ) are greenhouse gases and emissions of these gases could be assigned to the impact category 'global warming'. However,  $CCI_3F$  and  $CCI_4$  also deplete ozone and emissions of these gases could also be assigned to the impact category 'global varming'.

#### 4.3.1.5 Characterisation

Characterisation is the process of converting LCI results to common units, using characterisation factors, and aggregating the converted results within the impact category (Figure 3; ISO 14044 2006).

GW	CO <sub>2</sub> 1	CCl₃F 4750	CCl₄ 1400	····]	CO <sub>2</sub> CCl <sub>3</sub> F	1200 kg 0.1 kg	GW	1815 kg $CO_2$ eq.
OD :	0.0 :	1.0 :	1.1 :	·	CCl₄ ∶	0.1 kg :		0.21 kg Cl C eq.

Characterisation Factors

LCI Results Category Indicator Results

Figure 3: Characterisation within LCIA using matrix notation based on notional LCI results and characterisation factors (i.e. global warming potentials over a 100 year time horizon) taken from Solomon et al. (2007). GW = global warming potential and OD = ozone depletion.

#### 4.3.2 Optional elements of LCIA

#### 4.3.2.1 Normalisation

Normalisation is the process of expressing the magnitude of category indicator results relative to reference information. For example emissions of  $CO_2$  equivalents may be expressed as a proportion of total emissions in a given area (global, regional, national or local) or, alternatively, relative to a baseline scenario (Hertwich et al. 2002; ISO 14044 2006).

#### 4.3.2.2 Grouping

Grouping assigns impact categories to groups of similar impacts or ranks these categories in a given hierarchy, for example, high, medium and low priority. (Hertwich et al. 2002)

#### 4.3.2.3 Weighting

Weighting involves the conversion of indicator results of different impact categories to a common scale using selected weighting factors. These weighting factors are based on value-choices, not science (ISO 14044 2006). This can potentially involve aggregation to a single environmental indicator or score (Figure 4). However, given that weighting factors are based on value-choices, to provide transparency, weighting methods should be documented and indicator results reached prior to weighting should be made available (Hertwich et al. 2002; ISO 14044 2006).

GW 1	OD 4000	]×	GW OD :	1815 0.21 :	= 1815 + 840
Ca	ategory		Cate	egory	Weighted
N	/eights		Indi	cator	Indicator
			Res	ults	Results

#### Figure 4: Weighting within LCIA expressed using matrix notation based on notional category indicator results derived from Figure 3 and notional category weights. GW = global warming potential and OD = ozone depletion.

#### 4.3.2.4 Data quality analysis

Data quality analysis involves the adoption of techniques to better understand the significance, uncertainty and/or sensitivity of LCIA results (e.g. Pareto analysis, uncertainty analysis or sensitivity analysis) (ISO 14044 2006).

## 4.4 Interpretation

The final phase of LCA is interpretation. In the interpretation phase LCA practitioners evaluate the study, draw conclusions and make recommendations, taking into account both quantitative results produced by the LCI and LCIA, and qualitative issues. These issues may include the sensitivity of results to assumptions, the effects of value choices and data quality (Hertwich et al. 2002).

#### 4.5 Limitations of life cycle assessment

Although LCA is a powerful tool for comparing the environmental impacts of different products and processes it has some inherent limitations.

# 4.5.1 Life cycle assessments address only a limited set of environmental issues

LCAs never represent complete assessments of all environmental issues. Accordingly, it is possible for LCA practitioners to present misleading conclusions about the environmental impacts of a product by inadvertently or deliberately excluding important environmental impacts from the goal and scope of a study. For example, it may be difficult to come to a meaningful conclusion about the relative environmental merits of coal and nuclear electricity generation if either greenhouse gas emissions or issues associated with nuclear waste disposal were not examined.

#### 4.5.2 Value judgements

Value judgements are difficult to avoid in all phases of LCA. The definition of the goal and scope of a study is potentially influenced by the values of the LCA practitioner, as is the extent and type of data recorded in the LCI. Within LCIA, value judgements are made in the selection of impact categories, category indicators, characterisation models, and in normalisation, grouping and weighting (ISO 14044 2006). Finally, value judgements are required in the interpretation phase of LCAs.

Accordingly, there is a risk that the results of an LCA could be presented as being based on technical and scientific knowledge, when, in actual fact, they are principally driven by the values of the LCA practitioner (e.g. the perceived relative importance of current versus future, local versus global, and human versus non-human factors; Figure 5). Where possible, value-choices should be documented in a transparent manner.



Figure 5: The components of our society/ environment that a person may wish to protect. The relative importance of these components is determined by an individual's value system, perceptions and degree of ignorance.

# 4.5.3 The trade-off between certainty, meaningfulness and practicality

Ideally LCAs would utilise LCI databases incorporating all relevant data, and damage models capable of quantifying, in a meaningful manner and with a high degree of certainty, all impacts on all valued items (i.e. category endpoints). However, LCAs are limited by data availability and the extent of human understanding of the environmental mechanisms driving relationships between LCI results and impacts on valued items. Accordingly, LCAs incorporate trade-offs between the practicality of data capture and processing, and the certainty and meaningfulness of conclusions.

#### 4.5.4 Spatial and temporal scale

LCIA typically excludes spatial and temporal information. However, in some circumstances, the manner in which issues of space and time are dealt with can substantially affect the conclusions of an LCA (Figure 6; ISO 14044 2006). This issue is particularly pertinent when the impacts of renewable and non-renewable resources are being compared in an LCA, as their relative impacts are highly dependent on the temporal and spatial scales considered.



# Figure 6: Characterisation within LCIA for two processes yielding the same functional unit.

The results presented in Figure 6 are in matrix notation based on notional LCI results and characterisation factors for global warming potential (GW) over three different time horizons, taken from Solomon et. al. (2007). Very different conclusions could be drawn as to which process was best in terms of global warming potential depending on the time horizon (and thus characterisation factors) considered.

#### 4.5.4.1 Temporal scale and impacts of land use

In the case of non-renewable resources it is possible to estimate the area of land required to produce a unit of product (e.g. ha/tonne of mineral sands). However, in the case of renewable resources (e.g. timber), yield per unit of land is time dependent (i.e. the quantity of a renewable resource that can be extracted from an area is theoretically infinite).

Although there are a number of possible approaches that can be adopted to allow comparison of the impacts of renewable and non-renewable resource use within an LCA framework, none are completely adequate (refer to Section 5.5.2).

#### 4.5.4.2 Spatial scale and impacts of land use

Land uses that appear to have a minor impact on biodiversity when examined at a broad bioregional scale can have a major impact on specific ecological communities or species. For example, mining that affects limestone karsts, which often contain high levels of endemism (Clements et al. 2006), may utilise a relatively small area of land but may have a severe and irreversible impact on ecological communities or species that inhabit such karsts.

# 5. Incorporating land use impacts on biodiversity into LCA

## 5.1 Land management categories

#### 5.1.1 The need for land management categories

At the LCI level it is theoretically possible to enter separate entries for each of the elemental activities that comprise a land management practice, such as ploughing, thinning, harvesting, extracting, burning etc. However, from a practical perspective this is unrealistic, particularly if the LCA system boundary incorporates large spatial areas and numerous land management practices.

The allocation of areas to land management categories is an alternative and more practical approach (Lindeijer et al. 2002). Land management categories should represent a predefined set of elementary land management activities and thus represent areas that have similar impacts on biodiversity. There are a number of issues surrounding the allocation of areas to land management categories that must be considered, some of which are discussed below.

#### 5.1.2 Land tenure versus land management practice

Different areas of land owned by an individual or organisation may be managed in very different ways. For example, within agricultural zones there are substantial areas of remnant vegetation on private property that are not used, or are less intensively used, for agricultural production, and within plantations and native forests managed for timber production there are areas that are not available for harvest under relevant state regulations, codes of forest practice and certification schemes.

Ideally, all areas within the LCA system boundary would be allocated to different land management categories based on the activities that are undertaken within them (i.e. land tenure should be ignored). However, in some cases this may not be possible due to the scale at which land management data is available. Accordingly, it may be necessary to allocate some areas to land management categories according to the dominant land management practices of the landowner rather than specific land management practices.

#### 5.1.3 Notional land use versus actual land use

In some instances land may be notionally allocated to a particular land management practice (e.g. multiple-use forestry, intensive agriculture or urban development) without having been exposed to all the human interventions associated with that land management practice (e.g. harvesting of trees or clearing of vegetation). In such instances, the way the transition from one land use to another is dealt with could alter the conclusions of the LCA. For example, the LCA practitioner could allocate areas to:

- different land management categories based on historic land management practices
- one land management category and assume that current impacts on biodiversity of the combined area reflect future impacts (i.e. ignore changes that are expected to occur)
- one land management category and assume the whole area has already been exposed to all interventions (i.e. account for changes that are expected to occur).

#### 5.1.4 Accounting for past land use

Transformation from one land use to another is an ongoing process in the landscape. The value of biodiversity of land under a given land use (e.g. plantation forestry) may be a function of past land management practices (e.g. intensive agriculture or multiple-use native forestry). Within the LCA context this creates difficulties in the allocation of impacts to different land uses.

Ideally, the ongoing impacts of past land uses would be allocated to the product classes produced from those past land uses. However, it is difficult to imagine a circumstance where this could be undertaken in a practical manner without making some highly speculative assumptions. Practical options to addressing this issue include:

- ignoring the impacts of past land management (i.e. allocating all impacts on biodiversity to the current land use)
- allocating areas to different land management categories based on their history. For example, plantations established on an ex-agricultural site may be allocated to a different land use category than plantations established on exnative forest sites. In the interpretation phase of LCA, possible reasons for differences in the impact of these land management categories could then be discussed.

#### 5.1.5 Available land use data

The Australian land mass has been divided into land use/management categories by the Australian Collaborative Land Use Mapping Program (ACLUMP) using the Australian Land Use and Management (ALUM) classification framework (Figure 7; Lesslie et al. 2006). The ALUM classification framework is a hierarchical structure that has been designed with 'sufficient generality to provide for users who are interested in processes (e.g. land management practices) and outputs' (e.g. commodities) (Lesslie et al. 2006).

Whether or not it has a sufficient level of detail to be useful for LCAs wishing to examine the impacts of building materials on biodiversity is questionable. For example, in ALUM version 6 (Lesslie et al. 2006), a distinction is made between hardwood and softwood plantations but no distinction is made between plantations on the basis of rotation length. Furthermore, mining areas are divided into mines, quarries and tailing, and mining areas being rehabilitated are classified as 'land under rehabilitation or unused because of weed infestation, salinisation, scalding and similar problems' (BRS 2006a).

However, the hierarchical nature of ALUM makes it a highly suitable framework from which to develop more detailed classifications of the Australian land mass based on land management practices and their outputs.



Figure 2. 2001/02 Land Use of Australia, Version 3 (Bureau of Rural Sciences)

#### Figure 7: Land use in Australia in 2001/02 (BRS 2006c).

More detailed land use data could be incorporated into the ALUM classification framework from other government and private industry-specific databases. For example, the National Forest Inventory (NFI), a partnership between the Commonwealth and all state and territory governments, collates information about a wide range of forest attributes including their type, location, distribution, height, crown density, growth stage and/or planting date, ownership and protection status.

The NFI covers native and plantation forests on public and private land and can be used to map the extent of native forest cover; the extent, species, period of planting, and location of plantation forests; changes in forest cover over time; the presence of rare and endangered species; vegetation as it might have been before European settlement; and the extent of major forest types and their representation in conservation reserves (DAFF 2007b). For other industries, sources of data might include that being collated as part of Signposts for Australian Agriculture (Chesson and Whitworth 2005) and environmental impact statements.

# 5.2 Allocating inputs to land management categories

In most cases, raw materials used to produce a functional unit will have been sourced from a number of potentially very different land management zones. For example a house may utilise raw materials from pine plantations and open-cut mines. Even raw materials with similar characteristics may have been sourced from different land management zones. For example, a certain proportion of the timber used to produce a functional unit may have been sourced from pine plantations and the rest from multiple-use native forests. Adding to the complexity of allocation, many land management zones produce multiple products (e.g. cropland can produce different types of crops in successive years, a mine can produce different types of metals and a pine plantation can produce woodchips, structural grade timber and appearance-grade timber). Land management impacts on biodiversity must be allocated to each of these materials. This must be undertaken in a justifiable and clearly-documented manner, as the approach adopted may substantially change the allocation of impacts and thus influence the conclusions of the LCA. For example, land management impacts could be allocated to materials according to their volume or economic value.

In some instances, data on the origins of materials are likely to be severely limited (e.g. timber products without chain-of-custody certification), making the process of allocating inputs to land management categories particularly difficult.

#### 5.2.1 Accounting for yield across land management categories

The quantification of yield of outputs per unit of land is central to any LCA incorporating land use, as it is required to estimate the area of land required to produce a functional unit. However, yields can fluctuate over time and space. For example, if the price of a metal increases due to greater demand or decreased supply, the extraction of lower-grade ores may become economic, reducing the average yield of that metal per hectare.

In the case of renewable resources, such as wood and agricultural crops, yields may fluctuate over time due to changed genetics, management practices, seasonal differences and/or long-term changes in climate. However, for the purposes of the LCA, it will likely be necessary to assume that outputs per unit of time are fixed within each land management zone over time.

## 5.3 Measuring biodiversity

Substantial effort has been devoted to the development of surrogate indicators of biodiversity in Australia to enable monitoring of biodiversity through time and to assess performance against biodiversity conservation priorities. Biodiversity conservation priorities are outlined in intergovernmental agreements (Appendix 2) and state and federal government legislation (e.g. the *Environment Protection and Biodiversity Conservation Act 1999*) (Australian Government 1999).

Biodiversity indicators have been developed for application across a range of spatial scales, from national (e.g. those used in National Land and Water Resources Audit and State of the Environment reports) to local (e.g. those used in biodiversity toolkits). Furthermore, some private companies routinely report their performance with respect to biodiversity management through environmental certification schemes. Appendix 3 reviews biodiversity reporting that has been undertaken in Australia; however source documents should be viewed to gain a complete picture of the type, purpose and number of biodiversity indicators that have been developed in recent decades.

Although the definition of specific biodiversity indicators for application within LCA was outside the scope of this study, examples of how previously developed indicators could be utilised within an LCA framework are outlined in following sections. Ultimately, new or modified indicators may be required, if land use impacts on biodiversity are to be meaningfully and practically assessed within an LCA framework. Ideally such indicators would be developed utilising expertise and data assembled for other biodiversity reporting purposes.

#### 5.4 Transformation, occupation and relaxation

One means of assessing land use impacts on biodiversity is to distinguish between transformation, occupation and relaxation processes (Milà i Canals et al. 2007). Land transformation involves a change from one form of land use to another (e.g.

establishing eucalypt plantations on ex-pasture sites or ex-native forest sites, clearing land for agriculture, clearing land for urban development, etc).

Transformation processes represent one-off events and differ from routine interventions undertaken as part of a given land management practice. For example, harvesting that occurs in multiple-use native forests does not necessarily represent a transformation processes but a routine human intervention that is integral to that land management practice.

Land occupation involves the use of an area of land for a certain human-controlled purpose after transformation, assuming no change in broad land management practices. Finally, renaturalisation (or relaxation) can be viewed as a transformation process in reverse (Lindeijer et al. 2002). If an area is abandoned or regenerated after a period of occupation, the value of biodiversity in that area is likely to change. The extent to which such renaturalisation occurs determines the net impact (i.e. irreversible impact) of transformation and occupation. These processes are shown diagrammatically in Figure 8.



#### Figure 8: Transformation, occupation and relaxation on a given area of land.

The model in Figure 8 is an easily interpreted representation of the value of biodiversity under a specific land management regime in a specific place. However, the threat that land use poses to the ongoing existence of biodiversity is highly dependent on the place in which that land use occurs. Many land uses have an impact on biodiversity disproportionate to the surface area they occupy because they require the same environmental attributes as particular ecological communities and/or species. For example, intensive agriculture has had a disproportionate impact on ecological communities and species occurring in areas with relatively fertile soils and reasonable rainfall (Cofinas and Creighton 2001), and urban development disproportionately affects riparian, estuarine and coastal ecosystems.

It is arguable that transformation and occupation impacts are only important if they result in a permanent depletion of biodiversity or increase the risk of a permanent depletion of biodiversity. For example, occupation and transformation processes may be deemed most damaging if they occur in areas where threatened ecosystems, species or genes are known to exist, they occur in biogeographical regions where ecosystems in good condition are uncommon, or if they impact on ecological communities and species not well represented in the national reserve system. Conversely, if ecosystems, species and genes affected by a land use in a specific place are preserved elsewhere, the extent of decline in biodiversity at that place may be deemed of little consequence in terms of the maintenance of biodiversity on the broader scale (Figure 9). The manner in which land use impacts on biodiversity are judged should be aligned with national biodiversity conservation priorities (Appendix 2) and/or the views of a broad range of stakeholders rather than the value systems of individual LCA practitioners.



Figure 9: The combined and individual impacts of three different land uses on an ecological community.

The combined impact of these land uses shown in Figure 9 could be assessed according to

- A the extent and quality of protected areas containing the ecological community (i.e. land use impacts for agriculture and open-cut mining may be deemed non-existent in this example as 30% of the potential distribution of the ecological community is protected in a national park) or
- B the weighted average biodiversity value across all land uses occurring within the potential distribution of the ecological community.

# 5.4.1 Difficulties in applying simple transition, occupation and relaxation models

The incorporation of transformation, occupation and relaxation models into an LCA framework is not straightforward. If such models are to be utilised in LCA a reference state must be defined, from which the magnitude of land use impacts on biodiversity can be assessed. However, there are both theoretical difficulties in defining an appropriate references state (Figure 10) and practical difficulties in measuring divergence from any current, let alone past or future, reference state.

Depending on the goal and scope of the LCA, the reference state could represent biodiversity value prior to human intervention, biodiversity value prior to the current land use, the biodiversity value after renaturalisation assuming land occupation ceased immediately, or the value after renaturalisation once land occupation ceased at some point in the future (Blonk et al. 1997; Lindeijer et al. 2002; Milà i Canals et al. 2007). Furthermore, in circumstances where multiple land uses have occurred on a particular site, the manner in which biodiversity impacts should be allocated to each land use is not necessarily clear (Lindeijer et al. 2002).



Figure 10: Possible reference states against which to judge impact on biodiversity

In Figure 10, t1 is the time of initial human intervention, t2 is the time of land use transformation from a previous land use to the current land use, t3 is the present time, t4 is the hypothesised time at which current land occupation will cease, A is the biodiversity value prior to human intervention, B is the biodiversity value prior to the current land use, C is the biodiversity value after renaturalisation if land occupation was to cease immediately and D is the biodiversity value after renaturalisation if land occupation if land occupation ceases in the future.

## 5.5 Accounting for occupation and transformation impacts

#### 5.5.1 Occupation impacts of land use on biodiversity

Although there are a number of different ways in which the occupation impact of a land use can be viewed (Lindeijer et al. 2002), we propose that it should be viewed as the 'opportunity cost' of not allowing renaturalisation to occur. However, the extent to which this opportunity cost can be meaningfully accounted for in LCA is restricted by data availability. Although relatively predictable in some cases (e.g. in the case of relatively recently cleared farmland with few weed species surrounded by forest in a near-natural state), estimating the extent to which biodiversity quality recovers, and the time frame over which renaturalisation may take place, will always require a degree of speculation on the part of the LCA practitioner.

The occupation impacts of land use on biodiversity can be considered a function of the units of land used; the conservation status and/or irreplaceability (Pressey et al. 1994) of the ecosystems, species and genes affected by it; and the current renaturalisation potential (i.e. reversibility of land use impacts; Figure 11). Renaturalisation potential is in turn a function of many factors including:

- current biodiversity condition
- the extent of vegetation fragmentation and the biodiversity condition of surrounding areas
- the history of land use and the longevity of occupation
- the presence of alien species
- extent of soil/land degradation
- extent of change in fire regimes.

Theoretically the timeframe over which renaturalisation might occur should also be accounted for in LCA (Blonk et al. 1997). However, this would add complexity to the method and require a further element of speculation on the part of the LCA practitioner.



# Figure 11: Renaturalisation potential (A, B and C) of biodiversity in three notional land management zones.

# 5.5.1.1 A landscape scale approach to incorporating occupation impacts into LCA

An easily implemented approach to incorporating land use impact on biodiversity into LCA would be to utilise an indicator, or combination of indicators, of the conservation status and/or irreplaceability of biodiversity within broad ecosystem-based zones, and to exploit generic indicators of renaturalisation potential for land management categories.

#### 5.5.1.1.1 Biodiversity indicators within ecosystem-based regions

The Interim Biogeographic Regionalisation for Australia (IBRA) (Environment Australia 2000; DEWHA 2007g), may be a suitable 'macro-scale' ecosystem-based system of regionalisation for adoption in LCAs (Figure 12). IBRA (Version 6.1) categorises the Australian continent into 85 bioregions and 404 sub-regions of related geology, landform, vegetation, fauna and climate. A similar ecosystem-based marine and coastal regionalisation for Australia has also been developed (IMCRA Technical Group 1998).

Many National Land and Water Resources Audit (NLWRA) projects utilise IBRA bioregions for monitoring, evaluation and reporting purposes (Morgan 2000; Cofinas and Creighton 2001; NRMMC 2002a; NRMMC 2002b; Sattler and Creighton 2002; NLWRA 2007). IBRA has also been used as a planning tool in the development of the national reserve system to safeguard endangered and vulnerable species and communities (JANIS 1997; NRMMC 2005). Accordingly, the status of biodiversity within each IBRA zone has been well documented. Indicators of the conservation status and/or irreplaceability of biodiversity within IBRA zones include:

- The percentage of threatened ecosystems and other ecological communities identified across bioregions (Sattler and Creighton 2002)
- bioregions of high relictual fauna value (Sattler and Creighton 2002)
- relative importance of bioregions to threatened bird taxa (Sattler and Creighton 2002)

- total number of threatened species by subregion as per State and Territory listings (Sattler and Creighton 2002)
- priority ranking, by bioregion, relating to the potential value of land reservation for developing a national reserve system (NRMMC 2005).

Note: consult documents reviewed in Appendix 3 for a more comprehensive list.

Another means of breaking the Australian land mass into macro-scale ecosystembased zones would be to utilise the estimated pre-industrial (1750) distribution of Australia's Major Vegetation Groups (Figure 13) (DEWHA 2007j; DEWR 2007). For example, the current distribution, as a proportion of estimated pre-1750 distribution, of each Major Vegetation Group and/or the extent to which they are represented in comprehensive, adequate and representative (CAR) (DEST 1996) reserves could be utilised as indicators of the conservation status or irreplaceability of biodiversity within each of these groups (DEWR 2007).

#### 5.5.1.1.2 The VAST framework as an indicator of renaturalisation potential

A commonly utilised framework for assessing vegetation condition is the Vegetation Assets, States and Transitions (VAST) framework. This framework provides a structure for monitoring and reporting vegetation modification at a range of scales (Thackway and Lesslie 2005; Thackway and Lesslie 2006).

[It] classifies vegetation by degree of human modification as a series of states, from intact native vegetation through to total removal (Figure 14). VAST is a simple communication and reporting tool designed to assist in describing and accounting for human-induced modification of vegetation. A benchmark is identified for each vegetation association based on structure, composition and current regenerative capacity. Benchmarks are based on the best understanding of pre-European conditions. Relative change in condition from this benchmark is assessed for each site or patch (Thackway and Lesslie 2006).

If utilised in LCA, different land management zones would need to be allocated to different VAST classes.



Figure 12: IBRA Version 5.1 bioregions



Figure 13: Estimated pre-1750 distribution of Major Vegetation Groups in Australia (DEWR 2007).

			Nativ	e Vegetation Cover	Non-native Vegetation Cover			
		Dominant struc	turing plant species indigenous to described using definitive ve	the locality and spontaneous in oc egetation types relative to estimate	Dominant structuring plant species indigenous to the locality but cultivated; alien to the locality and cultivated; or alien to the locality and spontaneous*			
Vegetation Cover Classes		Type 0: RESIDUAL BARE Areas where native vegetation does not naturally persist	Type I: RESIDUAL native vegetation community structure, composition, and regenerative capacity intact – no significant perturbation from land use/land management practice	Type II: MODIFIED native vegetation community structure, composition and regenerative capacity intact - perturbed by land use/land management practice	Type III: TRANSFORMED native vegetation community structure, composition and regenerative capacity significantly altered by land use/land management practice	Type IV: REPLACED - ADVENTIVE native vegetation replacement – species alien to the locality and spontaneous in occurrence	Type V: REPLACED - MANAGED native vegetation replacement with cultivated vegetation	Type VI: REMOVED vegetation removal
sria	Current regenerative capacity	Natural regenerative capacity unmodified - ephemerals and lower plants	Natural regenerative capacity unmodified	Natural regeneration tolerates / endures under past &/or current land management practices	Natural regenerative capacity limited / at risk under past &/or current land use or land management practices. Rehabilitation and restoration possible through modified land management practice	Regeneration of native vegetation community has been suppressed by ongoing disturbances of the natural regenerative capacity. Limited potential for restoration.	Regeneration of native vegetation community lost or suppressed by intensive land management. Limited potential for restoration	Nil or minimal
ignostic crite	Vegetation structure	Nil or minimal	Structural integrity of native vegetation community is very high	Structure is predominantly altered but intact e.g. a layer / strata and/or growth forms and/or age classes removed	Dominant structuring species of native vegetation community significantly altered e.g. a layer / strata frequently & repeatedly removed	Dominant structuring species of native vegetation community removed or predominantly cleared or extremely degraded	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
Di	Vegetation composition	Nil or minimal	Compositional integrity of native vegetation community is very high	Composition of native vegetation community is altered but intact	Dominant structuring species present - species dominance significantly altered	Dominant structuring species of native vegetation community removed	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
Examples		Bare mud; rock; river and beach sand, salt and freshwater lakes	Old growth forests; Native grasslands that have not been grazed; Wildfire in native forests and woodlands of a natural frequency and/or intensity;	Native vegetation types managed using sustainable grazing systems; Selective timber harvesting practices; Severely burnt (wildfire) native forests and woodlands not of a natural frequency and/or intensity	Intensive native forestry practices; Heavily grazed native grasslands and grassy woodlands; Obvious thinning of trees for pasture production; Weedy native remnant patches; Degraded roadside reserves; Degraded coastal dune systems; Heavily grazed riparian vegetation	Severe invasions of introduced weeds; Invasive native woody species found outside their normal range; Isolated native trees/shrubs/grass species in the above examples	Forest plantations; Horticulture; Tree cropping; Orchards; Reclaimed mine sites; Environmental and amenity plantings; Improved pastures. (includes heavy thinning of trees for pasture); Cropping; Isolated native trees/ shrubs/ grass species in the above examples	Water impoundments; Urban and industrial landscapes; quarries and mines; Transport infrastructure; salt scalded areas

#### Increasing vegetation modification from left to right

Figure 14: The Vegetation Assets, States and Transitions (VAST) framework (Thackway and Lesslie 2005).

#### 5.5.1.1.3 VAST and IBRA as an example

The VAST framework could be used as a generic indicator of the renaturalisation potential of land management zones and the percentage of threatened ecosystems within IBRA bioregions could be adopted as a measure of the conservation status of biodiversity where land use occurs. In this case, the output of the LCI would record the area required per functional unit by VAST class and IBRA bioregion, grouped by the percentage of threatened ecosystems (Table 2).

#### Table 2: Meters squared required per functional unit by the VAST class of land management zones and I BRA bioregions in which land use occurs, grouped by the percentage of threatened ecosystems.

Land management	Vast class of land	Percentage of threatened ecosystems within IBRA bioregion				
zone	management category	0-20	20-40	40-60	60-80	80-100
	Type VI					
	Type V					
А, В	Type IV					10
C, D, E	Type III	40	20	10		
	Type II					
	Туре І					
	Туре 0					

The VAST framework is a crude indicator of renaturalisation potential within land use categories. Furthermore, using VAST classes in this manner it would not be easy to identify true characterisation factors (i.e. based on scientific or technical information) linking the LCI output, with the occupation impact on biodiversity. The VAST framework ranks different vegetation cover classes in order of increasing vegetation modification but it does not quantify differences in the extent of vegetation modification or renaturalisation potential between classes. Two approaches to overcoming this problem are apparent:

- do not attempt characterisation but discuss the LCI output in the interpretation phase of LCA
- assess impacts according to weights, based on expert or stakeholder opinion, rather than scientific observation. If utilised, the origin of weighting factors would need to be emphasised in the LCA report.

Table 3 presents notional weights that could be used to develop a single indicator of land use occupation impact on biodiversity from the LCI output presented in Table 2. Utilising these notional weights, the weighted occupation impact per functional unit would be calculated as follows:

Weighted occupation impact per functional unit [1]

= 40 m<sup>2</sup> \* 0.08 bio.equ m<sup>-2</sup> + 20 m<sup>2</sup> \* 0.16 bio.equ m<sup>-2</sup> + 10 m<sup>2</sup> \* 0.24 bio.equ m<sup>-2</sup> + 10 m<sup>2</sup> \* 0.60 bio.equ m<sup>-2</sup>

= 14.8 biodiversity equivalents

VAST class of	Percentage of threatened ecosystems within IBRA bioregion						
management category	0-20	20-40	40-60	60-80	80-100		
Type VI	0.20	0.40	0.60	0.80	1.00		
Type V	0.16	0.32	0.48	0.64	0.80		
Type IV	0.12	0.24	0.36	0.48	0.60		
Type III	0.08	0.16	0.24	0.32	0.40		
Type II	0.04	0.08	0.12	0.16	0.20		
Туре І	0.00	0.00	0.00	0.00	0.00		
Туре 0	0.00	0.00	0.00	0.00	0.00		

#### Table 3: Notional weights of land use impact on biodiversity by VAST class and IBRA bioregional groups expressed in biodiversity equivalents per square metre.

#### 5.5.1.1.4 Other indicators of renaturalisation potential

Instead of using a previously developed categorical indicator of renaturalisation potential (e.g. VAST), a series of quantitative indicators could be developed. In this case, category indicators of renaturalisation potential would need to be identified and characterisation factors based on empirical observation developed. Characterisation factors would need to be developed for each land management zone and category indicator results would need to be expressed as deviations from a reference state. Ideally this reference state would represent the true renaturalisation potential of each land management zone. However, it is unlikely that this could be estimated with sufficient precision in all cases and it may be necessary to adopt an alternative reference state (e.g. near-natural environments). Individual category indicator results could be combined to produce a weighted indicator result of land use occupation impact, based on category weights developed by technical experts and/or through consultation with a diverse range of stakeholders.

The identification of specific indicators would need to be undertaken by technical experts utilising experience gained in the development and application of biodiversity indicators for other purposes (Appendices 3 and 4; Failing and Gregory 2003; Tarrant et al. 2003; Hagan and Whitman 2006). However, category indicators might include quantifiable indicators of the condition of indigenous biodiversity, the extent of vegetation fragmentation and the biodiversity condition of surrounding areas, the history of land use and the longevity of occupation, the presence of alien species, extent of soil/land degradation and extent of change in fire regimes. Off-site impacts of land uses should be considered when developing category indicators and weights (e.g. the potential for alien species to become naturalised beyond the boundaries of the land use responsible for their introduction or spread, or the impact of change fire regimes aimed at protecting assets in one land management zone on another).

#### 5.5.1.2 Individual ecosystem/ species approach

In addition to, or instead of, examining impacts of land use at a landscape scale (e.g. utilising IBRA or Major Vegetation Groups), land use impacts on individual ecological communities, species and other 'special values' should be assessed if the true impacts of different land uses are to be meaningfully compared. If impacts at the 'micro-scale' are not accounted for, the impacts of some land uses are likely to be underestimated. For example, if examining impacts at a landscape scale, limestone mining in karst systems containing a high degree of endemism may inappropriately be deemed to have little or no impact on biodiversity if it takes place in a bioregion in which all but karst fauna are well represented in protected areas.

However, accounting for impacts at finer spatial scales is data intensive and bound to encroach upon the bounds of human knowledge and understanding. It is unlikely that it will ever be possible to examine the extent to which different land uses impact on every ecosystem, species and gene, though it may be possible to examine a subset of ecosystems, species or genes. For example, Kollner (2000) outlines an approach to LCA that examines impacts on vascular plant species and Bare et al. (2003) utilises data on threatened and endangered species (Appendix 5).

Theoretically, a similar approach to that previously outlined at the landscape scale could be adopted at the individual threatened ecological community and/or species level. In this case LCI results would consist of estimates of the area required per functional unit in each land use category overlapping the potential range of the threatened ecological communities and/or species under consideration (Table 4). The impacts on each of these communities and species would then need to be weighted in some manner to derive a composite measure of impact.

The current distribution of many threatened communities and species is relatively well-documented (refer to the Australian Species Profile and Threats (SPRAT) Database (DEWHA 2008b) and the World Conservation Union (IUCN) Red List Database (IUCN 2001; IUCN 2007)). However, reliable estimates of the potential, or even pre-industrial (e.g. pre-1750) (IUCN et al. 1991), distribution of threatened ecosystems are not readily available across the entire Australian continent. Accordingly, an LCA method flexible enough to utilise data at a variety of spatial scales may be required. That is, a method that utilises high-resolution spatial data where available (e.g. in areas covered by Regional Forestry Agreements) (DAFF 2007a) and low-resolution spatial data where necessary.

Land management zone	Potential ecological community/species range							
	Ecological community 1	Ecological community 2	Ecological community 3	Species 1	Species 2			
A				2				
В								
С					1			
D								
E	10	3	5					
F								
G								

 Table 4: Meters squared required per functional unit by land use category and potential range of threatened ecosystems and species

#### 5.5.2 Accounting for transformation impacts

Transformation impacts represent one-off land use impacts that occur when one form of land management practice is adopted in place of another. Within LCA, transformation impacts, like occupation impacts, should be attributed to a functional unit based on the inputs to processes used in its manufacture.

We propose that transformation impacts should be judged according to the extent to which transformation results in a permanent depletion in renaturalisation potential (i.e. an irreversible change in the area transformed, depicted as a net transformation impact in Figure 15) and the conservation status and/or irreplaceability (Pressey *et al.* 1994) of biodiversity impacted upon (Pressey *et al.* 1994). For the sake of consistency, accounting for transformation impacts on biodiversity should be undertaken using a similar framework used to assess occupation impacts.

In some cases, transformation may result in a permanent change in the environmental attributes of a place, making renaturalisation to anything like its original state impossible (e.g. open cut mining may turn a forest into a lake). Such major changes in the environmental attributes of a place of would represent a particularly large net-transformation impact on the biodiversity initially present on the site.



Figure 15: Accounting for transformation impacts

In the case of the extraction of non-renewable resources, transformation impacts can be relatively easily attributed to functional units. For example, the extraction of a certain amount of iron ore may be required per functional unit and the extraction of this ore would require the transformation of a certain area of land. However, in the case of renewable resources, attributing transformation impacts to individual Theoretically, functional units causes substantial methodological difficulties. transformation impacts should be attributed to all subsequent resources produced as a result of the transformation process. In the case of renewable resources (e.g. biomass such as wood, grain etc), assuming sustainable production, this could amount to an infinite number of functional units because production is only limited by time. Furthermore, land management practices are likely to change over time producing various types of natural resources to which the transformation impact should, theoretically, be attributed (Lindeijer et al. 2002). These issues are widely discussed in the LCA literature but no perfect solutions are evident (Blonk et al. 1997; Lindeijer et al. 2002; Milà i Canals et al. 2007). Possible approaches include:

- assuming that transformation impacts extend over a finite period of time
- using methodologies adopted in economics and accounting, such as standard depreciation times and discounting
- utilising sensitivity analysis to test the importance of time-based assumptions
- adopting different approaches for renewable and non-renewable resources in the LCIA and interpretation phases of LCA.

We propose that contemporary transformation impacts be allocated to products produced in a land management zone according to current production levels across the entire land management zone and that transformation impacts associated with non-renewable and renewable resources be dealt with separately in the LCIA and interpretation phases of LCA. In the case of transformation to land uses producing non-renewable resources, characterisation or weighting factors could be specified to determine transformation impacts per functional unit. However, transformation to land uses producing renewable products may need to be considered from an inventory point of view only.

This approach would leave the LCA practitioner without a direct means of assessing the relative transformation impacts of renewable and non-renewable resources. One means of addressing this issue may be to assess the extent to which renaturalisation potential declines per year as a result of occupation for the production of renewable resources (i.e. the slope of the renaturalisation potential line in Figure 15; Table 5). However, in practical terms it is likely that substantial qualitative interpretation of the relative impacts of renewable and non-renewable resources would still be required in the interpretation phase of LCA if this approach were adopted.

Resource type	Product	Yield	Depletion in renaturalisation potential	Depletioninrenaturalisationpotentialperfunctionalunit(Biodiversity)
				equivalents)
Non- renewable	Metal	1000 functional units ha <sup>-1</sup>	150 biodiversity equivalents ha <sup>-1</sup>	0.15
Renewable	Plantation timber	10 functional units ha <sup>-1</sup> year <sup>-1</sup>	1.5 biodiversity equivalents ha <sup>-1</sup> year <sup>-1</sup>	0.15
Renewable	Clear fell native forest timber	2 functional units ha <sup>-1</sup> year <sup>-1</sup>	0.3 biodiversity equivalents ha <sup>-1</sup> year <sup>-1</sup>	0.15
Renewable	Selectively logged native forest timber	1 functional units ha <sup>-1</sup> <i>year<sup>-1</sup></i>	0.15 biodiversity equivalents ha <sup>-1</sup> <i>year<sup>-1</sup></i>	0.15

Table 5: A notional example of how the transformation impacts of nonrenewable resources could be compared with the impacts of renewable resources using common units within an LCA framework.

# 5.6 Global-scale LCAs

The goal and scope of individual LCAs will determine the extent to which land use impacts at a global scale need to be incorporated. However, in many cases it is likely that relatively limited international data (Appendix 4) will need to be integrated with more detailed Australian data. It is conceivable that an LCA method flexible enough to incorporate data from a range of spatial scales and with varying levels of precision could be developed. However, no matter how flexible the approach, it is likely that it will be necessary to revert to general assumptions about the impacts of imported products in some instances.

# 6. Conclusion

Any approach to incorporating land use impacts on biodiversity into LCA should account for both the reversibility of impacts and the conservation status/irreplaceability of the biodiversity affected. The incorporation of these factors into LCA could utilise composite and/or elemental biodiversity indicators. In any case, the approach should be practical to implement and produce meaningful and easily interpretable results. To this end, it is likely that it will be necessary to make assumptions about the generic impact of land management categories on biodiversity and utilise contemporary data to limit speculation about past and future impacts. Both occupation and transformation land use impacts should be examined in LCAs as they both represent important impacts on biodiversity.

This report provides a framework for dialogue between ecologists, LCA practitioners, government and industry by identifying and discussing specific issues associated with the incorporation of land use impacts on biodiversity into LCA. It is clear that there are substantial impediments to the incorporation of these impacts into LCA in Australia as there is no universally agreed upon LCA method or suite of suitable biodiversity indicators. Furthermore, there is substantial variation in the scale at which relevant data is available.

Despite the many difficulties, by utilising experience gained in the development of biodiversity indicators for other purposes it should be possible to develop a meaningful and practical means of incorporating land use related impacts of building materials on biodiversity into Australian LCAs.

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# Appendix 1 Construction industry environmental rating schemes and guides

## Australian

- Australian Building Greenhouse Rating (ABGR; NSW Department of Energy, Utilities and Sustainability) (DEUS 2007)
- Building Sustainability Index (BASIX; NSW Department of Planning) (DP 2008)
- Ecospecifier (Natural Integrated Living Pty Ltd) (NIL 2008)
- EnviroDevelopment (Urban Development Institute in Queensland) (UDIA 2008)
- Green Star, Australia (Green Building Council of Australia) (GBCA 2008)
- GreenSmart (Housing Industry Association) (HIA 2008)
- National Australian Built Environment Rating System (NABERS; NSW Department of Environment and Climate Change) (DECC 2006)
- Nationwide House Energy Rating Scheme (NatHERS; Ministerial Council on Energy) (DEWHA 2007i)

## International

- Building Research Establishment's Environmental Assessment Method (BREEAM), UK (Building Research Establishment Ltd) (BRE 2007)
- Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), Japan (Japan Sustainable Building Consortium) (JSBC 2006)
- Green Globes, USA, Canada and UK (GG 2008)
- Green Star, New Zealand (New Zealand Green Building Council) (NZGBC 2008)
- High Performance Buildings Initiative, USA (USDE 2008)
- GB Tool, Canada and elsewhere (International Initiative for a Sustainable Built Environment, iiSBE) (iiSBE 2008)
- Eco-Quantum, Netherlands (Research and Consultancy on Sustainability) (IVAM 2008)
- LEED (Leadership in Energy and Environmental Design), Canada and US (Canada and US Green Buildings Councils) (USGBC 2008)
- Project Regener, Five European countries (Peuportier 2008)

# Appendix 2 Key documents outlining national biodiversity conservation priorities

- Biodiversity The Role of Protected Areas (HRSCE 1993)
- Nationally agreed criteria for the establishment of a comprehensive, adequate and representative reserve system for forests in Australia (JANIS Criteria) (JANIS 1997)
- National Forest Policy Statement (Australian Government 1995)
- National Objectives and Targets for Biodiversity Conservation 2001–2005 (Environment Australia 2001)
- National Strategy for the Conservation of Australia's Biological Diversity (DEST 1996)
- Setting Biodiversity Priorities (Possingham et al. 2002)
- Directions for the National Reserve System A Partnership Approach (NRMMC 2005)
- Building Nature's Safety Net. A Review of Australia's Terrestrial Protected Area System (Sattler and Glanznig 2006)

# Appendix 3 Biodiversity reporting in Australia

## National Land and Water Resources Audit (NLWRA) Reports

# Landscape Health in Australia: A rapid assessment of the relative condition of Australia's bioregions and subregions

The Landscape Health in Australia report (Morgan 2000) was undertaken as part of the National Land and Water Resources Audit assessment of the condition of the natural resources of Australia. The report assessed 'landscape health' and presented findings graphically by IBRA Version 5 subregion.

#### Australian Terrestrial Biodiversity Assessment

The first Australian Terrestrial Biodiversity Assessment represented Australia's first comprehensive assessment of terrestrial biodiversity (Sattler and Creighton 2002). Biodiversity information collated in the Biodiversity Assessment included:

- natural values for each IBRA subregion
- nationally important wetlands—condition, trend and threatening processes
- wetlands of regional significance—values, condition, trend and threatening processes
- riparian condition, trend and threatening processes for each IBRA subregion
- threatened ecosystems categorised by the National Vegetation Information System Major Vegetation Subgroups, their recommended status (vulnerable or endangered), trend, threatening processes and bioregional distribution
- threatened species in each IBRA subregion, their status, trend, threatening processes and recommended recovery actions
- distribution of eucalypts and acacias, identification of centres of endemism, richness and assessment of irreplaceability
- status and trend of birds and mammals
- protected areas and assessment of the comprehensiveness, adequacy and representativeness for IUCN reserve categories (I–IV) and (V–VI) in each bioregion, priorities for additional reservation, and reserve management standards
- recovery actions for threatened species and threatened ecosystems across subregions
- assessment of the effectiveness of natural resource management activities, and opportunities for increased activity
- 14 detailed case studies stratified across all landscape health classes.

An interim approach to monitoring significant native species and ecological communities is to be determined as part of the NLWRA's second biodiversity assessment planned for release in 2008 and the National Natural Resource Management Monitoring and Evaluation Framework (see below).

#### Australian Native Vegetation Assessment

Australian Native Vegetation Assessment (Cofinas and Creighton 2001) reports the type and extent of Australia's native vegetation at a regional-scale.

#### Landuse Change, Productivity & Development Report

The 'Land use change, productivity and diversification' report (DAFF 2001b):

- provides an historical background to land use changes in Australia with major causes of changes
- spatial and temporal trends (1983 to 1997) in land use change, productivity and enterprise diversification
- trend projections into 2010 and 2020
- comments on the relationship of agriculture to natural resource management.

#### Australian Agriculture Assessment

The Australian Agriculture Assessment (DAFF 2001a) reports on links between natural resource condition and production, documents the condition of natural resources used in agriculture, and determines off-farm exports and fluxes of sediments, carbon and nutrients.

#### Landscape Health In Australia Report

The Landscape Health in Australia report (Morgan 2000) addresses the health of regional landscapes, considering the status of their natural ecosystems and associated biodiversity values.

# National Natural Resource Management Monitoring and Evaluation Framework

The National Natural Resource Management Monitoring and Evaluation Framework was developed to help monitor and report on the impact of the national natural resource management programs such as the National Action Plan for Salinity and Water Quality (NRM 2008a) and National Heritage Trust (NHT) (NRM 2008b) and is utilised by the National Land and Water Resources Audit (NLWRA 2008). The framework identifies 'matters for target' that relate to absolute improvement in resource condition or decreases in the rate of degradation (NRMMC 2002a; NRMMC 2002b). Matters of target include:

- 1. Land salinity
- 2. Soil condition
- 3. Native vegetation communities' integrity
- 4. Inland aquatic ecosystems integrity (rivers and other wetlands)
- 5. Estuarine, coastal and marine habitat integrity
- 6. Nutrients in aquatic environments
- 7. Turbidity/suspended particulate matter in aquatic environments
- 8. Surface water salinity in freshwater aquatic environments
- 9. Significant native species and ecological communities
- 10. Ecologically significant invasive species

#### State of the Environment Reports

Three federal State of the Environment Reports have now been completed: 1996, 2001 and 2006. The 2006 State of the environment report (Beeton et al. 2006) grouped environmental indicators into eight reporting themes:

- Atmosphere
- Biodiversity
- Coasts and oceans
- Human settlements
- Inland waters

- Land
- Natural and cultural heritage
- Australian Antarctic Territory

# State of Australia's Birds Reports

Birds Australia has produced annual State of Australia's Birds (SOAB) reports since 2003 (Birds Australia 2008).

### Biodiversity toolkits

'Biodiversity toolkits' have been developed by a number of state governments as a means of assessing the relative value of remnant vegetation for habitat protection. Toolkits include 'Habitat hectares' (Victorian Department of Sustainability and Environment; Parkes et al. 2003), 'BioMetric' (NSW Department of Environment and Climate Change; Gibbons et al. 2005) and 'BioCondition' (Queensland Environmental Protection Agency; Eyre et al. 2006). Although designed to be applicable to a wide variety of vegetation communities within individual states, none of these systems have been applied nationally. Some of the indicators used to developed measures of vegetation condition could theoretically be applied across broad geographic areas.

### Agricultural sector

#### Signposts for Australian Agriculture

Signposts for Australian Agriculture (Signposts) is a collaborative project involving the Department of Agriculture, Fisheries and Forestry (DAFF), the Bureau of Rural Sciences (BRS) and Research and Development Corporations (RDCs), and is managed by the National Land & Water Resources Audit (the Audit). Signposts has developed a preliminary framework for reporting on the environmental, economic and social contributions of Australian agricultural industries and presented preliminary industry profiles (Chesson and Whitworth 2005). Indicators of the state of agricultural lands and other bio-physical systems are in development.

#### Forestry Sector

#### The Montréal Process

The Montréal Process outlines criteria (categories of conditions or processes by which sustainable forest management may be assessed) and indicators (measurements of an aspect of the criterion) for the conservation and sustainable management of temperate and boreal forests (Montreal Process 1999). All signatory countries are expected to report progress toward achieving sustainable forest management. However, the Montreal Process is structured in such a way that individual countries are free to develop specific measurement schemes appropriate to their national conditions. Australia's first approximation report for the Montreal Process was produced in 1997 (DPIE 1997). More recently the Australian Government has produced State of the Forests Reports (1998, 2003 and 2008) (NFI in press), which report against the Montreal Process criteria and indicators.

#### **Regional Forest Agreements**

Regional Forest Agreements (RFAs; DAFF 2007a) are in place in four Australian States. These RFAs cover ten regions where commercial timber production is a major native forest use. The framework for regional forest agreements were provided by a series of Comprehensive Regional Assessments (CRAs) of the social, economic, environmental and cultural and natural heritage values of each region's native forests. The establishment of a comprehensive adequate and representative (CAR) reserve system, protecting the environmental and heritage values of forests, was a key outcome of the RFA process (JANIS 1997). The development of the CAR reserve system required detailed mapping of the vegetation communities present in areas covered by RFAs.

#### Forestry standards

There are two forestry certification schemes in operation in Australia: the Australian Forestry Certification Scheme, under the Australian Forestry Standard (AS 4708 2007) and the Forest Stewardship Council (FSC) Scheme, under Woodmark and SmartWood interim standards (Crawford 2006; Davidson et al. 2008).

#### Australian Forestry Standard

The Australian Forestry Standard (AFS) is incorporated into the formal Australian Standards process but is also recognised by the international Programme for the Endorsement of Forest Certification (PEFC) schemes. It draws heavily on the Montreal Process Criteria and Indicators and specifies nine criteria for sustainable forest management but does not specify indicators that must be used to measure all aspects of these criteria.

#### Forest Stewardship Council

Within Australia, Woodmark and SmartWood standards are based on Forest Stewardship Council (FSC) principles and criteria, with indicators adapted to suit Australian conditions. These currently represent interim/generic standards as a national Australian FSC standard is not yet in place (Anonymous 2006; Anonymous 2007).

#### Online resources

#### The Environmental Resources Information Network

The **Environmental Resources Information Network** (ERIN) 'aims to improve environmental outcomes by developing and managing a comprehensive, accurate and accessible information base for environmental decisions' (DEWHA 2007f). Relevant information services provided or hosted by ERIN include:

- The Australian Natural Resources Atlas provides online maps, graphs, data and reports from the National Land and Water Resources Audit (DEWHA 2007a).
- **Australian Wetlands Database** enables users to find information on Australia's Ramsar sites and nationally important wetlands (DEWHA 2007b).
- The **Collaborative Australian Protected Areas Database** (CAPAD) provides a national database of statutory protected areas in Australia, including their IUCN management categories. The database has been used to produce statistics on protected areas meeting the agreed criteria for the inclusion in the National Reserve System and terrestrial protected areas within each Interim Biogeographic Regionalisation for Australia bioregion. It is maintained by the Department of the Environment, Water, Heritage and the Arts with the cooperation of state and territory government departments and agencies. The ERIN platform provides the ability to receive summary statistics on National Parks and all other terrestrial and marine protected areas. However, CAPAD spatial data is not a freely available dataset (DEWHA 2007c).
- **Discover Information Geographically** enables users to search for and download datasets held by the Department of the Environment, Water, Heritage and the Arts (DEWHA 2007d).
- EPBC Protected Matters Search Tool enables users to generate reports that indicate whether matters of national environmental significance or other matters protected by the EPBC Act (Australian Government 1999) are likely to occur in a specific area (DEWHA 2007k).

- Land Cover Change and Condition Database is available online but is presently in draft form only. It is primarily based on information gained from a survey distributed by ERIN (DEWHA 2007h). The database is not a spatial database. It allows people engaged in land cover change and condition projects to list their work and/or list work being carried out by others around Australia.
- Environmental Reporting Tool (DEWHA 2007e) and My Environment (DEWHA 2008a) provide online local-scale information on environment and heritage values.
- The National Vegetation Information System is a collaborative program between the State, Territory and Australian governments that attempts to draw together detailed native vegetation information (DEWHA 2007j; DEWR 2007). See also the list of state and territory government sites below.
- The **Species Profile and Threats Database** (SPRAT) provides information about species and ecological communities listed under the EPBC Act (Australian Government 1999). A description of many listed species, their population and distribution, habitat, movements, feeding, reproduction and taxonomy is accessible online (DEWHA 2008b).

#### Other source of information

The **Land Use Mapping for Australia** (ACLUMP 2006) website contains information about land use in Australia, maps and data, the national land use classification system, technical reports supporting mapping work and analysis of land use information.

**Australian Natural Resources Data Library** (BRS 2008) distributes data provided by the NLWRA to participants in Audit projects and the public.

The **Australian Soil Resources Information System** (ASRIS) (CSIRO 2008) is a national database that compiles information on soil properties that contribute to productivity, soil resilience and processes controlling water, air and nutrients. It is designed to provide information suitable for use at national to large regional scale.

#### State and territory vegetation information

- Australian Capital Territory: Environment ACT (DTMS 2006)
- New South Wales: Department of Natural Resources (DNR 2007)
- Northern Territory: Department of Natural Resources, Environment and the Arts (NRETA 2007)
- **Queensland:** Environmental Protection Agency (QEPA 2008)
- South Australia: Department for Environment and Heritage (DEHSA 2007)
- Tasmania: Department of Primary Industries and Water (DPIW 2008)
- Victoria: Department of Sustainability and Environment (DPI Victoria 2008; DSE 2008)
- Western Australia: Department of Agriculture and Food (search term 'NVIS') (DAF 2008)

# Appendix 4 International land use and biodiversity data sources

Systems of Categorising land

# Food and Agriculture Organisation Land Cover Classification (FAOLCC)

The United Nations Food and Agriculture Organisation Land Cover Classification (FAOLCC) outlines a set of protocols for mapping land cover. Eight major land cover types are defined within the system:

- Cultivated and Managed Terrestrial Areas
- Natural and Semi-Natural Terrestrial Vegetation
- Cultivated Aquatic or Regularly Flooded Areas
- Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
- Artificial Surfaces and Associated Areas
- Bare Areas
- Artificial Waterbodies, Snow and Ice
- Natural Waterbodies, Snow and Ice.

Below these land cover types, land cover classes are created by the combination of sets of pre-defined classifiers tailored to each land cover type. The system is designed to map at a variety of scales. The Australian Bureau of Rural Sciences (BRS) investigated methods of classifying and mapping land cover in Australia and recommended that the FAOLCC be adopted to develop a national land cover dataset (Atyeo and Thackway 2006).

#### **UNESCO** Vegetation Classification

The UNESCO Vegetation Classification is a widely utilised hierarchical framework for the classification and mapping of vegetation (UNESCO 1973).

#### Environmental auditing and reporting tools

#### World Conservation Union (IUCN)

#### IUCN protected area management categories

The IUCN has defined a series of six protected area management categories (IUCN/UICN 1994) that have been widely adopted in Australia (DEWHA 2007c) and internationally (UNEP 2008).

#### IUCN Red List

The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on taxa that have been globally evaluated using the IUCN Red List Categories and Criteria (IUCN 2001). The IUCN Red List Categories and Criteria are intended to be an easily and widely understood system for classifying species at high risk of global extinction. The list of threatened taxa is maintained in a searchable database. It is possible to search the database online according to species, red list categories, countries, marine regions of the world, regions of the world, major habitat types, major threat types (e.g. crops, forestry plantations, mining, fisheries), assessment publication date and plant growth forms.

#### FAO databases

United Nations Food and Agriculture Organisation (FAO) databases provide extensive global scale information on water management, agriculture, fisheries and fish production, land use, forestry including imports and exports of wood and paper, forest cover, plantations and fires.

# Appendix 5 Examples of approaches used to incorporate land use impacts on biodiversity into LCA

## Area of land use as an indicator of biodiversity impact

The Department of the Environment and Heritage (DEH) commissioned a scoping study to provide information to the Australian Building Codes Board (ABCB) on the viability of developing regulations to constrain the environmental impact of building materials (DEH 2006). The study used an LCA approach. Although explicit conclusions about impacts of different building materials (e.g. timber, concrete and steel) on biodiversity were not drawn, the inclusion of land use in this study was justified on the basis that it was the 'most important cause of species loss in Australia'. The report quantified the area of land required for the production of different building materials without any specific weighting for the intensity of land use.

Adding up the areas of land used to produce different products represents an easily implemented but overly simplistic approach to assessing the impacts of land use on biodiversity. This was recognised by the study's authors, who did not specifically attempt to quantify the impacts of different building materials on biodiversity. However, the justifications given for the inclusion of land use as an indicator in this study inferred that it could be used as a proxy for biodiversity impact in LCAs.

#### Eco-indicator 99

As outlined by Kollner (2000), eco-indicator 99 utilises 'species-pool effect potentials (SPEP) as a yardstick to evaluate land-use impacts on biodiversity'. Specifically, it uses a narrowly defined measure of biodiversity (the occurrence of vascular plant species) to weight the impact of different land uses. Aspects of this approach have also been incorporated into the IMPACT 2002(+) life cycle impact assessment method (Jolliet et al. 2003).

This approach is relatively widely adopted. However, it recognises only one aspect of biodiversity (vascular plant species richness), it weights common and threatened species equally, and is based on complex models that utilise parameter estimates derived from limited empirical data.

## Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)

The impact assessment methodologies within TRACI are outlined by Bare et al. (2003). TRACI uses the density of threatened and endangered (T&E) species in a specific area (e.g. county) as a proxy for environmental importance and offers limited guidance as to which forms of land use modifications are considered significant enough to result in potential habitat effects and thus be considered in life cycle impact assessments. It applies the following equation to all forms of land use modifications deemed significant enough for inclusion in the LCA:

Land Use Index =  $A_i x (T\&E_i) / CA_i$ 

where  $A_i$  is the human activity area per functional unit of product, T&E, is the threatened and endangered species count for the country (or region), and CA, is the area of the county (or region).

TRACI is relatively easy to implement and globally applicable. However, it only addresses one element of land use impact on biodiversity (i.e. threatened and endangered species) and, although it partially recognises that location has a large role in determining the environmental importance of land use, it uses geopolitical rather than biogeographical land categories, does not clearly specify to which forms of land transformation to which it should be applied and does not address issues associated with ongoing occupation of land.