INDICATORS OF AGRI-BIODIVERSITY: AUSTRALIA'S EXPERIENCE

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Indicators of Agri-biodiversity– Australia's experience

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Abstract

Biodiversity is important in Australia – demonstrated by its explicit incorporation into two National Strategies and major environmental legislation. This has led to considerable work on biodiversity indicators. We provide an overview of some of this work, particularly that relating to agricultural systems.

Australia is a large, megadiverse, remote, lightly populated continent. Unique features pose special challenges in scale, measurement and management of agri-biodiversity. While indicators for the conservation of native biodiversity are well underway, those for the role of biodiversity in agricultural production and ecosystem processes are relatively neglected. 'Biodiversity' can refer to different aspects of biological resources depending on the context. It is important to identify which aspect is being addressed before effective indicators can be developed.

We discuss future directions, including the identification of the values associated with biodiversity, and the development of operational objectives against which progress can be measured and indicators have meaning. We propose a scheme for categorising agri-biodiversity issues, specifically those for which agriculture has management capability or responsibility, and a process for developing operational objectives across different spatial scales. Indicators will then align with management needs at the appropriate scale.

Current Australian initiatives will be important drivers of the further development and application of agri-biodiversity indicators that are practical and relevant to management decision making. Implications for trend and performance reporting at a national level include a greater emphasis on indicators such as 'the proportion of catchments meeting their individual biodiversity targets' as distinct from aggregated statistics such as number of species or area of habitat.

Introduction

Biodiversity is an important issue in Australia. Our National Strategy for Ecologically Sustainable Development (Council of Australian Governments 1992) lists the protection of biological diversity and the maintenance of essential ecological processes and life-support systems as one of its three overarching objectives. In 1996 this objective was elaborated in the National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia 1996). More recently Commonwealth (federal) environmental legislation has been consolidated in the *Environmental Protection and Biodiversity Conservation Act (1999)*. Associated with this emphasis on biodiversity, considerable amount of effort has been devoted to the development of indicators of biodiversity.

We have previously presented to an OECD forum on agriculture/environment indicators details of Australia's efforts to measure progress towards sustainable development using indicators (Delegation of Australia 1999).

This paper provides an overview of Australia's experience to date with indicators of biodiversity, emphasising those relevant to agricultural systems. It also discusses future directions and their implications for reporting on biodiversity at a national level.

Biological and institutional background

The biota of the Australian continent evolved in isolation from that of the other continents over the last 50 m years. The first significant incursion of exotic species was about 50 000 years ago when humans and the dingo (a wild dog) first came to the continent, but few other species came with them. At this time there was a drying of the climate and an almost total loss of the megafauna from the continent – only kangaroos and emus remained. Land use practices of these first humans altered the pattern and distribution of biodiversity over much of the continent over thousands of years.

At the end of the 18th century, a new incursion of humans from Europe began a train of exotic species introductions that continues to this day. Spreading over the continent with sheep and cattle, they indirectly effected considerable change to the biodiversity of the continent. Many endemic mammal and bird species became extinct as a result of habitat loss, competition and predation (State of the Environment Advisory Council 1996). Some introduced species became feral – pests and weeds – to both agricultural and native systems.

Australia is an ancient continent, and its fragile soils have been extensively eroded over time so that much of what remains has low structural stability, fertility and organic matter. Much of the continent is semi-arid, with highly variable rainfall both between and within years, which exaggerates the risks to production and environmental services (State of the Environment Advisory Council 1996). However, the wide range of climate in Australia, with latitudes ranging from 10 to 43 ^{o}S, permits considerable diversity of agricultural production on Australia's 120 000 farms, which occupy about 60% of the land area.

Most of this agricultural land is used for grazing and pastoralism with sheep and cattle. Only about 6% of the total area of Australia is cropped, and less than 3% in any year. Only 2.1 m ha are irrigated to some extent, about half of which is pastures, and represents less than 0.5 % of total agricultural land. Most of the horticultural produce is consumed domestically by Australia's 19 million citizens, but most (60-80%) of the products from broadacre agriculture (grains, meat, wool, sugar, cotton) are exported and now earn Australia about US$15 billion each year (see www.nlwra.gov.au/atlas).

However, the actions undertaken in agriculture often have impacts on the condition of land, vegetation and water resources. For instance, within the last 200 years, nearly 90% of temperate woodlands and mallee have been cleared, and more than 99% of temperate lowland grasslands in south-eastern Australia have been greatly modified.

Overarching issues between federal and State levels of government are coordinated through high level councils, supported by public service committees. The councils of most interest to this forum (Agriculture and Resource Management Council of Australia and New Zealand – ARMCANZ – and the Australian and New Zealand Environment and Conservation Council – ANZECC) strongly contributed to the National Strategy Ecologically Sustainable Development (ESD) and the National Strategy for the Conservation of Australia's Biodiversity. Later, their standing committees coordinated the development of indicators for sustainable agriculture and for the State of Environment reporting.

Biodiversity Indicators Used in Australia

We describe several recent exercises at a national scale that include development of indicators of biodiversity. We have selected those indicators, relevant to agriculture, that are used for measures of the impact or condition of biodiversity likely to be of most interest to this audience. They include both endemic and exotic organisms at the three levels of gene, species and ecosystem. Further details of the exercises are given in the Appendix.

Indicators of sustainable agriculture (SCARM 1998)

The Standing Committee on Agriculture and Resource Management (SCARM) instigated the development of indicators of sustainable agriculture as a direct result of the 1992 National Strategy for Ecologically Sustainable Development. The first results were presented in SCARM (1998). The indicators, which are part of a larger group, that are particularly relevant to biodiversity are:
Natural resource condition indicator included these attributes or measures;

- Rangeland condition and trend – representing the ability of the landscape (used here as a scale between habitat and catchment) to respond to rainfall, a surrogate for landscape functioning. Below average response is often associated with erosion or weedy shrub development while above average response indicates a productive, resilient landscape that recovers well from grazing.
- Agricultural plant species diversity – provides some estimate of biological resilience for a region over time, by maximising ability to withstand adverse climate and minimise build-up of diseases, weeds and pests. It is less useful to compare between regions. There was no evidence of a decline in this index.

Off-site environmental impacts indicator included these attributes or measures of the impact of agriculture on native vegetation (representing the whole ecosystem);

- Impact of agriculture on native vegetation in conservation reserves. The results ranged from a very low estimated impact in the arid regions to a potentially high impact in the semi-arid tropical and subtropical regions.
- Impact of agriculture on biodiversity of native vegetation. The need for conservation of biodiversity off-reserve appears to be highest in the cropping zone, and the semi-arid tropical/subtropical slopes and plains.

State of Environment reporting

The National Strategy for Ecologically Sustainable called for regular state of the environment (SoE) reporting. Most of the major government jurisdictions, State and Commonwealth, undertake reports on the state of their environment every two to five years. They commonly include biodiversity as a major component with emphasis upon native biodiversity (Saunders *et al 1998)*, but the development of suitable indicators is a continuing project (ANZECC 2000).

The 1996 national State of the Environment report (Commonwealth of Australia 1996) reported on the basis of biogeographical units and included the following aspects of biodiversity:
Gene

- Cryptic species
- Exotic genes
- Changes in gene flow vectors
- Habitat loss
- Habitat fragmentation

Species

- Species richness
- Percentage described
- Conservation status of species

Ecosystem

- Representation in protected areas

- Area of vegetation cleared
- Percentage of area in intensive production
- Livestock densities on pastoral land

The next Commonwealth State of the Environment report, to be released in early 2002, will use a revised set of biogeographical units and a set of indicators that will be continued in subsequent reports. The indicators relevant to measuring changes in biodiversity (but mostly off-farm) are:

- Native vegetation clearing – decreases the total area of habitat available to species;
- Introduced species – contribution to species loss by predation and economic loss to agriculture;
- Species outbreaks – can be a threat to other native species and commercially valuable resources;
- Extinct, endangered and vulnerable species and ecological communities – the best available surrogate for loss of species or a loss of diversity;
- Extent and condition of native vegetation – a surrogate for terrestrial ecosystem diversity;
- Populations of selected species – a surrogate for identifying trends in genetic diversity.

Australia's National Land and Water Resources Audit

The National Land and Water Resources Audit (http://www.nlwra.gov.au) is a four year program to improve decision making on land and water resource management by providing (*inter alia*):

- a clear understanding of the status of, and changes in, the nation's land (including vegetation) and water resources and implications for their sustainable use; and
- a framework for monitoring Australia's land and water resources in an ongoing and structured way.

It has seven themes one of which, Ecosystem Health, includes the project Landscape Health that deals with biodiversity at a systems level. The reporting framework is based on the State of Environment national indicator system with condition and trend attributes. This project reports on condition indicators (described in the Appendix) at Interim Biogeographical Regionalisation of Australia (IBRA 5) subregions (354 in total) that are distinctive landscapes with characteristic patterns of landforms, soils and vegetation.

This project synthesised the indicators into a Landscape stress rating (that accommodates the primary determinants of the remaining native biodiversity in a region). The map for this synthesised Continental landscape stress (figure 84 in Morgan 2001) and other maps from the Audit will be available at www.nlwra.gov.au/atlas . This study showed the geographic distribution of biodiversity status across the continent, and the scale of the challenges to landscape health. At present, there are severe limitations in terms of the quality of the data. In the absence of appropriate data, surrogates have been used that are not underpinned by a body of clear and irrefutable scientific literature.

A partnership of a dozen agencies will form the Australian Collaborative Rangeland Information System to coordinate rangeland information from a wide range of sources. In particular, as a result of the Audit's work, they are developing a framework for monitoring biodiversity within the rangelands. It will be an operational system using remote sensing and approaches rangelands management from a perspective of how landscapes function, rather than how they are used. Key attributes for monitoring changes in biodiversity include:

- change in composition of perennial plant species and abundance of specified invasive, fire sensitive, threatened and grazing-sensitive species;
- change in the composition of ant communities; and
- change in distribution and abundance of threatened vertebrates (mammals and birds) from repeat surveys of wildlife.

Other themes of the 'Audit', such as Agricultural Productivity and Sustainability and Catchment Condition, contain indicators of relevance (see Appendix).

Montreal process of indicators for forests

Australia, as a member of the Montreal Process, has been developing criteria and indicators to assess sustainable forest management at national and regional levels. We include it here because of potential synergies – and possibilities of harmonisation of indicator systems – particularly concerning remnant vegetation in rural areas.

This sub-national framework takes a pragmatic, phased approach to implementation (MIG Secretariat 1998). The indicators that are largely implementable now, rather than in the next 5 years, are the only ones that have been seriously addressed so far. They include:

- Extent of area by forest type and tenure
- Area of forest type by growth stage distribution by tenure.
- List of forest-dwelling species.
- The status (rare threatened vulnerable endangered or extinct) of forest-dwelling species at risk of not maintaining viable breeding populations as determined by legislation or scientific assessment.

As with the other exercises, there are major issues relating to consistency of data, its availability and timely analysis. There are some confidentiality concerns regarding data from private land owners.

Discussion

The indicators described above address a variety of issues, such as on-site and off-site changes to cultivated, feral and native components of biodiversity, with an emphasis on wild biodiversity. The SCARM indicators for sustainable agriculture form the only set that explicitly addresses biological resources needed for agricultural production, although some products of the National Land and Water Resources Audit do address diversity on farms and in cropping systems. The State of the Environment and landscape health indicators in the 'Audit' are quite explicitly concerned about the 'natural' state and do not consider productive condition. The SCARM indicator set is also the only one that explicitly considers the impact of agriculture on biodiversity although some of the general indicators such as native vegetation clearing could be regarded as impacts of agriculture in at least some regions.

Saunders et al (1998) concluded from a review of biodiversity indicators that there is a distinct bias towards species level indicators and a focus on nature conservation. This focus is at the expense of ecosystem processes noted as a major reason for conservation of biodiversity (along with ethical, aesthetic, cultural and economic reasons). A scan through recent issues of the *Australian LANDCARE* magazine, which is supported by the National Heritage Trust partly to distribute information about community Landcare activities, shows that articles about biodiversity conservation on farm are mostly concerned with trees and native pastures.

There is a tendency to regard biodiversity as something that is inherently desirable without describing what is meant by 'biodiversity' in a particular context, the values associated with that aspect of biodiversity and the objective we wish to pursue. We believe that this situation needs to change before biodiversity indicators can play an effective role in the management of agricultural systems and the development of agricultural policy. We discuss this more fully in the next section and provide some suggestions for the way forward.

Future Directions

Definition of biodiversity and agri-biodiversity

Strictly, biodiversity (literally the "variety of all life forms") is a particular property of a collection of biological entities distinct from other properties such as abundance or distribution. From an evolutionary perspective, biodiversity provides the raw material on which a range of pressures act to select the best adaptations to current environments and niches. In agricultural systems, cultivation selects those species and varieties that provide goods and services of importance to human society. These goods and services include nutritious food such as meats, milk, eggs, grains, vegetables and fruit; fibres for clothing and furnishings; and industrial products like oils, leather, starches and building materials. However, there is an emerging recognition that the breeding of these productive species may need to also consider their contribution to ecosystem functions (Williams 2000). The prevalence of weeds and pests could be a symptom that ecological niches are not being effectively filled by cultivated species and systems.

It is not uncommon for the term 'biodiversity' to be used more broadly to the point where it becomes almost synonymous with 'biological resources' and encompasses issues such as quantity and productivity in addition to the more precise ecological notion of diversity or variety.

Because 'biodiversity' can encompass a variety of issues involving different values and objectives depending on the context, we propose a simple two-way classification in order to define the scope of agri-biodiversity indicators (Table 1). The classification is based on two simple dimensions: the extent to which particular biological resources are needed for agricultural production; and the extent to which agriculture has management capability or responsibility.

Consistent with this workshop's objective of tracking the state and trends in agriculture's impact on biodiversity, we define the scope of agri-biodiversity as biodiversity issues for which agriculture has management capability or responsibility (categories 1 and 2 in Table 1). These categories encompass biodiversity issues on which agriculture has an impact and therefore has the potential to modify the biodiversity outcome. Agri-biodiversity indicators are quantities used to measure that impact and inform subsequent management decisions. Ideally, of course, jurisdictions would specify objectives in relation to biodiversity and use indicators as simple measures of performance.

Table 1. A classification system for specifying the scope of agri-biodiversity indicators.

	Biological resources that directly influence agriculture	Biological resources that do not directly influence agriculture
Situations for which agriculture has management capability/responsibility	**1** Livestock, crops, pastures, soil biota On-farm pollinators, biological control agents, pests, diseases, weeds, etc.	**2** Remnants of native biodiversity, endangered species, wildlife corridors, etc.
Situations for which agriculture has no or limited management capability/responsibility	**3** Off-farm pollinators, biological control agents, pests, diseases, weeds, etc	**4** Reserves, national parks, etc.

1, 2	Issues for which indicators of the impact of agriculture are appropriate
3	Issues that affect the ability of agriculture to perform
4	Issues that are not relevant to the topic of agri-biodiversity

Category 1 covers biological resources on which agriculture depends and influences directly through its actions. Agriculture seeks to manipulate these resources to obtain the best outcome. This requires the reduction of some aspects of biodiversity (eg, genetic diversity within a crop or livestock to provide uniform products, elimination of pests and diseases), modification of other aspects (eg, soil biota conducive to legume growth) and enhancement of yet others (eg, insect predators, pollinators). Some of these modifications that are designed to increase production and profits may also increase risks of system failure. Examples include increased susceptibility to pandemics of diseases like the southern leaf blight of corn and stem rust in wheat, and wider impacts such as dryland salinity. On the other hand, increased diversity of biological resources can sometimes provide resilience to agricultural systems in the face of uncertainties and stresses such as those imposed by the weather (SCARM 1993), and 'biological ploughing' with well chosen crop rotations.

Category 2 covers biological resources that are not required by agriculture but are valued by the community at large for a variety of reasons. They include nature conservation which can be expressed in terms of reserve systems, wildlife corridors, habitat for endangered species etc; ecosystem functions for purposes such as water catchment, salinity management etc.; and many other objectives.

The separation of agri-biodiversity issues into these two categories allows the explicit identification of corresponding objectives and the opportunity to explore the impact of various policy instruments. In particular, it facilitates the identification of policies that do not distort production or trade, but focus specifically on biodiversity indicators.

A framework for developing operational objectives

The specification of objectives is a precursor of indicator development. This is particularly true with biodiversity, because the word is used by different people to mean different things and without a clear statement of an objective in each case, the relevance and interpretation of any indicator will be ambiguous.

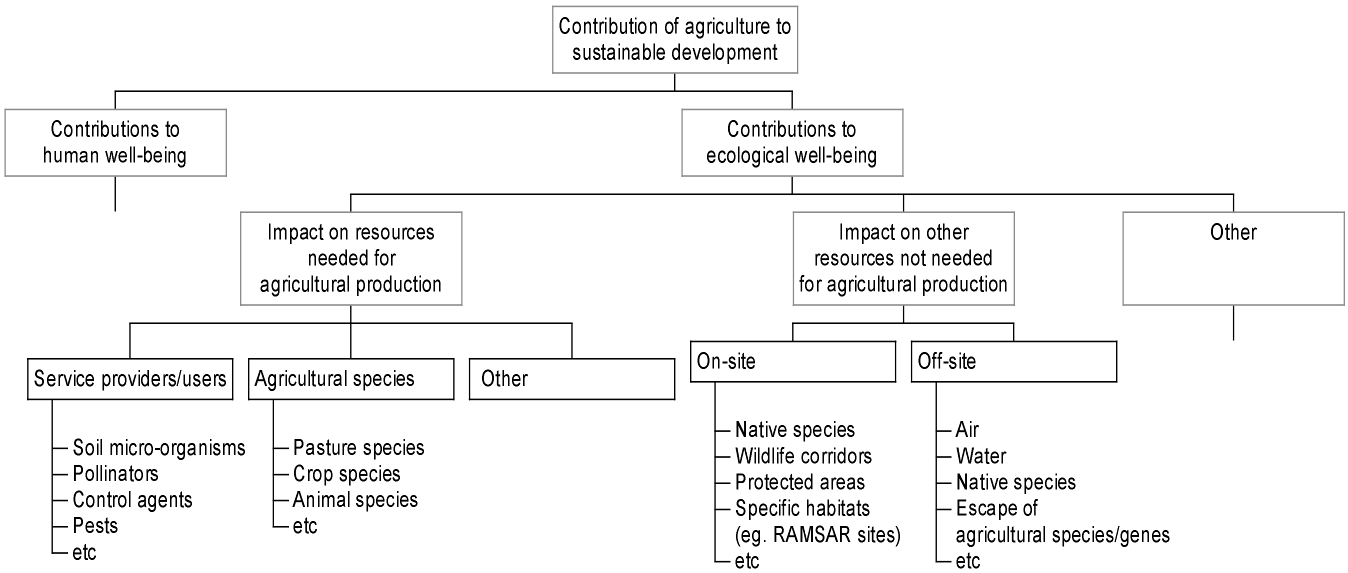
The Bureau of Rural Sciences (BRS) has developed an evaluation framework which facilitates the specification of sustainability objectives and can be applied at any scale (Delegation of Australia 1999, Chesson and Smith 2001). The framework is designed to address the question 'How does this entity contribute to sustainable development?' where the entity can be, for example, an individual agricultural enterprise, a catchment, a region or a state.

Contributions to sustainable development are first subdivided into two components: the direct contributions (both positive and negative, short and long term) to human well-being and to ecological well-being (which indirectly affects human well-being). These components are further subdivided in a hierarchical fashion until all relevant issues have been included and a level of specificity has been reached where it is feasible to specify objectives against which performance can be measured. We call these measurable objectives 'operational objectives'.

Ideally, the identification of relevant components and specification of operational objectives is carried out in an open, consultative manner involving all stakeholders. We have found the visual impact of the hierarchical structure extremely useful in encouraging and structuring stakeholder participation in a series of case studies applied to Australian fisheries. Using computer projection equipment, components can be added, deleted, moved and modified on the spot in response to stakeholder input. Component identification is carried out first. Operational objectives, the most controversial part of the process, are tackled only after components have been agreed. Once an operational objective has been specified, the development of an indicator to measure performance is relatively straight forward.

Figure 1 illustrates a hypothetical result of applying the BRS framework to an individual farm. Only those parts of the structure containing components relating to agri-biodiversity are expanded. Following the classification scheme in Table 1, the structure makes a distinction between the impacts of the farm on biological resources needed for agricultural production and the impacts of the farm on biological resources valued for other reasons. Objectives for resources needed for agricultural production should be consistent with obtaining good performance over the long-term. These objectives will not necessarily correspond to maximising biodiversity or mimicking a natural system. Objectives for resources that are not needed for agricultural production are likely to be motivated by objectives set a larger spatial scale by, for example, a catchment management group or a national conservation plan. The BRS framework is equally applicable for specifying objectives at any of these scales. Clearly, objectives at each scale need to be consistent and using a common approach at each scale encourages consistency.

Figure 1. A hypothetical example of an ESD framework applied to agriculture with components relevant to agri-biodiversity shown in expanded form.



Drivers of the need for agri-biodiversity indicators

Several recent policy developments in Australia are driving the need to specify objectives that only make sense above a certain spatial scale (eg bioregion, catchment) but require action at a smaller scale (eg farm) for their implementation. They include:

- The setting of national objectives and targets for biodiversity conservation for 2001-2005 as part of the National Strategy for Biodiversity Conservation. It includes targets for representative samples of each bioregion to be protected in part on private land and levels of grazing pressure by livestock within threatened native grasslands;
- A National Action Plan for Salinity and Water Quality that was endorsed by the Council of Australian Governments in November 2000 (www.affa.gov.au/actionsalinityandwater) to support regional action by communities to control salinity and improve water quality. As part of this plan, and recognising the influence of biodiversity in salinity and water quality and to further implement ESD, national outcomes and targets will be developed for biodiversity conservation by December 2002.
- The Murray-Darling Basin Commission, a consortium of 6 governments to oversee activities that concern cross-border issues in Australia's largest drainage basin, is investigating the setting of targets for biodiversity management within its jurisdiction.
- Work on developing market-based incentives to manage biodiversity, including the use of Environmental Management Systems (EMS) for gaining market acceptance, is in train in several arenas.

Most of these initiatives recognise the central role of local communities within catchments in managing and conserving biodiversity. In some places this is likely to have significant implications for agricultural land use. These initiatives will obviously require the setting of clear objectives with measurable targets, the development of indicators to measure progress, their monitoring and interpretation.

Implications for reporting at a continental level

Dealing with an issue not specifically assigned to Commonwealth responsibility covering a large land area, but with only a medium size economy, means that there are limited resources given to indicators of agri-biodiversity at a continental and national scale. Therefore, to be useful for policy purposes and for decision-making the indicators have to capture the essence of the local variability, but provide a broader summary. In other words the indicators attempt to capture the variety of biota at several scales – of organisation, time and space. In particular, the setting of desirable standards requires greater understanding of the system ie agriculture's biodiversity needs differ from those of, say, nature conservation.

Biodiversity indicators such as the number of threatened species or the area of natural vegetation will not be sufficient to deal with the very specific management issues that these initiatives are attempting to address. Thus, while these types of indicators will undoubtedly continue to have a role in places such as state of environment reporting, the focus in Australia is likely to be directed more and more towards indicators with direct management implications. We expect to see more indicators expressed in terms of the proportion of catchments meeting their individual biodiversity targets.

There is intuitive appeal in the ecosystem approach of the FAO Committee for Genetic Resources for Food and Agriculture (CGRFA) that recognises the utility of a framework based on appropriate scientific methodologies and focused on biological organization as well as on human interactions. However, implementing this for agri-biodiversity is difficult: much of the changes to the ecology in Australia remain unknown; understanding of the broad-scale processes is at best rudimentary (Morgan 2001); and there is still much work to be done in constructing models of the roles and functions of biodiversity in agriculture.

The quality of data has a large bearing on the usefulness and credibility of indicators. Promotion of agri-biodiversity as an issue in policy arenas is also dependent upon good data that can be used to demonstrate the costs and benefits of biodiversity to agriculture. There are a range of data sources commonly used in Australia for compiling indicators including: expert opinion and ground-based judgements; small surveys are commonly conducted for unique purposes; large regular surveys conducted usually of farmers; quantitative ground-based monitoring of sentinel sites; and remotely sensed information, commonly the Normalised Difference Vegetation Index (NDVI). Developments in technology may allow fine scale Thematic Mapper (TM) images to differentiate grass from trees to link them to calibrated models to estimate growth and biomass in the field (Hume et al 2000) and examine impacts of drought and grazing management (McKeon et al 2000).

Conclusions

Conservation of biodiversity has a high priority in new policy and legislative initiatives in Australia. Understanding the implications of agricultural ecosystems for biodiversity is a significant national activity and there is strong interest in its role in the conservation of representative species and ecosystems outside reserves. Targets for biodiversity are also beginning to be included in contributions to the management of other environmental issues such as salinity. Several trends may thus be converging on the need for indicators of this issue.

Our strongest lesson from using indicators is to set clear objectives first. Once clear objectives have been set, the choice and use of indicators follow logically. In their absence, indicator 'shopping-lists' develop with tenuous relationship to management or decision making. Our sense is that conservation and biodiversity theory and management still have some way to go to be able to devise the best framework for assessing biodiversity, setting objectives and guiding agri-biodiversity indicators. This appears particularly the case for the contribution of biodiversity to delivery of ecosystem services.

There is increasing awareness that the standards of biodiversity for optimum and minimum levels for resilience should be set at local (eg catchment) spheres of influence. If agri-biodiversity encompasses those biodiversity issues for which agriculture has management capability or responsibility, then agri-biodiversity indicators are quantities used to measure that impact and inform subsequent management decisions. We then expect to see more indicators expressed in terms of the proportion of catchments meeting their individual biodiversity targets.

A recurrent comment from the different developers of indicators is the availability, consistency, currency and quality of data to put into the indicators. Increasingly, remote sensing is being used for monitoring vegetation cover and is developing towards monitoring vegetation classes and even species.

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Appendix

We describe several recent exercises to develop indicators at a national scale that include biodiversity. Here we note that Australia has 245 major catchments, 10 major climatic regions, 11 major agro-ecological regions, 85 bioregions and 34 landcover types all of which have claims as a reporting unit for some purpose (Hamblin 1998).

Indicators of sustainable agriculture (SCARM 1998)

1) Rangeland condition and trend

Three methods were employed to assess this attribute: remotely sensed Normalised Difference Vegetation Index (NDVI) data; survey and ground-based judgements; and quantitative ground-based and remotely-sensed monitoring. This indicator is the ability of the landscape (where landscape is a scale larger than habitat but smaller than catchment) to respond to rainfall, where vegetation response is a surrogate for landscape functioning.

2) Agricultural Plant Species Diversity

This information is derived from the annual Agricultural Census or Survey, a self-reporting mechanism by agricultural land owners. The attribute is the diversity of plant species used for agricultural production in a region expressed as an index (a modified Two-Way Shannon Index of Diversity) based on the number of species grown, the area of each species, and number of farms growing each species. Provided the set of questions in the Survey remains constant then the index does provide some estimate of biological resilience for a region over time. It is less useful to compare between regions, and because of data limitations is not suitable for sub-regions (confidentiality) nor for rangelands (does not include the constituents of pasture).

3) Impact of native vegetation in conservation reserves

Composed of 3 attributes:

- Total length of the boundary between conservation and agricultural areas (km)/total area of conservation reserves (ha). Interpretation poses a problem if some small areas of conservation are added the ratio may increase instead of desired decrease.
- Total area of agricultural land (ha)/total area of conservation reserves (ha) would help overcome the above difficulty
- Intensity of agricultural production – sown pasture and crops/total agricultural area (%).

4) Impact on biodiversity of native vegetation

Composed of 3 attributes:

- Conservation – percentage of original area of each vegetation type now in conservation reserves;
- Disturbance – percentage of original area of each vegetation type occurring on agricultural land that has been disturbed by clearing or grazing;
- Remnant area on agricultural land – percentage of total undisturbed area of each vegetation type that occurs on agricultural land.

This system uses coarse vegetation classification, which may conceal or under-represent some biota; it will not be very responsive to change of policies. Other measures contemplated include land clearing rates and fragmentation of remnant vegetation. These categories have changed from their original proposal, as they were measured and implemented. For instance, indicator (2) was initially proposed as a measure of 'biological resilience', but other measures have since been added such as 'enterprise diversity' and 'rangeland condition'.

State of Environment reporting

Commonwealth SoE 1996

The indicators for condition used in 1996 State of the Environment report (Commonwealth of Australia 1996) were presented at three levels. At the ecosystem level it was acknowledged that there is no agreed classification system for ecosystems in Australia – Interim Biogeographical Regionalisation for Australia (IBRA 4) of 80 biogeographic regions (Thackway and Cresswell 1995) were used for this report. The report used the representation in protected areas (% area) and threatening processes such as area of vegetation cleared (% area), intensive production (% area), livestock densities on pastoral land (number/ha) as surrogates to report at the ecosystem level. At the species level relevant indicators included estimates of species richness (number/ha), percentage described, and conservation status of species. Gene level indicators included cryptic species, exotic genes and changes in gene flow vectors as well as the threatening process of habitat loss and habitat fragmentation.

Commonwealth SoE 2001

The State of the Environment report for 2001 will report at biogeographical scales of IBRA 5 of about 354 subregions in the 85 bioregions across the continent (Environment Australia 2000). Core indicators, to be used for later reports, for biodiversity (ANZECC 2000) that are relevant to this forum include:

- BD1. Native vegetation clearing. The rate of clearing, in hectares per annum, of terrestrial native vegetation types, by clearing activity. A direct measure of a threatening process. Preliminary assessments note that remote sensing does not yet pick up sparse woodlands and grasslands. The National Vegetation Information System under development may contribute to this.
- BD4. Introduced species. The distribution and abundance of non-indigenous species (plants, vertebrates, invertebrates, and pathogens) identified as pests. The indicator also includes displaced/translocated native species. This is a direct measure of a threatening process. The weeds of national significance is a first start, but some regions are not easy to assess.
- BD5. Species outbreaks. The number and identity of native species outbreaks and the location and area affected. A direct measure. Usually a localised occurrence, and may be combined with BD4.
- BD6. Extinct, endangered and vulnerable species and ecological communities. Number of species and ecological communities presumed extinct, endangered or vulnerable, reported by major group together with the estimated number of endemic species per major group. A surrogate for loss of species.
- BD7. Extent and condition of native vegetation. The vegetation assemblages, by type, to be used as surrogates for ecological communities and ecosystem diversity.
- BD9. Populations of selected species. Estimated populations of selected species, are an important measure for assessing the conservation status of species and surrogates for changes in genetic diversity. Selection of target species a challenge – bird abundance relatively easy, fungi could be useful.

National Land and Water Resources Audit

Landscape health

Condition attributes (Morgan 2001) of interest to this group includes:

- current extent of native vegetation – a surrogate for ecological disruption.
- Degree of connectivity in native vegetation – where decreasing connectivity (increasing fragmentation) is considered to lead to a general decline in biodiversity, particularly of the less mobile vertebrates with more complex habitat or large home area requirements.

- Protection of native vegetation
  - Conservation reserves – protection and conservation of representative areas of the natural environment is seen as a fundamental part of sustainable land use. Uses the percentage of subregion with protected areas as a surrogate for comprehensive, adequate and representative reserves from the 1999 Collaborative Australian and Protected Area Database. Many of the sub-regions, 173 or 49%, have less than 2% of their area protected and 20% have no protected area.
  - Native vegetation outside conservation reserves – an indication of opportunities to increase representation of poorly protected subregions. There are options for significant conservation as 158 of the subregions have more than 70% of remaining vegetation outside conservation reserves.
- Condition of native vegetation – limited data available, so surrogates such as likely intensity of past and present land uses.
  - Impact from total grazing pressures – an indication of 'biophysical naturalness' which also incorporates tenure, rangeland type, and distance to permanent water.
  - Native vegetation in land tenures associated with less intensive land use practices – tenures such as conservation reserves, vacant crown lands, crown reserves, aboriginal reserves, or armed forces reserves.
- Feral plants and animals
  - Distribution and density of non-indigenous plant species (weeds) of national importance.
  - Distribution and density of non-indigenous vertebrate species (feral animals) of national importance.
- At-risk ecological communities and threatened species (those with greater than 70% of original ecosystem cleared and with an original area of less than 10 000 ha)
  - Ecosystems at risk.
  - Threatened species

Trend attributes were also presented including current rates of clearing of native vegetation (eg the area of woody native vegetation cleared each year between 1990 and 1995 and change in annual rate of clearing). This report then attempted a synthesis by calculating a Landscape stress rating (remaining biodiversity) using attributes in a hierarchy of priorities going down from (in the case of the more intensive zones):

- Current extent of native vegetation;
- Connectivity of native vegetation (fragmentation);
- Percentage of native vegetation in land tenures associated with conservative land use practices
- percentage of subregional ecosystems threatened.

Some subsequent modification of the index (up or down) was allowed using the following attributes by:

- percent of native vegetation with high dryland salinity
- density of weeds
- density of feral animals
- number of threatened species

The map for this synthesised Continental landscape stress (figure 84 in Morgan 2001) and other maps from the Audit will be available at http://audit.ea.gov.au/ANRA/atlas_home.html .

Agricultural Productivity and Sustainability

Other indicators from other NLWRA projects of relevance include:

- agricultural plant species index (the same method as used for the SCARM indicators) available at Local Government level, data from Australian Bureau of Statistics (ABS);
- diversity on broadacre farms using financial and production data based on enterprises was interpolated from survey data for the continent;
- diversity in broadacre crops using the proportion of total crop area represented by a particular group, such as pulses, oilseeds, cereals. This was calculated at Local Government level from ABS data.

Catchment condition

The project on developing estimates of Catchment Condition is taking an approach of the user being able to define combinations of attributes, including a layer for biota condition. A working demonstration of the method is given at the website http://www.brs.gov.au/mapserv/catchment/catchment_map.html . Although these attributes are represented at catchment scale and thus represent both agricultural and non-agricultural land, they may help to provide an overview of some aspects of agri-biodiversity. All the attributes are normalised to a 5 point scale ranging from better to worse. Some relevant attributes include:

- % area of catchment cleared of trees (surrogate for habitat quantity and distribution)
- % area of protected lands (surrogate for habitat protection)
- Remnant tree cover occurring in stands of >50 ha as % of catchment area (surrogate for habitat fragmentation)
- Number of feral animals per unit area (decline of native biodiversity)
- Number of weed species or number of weed species-density combination (decline of native biodiversity)

Montreal process of indicators for forests

This sub-national framework (www.affa.gov.au/docs/forestry/sustainability) recognises that it is not possible, practical or cost-effective to fully implement and monitor all identified indicators at this time and provides a phased approach to implementation (MIG Secretariat 1998). The indicators have been placed into three broad categories following an initial evaluation of Australia's capacity to report on indicators. These are:

- Category A – indicators which are largely implementable now;
- Category B – indicators for which new data needs to be collected or some development work done (3-5 years); and
- Category C – indicators that require longer-term research and development before they can be applied extensively (> 5 years).

The first criterion in the set of indicators is for **Criterion 1: Conservation of biological diversity.** This is considered at 3 levels 1.1 ecosystem diversity; 1.2 species diversity; and 1.3 genetic diversity. The category A indicators are:

- Indicator 1.1a Extent of area by forest type and tenure. Refinement of protocols for assigning areas to fit IUCN protected area categories and differences between States in tenure arrangements.
- Indicator 1.1b Area of forest type by growth stage distribution by tenure. Definition of growth stages may need some refinement.
- Indicator 1.2a A list of forest-dwelling species. Scientific names, taxonomy and standards of description needs some harmonisation
- Indicator 1.2b The status (rare threatened vulnerable endangered or extinct) of forest-dwelling species at risk of not maintaining viable breeding populations as determined by legislation or scientific assessment. This indicator is slow to react and needs routine updating of species and categories.

The category B indicators are:

- Indicator 1.1e fragmentation of forest types

The category C indicators are:

- Indicator 1.2c Population levels of representative species from diverse habitats monitored across their range.
- Indicator 1.3a Amount of genetic variation within and between populations of representative forest dwelling species.