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Ecosystem Assessment for Ecosystem Services Markets in Alberta

Alberta Biodiversity Monitoring Institute
March 4, 2010

Contents

Introduction

Ecosystem services are the benefits that people get from ecosystems. Markets for some of nature's benefits are already well developed, such as the provision of forest products and agricultural crops. However, markets for most ecosystem services are only beginning to emerge, even though they provide important benefits such as climate moderation, water regulation, pest control, and wildlife habitat, to name but a few.

The Institute for Agriculture, Forestry and Environment (IAFE) is developing an Ecosystem Services Market Policy Framework to expand business opportunities and investment in Alberta's agriculture and forestry sectors while protecting and restoring the services provided by Alberta's ecosystems for which markets are lacking. By creating economic and regulatory incentives for conservation and stewardship of ecosystem services, markets can guide people’s behaviour in directions that support desired environmental and economic outcomes. Under a market approach, people and businesses that are able to provide ecosystem services such as fresh water, erosion control, and wildlife habitat can be economically rewarded for doing so. Establishing markets for ecosystem services can also encourage people to limit their use of ecological resources and reduce their environmental impact.

Ecosystem services markets have been implemented around the world in places such as Australia, the United States, and Latin America. For example, ranchers in Australia can be compensated for conducting management activities that protect and restore ecosystem services such as water quality and native vegetation[1]. In the United States, landowners are paid to manage their land for the benefit of endangered species[2]. Farmers in Mexico receive payments in return for preserving forest cover on their property, which provides water filtration and water storage services for downstream users[3]. These are just a few examples of ecosystem services markets used to support a variety of conservation and stewardship objectives.

Markets work well when the value of a good or service is readily understood. In the case of ecosystem services markets, an understanding of value may not be easy because many ecosystem services are difficult to measure. For example, when a shopper buys a loaf of bread, its value can be assessed by looking at the loaf, perhaps reading the label, and considering whether the price is fair. Determining the value of ecosystem services such as fresh water, erosion control, and wildlife habitat requires specialized forms of assessment using appropriate scientific methods and information.

This report describes an approach for assessing ecosystem services to support the IAFE's Ecosystem Services Market Policy Framework. Based on purpose-driven principles, the approach uses existing

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[1] Victoria Department of Natural Resources and Environment. 2002. Victoria’s Native Vegetation Management: A Framework for Action. Department of Natural Resources and Environment, East Melbourne.

[2] US Fish and Wildlife Service. 2003. Guidance for the Establishment, Use, and Operation of Conservation Banks. http://www.fws.gov/endangered/pdfs/MemosLetters/conservation-banking.pdf

[3] Alix-Garcia, J., A. de Janvry, E. Sadoulet, and J.M. Torres. 2005. An Assessment of Mexico’s Payment for Environmental Services Program. Report prepared for the Comparative Studies Service Agricultural and Development Economics Division, United Nations Food and Agriculture Organization (FAO). Pp. 79.

information, supplemented by rapid ecosystem assessments and calculations to measure a range of ecosystem services at local, regional, and provincial scales. Because the Policy Framework encompasses a wide range of potential ecosystem services markets, the approach focuses on the general structure of the assessment function, which will require further refinement for implementation in the context of specific market instruments such as conservation easements, offset programs and payment schemes[4].

This report also provides recommendations for institutional alignment and strategic investment to support and further develop the assessment approach. A significant part of the infrastructure required to support ecosystem service assessment already exists in Alberta, most notably through the Alberta Biodiversity Monitoring Institute (ABMI). The ABMI has developed measurement protocols, ecological models, and information management systems to support an ongoing program of long-term ecological monitoring throughout Alberta. By building on this existing capacity through strategic investment and consultation, the assessment requirements for a range of ecosystem services markets could be efficiently and effectively met.

Assessment principles

> Markets need certainty and clarity about what is being bought. This knowledge must be efficiently obtained to maintain value in the market.

Ecological assessments are conducted for many purposes, including environmental impact assessment, natural resource management, and scientific research. Depending on the purpose, the attributes chosen for assessment, and the methods used to measure and communicate the results, may vary considerably. Although ecosystem services markets involve people and businesses that may lack specialized ecological knowledge, the market transactions of buying and selling are based on "units" of ecosystem services whose measurement may require just this sort of specialized ecological knowledge. For example, a mining company that wishes to purchase credits to offset the impacts of its development on wildlife habitat (i.e., a transaction) may need an assessment of the amount and quality of wildlife habitat in their mining lease (i.e. specialized ecological knowledge). Finding the appropriate balance between simplicity and credibility while keeping costs low, is essential to ecosystem services markets. Therefore, the assessment approach needs to follow three key principles:

1. Grounded in science

Markets work best when there is certainty that transactions are conducted in a fair and transparent manner. The assessment approach needs to be scientifically credible and verifiable so that market participants and stakeholders are confident in the process. In other words, there needs to be clarity and confidence around what is bought and sold, and that the price is fair.

2. Easily understood

Market participants need to clearly understand what is being bought and sold. This requires that an assessment be conducted and presented in a simple and intuitive manner.

[4] See glossary for definitions

3. Cost effective

Because assessment represents a form of overhead to be minimized in a market transaction, it should lean heavily on available sources of information, existing knowledge and rapid, inexpensive ecosystem assessment methods.

Assessment approach

This section describes several steps for assessing ecosystem services to support ecosystem services markets, including defining the ecosystem services of interest, reviewing existing information, collecting new information, and calculating marketable ecosystem service units. Depending on the assessment requirements of a specific market instrument or type of transaction, some steps may be more important than others. For example, payments for the provision of ecosystem services over large areas may need to lean more heavily on existing information to keep transaction costs low, while transactions based on small areas may require the collection of new site-specific information to ensure accuracy.

1. Define the ecosystem services of interest

Ecosystem services markets must be clear about which ecosystem services are to be bought and sold, so that appropriate assessment approaches can be developed and implemented. A good starting point for defining ecosystem services is the Millennium Ecosystem Assessment[5], which identified 31 services, divided into four categories: provisioning, regulating, cultural, and supporting (Table 1). While comprehensive, this list does not explicitly include biodiversity, which is considered the foundation for all life on earth. Because biodiversity and related ecosystem services such as wildlife habitat may be highly valued in their own right, numerous markets and accompanying assessment approaches for such services have been developed and implemented.

Table 1. Ecosystem services identified by the Millennium Ecosystem Assessment. See Appendix 1 for details.

Provisioning	**Regulating**	**Cultural**	**Supporting**
Food	Air quality regulation	Cultural diversity	Soil formation
Fiber	Climate regulation	Spiritual & religious values	Photosynthesis
Fuel	Water regulation	Knowledge systems (traditional & formal)	Primary production
Genetic resources	Erosion regulation	Educational values	Nutrient cycling
Biochemicals, natural medicines, pharmaceuticals	Water purification, waste treatment	Inspiration	Water cycling
Ornamental resources	Disease regulation	Aesthetic values	
Fresh water	Pest regulation	Social relations	
	Pollination	Sense of place	
	Natural hazard regulation	Cultural heritage values	
		Recreation, ecotourism	

[5] Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: Synthesis. Island Press, Washington, DC.

Because many of the ecosystem services listed in Table 1 are interrelated[6], assessments must be careful to avoid multiple counting[7]. For example, the provision of fresh water is an ecosystem service that depends on two other services: water regulation and nutrient cycling. Therefore, while it may be possible to assess each ecosystem service individually, it is difficult to combine them into some overall measure of ecosystem services. Such efforts to combine ecosystem services require that each service be represented in common units. They also require decisions on whether each service is weighted equally or not. Most ecosystem service markets are best supported by assessments in which each ecosystem service is considered separately.

Why ecosystem services?

The concept of ecosystem services has been adopted by many governments and stakeholders because it implies that actions to protect and restore ecosystems will improve human well-being. In theory, if people better understand the benefits they receive from nature, they will be more willing to support and conduct actions that reverse negative ecological trends. Actions that carry an economic or social cost are more likely to be supported if they are perceived to result in tangible benefits. Because the value of conserving species and ecosystems for their own sake, or for some unspecified potential future benefits, is not universally shared, arguments to conserve ecosystems for their intrinsic properties are often considered insufficient to motivate environmental policies and actions.

Another reason for the increased attention to ecosystem services is that the concept can be used to express the value of ecosystems in monetary terms. For example, the economic value of 17 ecosystem services produced by the Mackenzie watershed in northern Canada was estimated at $570 billion per year, more than 10 times the region's gross domestic product[8]. This sort of valuation was stimulated by an earlier study[9], in which economic value of the world's ecosystem services were estimated to be far greater than the global gross natural product. (The economic valuation of ecosystem services is still constrained by high uncertainty, inadequate data sources and inconsistent methodology.)

Most regulating, cultural, and supporting services are considered public services, for which markets are only just starting to emerge. The benefits of many provisioning ecosystem services are already well understood through the existence of markets; for example, the value of wheat production is well known because the costs of growing it and buying it are known or can readily be estimated. Therefore, the

[6] Fisher, B., Turner, R.K. Morling, P. 2009. Defining and classifying ecosystem services for decision making. Ecological Economics 68:643-653.

[7] Boyd, J., Banzhaf, H.S., 2006. What Are ecosystem services? The need for standardized environmental accounting units. RFF DP 06-02, Discussion paper (http://www.rff.org/rff/Publications). Resources For the Future.

[8] Anielski, M. and S. Wilson. 2007. The Real Wealth of the Mackenzie Region: Assessing the Natural Capital Values of a Northern Boreal Ecosystem. Canadian Boreal Initiative, Ottawa. ISBN 978-0-9733409-4-5

[9] Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, S. Naeem, K. Limburg, J. Paruelo, R.V. O'Neill, R. Raskin, P. Sutton, P. and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253–260.

emphasis of ecosystem service assessments for emerging markets is on regulating, cultural, and supporting services.

2. Identify indicators of ecosystem services

After ecosystem services have been identified and defined, it is necessary to select one or more indicators. In the context of ecosystem service assessment, indicators are measurable entities that provide relevant, useful information about the status of an ecosystem service. Because ecosystems consist of countless inter-related components and processes, the choice of indicators may not always be obvious. A comprehensive ecosystem classification can guide such choices by dividing ecosystem components and processes into broad classes such as the six categories depicted in Figure 1. Each category can be further divided into multiple subcategories, which may in turn be divided into discrete, measurable indicators such as population size, pH, rate of primary production, and water storage capacity.

The main contribution of a hierarchical ecosystem classification such as that depicted in Figure 1 is that it provides a logical structure for selecting, organizing and aggregating ecosystem service indicators. For example, market approaches intended to conserve native vegetation would need to include indicators of landscape and biotic condition; those intended to protect and restore water quality might include indicators of the chemical and physical characteristics of water. Additional considerations include the availability of existing information, and the resources and expertise required to process such information, or collect new data. Indicators requiring specialized expertise or equipment that is not available, or is prohibitively expensive, would not be good choices for assessments to support ecosystem services markets.

What is an ecosystem?

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. While ecosystems are sometimes delineated on maps based on landforms and vegetation types, there is no agreed-upon basis for defining their size. Ecosystems can be smaller than a drop of water, or larger than the boreal forest, depending on which organisms and ecological processes are considered. The common theme in defining ecosystems is the presence of living and non-living components and structures, and the ecological processes that connect them through the movement of materials and energy.

Examples of indicators used in assessments to support ecosystem services markets are listed and described in Appendix 2.

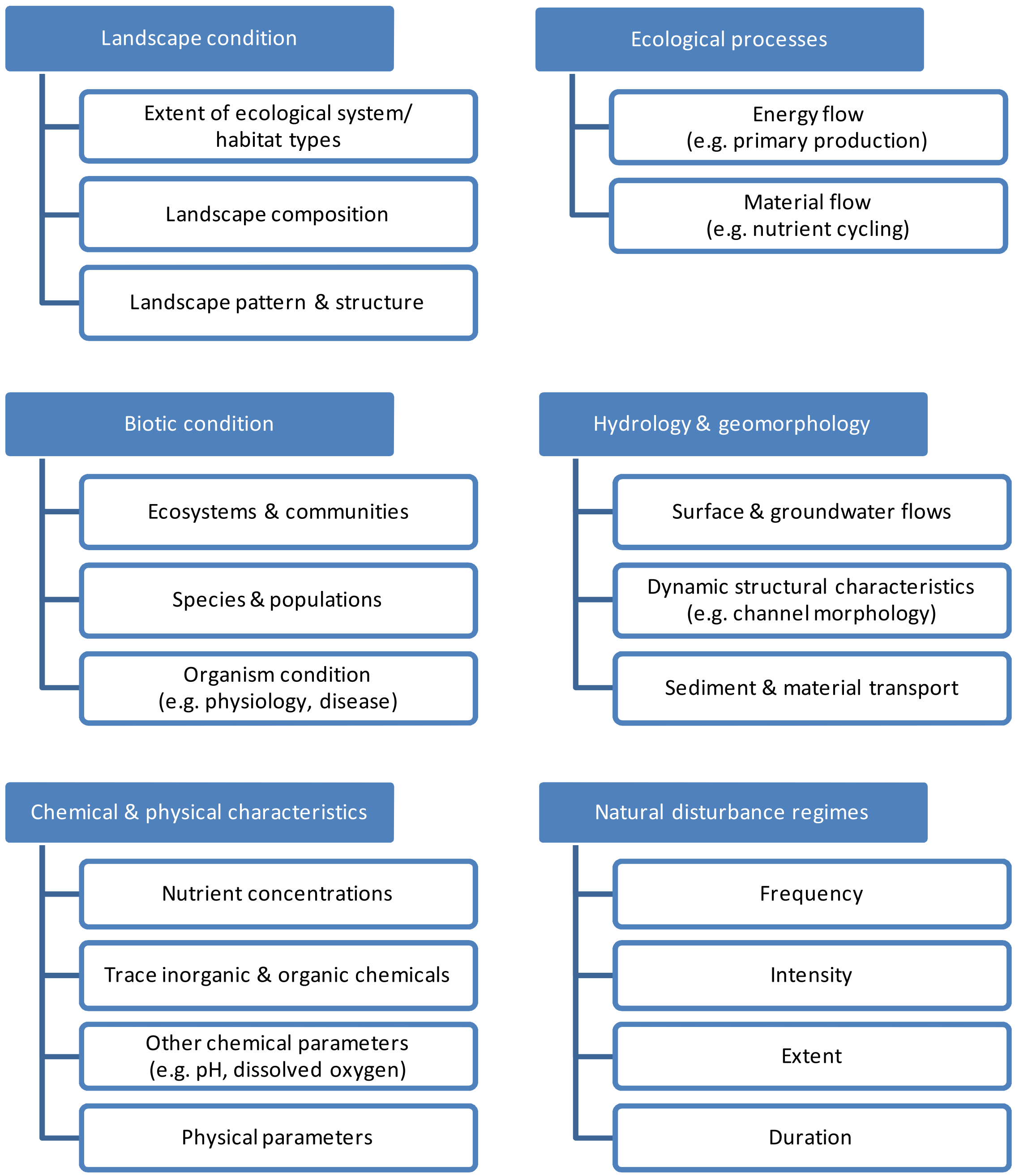

Figure 1. Ecosystem classification to guide the design of assessment programs[10]. Elements on the left and right are considered ecosystem components and processes, respectively.

[10] U.S. Environmental Protection Agency.2002.A framework for assessing and reporting on ecological condition: An SAB Report. EPA-SAB-EPEC-02-009.

3. Identify existing sources of information

Ecological indicators to support ecosystem services markets can be obtained from existing sources of information. Sources relevant to selected ecosystem services in Alberta are listed in Table 2; these can be divided into two categories: 1) maps and 2) ecological inventory and monitoring programs.

Maps

Maps can be used to calculate a range of ecosystem service indicators. Examples of potentially useful maps include those that portray:

- elevation and topographical relief
- vegetation structure and composition
- distribution, depth, and other attributes of rivers, lakes, and wetlands
- distribution and abundance of selected plants and animals
- human footprint from forestry, agriculture, energy, transportation, and other developments.

The key strength of maps for ecosystem service assessment is their geographic completeness: they can be used to assess ecosystem services over the entire mapped area, or some portion thereof. However, a map is limited by the spatial resolution of the information used to build it, meaning that they cannot be used to assess ecosystem services within very small areas. Additional weaknesses of maps include the limited number of attributes they portray, and the problem of out-dated information. Maps that portray dynamic features can quickly become inaccurate. Ecosystem service assessments for which existing maps may be useful need to take into consideration how the attributes, spatial resolution, and currency of such maps affect the accuracy with which indicators can be derived.

Ecological inventory and monitoring programs

This category of information is not necessarily independent of maps, because information obtained through inventory and monitoring programs is frequently summarized in the form of maps. Inventories are generally designed to accurately portray the status of an ecological attribute at a single point in time, whereas monitoring programs tend to trade off some of this accuracy in favour of the capacity to record trends over time. Both are potentially useful for calculating ecosystem service indicators.

Ecological inventory and monitoring programs useful for calculating ecosystem service indicators include:

- measurements of water flow and water quality
- fish and wildlife population surveys
- vegetation inventories and monitoring programs
- biodiversity monitoring programs.

Perhaps surprisingly, the relevance of information from ecological inventory and monitoring programs to the calculation of ecosystem service indicators is often limited. Information from such programs is generally obtained from a one or more locations in a region, using sampling techniques such as field or aerial reconnaissance, sample plots, transects, water samples, and specialized recording devices such as flow metres. The resulting information is often applicable only to the sampled locations or, through extrapolation, a surrounding region. If the location or region does not correspond to the area of interest for ecosystem service assessment, then ecological inventory and monitoring programs are of limited relevance.

Table 2. Sources of existing information to support the assessment of selected ecosystem services in Alberta. Other potential sources were listed in two recent reports by Alberta Environment[11].

Ecosystem service	Ecosystem service indicator	Source
Water provision	River flow volume Lake & wetland depth Net water influx (e.g., precipitation minus evapotranspiration)	Alberta Environment Alberta Environment Weather stations and hydrological models
Climate regulation	Volume of carbon stored in soil and vegetation	AVI, GVI
Water regulation (flood & erosion control)	Watershed cover composition	AVI, GVI
Water purification	Watershed cover composition Water quality	AVI, GVI Alberta Environment
Biological control	Intactness of species that provide biological control	ABMI
Crop pollination	Intactness of habitats that provide refugia for pollinator species	ABMI
Outdoor recreation	Area of accessible natural & semi-natural landscapes	AVI, GVI, Base Features
Biodiversity	Fish and wildlife population status Species & habitat intactness	Sustainable Res. Dev't, ABMI

ABMI: Alberta Biodiversity Monitoring Institute
AVI: Alberta Vegetation Inventory
GVI: Grassland Vegetation Inventory

The availability and accuracy of existing information varies widely among ecosystem services. For example, information on provisioning services, such as crop yield and timber production, is readily available (although provisioning services are generally outside emerging ecosystem services markets). Information on regulating, supporting, and cultural services tend to be more difficult to obtain because of their complexity (e.g., disease regulation) and the large areas over which they operate (e.g., climate regulation, nutrient cycling). Some ecosystem services are difficult to define (e.g., aesthetic values), let alone measure.

[11] Alberta Environment. 2007. Ecosystem goods and services assessment - southern Alberta: Phase 2 Report - Version 2: Conceptual linkages and initial assessment. Contract report prepared by Integrated Environments (2006) Ltd. and O2 Planning + Design Inc. 138 pp.

Alberta Environment. 2009. Ecosystem goods and services, southern Alberta: A framework for assessing natural asset condition. Contract report prepared by O2 Planning and Design Inc. 216 pp.

4. Obtain new information

As noted in the previous section, information from existing maps, inventories, and monitoring programs may be inadequate to assess the ecosystem services of interest in a given location. For example, transactions based on ecosystem services provided on small parcels of land may require the collection of additional data if information obtained elsewhere is not applicable. Transactions may also require information that is more recent than any existing sources.

Because assessment represents a form of overhead to be minimized in an ecosystem services market, only rapid assessment methods for obtaining new information are reasonable to consider. Such methods must use well-documented and repeatable protocols. Where possible, the measurements should also be compatible with ecological models that translate raw field data into useful attributes.

The Alberta Biodiversity Monitoring Institute has conceptually developed an approach to rapidly assess a range of ecosystem services. The approach is a scaled-down version of the full ABMI sampling protocols[12], which use credible and repeatable sampling methods to determine the presence and abundance of species, vegetation structure and composition, along with numerous chemical and physical characteristics of terrestrial and aquatic environments. These measurements are used, in conjunction with ecological models, to estimate key indicators of ecosystem services. Because a rapid assessment protocol can measure only a limited number of ecosystem service indicators, modifications to the full ABMI protocols would be required to support ecosystem services markets.

Aspects of other assessment programs could be integrated with the ABMI's rapid assessment protocol to expand the number of ecosystem service indicators. For example, the Alberta Rangeland Health Assessment[13] consists of three sets of protocols for assessing ecosystem health from a rangeland perspective in native grassland, forest, and tame pasture. Each of the three protocols involves the scoring of factors considered important to rangeland health, including community structure, moisture retention, soil erosion, non-native species including noxious weeds, and grazing intensity. Another program, the Alberta Lentic Wetland Health Assessment[14] involves the scoring of vegetation, soil, and hydrological factors considered important to wetland health, including native and invasive plant cover, human alteration of vegetation and water level, and erosion potential.

5. Calculate marketable ecosystem service units

Marketable ecosystem service units are measurable amounts of ecosystem services that can be bought or sold in a market. They can be calculated from existing information, new information, or some

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[12] Alberta Biodiversity Monitoring Institute. 2008. Wetland field data collection protocols (10035), Version 2008-04-29 Alberta Biodiversity Monitoring Institute, Alberta, Canada. abmi.ca.

Alberta Biodiversity Monitoring Institute. 2007. Terrestrial field data collection protocols (10001), Version 2007-12-13. Alberta Biodiversity Monitoring Institute, Alberta, Canada. abmi.ca.

[13] Adams, B.W., G. Ehlert, C. Stone, D. Lawrence, D. Alexander, M. Willoughby, C. Hincz, D. Moisey, A. Burkinshaw and J. Carlson. 2005. Rangeland health assessment for grassland, forest and tame pasture. Alberta Sustainable Resource Development Pub. No. (T) 044. http://www.srd.gov.ab.ca/lands/managingpublicland/rangemanagement/healthassessment.aspx

[14] Cows and Fish. 2008. Alberta lentic wetland health assessment (survey) user manual (Current as of 5/28/2008). http://www.cowsandfish.org/riparian/health.html

combination of both. Regardless of the source of information, the methods and calculations used to calculate such units must be objective, transparent, and repeatable, to ensure the credibility and confidence required for markets to function well.

Marketable ecosystem service units may be based solely on the quantity of some attribute such as area. For example the area of forest may be used as an indicator of water regulation services, in which case one hectare of forest may equal one ecosystem service unit. In this example, landowners could receive payments based simply on the area of forest they promise to protect.

While quantity-based ecosystem service units are simple to calculate, they do not consider differences in the condition of ecosystem services provided at different locations. Therefore, many ecosystem services markets are based on assessments of quantity adjusted for condition (or "quality"). For example, offset programs in Australia have developed and applied ecosystem service units that incorporate both quantity and condition of native vegetation, which are combined into a metric called habitat hectares. Landowners can receive payments based not only the area of native vegetation they protect and restore, but also on the improvements to the condition of that vegetation.

Obtaining useful, reliable measures of ecological condition is the most challenging aspect of ecosystem service assessment. Because ecosystems are complex and poorly understood, assessing their condition requires specialized methods and expertise to: 1) consolidate ecological information into useful indicators; 2) scale measurements to a meaningful reference level or benchmark; 3) predict future ecological condition after management actions have been completed; 4) consider landscape context; and 5) conduct assessment audits. Example methods for calculating ecosystem service units that consider both quantity and condition are described in Appendices 3, 4 and 5.

1. Consolidate ecological information

Ecological information obtained from existing or new sources may need to be consolidated to provide useful information to calculate ecosystem service units. For example, under the US Conservation Reserve program, an Environment Benefits Index is calculated from measurements of wildlife habitat, water quality, soil erosion potential, and other attributes. The value of this index affects the payment received by a land-owner in return for retiring cropland and restoring native vegetation. In the state of Victoria, Australia, land owners can be paid under an auction process for conducting management actions that replace or restore native vegetation. In this program, payments are based on a Biodiversity Benefits Index[15] that estimates the amount by which a land-owner's management actions would improve the condition of ecosystems on their land.

[15] Natural Resources and Environment. 2002. Victoria's Native Vegetation Management: A Framework for Action. Department of Natural Resources and Environment, East Melbourne.

Information pyramids (Figure 2) are a good way to generalize and integrate such information using objective and explicit methods. At the base of such pyramids are ecological measurements data such as those obtained from maps, inventory and monitoring programs, as well as rapid assessment protocols. Such measurements can be combined to create successively more aggregated and integrated forms of information such as indicators and indices. For each level of the pyramid, assumptions and decisions used to obtain data and calculate indicators and indices can be explicitly recognized and stated. This allows the process to be repeated with updated data or under changed conditions.

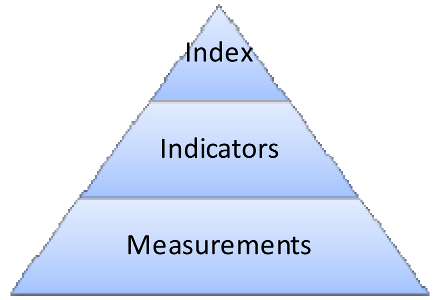

Figure 2. Information pyramids used to aggregate and integrate ecological information.

Indices of ecological condition require considerable scientific research to develop and calibrate, because the species and environmental factors on which they are based vary from place to place. The statistical distribution of many ecological variables, and their relationships to land use and other drivers, make it difficult to extrapolate an index from one location to another. But, once developed and calibrated for a given region, the required data are relatively inexpensive to obtain and manage. For example, the assessment portion of an offset program intended to protect and restore native vegetation in Victoria, Australia requires less than a day in the field (G. Stoneham, pers. comm.; that said, the research and development behind the assessment protocol took several years to complete.)

2. Establish reference conditions

When calculating marketable ecosystem service units that consider both quantity and condition of ecosystem services, it is frequently necessary to scale measurements of ecological condition to a reference level or benchmark. Such levels are frequently represented by natural, undisturbed ecosystems. (This does not mean that the condition of natural, undisturbed ecosystems is an appropriate management goal. Indeed, desired ecosystem conditions may be very different from those in natural ecosystems. As noted by one observer, "natural" is simply a descriptor and may not be an appropriate goal[16].)

Determining and using reference conditions for ecosystem service assessment is challenging because the ecological processes that affect ecosystem condition, such as nutrient cycling, hydrology, material transport, and natural disturbance, are dynamic over time and space. In other words, the rates of such processes vary over time and among different locations. Therefore, measures of ecological condition are often highly variable, and statistical approaches are required to extrapolate conditions that would be found in natural, undisturbed ecosystems. One type of approach has been developed by the Alberta

[16] Karr, J.R. 2009. Natural: A benchmark, not a bias. Northwest Science 83(3): 294-297.

Biodiversity Monitoring Institute[17], based on samples of biodiversity (e.g., plants, birds) in locations that differ in the amount of human footprint (e.g., roads). The data were used construct ecological models (Figure 3) to extrapolate the level of biodiversity that would be observed in natural, undisturbed locations, making it possible to represent ecological condition a scale of 0 (low condition) to 100 (high condition). The resulting ecological models also make it possible to predict ecological condition (in this case, biodiversity intactness) based on the amount of human footprint (Figure 4).

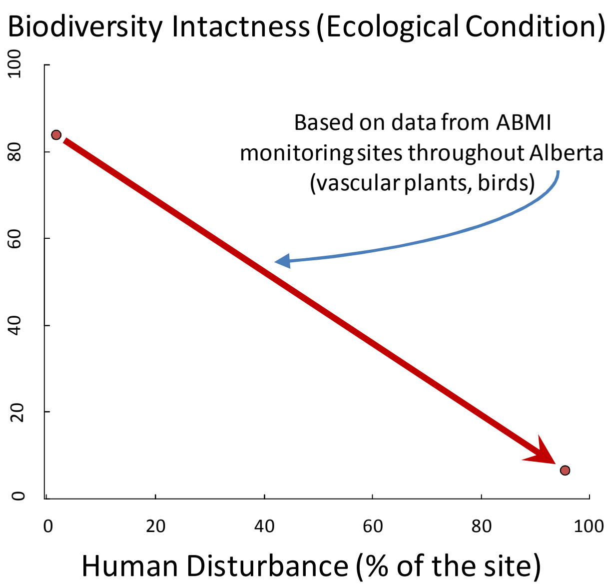

Figure 3. Example ecological model based on analyses of the occurrence and abundance of biodiversity (plants and birds) at long-term monitoring plots in Alberta. Source: ABMI.

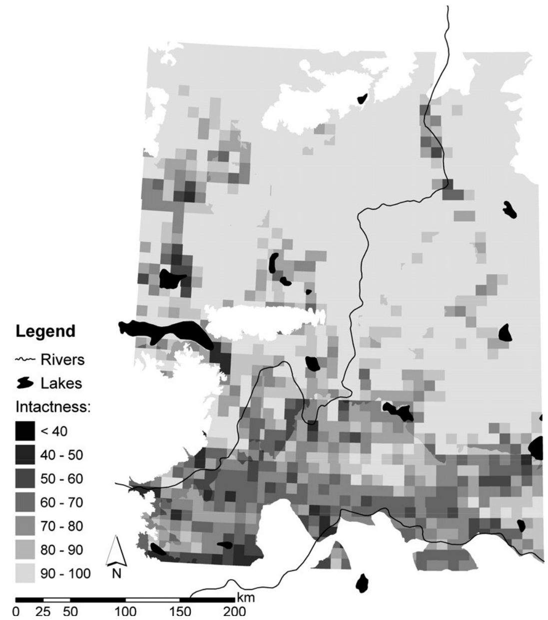

Figure 4. Predicted intactness (%) of biodiversity in the southern boreal forest of Alberta, based on an ecological model of the relationship between road density and the occurrence and abundance of several mammal species[18].

The use of statistical approaches to estimate reference conditions relies on the availability of data suitable for constructing ecological models. In practice, this requires field observations from locations along a gradient of human influence and from a diversity of ecosystems in the region for which reference conditions are to be estimated. Thus, the use of statistical approaches to estimate reference conditions may be constrained or impractical in situations where such information and understanding is lacking, or where relevant ecological research and monitoring programs (such as the ABMI) are absent.

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[17] Alberta Biodiversity Monitoring Institute. 2008a. Manual for estimating biodiversity intactness for species (20029), Version 2008-06-11. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at: abmi.ca.

Alberta Biodiversity Monitoring Institute. 2009a. Manual for estimating habitat intactness (20028), Version 2009-04-20. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at: abmi.ca.

[18] Nielsen, S.E., E.M. Bayne, J. Schieck, J. Herbers and S. Boutin. 2007. A new method to estimate species and biodiversity intactness using empirically derived reference conditions. Biological Conservation 137(3): 403-414.

3. Predict future ecological condition

Ecosystem services markets may require predictions of future ecosystem services after one or more management actions have been completed. Qualitative predictions may be based on the opinion of specialists familiar with how ecosystems change in response to management actions such as restoration, reclamation, and preservation[19]. However, predictions based on quantitative models are preferable because they are more objective and transparent predictions. This is particularly important when limited ecological knowledge makes such predictions uncertain, in which case quantitative estimates of variance can lend credibility to the process.

For example, ecological models developed by the ABMI (Figure 3) can be used to objectively predict aspects of future ecological condition after human footprint has been reduced through reclamation. While such models are already useful, additional research is required to refine and improve their breadth and accuracy. Current limitations include geographic variability in model reliability, the ability to predict ecological condition for only broad categories of management actions, and the limited number of variables sampled by the ABMI (e.g., species, habitat, landscape composition).

4. Consider landscape context

Ecosystem services can also be influenced by factors in the surrounding landscape. Such factors include fragmentation, connectivity, and related landscape metrics that may affect the movement of organisms and ecological processes such as hydrology and natural disturbance. For example, the BushTender ecosystem service assessment in Australia includes three landscape-level attributes believed to affect the quality and long-term persistence of remnant patches of native vegetation: patch size, isolation, and distance to core area[20].

5. Conduct assessment audits

Auditing of the assessment function is an important but often overlooked aspect of assessments conducted under an ecosystem services market. The implementation of such markets requires considerable effort and decision-makers should demand the ability to determine how well they are working. This would also enhance stakeholder support required to initiate an ecosystem services market and can help existing markets remain viable stewardship and conservation tools. Audits of the assessment function can be as simple as having a trusted, third-party review a sample of the ecosystem services assessment program from time to time.

6. Assess regional performance

If an ecosystem services market is intended to support desired environmental outcomes, it should be accompanied by assessments of progress towards such outcomes. For example, if an offset policy is intended to increase the level of an environmental endpoint, such as biodiversity in a region, then regional monitoring of biodiversity would provide information on whether the policy is successful, how successful it is, and how it can be adapted to further support desired environmental outcomes. Regional

[19] See Glossary for definitions

[20] Parkes, D., G. Newell, and D. Cheal. 2003. Assessing the quality of native vegetation: The 'habitat hectares' approach. Ecological Management & Restoration 4: S29-S38.

performance evaluation can be fundamental to an ecosystem services market because it provides the foundation for planning, design, and evaluation.

Ecological performance evaluation generally requires some form of long-term monitoring in which ecosystem services can be compared between one time period and another. In this context, maps and inventories are less useful than carefully designed long-term monitoring programs. Such monitoring programs frequently involve a combination of ground-based sampling and analysis of remotely-sensed data such as satellite imagery; examples include the ABMI and the National Forest Inventory.

Ideally, the regional monitoring approach would be integrated with the assessments that facilitate market transactions, because this would help determine how areas directly involved in the market contribute to regional performance. Such integration could also enhance the accuracy of the regional monitoring program by adding to the sample of monitored locations.

Provided that the information about ecosystem services can be represented spatially, the resulting maps may also be useful to characterize ecosystem services in different parts of a region for planning purposes. Predictions of future ecosystem services in a region under hypothetical scenarios that include ecosystem services markets can also provide insights into the potential contribution of ecosystem services markets to regional ecosystem outcomes. This approach was used in the Willamette Basin, Oregon, where the predicted performance of incentive-based programs such as the Conservation Reserve Program were compared to existing policies in terms of the ecosystem services of carbon sequestration and biodiversity[21].

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[21] Nelson E, Mendoza G, Regetz J, et al. 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Frontiers in Ecology and the Environment 7(1): 4-11.

Future directions: Accounting for people that receive ecosystem services

Strictly speaking, ecosystem services are the benefits that people get from ecosystems, which is different from the condition of the ecosystems themselves. Technically, without a human beneficiary, there are no services, only the living and non-living structures or components of ecosystems and the ecological processes that connect them to each other. It is reasonable to expect a positive relationship between ecosystem services and ecosystem condition (Figure 5), although many relationships between ecosystem services and ecosystem condition may not be linear. Exploring this relationship would be a useful direction for research to support the assessment of ecosystem services.

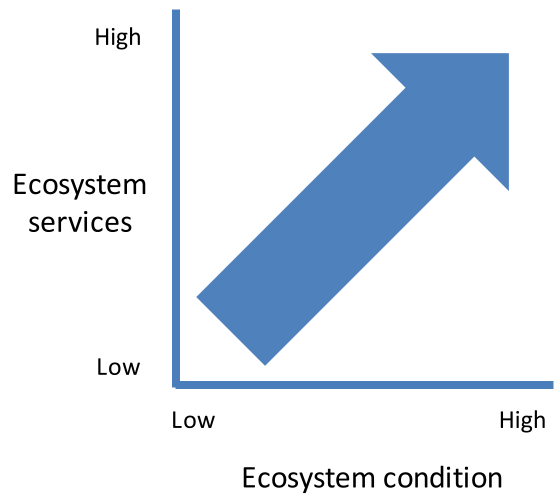

Figure 5. Conceptual representation of the relationship between ecosystem services and ecosystem condition. As ecosystem condition increases, so do ecosystem services (but not necessarily in a linear fashion as portrayed here).

A related complication is the location of ecosystem services relative to the benefits they provide. Some services, such as carbon sequestration, provide the same benefits regardless of where they occur. When assessing the benefits of carbon sequestration, the location and number of human beneficiaries is irrelevant. Other services, such as disturbance regulation, depend on the distance between the ecosystem that provides the service, and the human beneficiaries that receive the service (Table 3).

Table 3. Classification of ecosystem services according to their spatial characteristics[22].

Spatial characteristic	Description	Examples
Global	Provide the same benefits regardless of where they occur	carbon sequestration, global climate regulation
Local	Depend on the distance between the ecosystem and the human beneficiaries	disturbance regulation, waste treatment, pollination, biological control, habitat/ refugia, local climate regulation
Directional	Depend on the flow of energy and materials, such as water from upstream to downstream	water regulation, water supply, sediment regulation, nutrient regulation
Point	Provide benefits only at the location where they occur	soil formation, food production, raw materials
User movement related	Depend on the flow of people to unique natural features	genetic resources, recreation potential, cultural

[22] Costanza, R. 2008. Ecosystem services: multiple classification systems are needed. Biological Conservation 141 (2):350–352.

For example, consider two hypothetical wetlands that are identical in all respects except for their proximity to a city. Both wetlands make the same contribution to the regulation of water quality and water flow in a nearby river. However, one wetland is upstream of a city that withdraws water from the river for domestic and industrial use, while the other is not. A purely ecological assessment of the condition of the two wetlands would ignore the presence of the city downstream of one wetland, and would conclude that the wetlands were ecologically identical. A more accurate assessment of ecosystem services would conclude that the ecosystem benefits provided by the wetland upstream of the city were greater than those provided by the other wetland.

In the context of the assessments needed to support ecosystem service markets, considering the location of people who benefit from ecosystem services is an important future direction for research and development.

Recommendations

1. Choose a business model for ecosystem service assessment

Ecosystem service assessments to support ecosystem services markets could be conducted by government, market participants (buyers and sellers), or third parties such as brokers. While the choice of an appropriate business model will depend on the design of the specific ecosystem services market, a business model in which a third party is responsible for assessing ecosystem services is recommended. Market participants should not play any role in the assessment function because they will have a vested interest (financial incentive) in the outcome of transactions. Separating the assessment function from government, buyers, and sellers helps ensure there is no conflict of interest, and enhances credibility. This is akin to having an independent, credible home inspection to help facilitate the buying and selling of homes.

It is recommended that the business model for the assessment function have the following characteristics:

1. Independent of market transactions: The assessment provider cannot have a vested interest in the outcome of the market transaction;
2. Scientifically credible: The assessment provider need to be able to credibly defend and discuss findings;
3. Not a management agency: The assessment provider should not advocate any land ethic agenda;
4. Accountable for performance: The assessment provider needs to be held accountable for performance including timeliness of assessment, cost, and findings;
5. One organization responsible: In the short-term it is recommended that one organization is responsible for delivering the assessment function. This enables the assessment organization to work with stakeholders to facilitate the development of markets. It also enables stakeholders to hold this organization accountable for performance.

The assessment function includes the development, collection, management, and communication of ecological knowledge and is a significant undertaking. It is recommended that the Alberta Biodiversity Monitoring Institute (ABMI) house the central, integrated assessment function. The ABMI already has several desirable characteristics including:

1. Independent governance: The ABMI is a not-for-profit society that is arms-length from government, industry, and environmental groups;
2. Assessment not management: The institute is not a management agency and has no vested interest in the outcome of any market transactions;
3. Proven scientific track-record: The ABMI is built on a foundation of high-quality science with contributions from more than 40 Alberta-based scientists;
4. Broadly supported: The institute is recognized as one of the most broadly supported monitoring programs in Alberta;
5. Value-neutral: The ABMI reports and communicates in a value-neutral manner;
6. Building upon success: The ABMI is already considered an essential piece of Alberta's overall approach to land planning and evaluation of land management results under the Land-use Framework and other provincial policy.

2. Establish a common assessment platform

Regardless of which business model is established to deliver the ecosystem assessment function of emerging markets, a common platform is recommended. Because the development of systems to collect, manage, and communicate ecological knowledge is a significant undertaking, and because the ABMI has already developed much of the required capacity, the ABMI can provide a central integrating role. The ABMI is already a world-class, science-based initiative that monitors and reports on the status and trends of many ecosystem services across the province. Designed to monitor Alberta in perpetuity, many of the ABMI's business activities have direct relevance to the design, implementation, and evaluation of ecosystem services markets in Alberta. Formalizing the role of the ABMI would help emerging markets gain synergies and efficiencies through shared assessment protocols and information management systems.

The development of a common ecosystem service assessment platform should occur in consultation with relevant provincial government departments such as Alberta Environment and Alberta Sustainable Resource Development, and non-government organizations that currently conduct market-related ecosystem assessments such as the Alberta Conservation Association, Ducks Unlimited Canada, and the Nature Conservancy of Canada. Additional expertise may be found in the list of key actors and initiatives related to ecosystem service assessment in southern Alberta[23].

3. Develop the ecosystem service assessment functions

Ecosystem service assessments to support emerging markets would need to provide the following functions:

[23] Alberta Environment. 2007. Ecosystem goods and services assessment - southern Alberta: Phase 1 Report: Key actors and initiatives. Contract report prepared by Integrated Environments (2006) Ltd. and O2 Planning + Design Inc. 77 pp.

1. Protocol development and maintenance, including measurement methodologies, predictive modeling capability, and verification standards.
2. Development of training and certification standards to ensure assessment protocols are implemented in a consistent and accurate fashion.
3. Research and development to address shortfalls in available understanding, particularly of the ecological response to management actions intended to improve ecosystem services. This would also facilitate the development and refinement of new management actions intended to produce positive environmental outcomes.
4. Software development to expedite and at least partly automate the storage and manipulation of information collected during an assessment and, where appropriate, to generate estimates and predictions of ecosystem services.
5. Regional ecosystem assessment and monitoring to guide the design and evaluate the performance of ecosystem services markets.

4. Align market design with the design of assessments

Because the design of ecosystem assessment approaches needs to consider the design of the ecosystem services markets they are intended to support (and vice versa), the two design processes should be integrated. For example, if the conceptual business model and policy framework for regulated offsets recommended by the Alberta Boreal Conservation Offsets Advisory Group[24] moves to the policy design stage, there would be an excellent opportunity to integrate with the design an appropriate and supportive ecosystem assessment approach.

5. Fill critical knowledge gaps on a priority basis

As a priority for the organization governing the ecosystem services assessment function, province-wide geographic information related to soils, land cover, hydrology, and human footprint needs to be developed, aggregated, and maintained. A province-wide ecosystem map should be completed that integrates existing sources such as the Alberta Vegetation Inventory, Grassland Vegetation Inventory and the Alberta Ground Cover Classification. This is a significant undertaking but the information is required as a foundation for assessing ecosystem services at a range of spatial scales.

6. Ensure assessments become financially self-sustaining

It is recommended that the assessment function be financially self-sustaining using a fee-for-service business model. For every ecosystem service assessment conducted, a fee would be collected to cover the costs of assessment function.

Until ecosystem service markets are successfully implemented, a fee-for-service model will not generate enough revenue to develop and maintain the assessment function. Therefore, it is recommended that

[24] Alberta Boreal Conservation Offsets Advisory Group. 2009. Regulated conservation offsets with banking: A conceptual business model and policy framework. Unpublished report.

government invest in building and maintaining the assessment function until market transactions enable it to become self-sustaining.

Glossary

Conservation easement: A voluntary legal agreement between a landowner and a qualified organization, such as a land trust, to permanently limit uses of the land in order to protect its conservation values.

Offset: Conservation actions intended to compensate for the residual, unavoidable harm to ecosystems caused by development projects, so as to aspire to no net loss of ecosystem condition

Payment scheme: A voluntary, conditional agreement between at least one "seller" and one "buyer" over a well defined environmental outcome, or a land use presumed to produce that outcome

Preservation: To keep up and reserve lands for personal or special use.

Reclamation: The stabilization, contouring, maintenance, conditioning, or reconstruction of the surface of land.

Restoration: Re-establishment of habitat and/or other ecosystem resource characteristics and function(s) at a site where they have ceased to exist, or exist in a substantially degraded state.

Appendix 1. Annotated list of ecosystem services in the Millennium Ecosystem Assessment

Provisioning services are the products obtained from ecosystems, including:

Food: This includes the vast range of food products derived from plants, animals, and microbes.

Fiber: Materials included here are wood, jute, cotton, hemp, silk, and wool.

Fuel: Wood, dung, and other biological materials that serve as sources of energy.

Genetic resources: This includes the genes and genetic information used for animal and plant breeding and biotechnology.

Biochemicals, natural medicines, and pharmaceuticals: Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.

Ornamental resources: Animal and plant products, such as skins, shells, and flowers, are used as ornaments, and whole plants are used for landscaping and ornaments.

Fresh water: People obtain fresh water from ecosystems and thus the supply of fresh water can be considered a provisioning service. Fresh water in rivers is also a source of energy. Because water is required for other life to exist, however, it could also be considered a supporting service.

Regulating services are the benefits obtained from the regulation of ecosystem processes, including:

Air quality regulation: Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.

Climate regulation: Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.

Water regulation: The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.

Erosion regulation: Vegetative cover plays an important role in soil retention and the prevention of landslides.

Water purification and waste treatment: Ecosystems can be a source of impurities (for instance, in fresh water) but also can help filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and can assimilate and detoxify compounds through soil and subsoil processes.

Disease regulation: Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.

Pest regulation: Ecosystem changes affect the prevalence of crop and livestock pests and diseases.

Pollination: Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.

Natural hazard regulation: The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves.

Cultural services are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

Cultural diversity: The diversity of ecosystems is one factor influencing the diversity of cultures.

Spiritual and religious values: Many religions attach spiritual and religious values to ecosystems or their components.

Knowledge systems (traditional and formal): Ecosystems influence the types of knowledge systems developed by different cultures.

Educational values: Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.

Inspiration: Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.

Aesthetic values: Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations.

Social relations: Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.

Sense of place: Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.

Cultural heritage values: Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.

Recreation and ecotourism: People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion regulation, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people.) These services include:

Soil Formation: Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.

Photosynthesis: Photosynthesis produces oxygen necessary for most living organisms.

Primary production: The assimilation or accumulation of energy and nutrients by organisms.

Nutrient cycling: Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.

Water cycling: Water cycles through ecosystems and is essential for living organisms.

Appendix 2. Examples of assessments to support ecosystem service markets.

BushTender: Toward advancing the overall goal of net gain of native vegetation, the BushTender program was introduced to encourage the stewardship of native vegetation on private land (Parkes et al. 2003)				
Ecological goods & services	**Indicator**	**Field variable**	**Field Measurement Description**	**Calculation**
Biodiversity value	Habitat condition	Large trees	Estimate of number of large trees compared to benchmark number per hectare, qualified by tree health.	A total habitat score (out of 100) is tallied by summing the individual scores for each site attribute and landscape context component. This habitat score is converted to scale from 0 to 1, and multiplied by the total area assessed to calculate the final habitat hectare value, a combination of vegetation quality and area for a particular habitat type. Key to this method is the assessment of how "natural" a remnant patch of native vegetation is compared to benchmark conditions. Benchmark conditions are represented by average characteristics of mature, undisturbed stands of the same vegetation type or Ecological Vegetation Class (EVC).
		Tree (canopy) cover	Estimate of the projective cover of the tree canopy compared to benchmark percent cover estimates, qualified by tree health.	
		Understory (non-tree) layers	Estimate of the number of understory layers compared to benchmark, assessed for modification in diversity and cover.	
		Lack of weeds	Estimate of the percent cover of weeds and the proportion of this cover due to high threat weeds.	
		Recruitment	Assesses the presence of recruitment, qualified by the adequacy and diversity of this recruitment.	
		Organic litter	Estimate of the percent cover of organic litter compared to benchmark, qualified by the proportion of litter that is composed of native species.	
		Logs	Estimate of the length of logs present compared to benchmark log length, qualified by the presence of large logs.	
		Patch size	Patches of native vegetation, which may include a range of vegetation types), are scored according to their size.	
		Neighbourhood	The amount and configuration of native vegetation patches are assessed within three neighbourhood radii (100 m, 1 km, 5 km), qualified by degree of disturbance of the native vegetation.	
		Distance to core area	Estimate of the distance to nearest core area (i.e. patch of native vegetation > 50 ha), qualified by condition of core area.	

Natural Capital Program: Compared the performance of land-use conservation schemes that mimic incentive-based programs such as the Conservation Reserve Program (CRP) relative to baseline (1990) land-use patterns assuming no conservation policy to increase the provision of carbon sequestration and species conservation (Nelson et al. 2008). Modeled land use over a 50 year time horizon in the Willamette Basin, Oregon, under 5 policy scenarios; each scenario specified different levels of conservation targets to meet carbon and biodiversity goals.				
Environmental goods & services	**Indicator**	**Field variable**	**Field Measurement Description**	**Calculation**
Biodiversity value	Species habitat - simple model	Species habitat for 37 listed or sensitive species.	The amount of breeding and foraging habitat area.	For each generated land-use pattern, calculated the following ratio for each species: the amount of breeding and feeding habitat area provided for the species vs. the maximum amount of breeding and feeding habitat area that could be provided if the landscape was completely managed for the benefit of the species. The overall species conservation score for a land-use pattern is the average of all 37 species ratios.
	Species habitat - complex model	Species habitat	Predicts species persistence as a function of the amount and spatial pattern of breeding and foraging habitat, as well as breeding and foraging area requirements and dispersal abilities. Determines the expected number of species that would persist on the landscape for an indefinite time period for a given a land-use pattern predicted from conservation payment options.	The complex species conservation model results are normalized by dividing a land-use pattern's predicted species conservation amount by 37.
Regulation (Pollution)	Carbon sequestration - simple model	Carbon storage	Estimates terrestrial carbon storage values as a function of land use specific to the Basin's ecoregion and climate. Carbon stored in the land is the sum of carbon stored in five pools: soil, below-ground biomass, above-ground biomass, deadwood and litter, and harvested wood products.	Difference between carbon stored on the initial and final land-use patterns represents the carbon sequestration that occurs on the landscape over a 50 year time horizon.
	Carbon sequestration - complex model	Carbon storage	Distribution of tree species, tree ages, and canopy densities across the landscape, along with characteristics of each parcel of land and tree stand allometric tables, were used to predict annual carbon sequestration on each parcel of land over the 50-year modeling time horizon.	Constructed mean sequestration values to score land-use patterns.

Natural Capital Program: Used program InVEST to model ecosystem services and biodiversity conservation over a 50 year time horizon under 3 alternative land management scenarios with different conservation targets. Program InVEST (Valuation of Ecosystem Services and Tradeoffs) is a tool to map and value ecosystem services (Nelson et al. 2009).				
Environmental goods & services	**Indicator**	**Field variable**	**Field Measurement Description**	**Calculation**
Regulating (Flood control)	Storm peak mitigation	Volume and timing of water flow	Volume and timing of water flow across the landscape are affected by water retention on the land, which is directly related to the land use/land cover (LU/LC) in the region.	
Provisioning (Water quality)	Phosphorus	Modelled landscape-level phosphorus levels	Used the discharge of dissolved phosphorus into the local watershed to measure water pollution. Potential runoff by location (discharge) was modeled as a function of geomorphology (location in catchment, slope), soil depth, soil conductivity, land cover pollutant loading rating, and the ability of downstream vegetation to filter out phosphorus.	
Regulating (Flood control)	Soil erosion	Soil erosion	Universal Soil Loss Equation (Wischmeier and Smith 1978) to predict the average annual rate of soil erosion in a particular area. This is a function of soil characteristics (rainfall erosivity index, erodability of soil), geomorphology (slope and gradient), land cover, and hydrological connections to the larger landscape.	
Regulating (Pollution)	Carbon sequestration	Carbon	Stored carbon was tracked in above and belowground biomass, soil, and harvested wood products using standard carbon accounting methods.	
Biodiversity value	Species habitat	Species area curve for 24 vertebrate species	A countryside species–area relationship (SAR; Pereira and Daily 2006) was used to determine the capacity of each land use/land cover (LU/LC) map to support vertebrate species that are sensitive to land use change in the environment.	Actual habitat area for a species was equal to the amount of land cover in the species geographic range that was compatible with its breeding and foraging requirement. Potential habitat area was given by a species' total mapped geographic range within the Willamette Basin. SAR scores depended on the ratio of actual habitat to potential habitat. SAR scores for each species were averaged to calculate an aggregate score for each scenario.

Conservation Reserve Program (CRP): Program to address farmland conservation; it is a voluntary long-term cropland retirement program. CRP provides participants an annual per acre rent and reimburses participants for half the cost of establishing a permanent land cover in exchange for retiring highly erodible and/or environmentally sensitive cropland from production for 10 to 15 years (Ribaudo et al. 2001, Farm Service Agency 2003). Uses Environment Benefits Index (IBI) to evaluate and rank land offered for enrolment in the CRP.

Environmental goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value	Wildlife Habitat	Vegetation cover	Cover quality and diversity of species planted for wildlife habitat.	The EBI is calculated out of 600 points, and is composed of six environmental factors plus a cost factor based on the per-acre rental rate. Score is based on the expected environmental benefits to soil resources, water quality, wildlife habitat and other resource values of concern during the time the land is enrolled in the program.
		Listed Species	Benefit to State or Federal threatened or endangered species.	
		Proximity to permanent water source	Location of offered land relative to year-round water source for wildlife.	
		Adjacency to protected wildlife habitat	Proximity of land to protected areas for at least the term of the CRP contract.	
		Wildlife enhancements	Size of offer relative to average field size in State.	
			Wetland restored or wildlife food plot established.	
		Wetland/Upland benefits	Ratio of restored wetland to upland to provide optimum nesting habitat for waterfowl.	
Provisioning (Water quality)	Water Quality	Water quality area	Location within designated State water quality areas.	
		Groundwater quality benefits	Relative vulnerability of soils offered and potential population impacted.	
		Surface water quality benefits	Relative sediment delivery potential of soils offered and potential population impacted.	
		Wetland benefits	Potential water quality improvements from enrolment of cropped wetland.	
Regulating (Soil erosion)	Soil erosion	Erodibility Index (EI)	Scored 0 to 100 depending on EI of soiled offered.	
Provisioning (Air quality)	Air quality	Wind erosion	Potential wind erosion reduction (wind EI) and potential population impacted.	
			Offer contains volcanic or organic soils susceptible to wind erosion or contribute to non-attainment of air quality standards.	

		Water quality area	Location within designated air quality zones or non-attainment areas.	
Biodiversity value	Protected areas	Conservation priority area	Location within designated state or national conservation priority areas (CPA) and benefits are consistent with established CPA goals.	
Endangered Species Conservation Banks (United States): Conservation banks are an economically effective process that provides options to landowners to preserve existing habitat with long-term conservation value and offset the adverse effects of proposed projects to listed species elsewhere. Credits are purchased from a conservation bank to offset impacts to listed species (USFWS 2009).				
Environmental goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value – endangered species	Varies depending on species, may include: habitat quality, habitat quantity (area, location, configuration), conservation benefits (e.g. contribution to regional conservation goals)	Varies	The credit system for conservation banks is ideally expressed and measured in the same way as the impacts of activities that are being offset, so that the conservation value is directly comparable. Requires consistent methodology for determining credits, which is also consistent with determination of mitigation requirements for other activities.	Credits are units in the conservation bank representing listed species, candidates, and other species-at-risk, or habitat for those species. In its simplest form, one credit will equal, for example: one hectare of habitat, area required to support one nest site or family group, area required to support a defined population, etc. Credit values are based upon a number of biological criteria and may vary by habitat types or management activities.
Florida Ranchland Environmental Services Project: Compensate cattle ranchers in the Everglades for providing water storage and nutrient retention services on private land, i.e. Pay-for-Environmental Services (PES) (Bohlen et al. 2009).				
Environmental goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Provisioning (Water storage/Water quality)			A multi-service environmental documentation approach is under development	

Zonation: A framework and software for large-scale high-resolution ecologically based conservation prioritization. It is best suited for data-based regional-scale planning of offsets where compensation can occur elsewhere and can come from biodiversity values other than from those that are being lost (Kremen et al. 2008, Moilanen et al. 2009)

Environmental goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value	Species	Species distributions	Large-scale grids describing distributions of biodiversity features including presence/absence data, probabilities of occurrence, abundance/density data, point observation data. Conservation weightings are assigned to each species based on proportional loss of suitable habitat (range reduction) within a given period of time.	Zonation software is used to rank prospective compensation areas that have no current protection (i.e. priority areas for biodiversity conservation). The amount of compensation needed will be proportional to the area that will be impacted; however, retention and transferability of threat also need to be accounted for. For example, if 10 units of lands are impacted and, by protecting these areas, retention increases from 60% to 85% (25% retention gain), the area needed to compensate for loss would be (1/0.25)*10 = 40 area units of top ranked conservation land. If the 25% gain comes from stoppable threat, then the 40 units calculation stands. If however, the threat is only partially stoppable, say that 80% of threat would transfer elsewhere, then the net gain would only be 20% of the above, implying a further multiplication by (1/(1-0.8)) ending at 200 area units needed for fair compensation.
		Map of protected areas	Present or proposed conservation areas	
		Cost of land	Dollar value of each unit of land	
		Connectivity needs of species	The software includes capability for dealing with structural connectivity and home-range requirements, long-distance kernel type connectivity and directed connectivity for riverine environments. This is achieved through the use of different algorithms (distribution smoothing, boundary quality penalty, boundary length penalty, directed freshwater connectivity).	

Mexican Program of Payments for Environmental Services (PES): Encompass payments for the continued existence of forests to ensure provision of hydrological services (water quality and quantity). The program targets communities that are close to large population centers because these are considered "reasonable" markets where there is a sufficiently large population to demand the water which is linked to the conservation of nearby forests (Alix-Garcia et al. 2005).				
Environmental goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Hydrological services (water quality/ quantity)	Forested lands	Location of the property	Potential beneficiaries are those properties with forests in priority watersheds (those with overexploited aquifers and/or serving as the main water source for large population centers). Also considered are those properties within National Protected Area or in a "Priority Mountain" area.	Beneficiaries are selected using a point system based on the field variables (i.e. criteria). Those properties with the highest scores are paid $40/ha for cloud forest and $30/ha for other types. To avoid slippage, removal of trees from the community's entire forested area (even outside of the area for which payments are being made) is considered a contract violation and result in non-payments.
		Forest cover density	Whether the property has more than 80% of forest cover or not	
		Ecosystems type	Whether the property has cloud forest or other types of forests	
		Property rights	Clear property rights are mandatory in order to qualify as a potential beneficiary.	

A landscape approach for estimating conservation value of sites and site-based projects (New Zealand): A proposed method for valuing sites based on the contribution to conservation goals specified in terms of landscape criteria (Dymond et al. 2008).

Environmental goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value	Natural habitats	Proportion of original (i.e. pre-human) habitat remaining	Area remaining of the habitat type (a_{ij}), divided by the original area of that habitat type (A_i).	This approach estimates the conservation value of a site by defining value as contribution or progress towards the conservation goal of “maintaining and restoring a full range of remaining natural habitats to a healthy and functioning state”. The value of a site may be derived as the contribution that the site makes to the total progress measure, using the formula: *Site value* = $P_i * \varphi * \sum(c_{ij} * a_{ij} / A_i) *(c_{ij} * a_{ij} / A_i)$ Additional calculations are presented for sites were restoration (i.e. changes to the condition (c_{ij}) of a site) or protection will take place.
		Condition of remaining sites for a given habitat type (c_{ij})	Measure of the health and functioning of each remaining site for a given habitat type. Perceived degree of naturalness (proportion of the indigenous species still existing at the site) is used as the measure of condition. This value varies between 0 and 1.	
		Habitat type weightings (P_i)	Habitats are weighted differently based on their distinctiveness or on known centers of endemism at their original extent.	
		Site rarity (ϕ)	A value function is defined to give more value to sites where little habitat in good condition remains (defined between 0 and 1).	

Payment for Ecosystem Services (PES): Assesses the feasibility of developing a payment for ecosystem services system with win-win solutions: improved water security, better water flow regulation and water quality, improved land management, improved livelihoods and reduced vulnerability (Maloti Drakensberg Transfrontier Project 2007).

Environmental goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Provisioning (Water quality and quantity)	Water flows	Baseflows Stormflow reduction	The difference in the winter (April-September) baseflow between a poorly managed and a well managed grassland. Poorly managed is defined as an annual winter burning with stocking rates in excess of recommended carrying capacity whereas a well managed practice is defined as biennal spring burning with recommended stock densities and the restoration of degraded areas.	An integrated hydrological, ecological restoration and economic model has been developed to calculate Unit Reference Values (URV), where: URV = Present value of all costs incurred over the economic lifespan of the project / Present value (m^3) of the benefit over the economic life span of the project • where the life span of the project is 50 years; • where the discount rate is 4%, 6%, and 8%; • where the costs refer to the restoration and the operation and maintenance cost; and • where the benefits refer to the value of the additional baseflow, the avoided sediment, and the carbon sequestration. A URV equal to 1 implies that the net present value of the cost and the benefits are equal. A number less than 1 implies the net present value of the benefits are bigger than that of the cost. Though no standard benchmark number exists, as an example most recent dams have URV's higher than 2.
Regulating (sediment retention)		Sediment yields	The difference in the sediment yields (for 12 month of the year) between the baseline scenario and the post-restoration and improved land-use management scenario. This value constitutes avoided sediment yield given the intervention.	
Regulating (Pollution)	Carbon sequestration	Carbon	It is assumed that only 15% of the carbon sequestration is additional due to improved land use management. For commercial farm lands, 50% of the carbon sequestration will be additional and for communal areas, 75%. Carbon is conservatively valued at an average sequestration rate of 2.25t/ha/y. This is the average between a low of 1.5t/ha and a high of 3t/ha and includes both above and below ground carbon. In winter, carbon is valued at a sequestration rate of 2.25t/ha for above and below ground carbon combined.	
	Landcover	Area containing degraded grasslands Area with dongas (eroded gullies) Area containing natural grasslands	Measured to estimate the total cost of restoration actions (i.e. restoration of dongas/eroded gullies and/or re-seeding of degraded grasslands) and management (fire and/or grazing management) of the area.	

Significant Environmental Benefit (SEB) for mining operations (South Australia): Intended to ensure a 'significant environmental benefit' outcome is achieved when native vegetation is cleared, through the establishment, regeneration or protection of native vegetation on offset lands, improving the condition of the environment and biodiversity of the region (Native Vegetation Council 2005).				
Ecological goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value	Native vegetation	Area proposed for clearance	The physical area of vegetation to be impacted.	If undertaking off-site offsets, the SEB value is calculated by simply multiplying the Area to be cleared by the SEB ratio. As an alternative, funds can be paid to the Native Vegetation Fund or provided for alternative offset activities. This cost is calculated as (Area x SEB ratio x Management Cost x Land Value).
		SEB ratio	Determined on the basis of the intactness of the native vegetation on the area to be cleared. For example, a 4:1 ratio is used for "native vegetation with considerable disturbance" (identified in the field by vegetation structure substantially altered, very obvious signs of long-term or severe disturbance, weed dominated with some very aggressive weeds, partial clearing and evidence of moderate grazing). Furthermore, if ecological restoration activities are achieved on-site, then the initial SEB ratio is reduced by 50%.	
		Management costs of cleared area	Based upon native re-vegetation cost estimates. As costs to revegetate will vary significantly, a flat rate of $800/ha is proposed for management costs.	
		Land value	Determined using the Valuer General's unimproved value for an equivalent area of land within the region, which could be set aside for restoration purposes.	

Significant Environmental Benefit (SEB) for clearance of scattered trees (South Australia): Intended to ensure a 'significant environmental benefit' is achieved that outweighs the value of retaining the original native vegetation. Through this process, landholders are encouraged to value and achieve improved biodiversity outcomes (Native Vegetation Council 2007).				
Ecological goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value	Native vegetation	Wildlife habitat value (Tree Score) of each tree proposed for clearance	Species, height, health, proximity to other vegetation, hollows, density, habitat potential for threatened fauna species, diameter, radius, and canopy is collected on each tree to be cleared. The first seven attributes are entered into the Native Vegetation Council's Point Scoring System (PSS) to calculate a score value for each tree.	The SEB scores for individual trees are summed to determine the total SEB requirement to off-set the proposed clearance using the formula: Total SEB requirement = ∑(Tree $score_n$ x $SEBMF_n$). The Offset SEB point score per hectare is then calculated by multiplying the Habitat Significance Rating score by the Landscape Context Rating score. To determine the area required to meet Total SEB requirement, the Total SEB requirement is divided by the Offset SEB point score per hectare. The point score per hectare influences the area needed to meet the SEB requirement, e.g. a higher point score per hectare will result in a smaller area required to meet the total SEB requirement. Finally, implemented Off-set areas must be maintained and managed in accordance with a native vegetation management plan that seeks to establish, restore, or manage native vegetation to achieve an appropriate SEB outcome.
		SEB multiplication factor	A multiplication factor is applied to each tree score, this SEB multiplication factor (SEBMF) increases in relation to the value of the individual tree score. For example, each tree with a score of >60 is applied a SEBMF of 12.	
		Habitat Significance Rating (HSR) of the offset site	There are 6 categories of habitat, based on the offset's relative habitat significance (e.g. species diversity, condition of tallest layer of vegetation and understory). A stepped rating score is assigned to each HSR category, higher scores are attributed to offsets with relatively higher biodiversity significance, e.g. category A HSR receives 400 HSR rating scores.	
		Landscape Context Rating (LCR)	There are three categories of LCR used (good, moderate, low), based on the offset location with regards to other patches of native vegetation, connectivity, etc. A stepped rating score is assigned to each LCR; higher scores are attributed to offsets that by virtue of their position in the landscape will contribute to a relatively higher biodiversity value in the landscape.	

Biodiversity offsets (Western Cape, South Africa): Offset ratios are intended to prevent significant decline in level of endangerment or threat and to ensure that offsets make a commensurate contribution to meeting conservation targets for the affected ecosystem (Department of Environmental Affairs and Development Planning 2007).				
Ecological goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value	Ecosystem status (based on vegetation type and conservation status)	Size and magnitude of affected area	The physical area where residual negative impacts on biodiversity are expected. Where the magnitude of the impacts on biodiversity is expected to be 'Very high', use of offsets is not appropriate; if the magnitude of impacts is expected to be 'High' or 'Medium', consideration of offsets is appropriate; if the magnitude of impacts is expected to be 'Low', no offsets are needed.	The area of ecosystem type to be needed as an offset is simply calculated as the physical area affected by high to medium impacts multiplied by the offset ratio determined on the basis of the conservation status of that ecosystem. For example, if the residual impact on endangered habitat of a proposed development were to affect 5ha, an offset of 100 ha of like habitat would be needed, assuming no adjustments have to be made to the offset ratio. Appropriate changes to offset ratios need to be advised by biodiversity specialists.
		Offset ratio	Informed by the ecosystem status of the impacted ecosystem. Offset of 30:1 for residual impacts in critically endangered ecosystems, only where there are exceptional circumstances that would make consideration of offsets appropriate. Offset of 20:1 for residual impacts in endangered ecosystems. Offset of 10:1 for residual impacts in vulnerable ecosystems. No offset is necessary in least threatened ecosystems.	
		Offset ratio adjustments	The basic offset ratio is adjusted where appropriate, depending on: the condition of the affected habitat; the presence of threatened species; the presence of special habitats; the biodiversity process value of the affected habitat; and the importance of biodiversity underpinning valued ecosystem services.	

Resource Equivalency Methods for Assessing Environmental Damage in the EU (REMEDE): This is a developing toolkit that uses Equivalency Analyses to determine the type and amount of resources and services that are lost over time as a result of an environmental damage, and the type and amount of actions needed to offset the loss (REMEDE 2008).				
Ecological goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value	Varies depending on the selected metric (e.g. species, habitats and/or ecosystem processes)	Debit	The loss in terms of a quantity of resource or service over time. The debit is often multi-dimensional. Typically, one or more measures (or "metrics") are defined to serve as indices of keystone resources or services that were damaged; in doing so an assumption is made that remediation addressing the chosen metrics will collaterally benefit aspects of the debit that were not specifically addressed.	Habitat Equivalency Analysis (HEA) (losses are expressed in terms of habitat and are offset by remediation of similar habitat) and Resource Equivalency Analysis (REA) (losses are expressed in terms of resource units such as numbers of fish or birds) are the currencies used in this toolbox. HEA or REA includes estimation of the debit, credit, and 'scaling' of complementary and compensatory remediation projects. Ensuring equivalency (scaling) between the debit and credit involves dividing the debit by the per-unit credit to yield the total amount of remediation needed. The type of environmental damage and opportunities for remediation influence the choice of a specific equivalency approach.
		Credit	Estimation of the quantity of resource or service gained through complementary and compensatory remediation, i.e. the benefit expected per unit of remediation.	

New Zealand Risk Index Method: Calculates biodiversity losses and gains, and is intended to inform the design of biodiversity offsets to ensure no regional scale biodiversity loss as a result of a development project. Offsets aim to fully compensate risk to biodiversity persistence caused by development impacts (Business and Biodiversity Offsets Programme (BBOP) 2009).

Ecological goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Biodiversity value	Biodiversity persistence	Impact footprint	The physical area where residual negative impacts on biodiversity are expected.	This approach is based on an index of 'persistence probability'. A proxy persistence measure, Susceptibility to Biodiversity Loss (SBL) provides the currency of exchange to compare loss at the impacted site with gain at offset sites. An Excel spreadsheet provides a template for the calculation, enabling the user to identify what spatial extent and intensity of conservation management is required to offset biodiversity loss caused by the development project. This index is still under development.
		Species and ecosystems within the impacted site	Inventory of species and ecosystems, including status and area occupied within the impacted site.	
		Species and ecosystems at a regional level	Current status and area occupied by each species and ecosystem at the regional level.	
		Historical species and ecosystems	Potential (historic) area occupied by each species and ecosystem at the regional level.	
		Offset site species and ecosystems	Status and target area to be occupied by each species and ecosystem in the offset site.	

Hunter River Salinity Trading Scheme (New South Wales, Australia): This scheme manages saline water discharges so as to minimize impacts on irrigation, other water uses, and on the aquatic ecosystems of the Hunter River catchment (Environmental Protection Agency 2008).

Ecological goods & services	Indicator	Field variable	Field Measurement Description	Calculation
Provisioning (Water quality)	Salinity	Measured river salinity levels	Real-time monitoring at several points along the river provides information on salinity levels of river water along the length of the river. Collected information determines how much discharge can take place.	A cap on acceptable salinity levels was defined after community consultations which corresponds to 1000 salinity credits. Each credit entitles the holder to discharge 0.1% of total salinity discharge per section of river. The credits may be traded so that holders who do not need to discharge can sell their entitlement to others with the greatest need in each high flow. Under low flow, salinity is already high and discharges are prohibited. Under high flow, discharges are allowed as long as the cap is not breached.

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Appendix 3. Case Study: BushTender

Context: The primary goal of Victoria's Native Vegetation Management Framework is to reverse the, long-term decline in the area and quality of native vegetation, leading to a "Net Gain" of native vegetation across the region (NRE 2002). This "Net Gain" approach applies to private lands as well as public lands. While only 12% of the land area in Victoria is privately owned, this area contains a disproportionately high level of threatened species populations (30%) and vegetation types (60%). Toward advancing the overall goal of net gain of native vegetation, the BushTender program was introduced to encourage its stewardship on private land.

How it works: The BushTender program is an auction-based system in which landholders submit bids for funding to manage parts of their land for native vegetation. There are several steps in this process (DSE 2004).

Step 1. Site assessment: The conservation value of each property is assessed during a site visit using a standardized index called the Biodiversity Significance Score (BSS). The BSS incorporates information about the type and quality of native vegetation present and its conservation status in the region, the presence of species of conservation concern and their habitat, and landscape preferences (patch size, connectivity) of key mobile species.

Step 2. Development of management plan: Based on the information obtained during the site visit, the landholder selects management actions they are willing to implement which are aimed to maintain or improve the quality of native vegetation on the property. From these management inputs, a Habitat Service Score (HSS) is calculated which estimates the expected habitat gains resulting from the selected management options.

Step 3. Submission of bid : The landholder determines the payment they require to undertake the agreed upon management actions and this value is submitted as their bid.

Step 4. Bid assessment: Bids are evaluated using the following formula:

$$\text{Biodiversity Benefits Index (BBI)} = \frac{\text{Biodiversity Significance Score (BSS)} \times \text{Habitat Service Score (HSS)}}{\text{Cost (landholder bid)}}$$

The Biodiversity Benefits Index (BBI) therefore incorporate the current condition of the site (BSS) and an estimate of improvement or habitat gain (HSS) as a result of management actions. The Biodiversity Benefits Index (BBI) scores are used to directly rank bids from landholders, identifying bids that provide the most environmental benefits for the least cost.

Step 5. Management agreements signed: Successful bidders sign management agreements with the government and receive periodic payments for management services they perform over a set contract period. (e.g. 5 years).

Field measurements: The Habitat Hectare method is used to assess current native vegetation quality for a site and establish baseline conditions against which vegetation quality gains can be evaluated as a result of landholder management actions (Parkes et al 2003; DSE 2004). The Habitat Hectares score contributes to the overall Biodiversity Significance Score (BSS) which is an important part of the bid assessment process. Key to this method is the assessment of how "natural" a remnant patch of native vegetation is compared to benchmark conditions. Benchmark conditions are represented by average characteristics of mature, undisturbed stands of the same vegetation type or Ecological Vegetation Class (EVC)[25]. For each EVC, benchmark conditions have been identified for: large trees, tree canopy cover, understory layers, organic litter, and logs.

Seven site-level attributes are assessed in the field, including (Table 1): large trees, tree canopy cover, understory layers, lack of weeds, recruitment, organic litter, and logs. Each of these attributes is individually scored based on specific criteria, including benchmarks where appropriate. For example, in a riparian forest the number of large (>90 cm dbh) trees per hectare is estimated in the field and compared to the benchmark number of 20 large trees/ha; based on this comparison and the overall health of the trees, a habitat score is calculated to a maximum of 10 for this attribute (Box 1).

[25] Ecological Vegetation Class (EVC) is the mapped vegetation unit considered as the benchmark for the Habitat Hectare methodology. EVCs represent clusters of floristic communities with similar species composition, structure, and environmental requirements.

Table 1. Summary of the components and weightings which combined make up the Biodiversity Significance Score of an assessed site.

Component	Description	Maximum Value (%)
Site Condition		
Large trees	Estimate of number of large trees compared to benchmark number per hectare, qualified by tree health	10
Tree (canopy) cover	Estimate of the projective cover of the tree canopy compared to benchmark percent cover estimates, qualified by tree health	5
Understory (non-tree) layers	Estimate of the number of understory layers compared to benchmark, assessed for modification in diversity and cover.	25
Lack of weeds	Estimate of the percent cover of weeds and the proportion of this cover due to high threat weeds	15
Recruitment	Assesses the presence of recruitment, qualified by the adequacy and diversity of this recruitment	10
Organic litter	Estimate of the percent cover of organic liter compared to benchmark, qualified by the proportion of litter that is composed of native species	5
Logs	Estimate of the length of logs present compared to benchmark log length, qualified by the presence of large logs	5
Landscape Context		
Patch size	Patches of native vegetation, which may include a range of vegetation types), are scored according to their size	10
Neighbourhood	The amount and configuration of native vegetation patches are assessed within three neighbourhood radii (100 m, 1 km, 5 km), qualified by degree of disturbance of the native vegetation	10
Distance to core area	Estimate of the distance to nearest core area (i.e. patch of native vegetation > 50 ha), qualified by condition of core area	5
Total		**100**

Box 1. Example of site-level attribute assessment: Large Trees

The number of large trees/ha in combination with their health determines the large tree component score for the assessed area. This score (to a maximum of 10) is determined by :

- estimating the number of large trees in the assessment area compared to the benchmark #/ha in the same EVC;
- estimating the proportion of canopy cover present compared to the expected "healthy" projective canopy cover
- combining the density of large trees and the percent of healthy canopy to determine the large tree component score.

Category and description	Percent Healthy Canopy		
	>70%	30-70%	<30%
0 to 20% of the benchmark number of large trees/ha	3	2	1
20% to 40% of the benchmark number of large trees/ha	4	3	2
40% to 70% of the benchmark number of large trees/ha	6	5	4
70% to 100% of the benchmark number of large trees/ha	8	7	6
≥ the benchmark number of large trees/ha	10	9	8

Three landscape-level attributes are also assessed using GIS, including: patch size, neighbourhood, and distance to core area. These landscape components are included in the habitat assessment because the quality and longterm persistence of remnant patches of native vegetation is also affected by its surrounding landscape context. Each landscape-level attribute is scored based on specific criteria. For example, for the patch size category, small remnant patches (i.e. < 2 ha) are given the lowest score of 1 while large, undisturbed remnant patches (i.e. ≥ 20 ha) are given the maximum score of 10 (Box 2).

Box 2. Example of landscape component assessment: Patch Size

The size of the patch and degree of disturbance determines the patch size component score for the assessed area. This score (to a maximum of 10) is determined by:

- delineating patch boundaries which may include multiple EVCs and calculating patch area;
- for patches ≥ 20 ha, level of disturbance is assessed as “significantly disturbed” or “not significantly disturbed” to determine the overall score.

Category and description	Value
< 2 ha	1
between 2 and 5 ha	2
between 5 and 10 ha	4
between 10 and 20 ha	6
> 20 ha but “significantly disturbed”	8
> 20 ha but “not significantly disturbed”	10

The overall habitat score (out of 100) is tallied by summing the individual scores for each site attribute and landscape context component. This habitat score is converted to scale from 0 to 1, and multiplied by the total area assessed to calculate the final habitat hectare value, a combination of vegetation quality and area for a particular habitat type.

Project Outcomes: The BushTender program supports the government’s overall goal of vegetation management which is to ensure a Net Gain in area and quality of native vegetation across the landscape (NRE 2002). Net gains in habitat quality and/or quantity is quantified by recalculating the Habitat Hectare score at the end of the contract period for an area and comparing this to baseline conditions at the start of the contract term. Overall, this is a cost effective program that improves management and protection of native vegetation on private lands, helping to support regional biodiversity goals.

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Appendix 4. Case Study: EcoTender

Context: EcoTender is a multi-outcome extension of the Bush-Tender auction approach. Initially developed as part of the National Market Based Instrument Pilot Program and supported by the National Action Plan for Salinity and Water Quality, the EcoTender auction system was introduced as a way to manage multiple environmental outcomes, in particular problems of salinity and water quality, within a single program (Eigenraam et al. 2006, 2007). This program has been continued by the Victoria government as part of their ecoMarkets initiative aimed at improving Victoria's overall landscape health and biodiversity, particularly stewardship of environmental resources (native vegetation) on private land.

How it works: The EcoTender program is an auction-based system similar to the BushTender program but with landholders submitting bids to manage parts of their land for multiple environmental services (terrestrial biodiversity, aquatic function, and soil salinity) rather than just one (Eigenraam et al. 2006, 2007). Key to this process is the development of an "environmental production function", or environmental benefits index (EBI), which expresses management actions in terms of environmental goods (Eigengraam et al. 2007). The Catchment Modeling Framework (CMF), a biophysical simulation model which evaluates multiple environmental outcomes as a result of different management actions, was developed to estimate the EBI.

Estimating environmental outcomes

Catchment Modeling Framework: The CMF estimates the environmental impacts of multiple environmental outcomes and spatially represents these results to potential bidders (landholders) and to the purchaser (Victorian Government) at the local (farm) scale and at the watershed scale (Eigenraam et al. 2006, 2007). The CMF is a biophysical simulation model which accounts for a number of ecological processes (e.g. hydrology, soil loss, carbon sequestration). The model provides spatial information about environmental outcomes across the landbase as a result of specific landholder actions, linking on and off-site environmental outcomes. The framework has been designed to explicitly model and report the joint production of environmental outcomes to efficiently allocate conservation funds based on priorities for different environmental services.

The modeling framework estimates the impact of various management actions using a combination of site (farm) scale models and a lateral flow model that are integrated into a regional catchment scale framework (Eigenraam et al. 2006, 2007). The CMF includes a surface element network defined by soil, topography, and landuse (e.g. crop, pasture, livestock, forest, and climate). It also includes a groundwater network (defined by aquifer properties and drainage information) as well as other information on stream flow, groundwater hydrograph, and water use. Simulations predict daily soil/water/plant interactions providing a comprehensive range of time-series outputs at the local scale, including:

- complete water/soil balance (soil moisture, soil evaporation, transpiration, deep drainage, runoff, erosion),

- vegetation dynamics (crop/plantation yield, forest stem diameter, forest density, carbon accumulation).

At the sub-catchment to catchment scale, simulated outputs include:

- stream dynamics (water quantity and salt loads);
- groundwater dynamics (depth to watertable, aquifer interactions, groundwater recharge/discharge).

Modeled outputs of the CMF can simulate changes in water balance, nutrient transport and production as a result of different management actions for a given combination of soil type, climate, topography and land practice. The output then represents the joint production of several environmental outcomes (e.g. water quality, habitat) resulting from one action. Each of the environmental outcomes are defined in terms of:

- **service**, the change in service resulting from landholder management actions, and
- **significance**, of the change in service in the broader landscape context.

Benchmarks: To estimate a change in service, the pre-1750 landscape serves as the "natural benchmark" to compare current ecosystem function and change in that function as a result of landholder management actions (Eigenraam et al. 2006). The pre-1750 landscape is modeled to predict pre-European settlement vegetation types. This landscape then serves as the reference point for assessing current vegetation and progression towards the 1750 reference point resulting from landholder interventions.

To simplify the analysis process, landholder actions were limited in the pilot to native revegetation and improving remnant native vegetation management to advance environmental outcomes in the region. Native revegetation required the establishment of indigenous species in cleared areas using the modelled pre-1750 vegetation types as the target for a particular site. Landholders are required to meet minimum standards for each vegetation type including species composition and target density, site preparation, and follow up management. Remnant native vegetation management requires that landholder improve the vegetation quality of the site compared to a 'benchmark' (i.e. average characteristics of a mature, undisturbed community) for each vegetation type (as decribed in the BushTender example) (Parkes *et al*. 2003; DSE 2004).

Environmental Benefits Index: Each landholders bid is ranked according to an Environmental Benefits Index (EBI) which is based on how much management actions implemented by the landholder moves each environmental outcome from the current state toward the 1750 benchmark (Eigenraam et al. 2006, 2007) (Table 1).

Table 1. Summary of outcomes, service and significance

Attribute	Change in level of service	Significance
Terrestrial biodiversity	Δ habitat score (maintained or improved per hectare)	Biodiversity conservation significance, threatened species conservation status, habitat quality, landscape preference
Aquatic function	Δ water "quality" (erosion measured in tonnes/ha) Δ water quantity (mm of water/ha)	Decrease (not applied in pilot)
Saline land area	Δ saline land (ha with groundwater < 2 m)	Can discriminate - but given equal weighting in pilot

- **Saline land:** or saturated land is defined as the area of land where the depth to the water table is less than 2 meters; this area is estimated using the CMF model. The service score is the change in saturated land area (ha) with the landscape-level goal of the watershed to reduce the hectares of land within 2 m of the water table.

- **Aquatic function**: metric is the product of water quantity, which includes both groundwater and surface water flows, and erosion, which serves as a surrogate measure of water quality.

- **Biodiversity**:
  - Native vegetation - conservation value determined in the same way as the BushTender process accounting for the current condition of the site (Biodiversity Significance Score or BSS which includes the 'Habitat Hectares' site assessment) and an estimate of improvement or habitat gain (Habitat Service Score or HSS) as a result of management actions; see Appendix 3 for a detailed description.
  - Revegetation - scoring similar to remnant native vegetation management, including a measure of change in the landscape context as a result of revegetation and estimated change in vegetation condition of the site.

- **Carbon**: calculated by estimating the change in accumulated carbon (t/ha) between the current condition and the established vegetation community (EVC) at maturity. Not included in the calculation of the EBI. Landholder has the option of selling carbon sequestration units at a fixed price ($12 per unit).

EcoTender Implementation: The steps in the EcoTender process are similar to the BushTender process (Eigenraam 2006, 2007), and are as follows:

Step 1. Expression of interest: Landholders register an expression of interest to participate in the EcoTender process.

Step 2. Site assessment: The conservation value of each property is assessed during a site visit for a range of environmental services. Data is collected on relevant site attributes (e.g. vegetation community condition) and revegetation and native vegetation management options are presented to the landholder.

Step 3. Development of management plan: Based on the information obtained during the site visit, the landholder selects management actions they are willing to implement and the field officer develops the management plan as the basis for the bid.

Step 4. Submission of bid: The landholder determines the payment they require to undertake the agreed upon management actions and this value is submitted as their bid.

Step 5. Bid assessment: Bids are evaluated using the following formula:

$$\text{Environmental Benefits Index (EBI)} = \left(\frac{A_i}{D_A} + \frac{S_i}{D_S} + \frac{B_i}{D_B} \right) * 100$$

- A_i, S_i, and B_i are the aquatic, saline, and biodiversity outcomes, respectively for site i.
- D_A, D_S, and D_B represent the difference in current conditions from reference (1750 conditions) for aquatic, saline, and biodiversity outcomes, respectively for site i.

The EBI scores are used to directly rank bids from landholders, identifying bids that provide the most environmental benefits for the least cost.

Step 6. Management agreements signed: Successful bidders sign management agreements with the government based on previously agreed draft management plans.

Step 7. Reporting and payments: As specified by the management agreement, periodic payments and reporting occur over a set contract period (e.g. 5 years).

Project Outcomes: The EcoTender pilot efficiently accounts for multiple environmental services associated with native vegetation management, including: salinity, biodiversity, water quality and carbon services. The Catchment Modelling Framework (CMF) was developed to estimate the environmental outcomes resulting from landholder management actions and spatially represent these to potential bidders (landholders) and the purchaser (Victorian Government). By effectively linking on and off-site environmental outcomes associated with on-site management actions on, government can efficiently allocate funds to meet regional conservation goals. Overall, this program has enhanced environmental stewardship on private land in the State of Victoria supporting the government's state wide goal of maintaining and restoring natural assets.

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Appendix 5. Case Study: Business and Biodiversity Offsets Programme

Context: The Business and Biodiversity Offsets Programme (BBOP), a partnership between companies, governments, conservation experts, and financial institutions, was developed to explore whether biodiversity offsets can cost effectively improve conservation outcomes while minimizing companies' risks, liabilities and costs during development projects (BBOP 2009a). Two of the tools BBOP partners are working to develop include:

1) a suite of best practices to support the design and implementation of biodiversity offsets, and,
2) a 'how to' toolkit on offset design and implementation.

How it works: BBOP defines biodiversity offsets as "measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development after appropriate prevention and mitigation measures have been taken." The overall goal of offsets is to ensure no net loss and preferably a net gain of biodiversity (BBOP 2009a). Based on this goal of no net loss, BBOP is developing support tools to implement biodiversity offsets including methods to calculate biodiversity losses as a result of development and biodiversity gains resulting from offset implementation. Biodiversity loss and gain calculations include metrics to maintain populations of species, habitats, and/or ecological communities. Overall, BBOP is not a regulatory mechanism but a voluntary approach which can be used to design offsets.

The Offset Design Process: There are many possible approaches to designing and implementing biodiversity offsets; BBOP provides guidance for this process which includes several suggested steps (BBOP 2009a):

Step 1. Review project scope and activities: Review the purpose and scope of the development project and the main activities likely to take place throughout the different stages of its life cycle. Identify key decision 'windows' and suitable 'entry points' to integrate biodiversity offsets into project planning.

Step 2. Review the legal framework and / or policy context for a biodiversity offset: Review legal requirements and policy documents that pertain to the design and implementation of offsets. This review includes (but is not limited to): government policies, financial or lending institutions' policies, as well as internal company policies.

Step 3. Initiate a stakeholder participation process: Identify relevant stakeholders at an early stage and establish a process for their participation in the design and implementation of any biodiversity offset.

Step 4. Determine the need for an offset based on residual adverse effects: Determine whether there are residual adverse effects on biodiversity after all reasonable efforts have been made to avoid, minimize, and/or rehabilitate/restore impacted areas. Only after adverse impacts have been mitigated, should biodiversity offsets by implemented to ensure no net loss to biodiversity.

Step 5. Choose methods to calculate loss / gain and quantify residual losses: Select methods and metrics that quantify how 'no net loss' will be achieved through biodiversity offsets. This step quantifies the loss of biodiversity as a result of the project's residual impacts, and CONSERVATION OUTCOMES or biodiversity gains as a result of offsets that compensate for those losses. Quantifying the biodiversity loss and gain is inherent to this process.

Step 6. Review potential offset locations and activities and assess the biodiversity gains which could be achieved at each: Identify potential offset locations using biophysical and socioeconomic criteria, and select preferred options for more detailed offset planning. Part of this process is deciding whether an 'in-kind' or 'out-of-kind' offset is appropriate, because the kind of offset determines the criteria to identify suitable sites. It is generally preferred to offset biodiversity components by targeting similar biodiversity components elsewhere i.e. an 'in-kind' offset. However, where impacted sites are not a conservation priority, an 'out-of-kind' offset that involves 'trading up' may be appropriate where offsets target biodiversity of higher priority than that which is impacted by development.

Step 7. Calculate offset gains and select appropriate offset locations and activities: Applying the same metrics and methods that were used to quantify losses due to project development, biodiversity gains are calculated for the shortlist of preferred offset options. After determining feasibility of acquiring sites, final offset location(s) and activities are selected ensuring no net loss of biodiversity.

Step 8. Record the offset design and enter the offset implementation process: Record a description of the offset activities and location(s), including the final 'loss / gain' account which demonstrates how no net loss of biodiversity was achieved, how stakeholders were satisfied and how the offset contribute to national/regional requirements, policies, and overall biodiversity goals.

Calculating Biodiversity Loss/Gain: The purpose of loss and gain calculations is to determine what constitutes a 'fair' offset for unavoidable residual impacts (Loss/Gain Consultation Working Group 2008b). BBOP offers guidance on metrics to measure losses/gains, multipliers to meet the goal of no net loss of biodiversity, and exchange rules to ensure ecological equivalency of offset sites relative to development sites.

Metrics are measures used to consider how much biodiversity will be lost through a project's impacts or gained as a result of a biodiversity offset in terms of its amount, distribution and/or persistence of a biodiversity component. Choosing the metrics involves selecting 'surrogates' or 'proxies' which can be quantified and which are considered representative of 'overall' biodiversity of the area. Often, land area is used as the basic unit for calculating the conservation gain that must be achieved through a biodiversity offset; however, more detailed information about the composition, structure and function of biodiversity, and its condition will vary depending on available information and the overall purpose of the offset (BBOP 2009a). The BBOP approach for quantifying biodiversity losses and gains can include biotopes and/or species habitat (type, area occupied, and quality) which is based on the "habitat hectares" method (Parkes et al. 2003), as well as species' populations (viability/persistence). For biotope and/or species calculations there are several steps (see Box 1 and 2); however, specific details of these steps, including the identification of benchmarks, depend on biodiversity components selected as targets.

Box 1. Calculating biotope/species habitat losses and gains (Loss/Gain Consultation Working Group 2008b)**:**

Step 1: Identify a benchmark

Identify a well-conserved example outside the project boundary of the biotopes/habitats that will be affected by development to serve as a benchmark, or create a create a composite benchmark using information from several sites, or based on historical information

Step 2: Select and weight benchmark attributes and record a reference level for each

The benchmark is comprised of characteristic attributes (e.g. density of large trees, percent cover of vegetation) that represent the type, amount and quality of biodiversity which will be lost/gained.

Step 3: Quantify pre-project condition of attributes

Quantify pre-impact baseline scores for attributes to establish baseline conditions.

Step 4: Predict the post-project condition for each attribute

This step predicts the condition of attributes after project implementation which can be compared to pre-impact baseline conditions (Step 3) to quantify the expected loss of biodiversity caused by the project.

Step 5: Calculate biodiversity loss

By subtracting the post-project habitat hectares from the pre-project habitat hectares the amount of residual biodiversity impact that will need to be offset can be calculated.

Multipliers refer to an offset ratio based on an observation of the area occupied by an offset divided by the area affected by an impact. Use of a 'multiplier' represents a decision made by an offset planner to increase the area of an offset by a certain factor, with the aim of improving the chances of achieving no net loss.

Exchange rules or criteria are used to consider whether the types of biodiversity provided through the offset sites are equivalent (or better) than those affected, and whether the offset location is sufficient (or better). In combination, these two types of information allow consideration of whether losses at impact sites and gains at offset sites are ***commensurate***.

Box 2. Calculating species losses and gains (Loss/Gain Consultation Working Group 2008b)**:**

Calculating population parameters for species of conservation concern is important when development may impact more than just habitat, such as increased mortality risk as a result of intensified hunting pressure or disruption in dispersal. It such cases it may be important to quantify species-specific losses because gains in habitat metrics may mask negative demographic impacts. The general steps in the process include:

Step 1: Identify species that require species-specific quantification of losses

Identify key species that are predicted to experience residual adverse impacts that may not be the result of habitat degradation or loss. Each species should be evaluated separately.

Step 2: Select an appropriate metric for each species

Impacts to species from development projects are experienced as increased mortality and/or reduced reproduction. The metrics used to quantify biodiversity loss should therefore relate to the likelihood of persistence of individual species. Possible metrics include:

- Population Viability Analysis (PVA) which requires models of species life histories to estimate of the probability of extinction of a population within a specific time frame.
- Species Occupancy (SO) measures which are based on comparing the actual distribution of taxa with the potential distribution in the absence of human induced disturbances.

Step 3: Identify a benchmark population for each species

A suitable benchmark population needs to be identified for each species to serve as a reference to compare the impacted population.

Step 4: Assess likelihood of persistence of the benchmark population

When the benchmark population has been identified, the population metric(s) is measured to establish a reference with which to compare the impacted population.

Step 5: Assess likelihood of persistence of the impact site population (pre-project)

Measure the population metric(s) at the impact site prior to the project commencement to establish baseline conditions against which losses can be measured. The metric for the pre-project population should be calibrated on a scale of 0 to 100, against the benchmark population.

Step 6: Calculate losses with respect to the species at the impact site

Step 5 is then repeated for the post-project population at the impact site. Species loss is calculated by subtracting the adjusted metric for the post-project population from the adjusted metric from the pre-project population.

Loss and gains are calculated by (Loss/Gain Consultation Working Group 2008a):

- *Loss*: predicted situation for the **affected area's biodiversity** with no project impact minus the predicted situation for the **affected area** after impact and restoration.
- *Gain*: the predicted situation for **offset area's biodiversity** with no offset intervention minus the predicted situation for the **offset area** after restoration or management and adjusted for risk factors associated with the predictions.

Project Outcomes: BBOP provides guidance for the design and implementation of voluntary biodiversity offsets to ensure the overall goal of "no net loss" of biodiversity is achieved. BBOP is working to compile and/or make available: methods, tools and guidelines on biodiversity offsets; case-studies; and relevant national and regional policy frameworks to develop biodiversity offsets as a practical tool supporting sustainable development (BBOP 2009b).

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