Ecosystem Services, Natural Capital & Nature's Benefits In the Urban Region

Information for Professionals & Citizens

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June 2013

Credits

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Financial support was provided by:

LANDSCAPE ARCHITECTURE CANADA FOUNDATION
FONDATION D'ARCHITECTURE DE PAYSAGE DU CANADA

real estate foundation
BRITISH COLUMBIA

Acknowledgements

We wish to thank Landscape Architecture Canada Foundation & Real Estate Foundation of British Columbia for recognizing this work as worthy of their support and for their tolerance in working with us.

Additional in-kind support was provided by the Fraser Valley Watershed Coalition, Smart Growth Abbotsford and the British Columbia Ministry of Agriculture.

Our thanks go to Sarah Nathan who edited final drafts and contributed to the case study section. Sarah Primeau assisted on the Ontario Greenway and Musselman's Lake Case Studies. Joshua Welsh was responsible for graphics and desktop publishing.

Margot Long, Principal in the Landscape architecture firm of PWL Partnership Ltd., was unstinting in her generosity in developing the Southeast False Creek case study. Her staff, Karin England, Mary Wong and Jordan McAuley contributed many hours of professional content. Scott Murdoch and Paul de Greeff of the Victoria, B.C landscape architectural firm of Murdoch de Greeff Ltd. supported the Fisherman's Wharf case study. In developing the two Collaborative Case Studies the authors were supported by the environmental staff of the Corporation of the Municipality of Delta B.C. and by the Fraser River Watershed Coalition. They each participated in a series of interactive information workshops in which they shared their passion for the environment, and their scientific and local knowledge with us.

The Fraser Valley Watersheds Coalition, and interested stakeholders participated in a workshop on the ecosystem services of agricultural lands in the Fraser River Valley.

In developing this document we gave presentations to the BC chapter of the International Association for Impact Assessment, the annual meeting of the International Association for Impact Assessment, staff at Hemmera Environchem Inc. and to members of the BC Society of Professional Biologists. Many of the participants at these public presentations requested a copy of our final document. We thank them for their interest.

Participation in workshops and/or discussions and feedback on ideas and approaches was provided by Erin Clement, Angela Danyluk, and Sarah Howie of the Corporation of Delta; Natashia Cox, Sarah Nathan, Monica Pearson and Detmar Schwichtenberg of the Fraser Valley Watersheds Coalition; and Annemarie de Andrade of the Burrard Inlet Environmental Action Program/Fraser River Environmental Management Plan.

Review of early drafts and feedback was provided by Katy Amon (LEES & Associates Landscape Architects), David Bernard (Demophora Institute), Gillian Kerr (Government of Alberta), Dr. Faisal Moola (David Suzuki Foundation) and Dr. Bo Yang (Utah State University).

Photographs were contributed by PWL Partnership and Murdoch de Greeff Ltd, Dr. John Lowman and Al Grass.

The document is made freely available for use by others. We ask that users reference the document appropriately.

Suggested citation:

Brown, G. and Mooney, P. 2013. Ecosystem services, natural capital and nature's benefits in the urban region: Information for professionals and citizens. Vancouver BC: School of Architecture and Landscape Architecture, University of British Columbia.

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Table of Contents

Case Studies

Special Topics

References & Resources Concerning Ecosystem Services

- Introduction
- Starting Points for Further Study
- Master List

An Introduction

This document is an information resource. It introduces ecosystem services, natural capital and nature's benefits and particularly how those ideas can be applied in urban regions. Our target audience is professionals as well as interested citizens and decision makers. We introduce this new and rapidly evolving field so readers may appreciate its merits, and use the concepts in their own work if they desire.

This document is an information resource. It introduces the field of ecosystem services and natural capital and particularly how those ideas can apply at the urban landscape scale.

The document contains four interconnected parts:

- *Foundations of Ecosystem Services* is a stand-alone summary of the field.
- Further *Examples* are found in the *Resources* section. The Case Studies section describes a variety of landscapes, and landscape interventions and their impact on ecosystem services.
- The five *Special Topics* expand upon the *Foundations* with more explanation and detailed links to technical resources.
- *References and Resources* lists all sources cited with hotlinks to websites and downloadable documents.

Natural capital—including forests, soils, and water—provides ecosystem services that benefit people. Harvested products are well known. Other ecosystem services, like water purification and soil creation, are less known but very important. Identifying services more clearly, explicitly showing their value, and preserving natural capital can protect ecosystem services. The field of ecosystem services addresses those topics.

Major projects, like the *Millennium Ecosystem Assessment, The Economics of Ecosystems and Biodiversity* and the *InVEST* mapping project, developed different ways to work with natural capital and ecosystem services. These projects provide inspirational benchmarks and methods that can work at the urban landscape scale.

Several major fields related to environmental design, planning and management provide technical tools and methods that can protect natural capital and ecosystem services. These fields are:

- *Multifunctional Landscapes*
- *Sustainable Ecosystems*
- *Ecological Restoration*

Policy and governance tools can support technical projects. Governments can use many kinds of legislation, indirect support for citizens and stewardship groups, and market based instruments to protect and enhance natural capital and ecosystem services. The Examples, Case Studies and Special Topics develop these basic ideas further.

An Overview

In this document, we introduce the ideas of ecosystems services and nature's benefits to readers interested in urban systems and connections between urban and rural landscapes. There are underlined hotlinks contained within the document that you can use to move between sections of the document, and resource links outside the document.

The main ideas related to ecosystem services are described in the *Foundations of Ecosystem Services*. More information and many technical details are provided in the ***Case Studies***, ***Examples*** and ***Special Topics***. The hotlinks, which you can click on, will take you to resources related to the topic. The links sometimes take the reader to other information within this package, and sometimes they connect to documents and websites available on the Internet. You can:

- Read a Summary of the entire document
- Start with the Foundations of Ecosystem Services
- Explore the Case Studies, Examples and Special Topics
- Examine the Master List of Resources

The document is divided into four interconnected parts. Briefly these are:

1. The *Foundations of Ecosystem Services* (Sections 1-4) provides a foundation to the field. It includes an overview from basic definitions to common technical tools of analysis and environmental management. It links to the rest of the document, which provides additional and complementary technical information.

2. The ***Case Studies*** describe technical projects such as residential and urban developments, parks and restoration projects, with special attention to the challenges they faced and the ecosystem services they protected or created.

3. The ***Special Topics*** sections provide explanations and technical details that expand upon the topics in the *Foundation*. They contain many references to technical literature so readers can pursue specific interests they might have.

4. The final section is a collection of *Resources and References*. It suggests where to start further research and lists key websites and journals. Each hotlink in the rest of the text connects to a citation in this section. Many of them have annotated descriptions. If the resource is available on the Internet, or is a website, the citation links directly to it.

The authors understand that readers will search the document looking for specific information relative to their interests or needs. Most readers are unlikely to read the document start to finish, at least on first encounter. For this reason we have attempted to make each section understandable in isolation. This has meant that there is some inevitable overlap between sections.

The *Foundations of Ecosystem Services* has four sections. These are:

Section 1: What are Ecosystem Services, Natural Capital, and Nature's Benefits?

Ecosystems and biodiversity provide a stock of natural resources, like forests and water, which can be thought of as natural capital. That natural capital generates a continuous flow of ecosystem services and benefits to people, like lumber, drinking water and fresh air. These features make up a 'cascade' of influence that flows from ecosystems to human well-being. We need to maintain and restore natural capital to ensure a continued supply of services and benefits. The field of ecosystem services tries to identify the full range of services and benefits, show their value in economic terms, and help protect natural capital with technical and policy tools.

Section 2: Approaches and Tasks that Focus on Ecosystem Services

Several international assessment programs established the importance of ecosystem services and improved methods for working with them. Major milestones included the Millennium Ecosystem Assessment (MA) (2005), The Economics of Ecosystems and Biodiversity project (TEEB) (2010), and the United Kingdom National Ecosystem Assessment (2011). Each involved multiple steps, from initial description of services, methods to estimate economic values of services, and steps to use the descriptions and values in planning. Several classification systems have come from these studies. While the MA's is best known, the TEEB classification system seems the most practical. Nevertheless, it is important to know about the other classification systems as well.

A different approach from assessment is geospatial mapping. These methods map and model the ecosystem services and economic values of specific locations. The best known such approach is the Natural Capital Project and its series of InVEST computer-based models. Other mapping approaches use Geographical Information Systems that map different 'layers' of natural landscapes and their services.

These assessment and mapping approaches are powerful but they can be complex and expensive. Following them exactly might not be appropriate for urban landscapes. More local projects can use the framework of sequential steps that they suggest, or use some but not all of the procedures they provide.

Three particular tasks used by large projects are often used separately and can be practical at local scales.

- Organized classifications of ecosystem services: Projects usually organize ecosystem service data into categories before using it. The TEEB classification system updates the MA one, but either can be helpful. Other specialized classification systems use spatial, economic or social criteria that can help for particular purposes.

- Economic valuation of ecosystem services and their benefits: A major goal of the MA project was to show the value of ecosystem services. The central goal of TEEB was to expand use of economic valuation. Only some harvested products have market prices. Economists have devised many ways to estimate monetary values for the remaining ecosystem services. Examples include valuing purification of water by forest soils by the cost to build a water filtration plant, and valuing recreation at a lake by the costs it takes to travel and stay there. There are also simpler methods of ranking benefits that do not involve monetary calculations. If people believe that nature has intrinsic value or other values separate from people, such approaches can complement economic valuation, but they are not part of it.

- Payments for Ecosystem Services (PES): Payments can be made to landowners to protect services their land provides that benefit other people. This approach is used mostly for watershed, biodiversity and carbon services. There are many legal and administrative challenges which can complicate PES efforts.

Section Three: Integrating Ecosystem Services with Environmental Planning and Management

Instead of adopting a major assessment or mapping method, professionals might like to start with simpler steps or methods that are closer to what they already do. Three existing and somewhat overlapping fields have goals and technical methods that can integrate with local plans to protect ecosystem services.

- Multifunctional landscapes: The goal of creating multifunctional landscapes is to maintain as many ecosystem services as possible within landscapes that people use, especially rural, agricultural or urban ones. Many landscape and site specific practices have been identified to help achieve that goal. Guidelines to good land planning and development practices have been summarized by the SITES program and Smart Growth approach.

- Sustainable ecosystems: Ideas from conservation biology and landscape ecology directed towards sustainable human use of ecosystems overlap with ideas of multifunctional landscapes.

They emphasize techniques that protect biodiversity such as protected areas, corridors, buffer zones and protecting specialized habitats and species.

- Ecological restoration: Many sites in urban landscapes are degraded in some way and might be more in need of restoration than protection. Techniques for planning and restoring different habitat types contribute to protecting ecosystem services.

Section Four: Policy and Governance

- Government rules and practices apply to, and can enhance the effectiveness of, technical approaches to ecosystem services. Four themes are described.
- Organized decision making and public participatory processes can be used with ecosystem services.
- Laws, regulations and guidelines, including land use requirements, zoning, taxes and subsidies can maintain or protect natural capital and ecosystem services.
- Governments can encourage voluntary action by citizens and stewardship groups. Action and educational programs can be supported with direct funding and logistical support.
- Market based instruments such as tradable permits, payments for ecosystem services, and offsets can encourage protection of natural capital using market direction to inspire innovative responses.

Section Five: Case Studies

The *Case Studies* describe a variety of landscape planning, management, development or rehabilitation projects from around the world. They include residential, recreational, and industrial site developments, regional planning and urban redevelopment projects and restoration efforts. Each case study describes the problem that was identified, how it was addressed, the main results, and the ecosystem services maintained or enhanced.

The *Special Topics* are:

1. Key Ideas and Lessons about Ecosystem Services
2. Comprehensive Approaches to Ecosystem Services
3. Common Tasks Used with Ecosystem Services
4. Integrating Ecosystem Services with Environmental Planning and Management
5. Policy and Governance

Each Special Topic expands substantially upon major themes summarized in the *Foundations*. They provide detailed explanations and background technical information so readers can investigate topics of their interest and find specific guidelines for implementation. The Special Topics contain many links to additional information and technical resources.

The *Resources and References* section provides information for readers to follow up ideas and citations mentioned elsewhere in the text. A short list of resources and websites suggests where to begin more detailed research. The *Master List of References and Resources* contains bibliographic details for all sources mentioned in the text, many with additional annotations. Links to the internet permit immediate access to websites and downloadable documents.

Foundations of Ecosystem Services

Section 1

What are Ecosystem Services, Natural Capital & Nature's Benefits to People?

1.0 What is in this Section?

- Definition of natural capital, ecosystem services and natures benefits.
- Explanation of why they are important and studied.
- How many kinds of ecosystem service are there? Classification systems.
- How natural capital yields ecosystem services and benefits: Cascade diagrams.
- Key ideas about ecosystem services.
- Frequently asked questions and links to further information.

1.1 Introduction

This first section of ***The Foundations of Ecosystem Services*** describes what ecosystem services and natural capital are and why they are important. More details and links to resources and other parts of the document are found in the Case Studies, Examples, Special Topics and References and Resources.

1.2 Key Definitions and Ideas

1.2.1 Definitions

"Ecosystem services can be broadly defined as the aspects of ecosystems that provide benefits to people." (Turner et al. 2008)

"Natural capital is the land, air, water, living organisms and all formations of the Earth's biosphere that provide us with ecosystem goods and services." (International Institute for Sustainable Development, 2008)

"Ecosystem: A natural unit consisting of all the plants, animals, and microorganisms (biotic factors) in a given area, interacting with all of the nonliving physical and chemical (abiotic) factors of this environment. An ecosystem can range in scale from an ephemeral pond to the entire globe, but the term most often refers to a landscape-scale system characterized by one or a specified range of community types (e.g., a grassland ecosystem)." (Levin 2009 p. 779)

The definitions above reveal two essential ideas that are at the heart of discussions about ecosystem services. These two ideas are represented in Figure 1 below. The first is that there are three major features to be considered: the natural ecosystems, the services they provide, and the benefits that people get from those services. The second is that nature provides a physical 'stock' of resources that provides a continuing 'flow' of services and benefits to people. Ultimately, to preserve the continuing flow of services and benefits, one must preserve or restore the natural ecosystems.

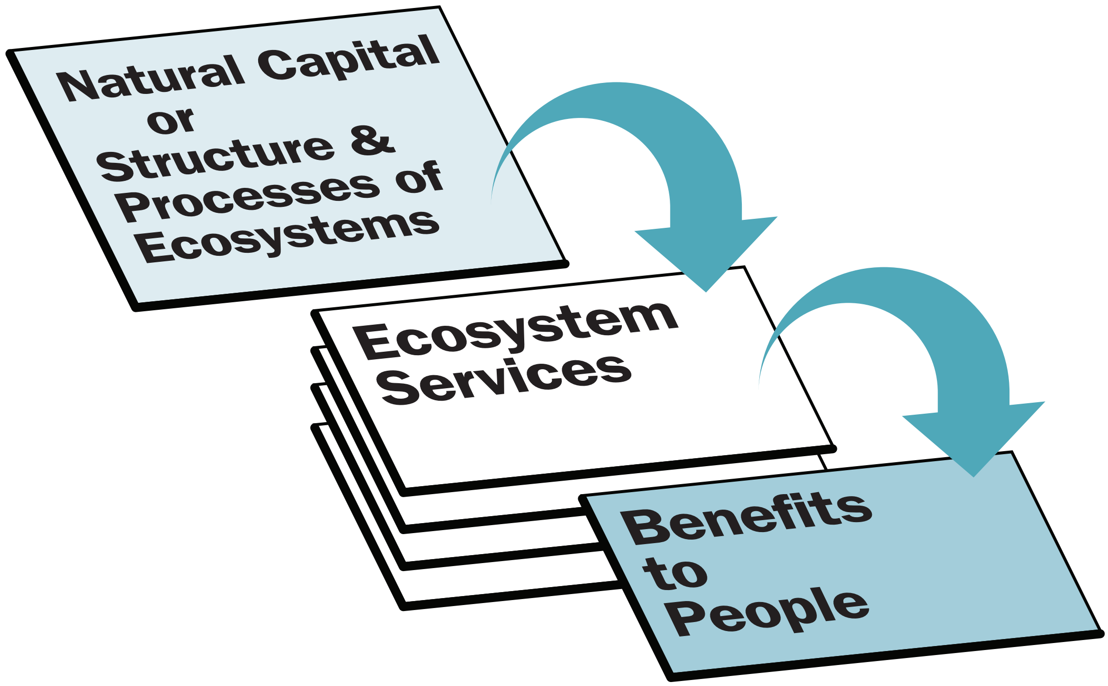

Figure 1: The relationship of nature capital to ecosystem services and nature's benefits

In the language of economics, money and resources, and buildings and machinery, are collectively called 'capital'. By analogy, the infrastructure of nature is referred to as 'natural capital.' Forests, rivers, soil, oceans, fish and wildlife, microorganisms and landscapes make up natural capital.

Economic capital produces the goods and services that society consumes. Likewise, natural capital produces the ecosystem goods and services that people use. (The term 'ecosystem services' is equivalent to the longer phrase 'ecosystem goods and services'.) Ecosystem services, therefore, are the goods—the water, trees and fish harvested from lands and waters—and the services—the filtration of water, pollination of crops and creation of soils—provided to people by ecosystems.

Economists tell us that there is an important difference between economic goods or services produced (e.g., a shirt) and the benefits people receive from them (i.e., keeping warm or looking stylish). Likewise, there is a difference between ecosystem services and the benefits they provide. For example, an ecosystem service (clean river water filtered by forest soils) can provide several different benefits (safe and healthy drinking water, irrigation of crops, and flood control). Hence the two ideas –services and benefits—are complementary and related, as shown in Figure 1.

Some people talk more about natural capital. Some discuss the ecosystem services. Others are more concerned with the benefits to people. These three ideas are linked as in Figure 1. One of the key messages is that in order to have a continuing flow of the things that people enjoy—the services and benefits—one must maintain the stock of natural capital.

Other people do not use economic language quite so explicitly. They refer to the features of nature—'the structure and function of ecosystems'—instead of natural capital, as the source of the services and benefits. For example, the structure of a forested ecosystem refers to the trees, soils, and landscape present there. The functions of the forest refer to the habitat provided, the filtration of water by the soil, and the other processes that take place there. The structure and function of ecosystems is what makes up the natural capital of those ecosystems. The two terms are equivalent, as shown by the 'or' in Figure 1.

1.2.2 'Ecosystem Services' Can Expand Perspectives and Aid Decision Making

Many people are concerned about reducing the negative influences of people's actions on the environment. One way to reduce such impacts is to show that environmental problems are not just about endangered species and lost habitats, although those things matter.

The services and benefits that *people* get from nature and natural resources are also deteriorating.

A key purpose for studying ecosystem services is to show people the many benefits they receive from nature, and that those benefits are being reduced by human actions. If more people understood the services they get from nature, society's decision making and actions might better protect the environment and maintain ecosystem services.

The study of natural capital and ecosystem services supports economic development. We want to encourage the wisest possible economic development, over the long term. Understanding more about ecosystem services often shows that short-term resource harvesting and habitat destruction may well cost more in lost benefits and development options in the future than the short-term benefits are worth.

Information about ecosystem services can give society and its decision maker's perspectives they were not aware of. Such knowledge can lead to better-informed choices. That is why people are studying ecosystem services.

1.3 Cascades & Classifications Give More Details

As people use the ideas of ecosystem services and natural capital for practical purposes, they need more detail. Two ideas, ecosystem cascades and classification systems, help people organize their understanding. We explore both here: you can find more discussion of definitions and concepts of ecosystem services in Special Topics 1 and 3.

1.3.1 Ecosystem Cascades

Figure 1 introduced a simple three part diagram of ecosystem services. To better manage and measure ecosystem services and their relationships, the TEEB project adopted a more detailed five-step 'cascade' of ecosystem services as part of the program's formal framework. The cascade model shows how nature's structure and processes 'flow' to influence the provision of services and benefits to people (Figure 2).

The five elements often need to be distinguished and measured separately from each other. The first two boxes describe aspects of natural capital. Biodiversity is part of ecosystems, but the authors felt it was so important that it needed to be emphasized specifically, and so it is part of the title on the right ('ecosystems and biodiversity'). They also found it necessary to distinguish between nature's benefits and the economic value assigned to those benefits. Thus there are two boxes within the part of the system called 'human well-being' on the left.

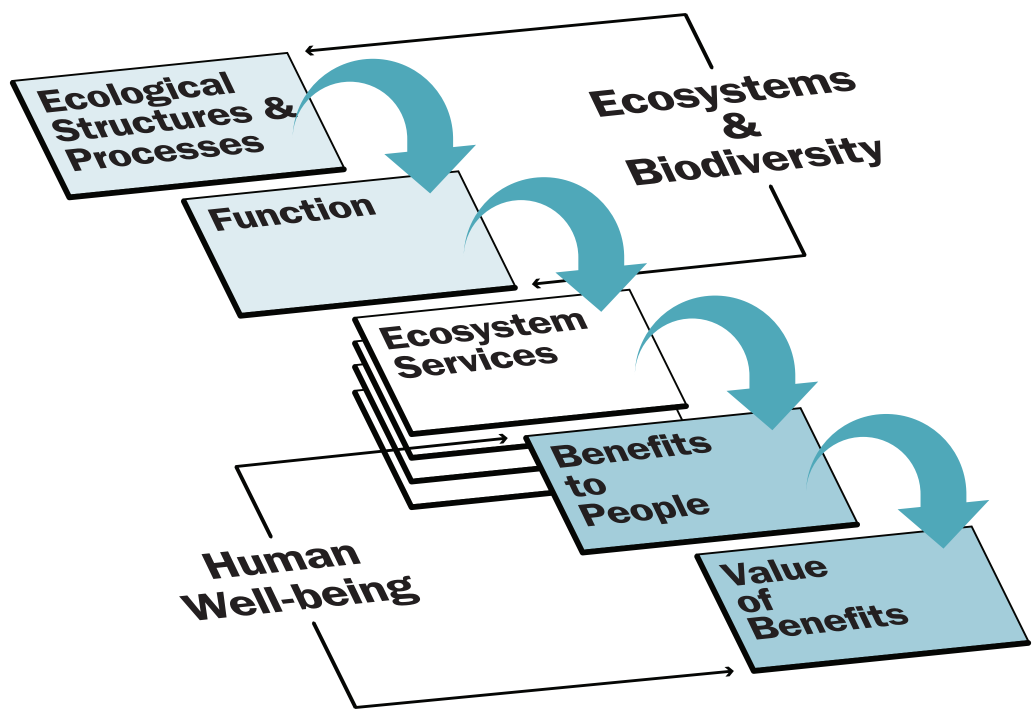

Figure 2: Pathway from ecosystems to human well-being: a five-step cascade.
Adapted from TEEB (Kumar 2010, p. 17)

Many studies of ecosystem services emphasize economic values of services and benefits (discussed in Section 2). The cascade diagram shows the inter-relationships of all the different elements, showing that no one element stands alone. It illustrates the big picture. It is a helpful tool for organizing ideas and further studies.

1.3.2 Classification Systems

n 2005 the United Nations completed a five year project that studied the state of the planet's resources an ecosystem services. With input from over 1300 scientists, the *Millennium Ecosystem Assessment* (MA) revealed that 60% of the planet's ecosystem services were in decline. These efforts popularized the idea of ecosystem services and showed some methods for using the ideas.

One of the first steps in dealing with ecosystem services in your area is to describe them. A major achievement of the MA study was the creation of a classification system to organize the descriptions. It is still commonly quoted and used (see Figure 3 below). Since then two major revisions have been made by international bodies. The *Economics of Ecosystems and Biodiversity* (TEEB) project released its major report in 2010. The *Common International Classification of Ecosystem Services* (CICES) project is still underway.

All three systems create categories to describe the kinds of services they provide. The titles of the main divisions are similar, although there are some differences in the meanings of the same title, between the systems. In general, Provisioning Services are the usable goods and services like lumber and water. Regulating Services are the processes that filter water or influence weather: that regulate aspects of nature. Cultural Services provide recreation and spiritual benefits. Supporting Services like photosynthesis provide the basis for all other services.

The revised system from TEEB is shown in Figure 4 and indicates the further detail that is addressed by the sub-categories. The TEEB and CICES approaches correct some difficulties found in the earlier MA version. Because CICES attempts to mesh its classification with a natural-asset accounting system, it provides a more carefully made hierarchy than its predecessors.

How do these different classifications influence the practitioner at the landscape level? Identifying important ecosystem services is an important first step in many studies. Using an established classification system ensures your work will be organized and consistent with other practitioners. This document assumes that the TEEB classification system and related cascade diagram is the most practical current organizing framework for most projects. We adapted it to use in

Figure 3: The major types of Ecosystem Services from three major classification systems (After MA 2003, p. 56-60, Kumar 2010 p. 26, CICES 2013 Version 4.3)

MILLENNIUM ECOSYSTEM ASSESSMENT (MA 2005)	THE ECONOMICS OF ECOSYSTEMS & BIODIVERSITY (TEEB 2010)	COMMON INTERNATIONAL CLASSIFICATION OF ECOSYSTEM SERVICES (CICES 2013)
Provisioning	Provisioning	Provisioning
Regulating	Regulating	Regulating & Maintenance
Cultural	Cultural & Amenity	Cultural
Supporting	Habitat	--
31 TOTAL SUBCATEGORIES	22 TOTAL SUBCATEGORIES	8 DIVISIONS, 20 GROUPS, & 48 CLASSES

the Case Studies. Many people still use the MA system (described further in Special Topic 2). Debate over classification systems continues, and readers might want to check out the state of the art.

There are guidelines for using the TEEB classification in an urban study (see TEEB Cities). However, you could further customize the TEEB process for your use. You might want to describe your services more precisely than the 22 sub-categories that TEEB offers.

A discussion of the history and debates around definitions and classifications of ecosystem services can be found in Special Topic 1: Definitions. More detail on the initial efforts of the Millennium Ecosystem Assessment in 2005 and the advances of its follow-ups, TEEB in 2010 and CICES in 2013, is in Special Topic 2: Comprehensive Approaches to Ecosystem Services.

1.4 Some Key Ideas About Ecosystem Services

Amid discussions about ecosystem services, a number of useful key ideas come up. Nine of them are described below. More details on each of these points, including citations to sources which discuss them more thoroughly, are available in Special Topic 1: Key Ideas about Ecosystem Services.

1. Not all parts of nature are related to ecosystem services.

A contemporary definition that we use is "ecosystem services can be broadly defined as the aspects of living ecosystems that provide benefits to people." (Turner et al., 2008). From this, it follows that ecosystems, rather than the physical environment, are the source of ecosystem services Thus mineral deposits and even fossil fuels produced by ancient ecosystems are not included in current ecosystem service typologies. Water is considered part of the ecosystem service cascade because of its many interactions with living creatures and its central role in ecosystem processes.

2. Ecosystems generate multiple services and benefits.

Each ecosystem usually generates more than one service that people can use. Different ecosystems generate different services (such as forests compared to grasslands). Multiple benefits can come from one service (e.g. clean water for drinking or irrigation). One benefit can come from more than one service, sometimes separately and sometimes combined (Recreational enjoyment might come from a forested landscape, birds being present, and from clear water to canoe upon).

Figure 4: The TEEB typology of Ecosystem Services: four main service types and 22 subcategories (After TEEB 2010 p. 26)

MAIN SERVICE TYPES	SUBCATEGORIES
Provisioning Services	Food, Water, Raw Materials, Genetic Resources, Medicinal Resources, Ornamental Resources
Regulating Services	Air Quality Regulation, Climate Regulation, Moderation of Extreme Events, Regulation of Water Flows, Waste Treatment, Erosion Prevention, Maintenance of Soil Fertility (Including Soil Formation) & Nutrient Cycling, Pollination, Biological Control
Habitat or Supporting Services	Maintenance of Life Cycles & Habitats for Species, Maintenance of Genetic Diversity
Supporting Services	Aesthetic Information, Opportunities for Recreation & Tourism, Inspiration for Culture, Art, and Design, Spiritual Experience & Sense of Place, Information for Cognitive Development

3. Two 'identical' ecosystems can yield different services and benefits to people.

The services and benefits an ecosystem produces are defined by how they are useful to people. Imagine two forests. One, near a city, might produce drinking water and recreational opportunities. A nearly identical forest, far from a city, will have the same natural capital, but if no one uses them, no ecosystem service or benefit was received, (except for those benefits like carbon sequestration which benefit people at a distance). When thinking of services and the benefits ecosystems provide, the extent to which people use them is the key concern.

4. Using one ecosystem services often results in a trade off, resulting in less of another service.

When people harvest forests for lumber, there are fewer trees left for fuel wood or to sequester carbon or support recreation. Often the situation is more complex than a trade-off of one service for another. For example, logging can cause soil compaction, erosion and landslides that will reduce forest growth in future. In this example, the natural capital of the watershed has been reduced. If the natural assets are reduced by logging in the short term, then the flow of many services might be reduced for the longer term. Harvesting the better recognized 'provisioning services' is often done at the cost of reduced 'regulating' and 'cultural' services. Conversely, enhancing one service can support others. Restoring a wetland to improve water quality can also enhance wildlife habitat and improve recreation opportunities.

5. Where is biodiversity?

Biodiversity is very important. It is the major component of the ecosystem that provides ecosystem services and their benefits. It is worthy of much management attention and protection. In most cases, a decline in biodiversity will lead to a decline in ecosystem services. However biodiversity is not an ecosystem service in and of itself. Recall that biodiversity is represented on the left side of the ecosystem cascade (Figure 2) and is not part of the middle box, which shows the services.

6. The precise details of relationships among nature, services and benefits are not clear. Details often need to be understood.

The ecosystem cascade is a helpful conceptual tool. But the exact mechanisms and specific mathematical relationships within that cascade are not at all clear. For example, we know water filtration (a natural process) leads to a service (clean water), which leads to benefits (drinking and irrigation water), which have some measure of value (perhaps captured by markets). But the distribution and value of these benefits is not clear. For any given location, specific studies might be needed to figure out the local details. In the case study section we have gone through the exercise of simply identifying the ecosystem services of a particular landscape. The many kinds of economic valuation described in Section 2 are a partial response to this complexity.

7. The concept of ecosystem services is centered on people

The ecosystem services approach is completely anthropocentric. Other aspects of the environment, which some people consider very important, such as the value of nature for its own sake, or the right of species to exist are not part of an ecosystem services approach.

8. Nature can be considered important for its own sake

The ecosystem services perspective addresses how nature benefits people. That does not mean that nature and living things do not have merits separate from their utility to people. But such a point of view is outside the natural capital approach. The intrinsic value of nature is a separate topic that can complement the ecosystem services approach.

9. There is a worldwide trend towards increasing use of ideas of ecosystem services and natural capital.

The ideas of natural capital and ecosystem services are expanding. Natural capital, ecosystem services and nature's benefits are increasingly being used in planning and management. We hope that increased use of ecosystem services in site planning and design follows. At this time ecosystem services are more commonly included in non-regulatory guidelines and planning, but it is an administrative requirement of some international agencies to study and report on ecosystem services. For example, the International Finance Corporation, the private sector division of the World Bank, includes ecosystem services in its required Performance Standards as do the Equator Principle guidelines followed by many international banks. The trends seem clear: ecosystem services and natural capital will have a larger role in many parts of society in the future. However, as indicated in point 6, uncertainties with technical details pose challenges for widespread use of ecosystem services.

More information on these nine topics is available in Special Topic 1: Key Ideas about Ecosystem Services.

1.5 Questions & Links to Resources

Section 1 introduces basic ideas in the field of ecosystem services and natural capital. The Special Topics are designed to provide more technical information to complement shorter summaries in the Foundations. Special Topics 1 and 2 expand upon ideas here, and provide more details and citations related to the material. How can you use these ideas in your work? Figure 5 lists some questions and topics related to this Section. It links to resources in this document that might help you learn more.

Figure 5: Possible questions, topics and references related to Section 1

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
How can I introduce ecosystem services to a business or government audience?	The document Nature and its role in the transition to a green economy reviews key ideas and puts them in a context useful for planners and policy makers. You can also explore Starting Points for Further Study to find sources that meet your audience's needs.
How can I find out more about ways that ecosystem services are defined and classified, or how they are described as cascades?	There is a lot of literature on definitions and classifications, that are discussed in Special Topic 2: Comprehensive Approaches. There is less information on cascades. They were introduced by Haines-Young and Potschin (2010) and prominently added to the world's perspective on ecosystem services in Chapter 2 of the TEEB summary. They are part of the CICES approach.
How can I find out what services and benefits come from different ecosystems?	The studies of the MA and TEEB projects described in Section 2 produced many examples, which are identified in the Examples: detailed links to finding them are provided in the Resources section. Each of the Case Studies identifies ecosystem services related to a particular development project. Investigate ones that interest you.

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
How can I get a deeper understanding of the economic perspective on natural capital and ecosystem services?	There is more description of economic analysis in Section 2, particularly in the Valuation and Total Economic Value and Payments for Ecosystem Services sub-sections and the in related sections of Special Topic 3.3: Economic Valuation and 4.4 Payments for Services. Reports by the David Suzuki Foundation calculation economic valuations for ecosystem services in urban regions around Toronto and Vancouver. The UK's 2013 State of Natural Capital report discusses conceptual issues related to a practical, national scale application. Several of the annotated Examples provide a strong economic perspective on ecosystem services.
How can I use the idea of ecosystem services or some specific tools?	Section 2 describes methods for using ecosystem services. There are two general 'approaches' to using ecosystem services, assessments and mapping, which might be useful for you. Three commonly used 'tasks' that people find useful (classification, valuation and payments for ecosystem services) might serve your purposes. Section 3 introduces specific technical tools from the fields of multifunctional landscapes, sustainable ecosystems and ecological restoration, related to using ecosystem services. Special Topics 3 to 6 discuss many aspects of using ecosystem services and provide links to resources.

ISSUE OR TOPIC	**POSSIBLE FOLLOW UP**
What approaches are there to classifying ecosystem services in the landscapes in my area?	The topic of classifications is examined in more detail in Section 2.3.1. Detailed background to classifying ecosystem services that could apply to work for local studies is found in Chapter 2 of the United Kingdom National Ecosystem Assessment. The challenges to definition and classification discussed in Special Topic 1: Definitions might interest you. You could apply the ecosystem services matrix which is used in the Case Studies for a local project. You might develop your own cascade diagrams for a site or landscape.
Where can I find a more thorough history and background to the concepts of ecosystem services and natural capital?	You can explore the options described in Starting Points for Further Study, browse the annotated listings in the Resources Section and check out the Examples and Case Studies to find resources specific to your interests. There are books, book chapters, journal articles, technical reports and websites listed.

Section 2

Approaches & Tasks That Focus on Ecosystem Services

2.0 What is in this Section?

- Different ways to study and use ecosystem services
  Description of two major ecosystem assessment projects:
  - The Millennium Ecosystem Assessment (MA)
  - The Economics of Ecosystems and Biodiversity (TEEB)
- Description of two kinds of geospatial mapping and modeling of ecosystem services:
  - Ecological production function models (InVEST)
  - Mapping integrated with planning models (GIS and others)
- Three major tasks used within many ecosystem service projects:
  - Classify services and benefits
  - Economic valuation studies
  - Payments for ecosystem services
- Key ideas about approaches and tasks that focus on ecosystem services
- Questions and links to resources

2.1 Introduction

This Section describes several ways to conduct studies focusing on ecosystem services. First we examine two approaches that explore ecosystem services to aid social planning and decision making:

- Ecosystem assessment
- Mapping and modeling ecosystem services

The Millennium Ecosystem Assessment is the most famous study of ecosystem services. Five years after the MA was complete, The Economics of Ecosystems and Biodiversity published a more focused and revised approach to assessment. These are the best known resources in the field. A different approach to studying ecosystem services is to connect specific services with specific places: to map them. We describe two ways to do that.

Both assessment and mapping approaches use ecosystem services as their central tool. Although they have distinct differences, the two approaches do not conflict. Both draw upon similar source ideas and use similar components, such as scientific and economic studies used to gather data. Both have multiple steps, starting with identifying ecosystem services and moving on to different ways to analyze, map or use them. Each is described by its sponsors as a self-contained approach and we describe them that way here.

Within the assessment and mapping approaches there are several components, or tasks, which are often used separately, in their own right. Because you might want to use these tasks on your projects, independently of an entire assessment or mapping effort, we describe them in the second part of this section. They are:

- Classifications of services and benefits
- Economic valuation studies
- Payments for ecosystem services

These topics are discussed in more detail in Special Topics 2 and 3, each of which includes more information and links to more detailed resources. There are Examples that illustrate these approaches which you can examine.

2.2 Comprehensive 'Approaches' Built Around Ecosystem Services

Here, we describe two methods for conducting ecosystem assessments and then two ways to map and model ecosystem services. Each is a self-contained approach to describing, organizing, valuing, planning and linking to policy using ecosystem services.

2.2.1 Ecosystem Assessment

2.2.1.2 The Millennium Ecosystem Assessment (MA)

The Millennium Ecosystem Assessment (2005) is the most famous example of an assessment of ecosystem services. Using the MA approach, one can undertake a careful and comprehensive review of the ecosystem services in an area. While the guidelines are quite general and flexible (see Ash et al., 2010; Ranganathan 2008), assessments of this type are usually very substantial efforts. As its name indicates, the process is an assessment of ecosystems and not just of ecosystem services. However, ecosystem services are the central element which the process addresses. Ecosystem services were studied because they were seen as "the link between ecosystems and human well-being and therefore as the focus of assessing the consequences of ecosystem changes for people" (Ash et al., 2010 p.1). An ecosystem assessment, as understood by the authors of the MA, goes well beyond documenting the ecosystem services of a particular area. It addresses all features of ecosystem services, and is intended to lead directly to their inclusion in regional planning and policy. Thus, it is a complex planning and management process. The titles of the major stages and their major steps, summarized in Figure 6 below, suggest the time and technical effort that could be involved.In the

Figure 6: Major stages and steps in an Ecosystem Assessment
(after Ash et al. 2010 Chapter 1)

STAGE	STEPS
Exploratory Stage	Examination of boundary conditions & potential constraints Need for an assessment Potential scope and users Potential funding
Design Stage	Determine user needs Establish governance structure Choose temporal and spatial scale Consider different knowledge systems
Implementing the Work Program	Develop conceptual model(s)Assess ecosystem services & human well-being Determine drivers of change Develop plausible futures Develop response options

STAGE	STEPS
Developing Output & Communicating Findings	Reports & summaries Pamphlets Atlases Popularized publications Educational material

"Implementing the Work Program" step above you will see the "Develop plausible futures" action. Thus, an assessment, in the sense of the Millennium Assessment, addresses all features of the status and trends of ecosystems, right up to planning for the future. A major challenge is the large and expensive sequence of steps that identify and measure ecosystem services in an area, and assemble that information for decision makers. The MA's results occupied multiple volumes. Assessments have been quite famously done for the whole planet by the Millennium Assessment itself, for Europe and for the United Kingdom. In principle, though, the process is flexible enough to apply to many different situations. Several regional and local examples done as part of the Millennium Assessment might be of particular interest to those interested in urban and regional scales. Three are described in the Examples.

TEEB documents (e.g. TEEB 2011 p. 11) implement the approach with a six steps to identify and then bring ecosystem services into policy in as much detail as needed:

Step 1: Specify and agree on the problem or policy issue with stakeholders
Step 2: Identify which ecosystem services are most relevant
Step 3: Determine what information is needed and select assessment methods
Step 4: Assess (future changes in) ecosystem services
Step 5: Identify and assess management/policy options
Step 6: Assess the impact of the policy options on the range of stakeholders

The economic evaluation that is the core of TEEB is embedded in steps 3 and 4. The other steps are needed to select, focus and use that information. In addition to its focus on economics, the TEEB project made several technical advances. They refined the definition of ecosystem services, revised the classification system for organizing ecosystem services, and introduced a cascade model of ecosystem services. The classification and cascade were introduced in Section 1.

Figure 7: The major tiers in the TEEB Approach to bring an economic perspective to ecosystems (TEEB 2010a)

TIER	PROCESS
Recognizing Value	Identify issues & assess ecosystem services
Demonstrating Value	Estimate & demonstrate the value of ecosystem services
Capture Value	Introduce mechanisms to use ES in public policy & processes

Despite the flexibility of approach that the MA and TEEB authors say is available, projects that try to follow the MA or TEEB processes are likely to be quite large, comprehensive and expensive. However, they are desirable in principle and as models. Some of the individual tasks used in both the MA and TEEB approaches, as described later in this section, are perhaps more likely to be practical at local scales. Readers can consult the TEEB Manual for Cities, which portrays their ideas for an urban audience, although the steps remain quite general. Several TEEB Examples show how the process is applied.

2.2.2 Mapping & Modeling Ecosystem Services

A different approach from ecosystem assessment is mapping ecosystem services and related landscape features. We describe two major approaches.

2.2.2.1 Map & Calculate Ecological Production Functions

One method of working with ecosystem services is to map 'ecological production functions.' This approach involves studying, modeling and mapping the complex features of a particular landscape that produce the services that people use. The rules that describe, usually mathematically, how nature produces the services are called ecological production functions. Computer models, most famously a series called InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), can be developed and used for this purpose. We describe the InVEST version here.

InVEST creates a model for each separate major service of the landscape (they model 12 services), for mapped units of the landscape. Examples include the stability and erosion of local soils, infiltration and purification of water by vegetation, and pollination of agricultural crops within different landscape units. Biophysical attributes can then be connected to separately modeled and mapped economic valuations associated with different land uses. The combinations connect to planning scenarios for the region.

The InVEST approach is intended for use with substantial stakeholder input. The models are based on ArcGIS software. Research and development is still underway. These models have the great merit of using specific, numeric data for specific regions. The models can be used with data of differing detail and complexity. However, acquiring even simple data can be quite demanding.

Several ecological production function approaches are described in the Examples section. More details about InVEST and alternatives such as the programs MIMES and ARIES are found in Special Topic 2.3: Geospatial Mapping.

2.2.2.2 Integrate Ecosystem Services into a Mapping & Planning System

Ecosystem services can also be mapped, using a landscape planning approach with 'layers' of information, as is commonly created with Geographical Information Systems. Turner et al., (2008), demonstrate this approach for wetlands, intending that their example be applied to other ecosystems. They consider the five layers listed in Figure 8 (on the following page), specifically recognizing that benefits are not always realized in the same location as the services are produced.

This kind of planning and mapping also focuses on a chain of 'production functions', although it does not model them in the same way as approaches like InVEST. Mapping all of the layers can be used as a comprehensive approach to management. However, mapping approaches more commonly map individual aspects of ecosystem services (one or several resources or services rather than the full five layers). Simpler mapping efforts have been used in many local studies. Several Examples provide more details.

More information about these four major approaches to studying ecosystem services is available here: Special Topic 2: Comprehensive Approaches.

2.3 Three Major Tasks Used with Ecosystem Services

In the previous section, we described assessment and mapping, each as a package of steps we called an approach. In this section, we address three somewhat smaller and more focused ideas. We call them 'tasks' because they are more specific and do not try to address the whole process of assessing or managing ecosystem services. Rather they deal with specific common and important tasks. They are often components of the previous approaches. These tasks are:

- Classification of services and benefit helps to describe and organize what we are dealing with.
- Economic valuation studies put various measures of 'worth' on ecosystem services or their benefits, as a key step towards public discussion and decision making
- Payments for ecosystem services provide an incentive for protection of ecosystem services.

More details on each can be found in Special Topic 2.

Figure 8: Mapping layers for documenting and analyzing ecosystem services (after Turner et al. 2008)

MAPPING LAYER	CHARACTERIZATION
Governance Layer	Formal & informal rights & agreements over resource management
Value Layer	Valuation or evaluation studies
Benefits Layer	Service flow, demographic, & land use characteristics
Service Flow Layer	Production & land cover, topography
Service Production Layer	Biophysical conditions & processes

2.3.1 Classify Services and Benefits

Classification of ecosystem services is an essential step in identifying, in an organized way, what services and benefits are present in a location. It is usually one of the first steps in a project, regardless of whether it is a simple study, which does not need much more information that the services, benefits and beneficiaries, or if it is a full assessment in the MA style. The TEEB classification with four service types and twenty-two subcategories (Figure 3 above) is a useful tool for a variety of such organizing purposes. The earlier, similar Millennium Assessment classification system is still the most common system used, even though it is now somewhat out of date and has been improved upon by the TEEB and CICES approaches. The five part cascade diagram (Figure 2), which complements the TEEB classification, also helps describe a local ecosystem and its services.

These are not the only ways to classify and describe ecosystem services. Several other approaches, described in more detail in Special Topic 2, could be used for more specialized purposes. One important step, adopted by the UK ecosystem assessment among others, is distinguishing intermediate and final services within the classification. This distinction becomes important in organizing data before or during valuation studies.

2.3.2 Valuation Studies and Total Economic Value

Most ecosystem services are not traded in markets and therefore do not have prices. But studies of natural capital are intended to contribute to social decision making, and much social discussion concerns monetary values. In the absence of prices, there are methods for estimating monetary values of ecosystem services. Such studies can be useful, for example, in assessing development options and forecasting the value of ecosystem services lost, retained or gained in different development scenario. These valuation methods are described in more detail in the Economic Valuation Studies section of Special Topic 3.

Evaluation methods recognize a range of kinds of economic value, within an overall framework called 'Total Economic Value' such as shown in Figure 9.

The direct use values represented by the lower left box are the easiest to recognize and assign values to. Many are directly harvested commodities like crops or lumber, which also have prices in markets. However there are direct uses of resources like water and recreation, which are known to be valuable but are difficult to price. The four other boxes in the bottom row represent other kinds of value that humans derive from nature, which are less tangible and more difficult

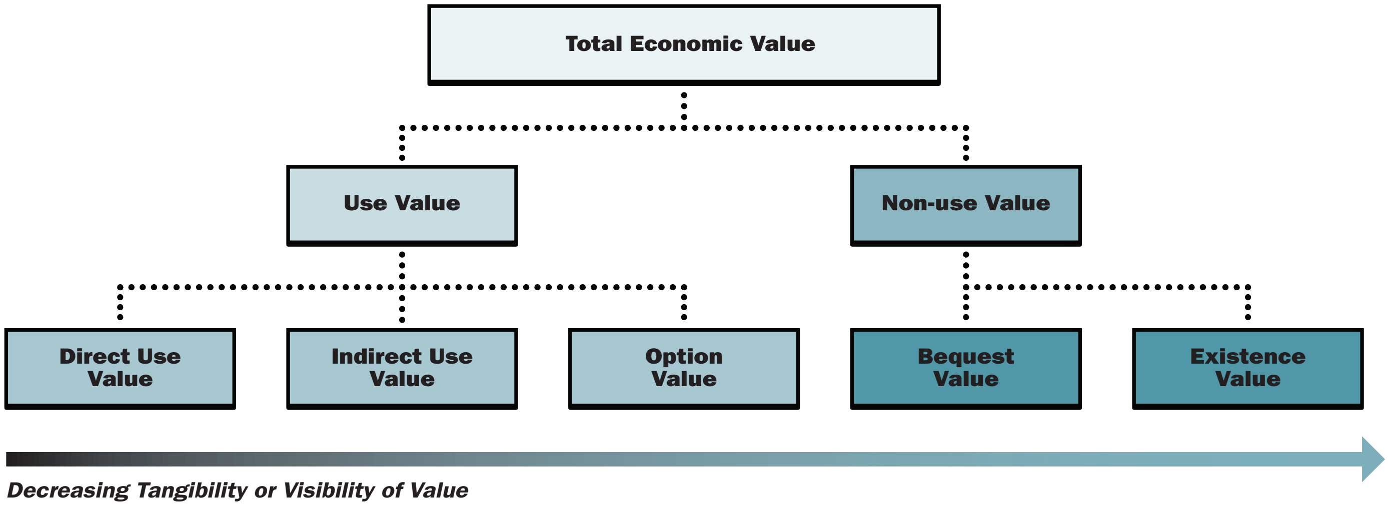

Figure 9: A model of the Total Economic Value that people obtain from nature (after DEFRA 2007)

to assign monetary values to. These five kinds of value are the targets that are estimated using different evaluation methods

There are two major categories of evaluation method, using market values and non-market values. Market values are monetary measures derived from the marketplace. The most obvious is price: if a resource like lumber has a market price that is a realistic measure of its value. There are other kinds of market values. For example, a watershed filters the water that a downstream city uses for drinking. Calculating the current market cost for building a water filtration plant (the 'replacement cost' technique) yields a market-based estimate of the monetary worth of the water filtration service. There are several Examples available with more details.

There are also non-market techniques, which estimate monetary values without market data. Some are quite specialized to particular purposes. For example, the 'travel cost' method estimates a minimal monetary value for the recreational benefits of an outdoor site by calculating the costs of travel and services at the site.

While most non-market techniques estimate monetary values, there are also some non-monetary measures. Some techniques rank people's preferences for one use compared to others, which does not involve calculating monetary worth. Such techniques can compare quite different values, including abstract values for which monetary estimates are difficult.

2.3 3 Payments for Ecosystem Services

One popular technique related to ecosystem services is Payments for Ecosystem Services or PES. Some ecosystem services are produced by a relatively small number of people who can be identified (e.g. forest owners or farmers), and they benefit a large number of others, who can also be identified (e.g. downriver city dwellers). In these cases, those who benefit could pay those who produce the service so they will continue providing it. PES methods are quite well established for some situations. They have been most used for watersheds and water quality, carbon storage, biodiversity, and retaining attractive landscapes. There have been successes, but there are practical difficulties as well. See the Payments for Ecosystem Services section in Special Topic 3 for more details.

2.4 Some Key Ideas about Approaches & Tasks that Focus on Ecosystem Services

Some specific ideas and lessons related to these approaches and tasks are assembled here.

1. Economic development depends on nature; development in the future is often constrained by development in the present.

The ecosystem services perspective supports economic development. However, current development can constrain future development if it decreases ecosystem services. Impacts on nature can reduce future development options.

2. It can be helpful, or even necessary, to think in terms of intermediate and final services.

Some ecosystem services contribute to other services. For example, water filtration contributes to clear drinking water. The former are called intermediate services and the latter, which provide the direct benefits to people, are final services. When measuring, one does not want to 'double count' by including both the intermediate and the final service. It is the final services that are most important for inventory purposes and those are often given special attention. In TEEB's classification of ecosystem services, the habitat and regulating services often contribute (as intermediate services) to the final provisioning and cultural services. However, to maintain the final service it is always necessary to maintain the intermediate service and the ecological function or process that produces it. Therefore a classification system aimed at protecting ecosystems services needs to account for the intermediate services.

3. Studies should distinguish nature and natural sciences from human benefits and social sciences.

Detailed planning and management often requires local studies of services and benefits. In thinking about the cascade diagram, the first three boxes (ecosystem structure, functions and services) are usually studied by natural scientists. The tools of the social sciences are best used to explore the final two-the benefits and values.

4. Economic valuation is not restricted to monetary evaluation.

Economic value refers to all kinds of utility, or value, that people get from nature. The Total Economic Value diagram in Figure 9 shows different kinds of value. Some aspects of that economic value can be assigned monetary measures or estimates, but not necessarily all of them. Non-monetary estimates of value can be made, but they are also economic valuations. That is, the terms economic value and monetary value are not synonyms: the latter is a partial measure of the former.

5 Economic valuation does not necessarily mean putting a value on all of nature.

Valuation is very useful in providing more specific information to decision makers. However, estimating the economic value of nature's benefits is not the same as putting a value or price on nature as a whole, an act many people think is unethical. Valuation procedures (despite what might be implied by their name) do not try to put overall monetary values on all of 'nature' or 'water' or 'the environment'. They estimate the monetary worth to people of one or more specific uses of services, or changes in usage, in a particular location at a particular time.

2.5 Questions & Links to Resources

The topics summarized in this section are dealt with in more detail, and with links to resources for further information, in several Special Topics. You can examine:

- Comprehensive Approaches to Ecosystem Services
- Common Tasks used with Ecosystem Services
- Key Ideas about Ecosystem Services

If you are interested in exploring some specific questions or topics, please refer to the information in Figure 10 on the following pages.

Figure 10: Possible questions, topics and references related to Section 2

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
This document shows that full ecosystem assessments are often quite demanding at the municipal scale. Where can I find examples so I can see for myself?	Two of the TEEB reports (for Cities and for Local and Regional Policy Makers) include specific how-to information and provide a good perspective. The United Kingdom national assessment and the State of Natural Capital report provide British examples. Many of the sub-global assessments that make up the Millennium Assessment are described individually. The MA manual for assessment practitioners provides guidelines for the assessment process.
Providing a dollar value for ecosystem services sounds very helpful. How do I do that?	Economic valuations are popular, but there are many different approaches. Some are very well accepted but others are quite controversial. Many, although not all, are quite complicated. The section of Special Topic 3.3 Economic Valuation Studies describes the topic. See the discussion, references and cautions there.
Do we have to use money as the sole measure of value? Many people in our community would object to that.	There are a number of non-monetary approaches to assessing community priorities which involve kinds of ranking, scoring or voting. Some details can be found in Valuation Studies and Total Economic Value. See also the discussion of participatory processes in Decision Making.

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
Our group already has a GIS department. How can we connect our GIS system to map natural capital and ecosystem services	An introduction to such approaches is found in Fisher et al. and Turner et al. Note that the production function modeling approaches include mapping options. For more details see the Special Topic 2.3 Geospatial Mapping. Several of the Examples have a substantial mapping component.
It sounds like it would be very helpful to produce scenario discussions and maps of future projections. Scenarios can be included in assessment and mapping approaches. How can we pick what we need?	Scenarios and maps are data summary tools that can be applied to many processes, and so are not unique to any one approach. How well they are done depends on the quality of the data and the analysis, and those steps can be expensive. There are quite detailed discussions of scenarios in Ash et al. and Ranganathan et al.
We already have many sound environmental practices. How can I show the relationship between what we do and ecosystem services?	Section 3 and Special Topic 3 are devoted to the linkages among environmental planning and management tools and ecosystem services.
I'd like to have farmers and landowners receive payments to protect their land. How do we start?	Payments for ecosystem services sound very appealing and have sound merits. They also have challenges, including a need for much data to justify payments or to permit monitoring and many legal requirements. Some guidelines and key points are found in Special Topic 3.4 Payments for ecosystem services.

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
I'd like to introduce natural capital and ecosystem services at the municipal scale, but I don't want to make huge changes at first. How can I start gently?	The UK State of Natural Capital report describes a careful set of steps for the nation which might give you ideas for a city. The technical steps in Section 3 can be introduced one at a time. The TEEB Cites Manual and their guidelines for Local Policy Makers offers a detailed process but with suggestions for simpler studies. Some policy changes that can be considered are described by Molnar. More policy options are described in Section 4. Some of the Case Studies describe what others have done with modest resources.

Section 3

Integrating Ecosystem Services with Environmental Planning & Management for Urban Landscapes

3.0 What is in this Section?

- Established techniques from three fields for implementing ecosystem services
- Multifunctional landscapes
- Sustainable ecosystems
- Ecological restoration
- Discussion of steps for integration

3.1 Introduction

This section examines a different scale of the landscape than Section 2, which addressed large areas and tasks, like regional ecosystem assessments and scenario planning. Such efforts require large multidisciplinary teams of experts, a good deal of time and large budgets. However, many people working at the urban landscape scale might see the worth of incorporating ecosystem services in their work. These people might need shorter, simpler and cheaper approaches. Instead of a complete assessment, large area plan or design, these individuals might want to make a particular improvement to natural capital, change a program, implement a site-scale landscape design or modify a regulation. Also, they might wish to use techniques and approaches that they are more familiar with, but to which they can add ecosystem services as an enriching idea.

Many of our readers no doubt understand the particular methodologies within the disciplines of physical geography, planning, engineering, architecture, landscape architecture, biology, forestry, agriculture or economics. Such expertise can be applied to three particular sub-fields that are particularly compatible with the ideas of ecosystem services. These are:

- Multifunctional landscapes
- Sustainable ecosystems
- Ecological restoration

Each of these fields has been around longer than ideas about ecosystem services. The ideas from each field overlap somewhat, and they are mutually supportive. These fields have begun to incorporate ideas of ecosystem services into their existing tools and approaches. Therefore, working with their goals and techniques can directly protect ecosystem services. Also, many professionals are already familiar with at least some of the tools and methods that are embedded in these approaches. Therefore, it might be easier to modify or expand your existing practices by investigating these fields, than to explore the larger ecosystem services approaches in Section 2. In our case studies section, the reader will find examples of regional and local planning, community and landscape designs that have incorporated ecosystem services, sometime without proponents being directly cognizant of this inclusion.

In recent years, the perspective of ecosystem services has been utilized within multifunctional landscapes, sustainable ecosystems and ecological restoration. However, ecosystem services are relatively new ideas, and not all of the literature of these three subjects uses the ideas of ecosystem services and natural capital explicitly or frequently. We will look at the basic approach of each area and identify guidelines and tools from each that might help practitioners at the urban landscape scale.

3.2 Multifunctional Landscapes

Multifunctional landscapes attempt to weave together human uses such as urbanization and agriculture with human-modified ecosystems, while maintaining ecosystem structure and function. Because they mix human use with ecosystem function, these landscapes inevitably preserve or enhance ecosystem services.

"Sustainable multifunctional landscapes are landscapes created and managed to integrate human production and landscape use into the ecological fabric of a landscape maintaining critical ecosystem function, service flows and biodiversity retention" (O'Farrell and Anderson, 2010, p. 59).

The origin of the concept comes from concerns about ecological sustainability, conservation, wise urban growth and livable communities. The fields of landscape architecture, landscape ecology, physical geography, agriculture and urban planning, among others, have been particularly interested in multifunctional landscapes. Professionals make substantial efforts to design landscapes specifically to introduce, maintain or enhance ecologically productive features as well as to create aesthetically attractive and psychologically supportive places in people live and work. The idea that a human-modified, multifunctional landscape can retain many ecologically important features is the central theme. The pursuit of multifunctional landscapes is supported by design, planning and management themes, and supporting techniques, from whole-landscape considerations to very local site practices, such as:

- Protect watersheds and their soils, forests, wetlands, streams and rivers
- Preserve or reestablish forests, grasslands and native vegetation
- Keep forested and vegetated patches where possible
- Retain vegetation and ground cover beside streams provide for vegetated corridors and buffer zones around development
- Provide local habitats for birds and other animals reduce impermeable surfaces and provide mechanisms for stormwater infiltration
- Use bioswales, retention ponds, green roofs and other specific techniques to manage urban runoff
- Reduce energy use in buildings and from transportation
- Provide more opportunities for bicycles, walking and interaction among people

One flexible and detailed resource for implementing steps towards multifunctional landscapes is the SITES program led by the American Society of Landscape Architects. Their guidelines and handbooks provide standards, measured by points for the kind and number of features included in a particular project design. They explicitly include ecosystem services among the many attributes that professionals should consider. Other ideas that lead to multifunctional landscapes are embedded in the goals and practices of the Smart Growth movement. It emphasizes methods to enhance growing cities and rural municipalities while preserving landscapes, water, soil and wildlife. The goal of sustainability can be challenging. Action to preserve ecosystem services is a way of creating multifunctional landscapes and operationalizing sustainability. Readers can find more information about these and related practices, including resources and links to Case Studies, in Special Topic 4.2 Multifunctional Landscapes.

3.3 Sustainable Ecosystems

The biologically-oriented fields of conservation biology, wildlife management and ecosystem management, among others, strive toward the sustainable human use of natural ecosystems. The idea of 'sustainable ecosystems' became a central goal for practical applications of scientific ecology:

"(the sustainable ecosystem approach) strives to maintain ecosystem structure and function as a means of maintaining both biodiversity and productive capacity. Thus, its twin goals, management to produce goods and services and to maintain species and communities, encompass the goals of both utilitarian and preservationist management" (Weddell 2002, p. 279).

How does one go about maintaining sustainable ecosystems? The field of multifunctional landscapes draws upon a wide range of landscape, watershed, planning and ecological methods to achieve this end. The ecological theme of sustainable ecosystems has a somewhat narrower, but more detailed focus, which complements the multifunctional landscape approach. Based upon ecological principles, Forman (1995) offered four 'indispensable patterns' to help managers preserve nature in urbanizing environments. They are:

- Maintain large patches of natural vegetation
- Protect vegetated corridors along water courses
- Provide connectivity for movement of key species among large patches
- Maintain smaller patches of vegetation throughout developed areas

Those guidelines help on their own to guide development activities. More specific practices, which support those themes, have been developed by conservation biologists and landscape ecologists. First, the major threats to be addressed or avoided are:

- Habitat degradation and loss
- Habitat fragmentation
- Species extinction
- Reduced population sizes and decline in genetic diversity
- Invasive species
- Global change, including climate change

Second, key tools and approaches for preserving biodiversity in general, or individual threatened species, include:

- Design and manage protected areas and systems of protected areas
- Outside protected areas: Manage modified, cultivated, or built environments for biodiversity and habitat protection
- Use habitat buffers, corridors, connectivity and networks
- Design and implement species management; provide resources, control threats
- Use population and metapopulation modeling and species management plans
- Establish and manage new populations
- Use ex-situ conservation-use zoos and gardens to maintain threatened species
- Cooperate on goals and share benefits with local communities

Techniques to carry out these goals are found in the books, journals and websites of conservation biology and related fields, including resources and links provided in Special Topic 4.3: Sustainable Ecosystems.

3.4 Ecological Restoration

The topics in the previous sections help maintain as much natural capital as possible in existing ecosystems. In many cases developed landscapes lose habitats and ecological functions. Sometimes land is left as derelict fields with little or no vegetation and sometimes with a degree of toxic contamination. But degraded areas can become assets. The field of ecological restoration is devoted to improving deteriorated sites. For example, landscape architects and others working to redevelop post-industrial brownfield sites will often incorporate ecological restoration or rehabilitation to restore or create ecological function (See the Southeast False Creek example in our case study section).

The Society for Ecological Restoration (SER) defines ecological restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." (SER 2004. p 3.) SER offers general guidelines that help organize key steps in design, planning and implementation, regardless of the specific habitat type. A restoration plan needs to be site-specific. Not only do original habitats vary greatly from place to place, but the kinds of disruptions also differ from site to site. Three key points for the design and planning phases of restoration follow.

1. Select goals carefully

The extent of the damage, the budget, the nature of the original habitat, and plans for future land use can all affect your goals. Is the damage so great that you can only try to smooth the surface and stop erosion with a vegetated cover, given your budget (as can sometimes be the case with mine sites reclamation)? Often the goal is to restore original conditions as much as possible, and future recreational or wildlife uses can influence what you do. You will probably have several goals.

2. Choose a reference ecosystem

The goal is often restoring a site as close to original conditions as possible. In the absence of detailed historic site data, you will need to find a local 'reference ecosystem' that you can use for comparison and guidance. Studies of soil, vegetation and wildlife conditions at the reference site can help you decide what needs to be done to your damaged site. The reference site can also help you monitor success at your restoration project by providing measures of biophysical conditions that you can set as targets and compare as the project proceeds. A reference ecosystem might provide a supply of soil or plants to help with your project.

3. Make a model of the process

Creating a conceptual model of the project, often using diagrams or maps, helps organize what you know, need to know, and are trying to accomplish. The model often identifies challenges and key tasks that need to be prepared for. The conditions of your reference ecosystem can give you important information for your model.

After these and other planning processes, projects must be implemented in the field. Though each project will be different, there are guidelines for many of the details related to different habitats or site conditions. Sources of more detailed information about ecological restoration can be found in Special Topic 4.4: Ecological Restoration. Restoration projects can be demanding but satisfying: They tangibly restore natural capital and recreate ecosystem services.

3.5 Discussion

Professional knowledge about multifunctional landscapes, sustainable ecosystems and ecological restoration provides rich resources to support newer goals of protecting natural capital and sustaining ecosystem services. If an ecosystem assessment or mapping approach does not meet your needs, but you want to protect or enhance ecosystem services near you, these tools can help you. Here are some additional general points about using ideas from these fields.

You can link tools of ecosystem services with those of environmental planning and management.

Here are steps you could take to integrate ecosystem services into your environmental planning and management approaches:

1. Think of how a natural capital or ecosystem services enhancement could work in your area. The approaches from Section 2, specific perspectives from Section 3, and the Examples and Case Studies can give you guidance for your early goals.
2. Identify the ecosystem services in your area. There are multiple tools and approaches, as described in Section 2 and Special Topic 1, but the first steps of the TEEB approach (described in pages 11-19 of the Cities Manual (TEEB 2011), are quite practical. The TEEB steps are reflected in the ecosystem services matrix used in the Case Studies section.
3. It is common to rank the importance of the services, or select a set of services that you want to work with first. You might also identify key benefits or beneficiaries at the same time. The Cities Manual gives suggestions on how to do these things.
4. Identify specific options for protecting or enhancing the ecosystem structure, function and processes that yield the key ecosystem services or benefits that you have identified. Comparing your system with the different steps of the cascade diagram can help you identify and separate these influences.
5. Link protecting of ecosystem services with careful plans for preserving or enhancing important habitats and ecological resources on the landscape. The guidelines for multifunctional landscapes and sustainable ecosystems in Section 3 and Special Topic 4 can help you do that. This step marks the clearest integration of ecosystem services with other technical steps.
6. You might want to estimate the economic value of some services, following the ideas from Section 2.3.2 or Special Topic 3.
7. You can consider some policy tools to protect or restore the ecosystem services you have, in addition to technical steps. These are introduced in Section 4.

Protecting biodiversity is not exactly the same as protecting ecosystem services.

Protecting biodiversity is a common and important goal. We know that the ecosystem, of which biodiversity is a key part, provides the natural capital that sustains ecosystem services. Biodiversity is strongly related to ecosystem services and protecting biodiversity does protect ecosystem services. However, ecosystem services are not related to biodiversity in a linear, predictable way. Implementing established good practices for multifunctional landscapes, sustainable ecosystems and restoration ecology will enhance biodiversity and strongly support ecosystem services. However creating good habitat corridors or protecting wetlands does not necessarily maximize ecosystem services. If your goal is to manage for ecosystem services, you need to plan for and monitor ecosystem services explicitly, in parallel with other environmental goals.

Include Adaptive Management to make technical projects more effective.

Adaptive management is an organizational approach that uses a repeated cycle of planning, monitoring and improvements to guide technical projects and make them more effective. Guidelines to apply the process to conservation projects are available from the Conservation Measures Partnership (2013).

More background and detailed references are available in Special Topic 4. There are multiple Examples and Case Studies considering multifunctional landscapes, sustainable ecosystems and restoration ecology. Looking at them might give you new ideas on the many things you can do.

3.6 Questions and Links to Resources

Some specific questions or topics that might be related to the material covered in this section can be found in the table below.

Figure 11: Responses to possible questions and topics related to Section 3

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
We want to enhance ecosystem services in our city, how can we do that?	The tools and guidelines summarized in the sub-sections about multifunctional landscapes, sustainable ecosystems and ecological restoration introduce the ideas, and Special Topic 4 provides specific literature and background resources with different techniques. The Examples and Case Studies can give you models that you can follow or use as guidelines.
We have been thinking of changing our park system, so there are smaller playing fields and more wildlife habitat. How do we find out more?	Restoring habitat is a major theme of ecological restoration and you can learn more by investigating the introduction to that topic in Section 3 or the more detailed background in Special Topic 4. The Case Studies include a number of park and restoration projects that might interest you.
There is a lot of talk about corridors and green spaces. How do they work?	Corridors and green spaces are ways to enhance and maintain wildlife habitat in urbanizing areas. They are key tools from the field of conservation biology used to promote Sustainable Ecosystems and to create Multifunctional Landscapes. You can find more details in those sections of Special Topic 4. The linkages to economic valuation of the Ontario Greenbelt might also interest you.

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
We have open spaces in our area that are empty and covered with weeds. Perhaps some of them are slightly contaminated from old businesses. How do we make better uses of these sites?	You are facing a restoration situation and you will have to prepare a plan specific for your needs. Special Topic 4.3 Ecological Restoration can give you some starting points. The special problems of abandoned lands might help you figure out how to improve your lands.
Our city already has many sound environmental protection practices that cost lots of money. Surely we are already protecting ecosystem services, so why should we do more?	Yes your existing practices will be protecting natural capital and ecosystem services to some extent. However, the services that people get are important, and just protecting a watershed or reducing erosion does not necessarily maximize protection of the benefits people get. As discussed more in Special Topic 4, you can enhance ecosystem services by building upon, and perhaps only modifying slightly, your existing practices. The guidelines of the SITES program and examples in the Case Studies can indicate practical ways to augment current good practices.
We will be creating wetlands that will probably store carbon. Can we get some help for our restoration program from a carbon market?	Carbon payments are one kind of payment for ecosystem services. That topic was introduced in Section 2 and more details are available in Special Topic 3.4: Payments for Ecosystem Services. If your restoration project does store carbon it might be eligible for revenue. There is much carbon specific information from the Carbon-Biodiversity Co-benefits website. You might find it interesting to look at the relative importance of different ecosystems services in the study by Nelson et al., where carbon was specifically measured.

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
We already have quite a bit of information about our district in GIS map databases. How can we use this information with ecosystem services?	The sections on geospatial mapping in Section 2 and Special Topic 2 might give you ideas about how your system could be used. A mapping effort can be important but cannot stand alone. Mapping must be connected to understanding the complex relationships between ecosystem services and landscape features and processes. The approach of multifunctional landscapes helps understand those relationships, so one can preserve the ecosystem structures and functions that generate the ecosystem services.
Our city wants to protect ecosystem services by providing better guidelines for developers, and preferably do so with fewer regulations. How can we do that?	The specific guidelines that follow from principles of multifunctional landscapes can be helpful to you. The examples from the SITES program and the Smart Growth guidelines can be helpful. Our case studies, some of which were taken from the Landscape Architecture Foundation website, show how multifunctional and sustainable landscapes also yield ecosystem services. The overall guidelines about policy and governance in Section 4 and Special Topic 5 address that topic as do the development tools and guidelines summarized by Perlman and Milder.

Section 4

Policy & Governance

4.0 What is in this Section?

- Decision making processes
- Legislation & Regulation
- Encouraging Social Action Without Legislation
- Market based instruments

4.1 Introduction

Public policy and governance refers to the making and implementing of the rules and guidelines which direct society. Governments are well positioned to influence the protection and maintenance of ecosystem services. We will explore some features of governments and policies as they relate to ecosystem services.

There are more details on each in Special Topic 5 on Policy and Governance.

4.2 Decision Making Processes

There is much discussion of the use of ecosystem services to influence decision making. Elected representatives take many of society's decisions, often on the advice of professional and knowledgeable staff. Government staff, professionals and citizens advise elected representatives and participate in a variety of decision making processes themselves. Ideas and information about ecosystem services can therefore influence decision making by elected officials, professionals and the public.

Many methods apply to each step of decision making. There are separate methods for:

- Gathering information
- Identifying alternatives from which to choose
- Identifying the important aspects (values) that are relevant for making a choice
- Calculating relative weights to be assigned to particular values, for different alternatives
- Assessing trade-offs between values and alternatives selecting and communicating recommended choices

One can do these things with complex numerical tools or simpler ranking methods.

A major topic related to decision making is the involvement of stakeholders and the use of participatory processes. Decision making can be done by small teams, and there are a variety of participatory methods for public groups that can be appropriate at different stages of data gathering, planning and decision making. A review of the some details and information resources about decision making is provided in Special Topic 5.

4.3 Legislation and Regulation

Governments make rules of various kinds: this is perhaps their most conspicuous function. A variety of rules apply to environmental matters. At the broadest scale, policy statements or overall guidelines can direct many aspects of government behaviour. Many towns and cities have adopted 'green charters' or 'smart growth' plans that influence many aspects of what they do. (See Examples)

Individual laws can be carefully targeted and can direct many kinds of land use and development practices. Many laws are associated with specific regulations that direct how they are to be applied. In urban areas there are many regulations about zoning and land use. Further, permits and licenses influence things citizens do, and can be applied to natural capital and ecosystem services. Taxes can be used to encourage or discourage particular lands uses or actions. See details in the section of Special Topic 5 on Legislation and Regulation or look at some Examples or Case Studies.

4.4 Encouraging Social Action without Legislation

Governments and large agencies can influence social actions in many ways other than with legislation. One major approach is to encourage the actions of citizens, individually or through non-government organizations like stewardship groups. Providing information, guidelines and encouragement is one way governments support civil society actions. They can also provide financial support from different kinds of grants and subsidies.

The establishment of a variety of networks is another way governments can support social actions. Government can help organize networks of organizations, and coordinate municipal staff and NGOs to work together. Government, through the rules it makes, can also encourage different forms of group organization such as co-operatives and co-management arrangements, which can create different mechanisms to protect natural capital.

Policies can also be supported via a whole range of communication, education and social marketing measures. These efforts can be taken directly by government staff or indirectly by citizen groups, NGOs or public schools. More details can be found in Special Topic 5.

4.5 Market Based Instruments

Market based instruments (MBIs) are policies that create an economic incentive rather than direct regulations to achieve environmental goals. MBIs were originally introduced to provide alternative mechanisms, other than legislation, to control pollution, especially water and air emissions. MBIs have two major advantages. They encourage innovation, and individual companies or citizens can customize their actions in ways that suit their circumstances. Both results come from people being guided by a target rather than specific rules of how to achieve that target.

Several different kinds of MBIs exist. There are 'price-based' mechanisms that can raise or lower costs or taxes. Payments for Ecosystem Services are a price-based mechanism, in that they lower (compensate for) the costs of protective actions by landowners. There are 'rights-based' mechanisms such as tradable permits that involve adjusting the 'right' to pollute or to develop land in a particular area. There are 'market-friction' mechanisms that can encourage or discourage consumer behaviour to the advantage or disadvantage of a particular goal.

Further information is provided in the section of Special Topic 5 on Market Based Instruments or you can examine some Examples or Case Studies.

4.6 Questions & Links to Resources

The questions and responses which follow might provide some practical suggestions you can use.

Figure 12: Responses to possible questions and topics related to Section 4

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
What policies or guidelines can be instituted at a municipal level that will enhance natural capital and ecosystem services?	Molnar's compilation of Policy Options to support natural capital would be a helpful document to review. There has been much effort devoted to guidelines and toolkits to promote Smart Growth and many of them are relevant to protecting ecosystem services. The development guidelines summarized by Perlman and Milder apply at multiple scales and can be used as examples. All of the policy options discussed in Special Topic 5 might be relevant in some way.
How can we build guidelines into a city charter to support natural capital?	There are many sound city charters that support environmental and social goals, or sustainability, generally. See those of Toronto and Surrey. But ideas about ecosystem services are newer and are not explicitly mentioned in many. North Vancouver is discussing changes to future plans. See the small changes the International Finance Corporation used to add ecosystem services within their required environmental and social goals.
Are there ways we can more explicitly include ecosystem services in our municipal decision making?	Ideas throughout this document show how to identify, value and connect ecosystem services to policy and decision makers. However the specific tools of structured decision making might give you a different kind of approach to use.

ISSUE OR TOPIC	POSSIBLE FOLLOW UP
How can we get started using market based instruments?	The Australian government has reviewed their experience with many market based instruments and provides suggestions for others. Stavins describes important ideas and cautions about MBIs.
The idea of paying local farms to protect water sources or wildlife habitat seems useful. What legal arrangements do we have to make?	There are many specific details you can explore under the topic of Payments for Ecosystem Services, which document the merits and the challenges of the idea. There are specific recommendations, including legal topics, related to agriculture that are worth investigating.

Case Studies

Case Studies

Introduction

In this section we provide a selection of case studies. These case studies present information on a range of land-use planning, restoration, management and design projects with a central focus on ecosystem services.

In developing this document our goals included being able to:

- show how ecosystem services might be utilized at the site scale
- guide professionals so that they could incorporate ecosystem services into their work
- help people understand the tradeoffs that go with developing land
- show the relationship between good environmental practices and ecosystems services

We hope the case studies will show readers how they might achieve similar goals in their particular circumstances.

There are three types of case studies in this section:

- Collaborative Case studies were developed with our project partners and relate to specific ecosystems in our home region of southwestern British Columbia, Canada
- Ecosystem Service Case studies are original case studies developed using ecosystem services practices
- Ecosystem Service Case Study Briefs are our re-assessment of existing case studies using the ecosystem services perspective.

In each case study we used a matrix of ecosystem services that we derived from the TEEB typology and our own literature review. We developed this matrix as the primary tool to bring the discussion of ecosystem services to the site level. Whereas the TEEB matrix cites climate regulation and modification of extreme events as ecosystem services relating to weather, at the site scale, ecosystem services relating to weather might be compensation for summer drought or microclimatic modification. The greatest differences between the TEEB classification and our own are within the categories of cultural services. There is a large body of research that documents the physical and mental health benefits that accrue to urban dwellers through frequent contact with urban green spaces (see Kuo, 2010). Other research documents such benefits as increased recreation and property values (see Konijnendijk et al., 2013). We used multiple research publications to support the cultural services of natural and designed landscapes in our case studies (see Table 13 Case Studies: Supporting Research).

5.1 Collaborative Case Studies

In developing the case studies format, we had two local partners: The municipality of The Corporation of Delta (Delta) and The Fraser Valley Watershed Coalition (FVWC). Over the course of several months we met with environmental staff from Delta and members of the FVWC. The Municipality of Delta is home to Burns Bog - a very significant, rare and large domed peat bog. The bog is principally known for the rare species of plants and animals that inhabit it and for the carbon sequestration that is derived from its peat formation. The members of the FVWC were concerned with saving riparian areas. In a series of workshops with our partners and subsequent literature review, we were able to qualify a large range of ecosystems services derived from two regional ecosystems: Burns Bog and Riparian Corridors of the Fraser River Valley. The results of our interaction with our partners are presented in the Burns Bog and Riparian Areas of the Fraser River Valley case studies that follow.

In each case, we and our partners learned more about ecosystem services. Because ecosystem services are highly site-specific, fixed guidelines or checklists are not sufficient tools for assessing them or using them in design and management. There needs to be active engagement of creative and knowledgeable people. The Collaborative Case Studies show a local process that led to describing the ecosystem services of two valuable and local ecosystem types. It was a key learning experience for the authors that only face to face discussion with people who combined scientific and local knowledge was able to uncover the ecosystem services that flow from these two ecosystems.

5.1.1 The Biodiversity and Ecosystem Services of Burns Bog: A Case Study

<table>
<tr><td colspan="2">Project type: Peat Bog Conservation</td></tr>
<tr><td colspan="2">The Biodiversity and Ecosystem Services of Burns Bog</td></tr>
<tr><td></td><td>Project Description
Burns Bog is a large raised bog ecosystem in the municipality of Delta B.C., one of the Metro Vancouver municipalities. It is the southern-most example of sphagnum-dominated domed bogs in Canada and is unique in chemistry, form, flora and large size.

From the early 1900's until the 1980's peat extraction, drainage, filling, conversion to agriculture, and adjacent urban and industrial uses damaged the bog, reducing its size from 48 km^2 to approximately 30 km^2. The result is a patchwork of regenerating plant communities of various ages.</td></tr>
</table>

Figure 1. Aerial view of Burns Bog showing the effects of past peat mining (Corporation of Delta available at www.burnsbog.ca

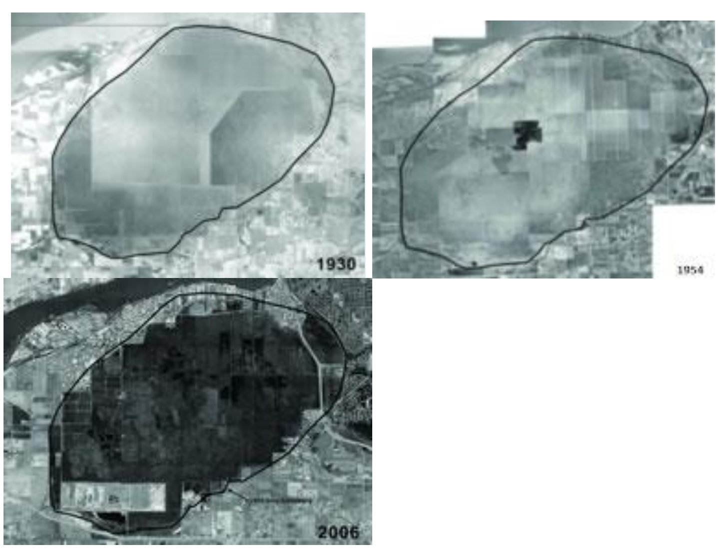

Figure 2, 1930, 1954 and 2006 air photos of Burns Bog. (Image from The Corporation of Delta. Available at: http://www.burnsbog.ca.

	In 2004 The Corporation of Delta, together with the Regional, Provincial and Federal governments purchased the majority of the bog, protecting it as an Ecological Conservancy Area. The total area of Burns Bog is 2,821 hectares (6,971 acres). Approximately 87% of Burns Bog or 2,477 hectares is currently owned and protected by government. The bog is being restored by blocking drainage ditches with the intention of raising the water table to re-establish *Sphagnum* moss cover and to re-start the peat-forming process in degraded sectors (Corporation of Delta). **References** Corporation of Delta. *The Lasting Legacy of Burns Bog.* Available at http://www.burnsbog.ca/index.html Hebda, R.J., K. Gustavson, K. Golinski and A.M. Calder,2000. *Burns Bog ecosystem review synthesis report for Burns Bog, Fraser river Delta, south-western British Columbia, Canada.* Environmental Assessment Office, Victoria, BC. Heijmans, M.M., Mauquoy, D. Geel, B., and Berendse, F. 2008 Long-term effects of climate change on vegetation and carbon dynamics in peat bogs. *Journal of Vegetation Science,* 19 (3) 307-320.) Manzo, L.C. and Perkins, D.D. 2006. Finding common grounds: The importance of place attachment to community participation and planning. *The Journal of Planning Literature,* 20 (4), 335-350. Metro Vancouver 2007. *Burns Bog Ecological Conservation Area Management Plan*. Available at http://www.metrovancouver.org/about/publications/Publications/BurnsBogManagementPlan.pdf Mitsch, W.J. and J.G. Gosselink, 1993. Wetlands. 2nd Edition. Van Nostrand Reinhold, New York. Proshansky, Harold M., Abbe Fabian, and Robert Kaminoff. 1983. Place-identity: Physical world socialization of the self. *Journal of Environmental Psychology* 3(1): 57-83. Strack, M. (Ed.) 2008. Peatlands and Climate Change IPS, International Peat Society. TEEB – The Economics of Ecosystems and Biodiversity (2011). *TEEB Manual for cities: Ecosystem services in urban management*. www.teebweb.org Vitt, D. H., Halsey, L.A., Bauer, I.E. and Campbell, C. 2000. Spatial and temporal trends in carbon storage of peatlands of continental western Canada through the Holocene. Canadian Journal of Earth Sciences, 37(5) 683-693. **Location** Burns Bog is located in Delta between the South arm of the Fraser River and Boundary Bay.

Figure 3. Location of Burns Bog

The Problem

Corporation of Delta environmental staff wanted a document that delineated the many ecosystem services of the bog. The staff believed that identifying the important ecological functions or processes that need to be retained to maintain these services would be useful for discussion and coordination within the municipality.

The Solution

The authors developed a draft of the matrix below from the ecosystem services literature and created a first draft that identified the ecosystem services of peat bogs. This was followed by a series of workshops with environmental staff in the Municipality of Delta. Staff provided us with local knowledge and connected us to relevant studies of the bog so that we were able to refine the document and make it specific to Burns Bog. (See acknowledgements.)

Benefits

The process revealed a wide range of ecosystem services that were delivered by Burns Bog to local residents, agricultural producers, First Nations, people in the region and beyond. It also revealed that the key driver to most of these ecosystem services was the formation of peat and thus that the continuance of the restoration process that focuses on hydrology, sphagnum growth and peat formation is of paramount importance. The process we used to develop this case study is itself an example of how the concepts of ecosystem services may be applied at the site scale.

	Biodiversity and Ecosystem Services Derived from Burns Bog
Biodiversity	
Maintain or increase biodiversity (includes genetic diversity)	**Ecosystem Service derived from Burns Bog:** Supports a high genetic diversity. Bogs are acidic because the dominant S*phagnum* moss, releases H+ ions (acidity), and the peat releases organic acids (Mitsch and Gosselink 1993). In response to this acidity, bogs have specialized and unique flora that has evolved in their nutrient-poor and acidic conditions. An example of this unique flora is the carnivorous sundew, which obtains nutrients from the flies it traps. It is not possible to determine the historic levels of diversity. Given the number of red and blue - listed species in Burns Bog, it is likely that rare bog-specific species have declined. The genetic diversity of Burns Bog is rare and should be preserved. **Relative increase or proportion within this case study:** Medium Although impacted by peat mining in the past and affected by surrounding activity, the core area is now protected and is recovering **Importance for Protection or Enhancement:** High The bog contains a high level of biodiversity that is unique in the region. Several of the bog's forested plant communities are considered rare within the Chilliwack Forest District (i.e. within the Metro Vancouver region forested lands) because much of the land in the district has been cleared. The Pine-*Sphagnum* community, although not a typical forest type, is also considered rare. At least 257 plant species live in the bog. Several plant species, including cloudberry, bog rosemary, crowberry and velvet-leaf blueberry, occur at the limits of their geographic range in Burns Bog and are recognized as genetically and ecologically important. The bog supports at least 12 species of *Sphagnum*, which constitutes 86% of the regional, and 31% of the provincial *Sphagnum* flora. About 100 species of fungi have been found in the bog. One species of fungi has only been collected once before in British Columbia and another is uncommon. Rare insects occur in the distinct wet habitats of the bog (Hebda et al. 2000). **Who Benefits:** The Public "Biodiversity of ecosystems and within ecosystems is integral to their functioning and the provision of ecosystem services." (TEEB Manual for Cities p.1)
Habitat for Native species	**Ecosystem Service derived from Burns Bog:** Provides habitat for a large number of rare and representative species. Rare species include Sandhill Crane, Southern Red-backed Vole and Pacific Water Shrew. Representative species include Black Bear and Black-tailed Deer, teal and Canada Goose.

	Relative increase or proportion within this case study: High **Importance for Protection or Enhancement:** High Burns Bog provides habitat for 175 species of birds, of which 2 species (Peregrine Falcon, anatum subspecies *Falco peregrinus anatum* and Purple Martin *Progne subis)* are red listed (threatened) and 12 are blue listed (vulnerable) species. The bog supports a large part of the Lower Mainland population of the blue-listed Greater Sandhill Crane (*Grus Canadensis)*. Many Lower Mainland cranes gather in the bog before flying south. The large breeding and refuge habitat, and its association with agricultural fields, likely attract Greater Sandhill Cranes to the bog. The bog is home to numerous mammals including: the provincially red-listed Pacific Water Shrew (*Sorex bendirii*) and Southern Red-backed Vole (*Clethrionomys gapperi occidentalis*) and provincially blue-listed (vulnerable) Trowbridge's Shrew (*Sorex trowbridgii*) (Hebda, et al. 2000).
Provisioning Services	
Food	**Ecosystem Service derived from Burns Bog:** Native Berries e.g. Black berries, salmon berries blueberries, cloudberries; Game - Deer Waterfowl duck as geese **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** Berries, Low With the exception of cloudberries, these wild foods are abundant in the region outside of Burns Bog. Game for Hunters, High: Deer are not hunted in Delta. The water fowl that use the bog as habitat will be hunted elsewhere and are a significant portion of overwintering waterfowl in the region. The use of the bog by waterfowl as a refuge during high wind and tide events is particularly important. Twenty-nine species of waterbirds occur in the study area with mallard ducks and geese being most abundant. At least 16 species of waterbirds breed in the bog, the major species being Canada Goose, Mallard and Green-winged Teal. The estimated number of ducks using the bog daily varies from as little as 700 to as many 10,000. It is highest in the winter. This number represents a significant proportion of the wintering Fraser River delta population. Much more work is needed to determine population numbers and the importance of the bog to breeding of waterbirds (Hebda, et al., 2000). **Who Benefits:** Public, Local Residents (on unprotected lands), Hunters, Bird watchers
Raw Materials	**Ecosystem Service derived from Burns Bog:** Eagles feathers-(ceremonial first

	Nations use) **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** Low The habitat provided in the bog is not irreplaceable and other prime eagle habitat occurs locally. **Who Benefits:** First Nations
Fresh Water	**Ecosystem Service derived from Burns Bog:** Irrigation water **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** High In 1930, only 43 km of ditches drained 17% of the bog area, whereas today, 110-115 km of ditches drain about 39% of the remaining bog. Drainage ditches are a serious threat to the bog's viability. The average position of the water table is lower than it was in the 1930s, prior to major drainage and disturbance. The overall water storage has declined by about 84 million cubic metres or about 60%. The critical dynamic storage in the acrotelm has been altered by the increase of rapid discharge by ditches and the loss of natural shallow pools. Only 29% of the bog's original acrotelm or dynamic storage zone remains intact. Activities that rewet the bog and promote *Sphagnum* growth and peat formation are critical to preserving this function especially in the face of climate change. (The acrotelm is the less dense and less saturated surface layer of peat in a peat bog). **Who Benefits:** Agricultural Producers
Medicinal Resources	**Ecosystem Service derived from Burns Bog:** Labrador tea and other –First Nations ethno -botanical plants **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** Medium These plants are not exclusive to Burns Bog. However their protection within the bog supports the precautionary principle as they will become rarer as the area develops and climate change impacts are felt. Bog habitat is necessary for some plants and bogs are uncommon and unprotected in BC's Lower Mainland. **Who Benefits:** First Nations- as they have the right to pick on Provincial Lands
Regulating Services	
Carbon sequestration and storage	**Ecosystem Service derived from Burns Bog:** This may be the highest value ecosystem service provided by Burns Bog. **Relative increase or proportion within this case study:** High

	Importance for Protection or Enhancement: High Sequesters carbon. Promotion of sphagnum increases sequestration. "Although peatlands cover only 2-3% of the global land surface, peat accumulation over thousands of years … is at least 20% of the global carbon store in terrestrial ecosystems" (Heijmans, et al. 2008). If the bog were to dry further, large amounts of stored carbon would be released. Average long-term C accumulation rates for northern bogs are 20-30 g m-2 yr-1 (Strack 2008). Average C accumulation rate for continental western Canada is 19.4 g m-2 yr-1 (this includes both bogs and fens) (Vitt et al. 2000). Open *Sphagnum* bogs (without trees) accumulate more carbon (up to 70 g m-2 yr-1) compared to fens or treed bogs (Strack 2008). Average C content of dried peat samples from continental western Canada peatlands was 48 ±5%. (Vitt et al., 2000). The value is the same (50%) as in Finland (Strack 2008). **Who Benefits:** The global population
Moderation of extreme weather events	**Ecosystem Service derived from Burns Bog:** Moderates temperature- (lower summer temperatures in the surrounding area than if the bog had been developed). **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** Medium This is not a high impact ecological service and it will continue to be provided as long and the bog remains vegetated. **Who Benefits:** Local residents
Pollution Mitigation (Air)	**Ecosystem Service derived from Burns Bog:** Releases oxygen and picks up gaseous and particulate pollutants (Emits methane- not a service). **Relative increase or proportion within this case study:** Medium These same services are provided by all plants. **Importance for Protection or Enhancement:** Low These same services are provided by all plants. **Who Benefits:** Local Residents, public
Maintain or increase Pollination	**Ecosystem Service derived from Burns Bog:** Provides habitat for wild pollinators such as bees and wasps. **Relative increase or proportion within this case study:** Medium Loss of this ecosystem type has been moderate. **Importance for Protection or Enhancement:** Medium

	With the decline of domestic honey bees, wild pollinators are increasingly important to producers. The pollinator habitat provided by Burns Bog supports adjacent agriculture. **Who Benefits:** Agricultural Producers and the Public benefit through lower costs and better food security.
Reduced Flooding	**Ecosystem Service derived from Burns Bog:** Absorbs extreme precipitation events at some times of the year, reducing local flooding and the need for stormwater infrastructure. Reduces flooding and volume of water that needs to be discharged through storm drains. **Relative increase or proportion within this case study:** Medium Prior to the bog being drained this effect would have been greater. **Importance for Protection or Enhancement:** Medium It would be difficult to increase this ecosystem service in the short term. Under current protection regime this function should be maintained at current or increasing levels. **Who Benefits:** Local Agricultural Producers and adjacent property owners
Disease and pest Regulation	**Ecosystem Service derived from Burns Bog:** Beneficial insects The Bog provides habitat for insects that are beneficial to farming other than pollinators. These include predator insects such as dragon flies, wasps and the Bog spider. **Relative increase or proportion within this case study:** Medium Loss of this ecosystem type has been moderate. **Importance for Protection or Enhancement:** Medium Burns Bog provides a nearby source of these insects. **Who Benefits:** Agricultural Producers and the Public benefit through lower costs and better food security.
Seasonal drought mitigation	**Ecosystem Service derived from Burns Bog:** Mitigates seasonal drought by infiltrating, storing and slowly releasing rainwater so that runoff to surrounding areas is much slower than if the bog had been developed. **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** Medium As long as the bog is protected and vegetated this service will be provided. If portions of the bog were to dry and the peat began to decompose this service would also decline. **Who Benefits:** Agricultural Producers, local residents
Supporting Services	
Preservation and generation of soils	**Ecosystem Service derived from Burns Bog:** Continuous peat soil development **Relative increase or proportion within this case study:** High Loss of peat soils has been high due to peat mining and surrounding

	agriculture. **Importance for Protection or Enhancement:** High The peat soils provide the key ecosystem services of the bog that have been reduced by human actions. Their regeneration should be a high priority. **Who Benefits:** The general public benefits though the sequestration of carbon in the peat soils generated.
Water Cycling	**Ecosystem Service derived from Burns Bog:** Absorption, filtration, storage and slowed release of rain water. Provides water for surrounding ecosystems and farms. **Relative increase or proportion within this case study:** High The overall water storage of Burns Bog has declined by about 84 million cubic metres or about 60%. **Importance for Protection or Enhancement:** High This is valuable function in terms of the farming occurs along the margins of the protected areas of the bog (e.g. cranberry farms on the western edge of the bog). It also helps to preserve the natural areas of the bog that are not protected. **Who Benefits:** Local residents, and the Public
Cultural Services	
Sense of Identity	**Ecosystem Service derived from Burns Bog:** People receive some of their sense of identity from their connection to the setting in which they live. **Relative increase or proportion within this case study:** Medium The bog has endured moderate degradation. Loss of the bog would change the character and perception of Delta. **Importance for Protection or Enhancement:** High Physical appearance of the landscape is a non- renewable natural resource that is closely linked to people's sense of their community local and personal identity. This concept is based on the understanding that a person's self-image and values are often influenced by their relationship with the physical environment they inhabit (Proshansky et al., 1983; Manzo and Perkins, 2006). **Who Benefits:** Local and Regional residents
Mental and physical well-being	**Ecosystem Service derived from Burns Bog:** Frequent contact with natural environments and views has been shown to support mental well-being. **Relative increase or proportion within this case study:** Medium **Importance for Protection or Enhancement:** Medium Although public access to the bog is confined to the Delta Nature Reserve, it offers a rare natural setting for contact with nature that is easily accessible to Delta and other regional residents. This should be preserved and/or expanded.

	Who Benefits: Local and regional residents
Recreation	**Ecosystem Service derived from Burns Bog:** Ecosystem provides multiple opportunities for recreation within the Delta Nature Reserve e.g. – Hiking – Walking – Photography – School tours – Birding. Potential future recreation in Burns Bog includes: – Walking – Photography – School tours – Birding. **Relative increase or proportion within this case study:** Medium Other similar recreational opportunities exist in Delta. **Importance for Protection or Enhancement:** High Similar recreational opportunities exist around Boundary Bay but access to a portion of Burns Bog provides a regionally rare type of recreational opportunity. **Who Benefits:** Local and Regional residents and tourists
Religious / Spiritual	**Ecosystem Service derived from Burns Bog:** First Nations Use **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** Medium **Who Benefits:** First Nations, Local people
Tourism	**Ecosystem Service derived from Burns Bog:** Both ecological and cultural tourism are potential future uses. **Relative increase or proportion within this case study:** Medium Moderate degradation has occurred. **Importance for Protection or Enhancement:** High If developed, the bog would provide unique ecotourism opportunities. **Who Benefits:** Public, Corporation of Delta, Tourists

5.1.2 The Biodiversity and Ecosystem Services of Riparian Corridors in the Fraser River Valley: A Case Study

Project type: Riparian Corridors

Biodiversity and Ecosystems Services of Riparian Corridors in The Fraser River Valley of British Columbia

Project Description

The riparian zone is the wetter zone adjacent to a flowing river or stream. Its high soil moisture level can make the land unsuitable for farming. For this reason, within the agricultural landscape, the riparian zone may appear as a corridor of woody vegetation on either side of a stream or river surrounded by actively farmed meadows and fields. Riparian corridors are characterized by changing water flows, a linear nature that connects other ecosystems and the ability to influence both stream flow and nonpoint pollution of surface waters (Lowrance et al. 1985.) They are also notable in that they support a high biodiversity (Naiman et al. 1993).

Recognizing that riparian corridors support important wildlife and that their condition was not always optimal, the authors partnered with the Fraser Valley Watershed Coalition (FVWC) to investigate the ecosystem services of riparian corridors in the Fraser River Valley. The FVWC is a non-profit, non-governmental coalition of individuals and organizations from the Fraser River Valley who work closely with municipalities, NGOs, consultants and conservation professionals to support local action and encourage communities to take a greater role in watershed management.

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Location

The Fraser River Valley is a fertile, agricultural valley in the eastern portion of the Metropolitan Vancouver Region and stretching south to the American border. The Valley remains primarily agricultural, due in large measure to the passing of the Agricultural Land Reserve Act (ALR) in 1973. The reserve effectively prohibits converting farmland in the Province of British Columbia to other uses (Berka et al., 2001).

Figure 1: Fraser Valley Farmland adjacent to the Fraser River with a riparian corridor in the foreground.

Figure 2: Overview of farms in the Fraser Valley

Healthy riparian corridor in Southwestern British Columbia (Photo courtesy of Al Grass)

The Problem

Throughout the agricultural zone of the Fraser Valley there is considerable concern regarding the environmental effects of farming. These concerns include eutrophication of streams, nitrate contamination of groundwater and the loss of biodiversity, especially salmonid populations, due to farming activity (Berka et al., 2001; Roseneau and Angelo, 2005).

The Solution

Directors and staff of the FVWC met the authors for 4 workshops in the period from December 2012 to

April 2013, and worked with the BC Ministry of Agriculture to provide an Ecosystem Services workshop with the Agricultural Industry Groups.

During the internal workshops, we prioritized agricultural producers as our target community, with the intent of finding common goals around which we could begin productive dialogue towards watershed health. Together, we identified important ecosystem goods and services provided by and used by agricultural producers in the Fraser Valley of BC, and the FVWC provided feedback on the processes and methods that worked well for them. Early in our discussion it became clear that a focus on improving riparian ecosystems could provide the widest range of ecosystems good and services. The outputs of the internal workshops were reviewed by the authors and literature review was conducted to support the anecdotal information discussed during the workshops. This led to the creation of this case study and supported the content of the external workshop.

The external workshop and dialogue, Ecosystem Services of Agricultural Lands, attracted agricultural producers, representatives from producer organizations, and staff from Municipal, Provincial and Federal ministries. The FVWC has since participated in a workshop on Agriculture and Environment hosted by the Agriculture Environment Initiative and ArdCorp (a producer's organization). At these workshops, Ecosystem Goods and Services are being recognized as a common goal, and a potential focal point for incentives to agricultural producers. The process has identified a common need for industry-specific case studies detailing and valuing the ecosystem services provided by and for agriculture which we hope will be the focus of future research.

Benefits

The participants learned a number of things in the process of conducting the workshop and developing the case study:

- The best way to preserve wildlife and fish values may be by focusing on a wider range of ecosystem goods and services.
- Many agricultural producers view themselves as stewards of the land and are interested in learning more about their provision and use of local ecosystem services.
- Many producers would do more to provide ecosystems good and services if some method of payment for ecosystem services were available to them. Presently this is not the case in this region but provision for this to happen exists elsewhere in B.C.
- Generally speaking the extent of the ecological goods and services provided by agricultural lands and by riparian corridors in agricultural landscapes was not known beforehand, by any of the participants. This process helped to reveal and support the knowledge of ecosystem services and also the land management practices that would maintain of enhance those services.
- Further research that would demonstrate the ecosystem services of particular land management strategies are needed.

Biodiversity and Ecosystem Services Derived from Riparian Corridors In the Fraser Valley	
Biodiversity	
Maintain or increase biodiversity (includes genetic diversity)	**Ecosystem Service derived from Riparian Corridors in the Fraser River Valley:** Maintenance of wildlife and fish. Riparian corridors are used by approximately 70 percent of vertebrates during their life cycle (Ewing and Hodder 1998; Olson et al. 2007) and are a significant landscape component in supporting the maintenance of regional biodiversity (Naiman et al. 1993). Depending on the composition of the buffer and the site characteristics, buffers can remove up to 97% of sediment from runoff (Vought et al., 1994) Maintaining riparian vegetation on headwaters and small tributaries is critical for maintaining downstream water quality (Parkyn et al., 2003). Thus, riparian corridors play a significant role maintaining water quality for fish, especially salmonid populations. **Relative increase or proportion within this case study:** Medium Some riparian corridors in the Fraser Valley are intact and diverse, others are totally absent. Thus, we have judged the overall level of service provided by these corridors to be moderate. **Importance for Protection or Enhancement:** High The Ecosystem services delivered by intact riparian corridors are very diverse and are highly valued in society (e.g. food production, reduction in flooding, local drinking water, irrigation water and a significant sport and commercial fishery. The Fraser River produces some of the world's largest salmon runs and over 50% of the salmon in British Columbia. The land base of the Fraser Valley that drains into the Fraser River is less than 5% of the entire Fraser Basin but supports approximately 80% of the Fraser River's total production of chinook and chum salmon, 65% of its coho salmon, 80% of its pink salmon and significant stocks of sockeye salmon. About 150 of the 300 significant salmon bearing streams in the Fraser River watershed flow through the Lower Fraser Valley (The Fraser River Action Plan, 1998; Roseneau and Angelo, 2005). We know that temperature is critical to fish migration and survival (Brett 1971, p. 99; Richter and Kolmes. 2005). A recent study shows that shading of streams by riparian vegetation reduces maximum temperatures supporting fish, amphibians and invertebrates (Bowler et al. 2012). **Who Benefits:** Public, sport and commercial fishers
Habitat for Native species	**Ecosystem Service derived from Riparian Corridors**

	in the Fraser River Valley: Provides habitat for a large number of rare and representative species. Red-listed species include, Pacific water shrew, and Oregon spotted frog. Representative species include Black bear and beaver. More individual of both birds and mammals are found in riparian habitats than in adjacent ones (Naiman and Decamps, 1977). **Relative increase or proportion within this case study:** Medium Some corridors are intact and diverse while others are totally absent. Overall the condition is moderate. **Importance for Protection or Enhancement:** High Riparian corridors connect wildlife habitat and increase safe dispersal of wildlife between natural habitat patches. The degree of effectiveness depends on buffer length and location (Henry et al. 1999; Schuller et al 2000; Grillmayer 2002). **Who Benefits:** Local conservation groups and citizens concerned with conservation and sport and commercial fishers.
Provisioning Services	
Food	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Native Berries- Salmonberry, Thimbleberry; non-native berries – blackberry. **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** Low These wild fruits are not exclusive to riparian corridors and are abundant in the region. **Who Benefits:** Foragers (Cottage Market), First Nations, the Public
Raw Materials	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Small materials for crafts **Relative increase or proportion within this case study:** Low **Importance for Protection or Enhancement:** Low The same materials are abundant elsewhere in the region **Who Benefits:** Local Crafts people
Fresh Water	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Well water, Irrigation water, Drinking water for livestock. **Relative increase or proportion within this case study:** Medium Loss of this ecosystem type has been moderate. **Importance for Protection or Enhancement:** High Reduction in quality of water either seasonally or throughout the year would have far reaching and irreparable negative impacts.

	Streams in riparian corridors contribute significantly to groundwater recharge (Woessner, 2000; Bharati, 2002). Riparian areas protect stream water quality (Lee et al., 2003) and hence also groundwater quality: this is an important service that should be protected. **Who Benefits:** Residents, Producers, and the Public (who benefit from food production and would lose the recreational fishery if water quality or quantity were reduced).
Medicinal Resources	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** First Nations' ethno -botanical plants **Relative increase or proportion within this case study:** Low **Importance for Protection or Enhancement:** Low These plants are abundant in the region. **Who Benefits:** Fist Nations
Ornamental Plants	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Nursery Plants Wild Harvest of seeds and plants Cedar Boughs Willow and Red-osier dogwood live wood cuttings **Relative increase or proportion within this case study:** Medium Some corridors are intact and diverse while others are totally absent. Overall the condition is moderate. **Importance for Protection or Enhancement:** Medium Most plants are abundant in the region, but some are abundant only in riparian areas. **Who Benefits:** Nursery Industry, Public, Foragers, Restoration industry
Regulating Services	
Carbon sequestration and storage	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** **Carbon sequestration and storage** **Relative increase or proportion within this case study:** M Loss of this ecosystem type has been moderate. Since all plants sequester carbon, this service is not unique to riparian corridors (US Department of Energy Information Administration, 1998). **Importance for Protection or Enhancement:** Medium Riparian corridors sequester carbon (Hernandez et al 2008). Since young plants store more carbon, enhancement of riparian vegetation would increase carbon sequestration. **Who Benefits:** Public
Moderation of extreme weather events	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Reduced wind damage Riparian areas dissipate wind energy that can damage agricultural land and are sometimes used as windbreaks (Lowrance et al., 1985).

	Relative increase or proportion within this case study: Medium- High In some places the complete lack of riparian vegetative cover means that the level of degradation is high. **Importance for Protection or Enhancement:** Medium These are important services but are not contained wholly in riparian areas. **Who Benefits:** Public, Producers, Local residents
Pollution Mitigation (Air)	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Adsorption of particulate and gaseous pollutants, Release of oxygen, Moderation of local wind speeds **Relative increase or proportion within this case study:** Medium (as above) **Importance for Protection or Enhancement:** Low These same services are provided by all plants (Nowak et al. 2006; Dobbs et al. 2011). **Who Benefits:** Public, Local residents, Agricultural Producers
Pollution Mitigation (Water)	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Absorption, filtration, storage and distribution of water. Provides potable well water and reduces mosquitoes. **Relative increase or proportion within this case study:** High This is a very high value service the loss of which will be immediately felt. **Importance for Protection or Enhancement:** High Agricultural activities can pollute surface and ground waters. Intact riparian corridors are an important tool to reduce this source of pollution and protect drinking water and fish populations. Vegetated buffers, like riparian corridors, can remove up to 100% of nitrogen and phosphorus and this effect is increased in wider buffers, up to 20 metres wide (Vought et al., 1994; Lovel and Sullivan, 2006). **Who Benefits:** Local residents, the Public, Fishers
Maintain or increase pollination	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Provides habitat for wild pollinators such as bees and wasps. **Relative increase or proportion within this case study:** Medium Loss of this ecosystem type has been moderate. **Importance for Protection or Enhancement:** High With the decline of domestic honey bees, wild pollinators are increasingly important to producers. On many farms the riparian vegetation may be their only habitat. Pollination services have been found to increase in proximity to natural habitat including riparian areas (Greenleaf and Kremen, 2006).

	Who Benefits: Producers benefit though higher yields and lower costs and the public benefits through lower costs and better food security.
Reduced Flooding	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Reduced flooding through reduction in Reed Canary grass. **Relative increase or proportion within this case study:** Low Management of Reed Canary grass would relieve local flooding of farmlands but is unlikely to affect larger scale flooding in the Fraser Valley. **Importance for Protection or Enhancement:** Medium Several studies have found that increasing shade reduces the above ground biomass of Reed Canary grass (Cooke, 1997; Forman, 1998; Kim et al. 2006). Since this plant colonizes and chokes ditches and drainage channels, shade control by riparian plants such as willows would improve drainage and reduced local flooding. The level of this service could easily be increased by planting willow live-wood cuttings adjacent to drainage channels and streams. **Who Benefits:** Producers and local residents.
Disease and pest regulation	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Provides habitat for insects that are beneficial to farming other than pollinators. These include predator insects such as dragon flies and wasps. **Relative increase or proportion within this case study:** Medium Loss of this ecosystem type has been moderate **Importance for Protection or Enhancement:** Medium Riparian corridors are nearby sources of these insects. Pest control by predator species such as spiders, wasps, birds, and bats is best facilitated at the farm scale by vegetation around drainages and ponds and at the watershed scale by vegetation cover in watershed (Zhang et al. 2007; Ober and Hayes, 2008). Removal of riparian buffers increases mosquito breeding habitat because sedimentation that results blocks off watercourses creating mosquito habitat (Rein, 1999). **Who Benefits:** Producers benefit though higher yields and lower costs and the public benefits through lower costs and better food security and fewer mosquitoes.
Supporting Services	
Primary Productivity	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** High primary productivity id related to nutrient cycling, and oxygen production. **Relative increase or proportion within this case study:** Low All plants create primary productivity as a product of growth. Since riparian corridors are a small percentage of the total vegetated landscape area the

	effect would be relatively small. **Importance for Protection or Enhancement:** Low Many riparian wetlands, including such managed wetlands as rice paddies, have higher rates of primary production (growth by vegetation) than adjacent upland systems (Lowrance et al. 1985 p. 87). **Who Benefits:** The Public
Preservation and generation of soils	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Reduced soil erosion, continuous soil development **Relative increase or proportion within this case study:** Medium Loss of this ecosystem type has been moderate. **Importance for Protection or Enhancement:** High Loss of agricultural soils and or sedimentation of streams and rivers represent a significant loss of ecosystem services. Riparian buffers hold the soil, preventing erosion of agricultural lands. The riparian tree roots improve stability of river banks even under worst-case hydrological conditions (Abernathy and Rutherford, 2000). Reduction in leaf –litter that accrues under riparian vegetation also leads to increased soil erosion (France, 1997). **Who Benefits:** Producers benefit though preservation of agricultural soils and the public and fishers benefit from higher water quality in streams.
Nutrient Cycling	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** By capturing nitrogen from agricultural activities that is dissolved in water moving through the soil, riparian stream buffers prevent stream and ground water pollution. **Relative increase or proportion within this case study:** High This is a high value service since it protects both fish populations and human health. **Importance for Protection or Enhancement:** High Riparian areas have high rates of denitrification and storage that result in enriched nitrogen zones as sinks for upland-derived nitrate (Hanson et al., 1994). **Who Benefits:** The Public, Fishers
Cultural Services	
Sense of identity	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** People receive some of their sense of identity from their connection to the setting in which they live. **Relative increase or proportion within this case study:** Low Loss of riparian would not eliminate strongly felt natural character of the locality in most areas of the Fraser Valley.

	Importance for Protection or Enhancement: Medium The physical appearance of the landscape is a non- renewable natural resource that is closely linked to people's sense of their community local and personal identity (Manzo, and Perkins, 2006; Proshansky et al. 1983). **Who Benefits:** Local and Regional residents
Mental and physical well-being	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Frequent contact with natural environments and views has been shown to support mental well-being. **Relative increase or proportion within this case study:** Low (as above) **Importance for Protection or Enhancement:** Medium Loss of riparian habitat would not eliminate strongly felt natural character of the locality in most areas of the Fraser Valley. A strong body of psychological research confirms that direct contact with nature leads to increased mental and physical well-being and psychological development. "land conservation can now be viewed as a public health strategy" (Frumkin and Louv, 2007 p.2; Kuo, 2010). **Who Benefits:** Local and regional residents
Recreation	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Ecosystem provides multiple opportunities for recreation i.e. – Hiking – Walking – Photography – School tours – Birding – Fishing **Relative increase or proportion within this case study:** Medium Most recreation opportunities are not tied solely to riparian corridors. Howeve,r its contribution to the sport fishery is irreplaceable. **Importance for Protection or Enhancement:** Medium-High Given that salmonid populations are declining in the Fraser River, the positive contribution of intact riparian corridors should be a high priority for protection. **Who Benefits:** Local and regional residents and tourists
Aesthetic Appreciation/ Spiritual / Religious	**Ecosystem Service derived from Riparian Corridors in the Fraser Valley:** Aesthetic appreciation of the beauty of the agricultural landscape and spiritual experience of nature. **Relative increase or proportion within this case study:** Medium-High The degree of this service varies between individuals. Nevertheless, it is a significant cultural service of agricultural landscapes. **Importance for Protection or Enhancement:** 82% of the general population has experienced the beauty of nature in a deeply moving way, while 49%

	felt this had a lasting influence (Wuthnow 1978). Forty-five percent of general population said that the beauty of nature had led to an intense spiritual experience (Greeley, 1974). **Who Benefits:** The Public

5.2 Ecosystem Service Case Studies.

In this section we present a number of original case studies that we developed using ecosystem services as the metric. It was our intention that the case studies would show a continuum of greenness from agricultural land to urban brownfield sites, of size from regional scale to site scale and of setting from rural to urban. As in the preceding case studies, our evaluations were done using a matrix of ecosystem services. Readers will notice in sections 5.2 and 5.3 that many of the possible ecosystem services are not "filled in" in the matrix. This was done intentionally to show which ecosystem services we were not able to demonstrate (although they might exist) and also to suggest, in some cases, that more might have been done if other ecosystem services had been considered.

5.2.1 The Ontario Greenbelt

Project type: Regional Greenbelt (Regional Planning)

The Ontario Greenbelt

Project Description

The Ontario Greenbelt is currently the world's largest greenbelt, at 1.8 million acres (~730,000 hectares). It surrounds the Greater Toronto and Hamilton Metropolitan Area in southern Ontario Canada. The Greenbelt was created by Provincial legislation in 2004 to act as an urban containment boundary to protect farmland and natural resources from urban sprawl. A study by the David Suzuki Foundation has also calculated the considerable ecosystem services contributed by the Greenbelt (Wilson 2008).

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See also

Friends of the Greenbelt Foundation: www.greenbelt.ca/home

Ontario Greenbelt Alliance: www.greenbeltalliance.ca

Location

The Ontario Greenbelt stretches from Niagara on the Lake on the Southern shores of Lake Ontario around the western edge of the lake and North to Orangeville and then east past Rice Lake creating an urban containment boundary to the Greater Toronto and Hamilton Area (GTHA), an area also known as the Greater Golden Horseshoe.

Ontario Greenbelt area and location, 2005. Ontario Ministry of Municipal Affairs and Housing
Available at http://www.mah.gov.on.ca/Asset1293.aspx

The Problem

Introduction to greenbelts and urban containment

Greenbelts are networks of managed land adopted to meet a wide array of ecological and other goals (Fung and Conway 2007). Most have been set aside to preserve ecologically sensitive lands.

Urban containment boundaries (also known as urban growth boundaries) are tools for growth management that establish lines around metropolitan areas, outside which growth is discouraged or prohibited (Moavenzadeh and Markow 2007). Both tools are designed to protect open space on the outside if the greenbelt or containment boundary and to encourage increased density on the inside.

The greenbelt concept was first proposed by Ebenezer Howard in his "London Plan" to define limits to the urban area and protect the rural lands beyond. The greenbelt in this plan was envisioned as a wide strip of rural land (5+ miles wide), defining the limits of the urban area and protecting the rural lands, delineating city and country (Searns, 1995).

Examples of urban containment / greenbelt attempts (from Carter-Whitney 2007)

- London Greenbelt, U.K (est. 1938) – also known as the "green girdle," the main intent was to set aside recreation land for the use of city dwellers.
- Ottawa, Ontario Canada (1950s) – an area of over 20,000 ha surrounding Ottawa, established with the intention of curbing urban sprawl and protecting open space; it is largely considered a failure because of extensive "leap frog" development, and it has not encouraged more dense development in the communities adjacent to it.
- Province of British Columbia (BC) Canada, Agricultural Land Reserve (1973) – established to

protect agricultural land from urban sprawl across BC; has been relatively effective at directing new growth into non-agricultural areas, but there has been a net loss of prime agricultural land in southern BC in exchange for less productive agricultural land in northern BC.

- Portland Urban Growth Boundary (1979) – forms a boundary around ~100,000 hectares (400 square miles) to restrict urban sprawl and protect agricultural and natural features; reviewed and adjusted periodically but strong case must be made based on "need"
- Netherlands's Green Heart and Randstad region (1950s) – a large agricultural / natural area completely encircled by the major Dutch cities of Rotterdam, Den Haag, Leiden, Haarlem, Amsterdam and Utrecht.
- Iron Curtain Green Belt, Germany (formalized after 1989) – green space that came to be as a result of the inaccessible border strip that lay between East Germany and West Germany.

The Ontario Greenbelt Purpose

The general motivation for the Ontario Greenbelt was to counter the loss of quality of life due to suburban sprawl. More specifically, this loss of quality of life was deemed to result from a loss of natural areas, loss of prime agricultural land, and increasing traffic congestion. Its vision was to:

- Sustain and nurture the region's agricultural land base
- Protect/enhance natural heritage and water resource systems
- Conserve the region's significant natural resources for sustainable use (e.g. aggregate extraction)
- Continue to provide high-quality and compatible recreational and tourism opportunities

Its Goals were to protect, maintain and/or improve :

- Ontario's urban and rural areas and overall quality of life by promoting agricultural protection
- natural heritage, hydrologic and landform features and functions, including protection of habitat for flora and fauna and particularly species at risk
- natural and open space connections
- the quality and quantity of ground and surface water and the hydrological integrity of watersheds
- culture, recreation and tourism
- a strong rural economy
- a sustainable approach to infrastructure and natural resources

The Solution

The Ontario Greenbelt Task Force was formed in 2004 and charged with providing recommendations on how to identify lands for protection. The Greenbelt Task Force Discussion Paper stated some of the key motivations for an Ontario Greenbelt, including the following:

- Projections of population growth and land-use development patterns in the GTA: The population of the Greater Toronto Area (GTA) is projected to increase from 7.5 million people in 2001 to 11 million people in 2031. If current land-development rates / density patterns continue, development would consume an area of land nearly twice the size of Toronto (mostly prime agricultural land) and rush hour travel would be expected to take 45% longer.
- Problems associated with unplanned, rapid growth:

> *...when rapid growth is not accompanied by long-term planning on a regional scale, inefficient development patterns can result. These patterns include increased air and water pollution, loss of green space and agricultural land, inefficient infrastructure investment, and fewer transportation options and an over-reliance on the private automobile resulting in traffic congestion.* (Greenbelt Task Force 2004 p. 6)

The proponents believed that the Ontario Greenbelt would result in:

- Increased infrastructure efficiency - a greenbelt can be a key component of a growth management strategy that directs urban development into existing or designated urban areas, increasing the efficiency of the region's existing infrastructure and services.

- Maintenance of ecological services – preserving greenbelt lands (agricultural lands, natural resources, environmentally sensitive lands, areas of natural and scientific interest, habitats of vulnerable, threatened and endangered species, valley and stream corridors, and woodlands) can maintain or enhance biodiversity, health, resiliency and connectivity of the natural environment, improving the overall health of human communities.
- Improved economic vitality – a greenbelt can improve local and regional economic vitality by improving environmental quality, protecting agriculture, attracting potential employees, providing recreational opportunities, and encouraging reinvestment.

Sequence of events leading to Ontario Greenbelt:

- 1985: Niagara Escarpment Plan (area now part of Ontario Greenbelt)
- 2001: Oak Ridges Moraine Conservation Plan (area now part of Ontario Greenbelt)
- 2003: Ontario Liberal government was elected on a greenbelt platform
- 2003-2004: Moratorium on development in greenbelt study area Public consultation
- 2004 The Ontario Greenbelt Task Force recommendations
- Late 2004: Ontario's Greenbelt Act and Places to Grow Act passed. This action:
    - led to creation of Greenbelt Plan
    - designated urban growth centers to which development is directed
    - required municipalities to adjust their Official Plans to be consistent with the Greenbelt Plan and
    - established a Greenbelt Council (see below)

Greenbelt Legislation

The Greenbelt legislation recognized:

- the environmental and agricultural significance of the area
- the area's importance as a source of food, water, natural heritage systems, green space, recreation, and natural resources – all of which contribute to quality of life
- the importance of continued protection for Niagara Escarpment and the Oak Ridges Moraine

Monitoring and revisions to plan

The Ontario Greenbelt Council will undertake a 10 year review of the Greenbelt in 2015. The Greenbelt Plan will be evaluated based on monitoring results and public consultation. Modest settlement area expansions will be considered based on:

- Available municipal services
- Assimilative / production capacities of the local environment
- The existence of and guidance of existing watershed plans

Revisions will not allow the Greenbelt to expand into natural heritage system or specialty crop areas and the area of Greenbelt cannot be reduced.

Managing the Ontario Greenbelt

The Ontario Ministry of Municipal Affairs and Housing is the Provincial agency that guides the implementation and management of the Ontario Greenbelt.

The Ontario Greenbelt Council is an 11 member multi-stakeholder council is an arms-length body that:

- provides advice to the Ministry on the implementation of the Greenbelt
- evaluates the Greenbelt Plan's effectiveness

- reviews proposals for amendments to the Greenbelt Plan and
- will undertake a 10-year review of the Greenbelt in 2015

The Friends of the Greenbelt Foundation are a not-for-profit organization that promotes greenbelt agriculture and protection of greenbelt's ecological features. They offer a grant program that funds activities that promote and sustain the Greenbelt; they also support local organizations/agencies, raise public awareness about the Greenbelt, and facilitate partnerships amongst like-minded organizations.

For information about the Foundation and Greenbelt see www.greenbelt.ca/home . Their food and farming website section can be accessed at http://greenbelt.ca/issue/food-farming .

Ecosystem Services of the Ontario Greenbelt

An initial estimate of the value of ecosystem services in the Ontario Greenbelt was conducted by Wilson (2008) for the David Suzuki Foundation and the Friends of the Greenbelt Foundation. The ecosystem services examined in the study included: carbon storage; oxygen production; air pollution removal; water filtration by forests and wetlands; flood control by wetlands; pollination value; seed dispersal (as a support for biodiversity); recreation value and agricultural value. The following were the most important ecosystem services deemed to be provided by each land cover type:

Wetlands

- Carbon storage (total in storage and uptake per year)
- water filtration (e.g. avoided drinking water treatment)
- Flood control
- Waste treatment
- Habitat – protection for one-third of Ontario's species at risk (based on cost of wetland restoration)
- Recreation (e.g. willingness to pay for nature-based activities)

Forests

- Carbon storage
- Air pollutant filtration
- Water run-off control (e.g. avoided stormwater management controls)
- Water filtration
- Recreation
- Pollination (e.g. crop productivity enhancement)
- Seed dispersal and forest regeneration (e.g. avoided costs of planting done by human)

Hedgerows

- Carbon storage
- Erosion control
- Nutrient cycling
- Soil formation
- Pollination
- Biological control
- Cultural value

Idle Agricultural land (in permanent vegetative cover)

- Carbon storage
- Erosion control
- Pollination

- Biological control

Grasslands

- Pollination
- Carbon sequestration
- Water regulation
- Soil formation
- Erosion control
- Biological control
- Recreation and aesthetics

Wilson recorded the following values for different components of the Ontario Greenbelt:

- Wetlands: ~$14,000 per hectare per year
- Forests: ~$5,000 / ha/year
- Hedgerows: ~$1,600 / ha/year
- Idle agricultural land: ~$1,600/ha/year
- Grasslands: ~$1,600/ha/year
- Orchards: ~$500/ha/year
- Cropland: ~$500 ha/year
- Rivers: ~$300 /ha/year

Thus, the total value of ecosystem services for the entire Ontario Greenbelt was estimated to be over $2.6 billion Canadian per year. In addition, it is clear that the greenbelt will preserve wildlife habitat and support the maintenance of biological diversity.

Successes

The Ontario Greenbelt is currently the world's largest greenbelt, at 1.8 million acres (~730,000 hectares). There are currently six municipalities along the Greenbelt that wish to have their municipal lands added (Ontario Greenbelt Alliance 2010a) and the Ontario government appears to be strongly enforcing the legislation to protect natural heritage areas and agricultural lands.

Challenges

There are inherent conflicts between the greenbelt goals – for example, "conserving and making available natural resources critical for a thriving economy" (i.e. aggregate extraction) may be in direct conflict with the goals of protecting ecological features and agricultural land. The Ontario Greenbelt Alliance cites several new quarries and quarry expansions planned for the Greenbelt area (Ontario Greenbelt Alliance, 2010). However while quarries that were proposed before the Greenbelt Legislation was passed have been allowed others have been rejected (Cornish, 2013).

Many agricultural organizations and individual producers have spoken out against the greenbelt, citing conflicts with urban settlement areas (e.g. adjacent residents complaining about farm vehicles, smells, etc.), and calling for better farm policies (see Murray, 2011).

"Leap frog" development may be happening in some municipalities outside of the Greenbelt, including the Lake Simcoe area, Guelph, Kitchener Waterloo, and others. At the same time, Fung and Conway (2007) argue that the "Places to Grow Act 2005" was important to reduce "leap frog" development by helping direct growth to key areas.

Lands outside of the Greenbelt still at risk – there is a risk that important natural features outside of the

Greenbelt will receive less protection if municipalities look to the Greenbelt for solving all natural heritage protection goals.

Benefits: The benefits here are the high levels of ecosystem services that will be maintained by the provisions of the Ontario Greenbelt. The longer-term effects of its use as an urban containment boundary will be dependent on how well it actually contains urban sprawl.

Biodiversity and Ecosystem Services Derived from The Ontario Greenbelt

Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study** **H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	M (Maintenance of existing)	Forests, (seed dispersal)	Habitat types
	Habitat for Native species	X	M	Wetlands, forests, Hedgerows, fallow or abandoned agricultural land	The various ecosystem or landcover types.
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	H Given the area of the Green belt this is a significant service	Wetlands, forests, hedgerows, agricultural lands grasslands	The various ecosystem or landcover types.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	M-H	Forests	Maintain Forest Cover
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				

	Maintain or increase pollination	X	M	Forests, hedgerows, undue agricultural lands, grasslands	Maintain a mix of these landcover types.
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	M	wetlands	Maintain wetlands
	Noise Reduction				
	Disease and pest Regulation (biological controls)	X	M	Hedgerows, unused agricultural lands and grasslands.	Maintain these cover types adjacent to cultivated lands
Water	Seasonal drought mitigation				
	Waste-water Treatment	X	L	Wetlands, forests	Maintain wetlands to purify runoff and forests to control surface water flows.
Soil	Maintenance of Soil Fertility				
	Reduced Erosion	X	M	Forests, hedgerows, unused or grassed agricultural lands.	Maintain these cover types.
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation	X	H This is a high value service because the	Wetlands, forests, grasslands.	Maintain these within proximity to urban centers.

			Greenbelt surrounds a large urban population		
	Aesthetic appreciation				
	Tourism				

5.2.2. Musselman's Lake Case Study

Project type: Landscape Assessment, Planning and Management

Musselman's Lake Watershed Assessment and Management

Project Description

Musselman's Lake is a small, shallow "kettle lake" (depression in glacial material that once held a detached mass of glacial ice) that is groundwater dominated. The Musselman's Lake watershed is about 460 hectares in size. Natural features make up about half of the watershed area (51%), with the remainder occupied by agriculture (24%), residential development (20%), and some aggregate extraction (3%). This case study documents the development and implementation of a plan to improve water quality in the lake.

References

Lake Simcoe Region and Conservation Authority and the Town of Whitchurch-Stouffville 2009. *Musselman's Lake Subwatershed Assessment and Stewardship Opportunities Report.* Available at www.lsrca.on.ca/pdf/reports/musselmans_stewardship_2009.pdf

Town of Whitchurch-Stouffville 2011 Ballantrae-Musselman Lake and Environs Secondary Plan. Available at http://www.townofws.com/pdfs/OPC/WS%20Official%20Plan%20Section%2011.pdf

Wilson, S.J. 2008. *Lake Simcoe Basin's Natural Capital: The Value of the Watershed's Ecosystem Services*. Friends of the Greenbelt Foundation Occasional Paper Series. Available online at: www.davidsuzuki.org/publications/downloads/2011/Lake-Simcoe-GreenbeltNaturalCapitalJune%2020_2_.pdf

Lake Simcoe Region Conservation Authority: www.lsrca.on.ca

Ontario Conservation Authorities (Conservation Ontario): www.conservation-ontario.on.ca

Location

Musselman's Lake is a community located northeast of Toronto on the Oak Ridges Moraine. The moraine is a large (190,000 hectares) glacial deposit that supports many important natural heritage features and forms the headwaters for nine major river systems. The community surrounds the 123-acre (0.50 km^2) Musselman's lake in the town of Whitchurch-Stouffville, Ontario, Canada. The lake's watershed drains into Lake Simcoe, and eventually to Georgian Bay and Lake Huron.

Figure 1. Musselman's Lake Community and Watershed Location

The Problem

Historically the lake was surrounded by small seasonal cottages and agriculture. The cottages have gradually been replaced by permanent residences, which are still dependent on septic systems for waste treatment.

The lake has intermittent outflow when lake levels are high. This causes the lake to have a long "residence time," meaning that it can take many decades for the water to be completely flushed through the system. Thus, contaminants that enter the lake can remain there for long periods of time and become increasingly concentrated. The lake has experienced ongoing water quality concerns for decades. Recent concerns have included increasing aquatic plants, rising water temperatures, and a toxic blue-green algae bloom in 2007. These concerns prompted the development of the Musselman's Lake Subwatershed Assessment +

Stewardship Opportunities Report in 2009.

The Solution

The goal of the Musselman's Lake Subwatershed Assessment + Stewardship Opportunities Report was "to describe the environmental issues facing Musselman's Lake and its subwatershed and put forward recommendations to remedy or control these environmental issues." The objectives were to:

- Identify the subwatershed location
- Establish the relationship of the subwatershed plan to other planning documents
- Describe and analyze the form, function and state of the natural systems contained within the subwatershed based on current information
- Outline resource management goals and objectives for the subwatershed
- Recommend options for protection, rehabilitation and enhancement of conditions
- Establish a baseline of information and provide recommendations based this information

Selected biophysical goals of the assessment included:

- Groundwater: Protect, restore and enhance groundwater quality and quantity and ensure sustainable groundwater use for a continuous supply of clean water to support environmental functions and human needs.
- Surface Water: Ensure that surface waters are of sufficient quality to support healthy aquatic communities and enable sustainable human uses including recreation and commercial uses.
- Aquatic Habitat: Musselman's Lake should support a sustainable fish population, including optimum habitat for its naturally reproducing native fish and maintain stability in the biodiversity of wildlife species and their habitat. The introduction of "invading species" such as zebra mussels and purple loosestrife must be prevented. The lake should have a healthy and diverse warm water fish community and bait fish community and a healthy and diverse benthic invertebrate population.
- Terrestrial Habitat: Protect, enhance and restore the natural features, to improve ecosystem function, enhance biodiversity and also mitigate the impacts of changing land uses. The protection and rehabilitation of the shoreline (littoral, riparian and upland areas) should be promoted to increase the amount of natural shoreline.

The Role of the Ontario Conservation Authorities

Conservation Authorities (CAs) are public planning agencies, established in 1946 under the Conservation Authorities Act. CAs are established on the basis of natural watershed boundaries. The original mandate of CAs was to reduce flooding and soil erosion, but their mandates have evolved to encompass the following:

- Protect people and their property from natural hazards of flooding and erosion
- Protect natural areas and open space
- Restore and protect aquatic and natural habitats and
- Provide recreational and educational opportunities to local residents.

Conservation Ontario is comprised of 36 Conservation Authorities. These are local watershed management agencies that deliver services and programs that protect and manage water and other natural resources in partnership with government, landowners and other organizations. The CAs employ an integrated watershed management approach that attempts to balance human, environmental and economic needs (Ontario Conservation Authorities).

Individual Conservation Authorities have the legal authority to :

- Provide input to / review municipal Official Plans and planning processes
- Have responsibilities to represent provincial interests regarding natural hazards (e.g. flooding, dynamic beaches, erosion)
- May develop service agreements with participating municipalities to offer planning advice to

municipalities / planning advisory services
- Can regulate development that may interfere with wetlands, shorelines and watercourses.

Other planning authorities and policies of relevance to Musselman's Lake:
- Town of Whitchurch-Stouffville's Official Plan + Secondary Plans (e.g. Ballantrae-Musselman Lake and Environs Secondary Plan)
- Province of Ontario's Oak Ridges Moraine Conservation Act (2001) and
- Greenbelt Plan (2005)

Natural Capital inventory in Lake Simcoe Watershed

Wilson (2008) estimated the total value of ecosystem services in Lake Simcoe watershed to be over $975 million per year. As part of this inventory, ecosystem services were estimated for each subwatershed within the Lake Simcoe Watershed. The estimated total value of ecosystem services for the Musselman's Lake watershed was over $1.3 million per year. Land cover of highest value was wetlands: ~$11,000/ha/year (~$280,000 total for watershed) for the following services: water regulation, water filtration, flood control, waste treatment, recreation and wildlife habitat. Land cover type of next highest value was forests: ~$5,000 / ha / year (~$480,000 total for watershed) for the following services: water filtration, carbon sequestration, habitat for pollinators, and recreation.

Implications of natural capital assessment for Musselman's Lake Watershed:
- This study demonstrates the ability to evaluate land use change scenarios by their anticipated impact on ecosystem service provision.
- It would support a greater awareness of "free" services being supplied by ecosystems and support identification of places where ecosystem services could be restored.

Outcomes: The State of the Musselman's Lake Subwatershed
Twenty-eight observations were made about the biophysical conditions under the following categories:
Groundwater, Surface water, General recommendations, Aquatic habitat, Terrestrial habitat, and Best Management Practices (BMPs).

Examples of observations by biophysical category:
- Groundwater: During periods of little to no rain, flow is maintained by groundwater seeps, wetlands, ponds and kettle lakes that release water over time.
- Surface water: There are 11 urban catchments that drain directly into the lake, contributing 98 kg of phosphorus per year to the lake.
- Aquatic habitat: Removal of vegetated buffers along shorelines contributes to bank erosion which is a source of excess sediment entering the water.
- Terrestrial habitat: The tree cover within the Musselman's Lake subwatershed is at a healthy level.

Management Recommendations
Seventy-one recommendations for protection and management were issued.
Examples by biophysical category include:
- Groundwater: The town's land use plan should limit use of impervious surfaces in new development
- Surface water: Residents should be informed of best practices for lawn care and shoreline protection

- Aquatic habitat: Shorelines should be naturalized around the lake
- Terrestrial habitat: Collect additional natural heritage information, determine priorities for protection/restoration, and incorporate this into land use plans and development permit considerations

Implementation Strategy

An "Implementation Group" consisting of residents, the Lake Simcoe Region Conservation Authority, the Town of Whitchurch-Stouffville, and other agencies as required (e.g. The Federal Department of Fisheries and Oceans (DFO) was created. The implementation group is tasked with writing an implementation plan, which will be based on prioritized recommendations from the Musselman's Lake Assessment and Stewardship Opportunities Report.

The Implementation Group is also responsible for guiding stewardship activities which include:

- Education and Communications
  - Recommendations for public education / awareness
  - Website/ newsletters about development permits and best land practices (e.g. yard and septic tank maintenance
- Restoration
  - Shoreline planting and clean-up events
- Monitoring
  - Additional monitoring and data gathering (e.g. paleolimnology assessment of lake history)
- Identification of potential funding resources
- Update of "Secondary Plan" incorporating natural heritage and hydrology

Summary

Musselman's Lake watershed assessment + stewardship report:

- A first step to understanding the state of the watershed
- Process has engaged diverse stakeholders and governmental agencies
- Clearly links the collection of biophysical data with biophysical goals
- Considers the value of ecosystem services in land-use planning
- Makes management recommendations based on available information and observations
- Identifies additional monitoring and information needs

Benefits: Maintenance of the ecosystem services shown below. In many cases the ongoing management of the lake will lead to an improvement or an increase in the ecosystem service(s).

Biodiversity and Ecosystem Services Derived from Management of Musselman's Lake					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, L**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)		M Maintenance of existing condition)	Forests (seed dispersal)	
	Habitat for Native species	X	M	Wetlands and Forests	Maintain these ecosystem types
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Forests, Wetlands	Maintain these ecosystems types at current or greater levels.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	M	Wetlands and Forests	Maintain wetlands for water capture and purification and forests for control of runoff
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
	Maintain or increase pollination	X	M	Forests	Maintain adjacent to cultivated lands.

Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	M	Wetlands	Maintain, buffer from sedimentation
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment	X	M	Wetlands	Maintain
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling (Water regulation and filtration)	X	M	Forests and wetlands	Maintain
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation	X	M	Forests and wetlands	Maintain (control invasive species.)
	Aesthetic appreciation				
	Tourism				

5.2.3 Iona Island Regional Park Wetland Restoration

Project type: Wetland Restoration

Iona Marsh Wetland Restoration

Project Description

A man-made freshwater marsh in a regional park that had been recently filled was restored to support general avian diversity and one locally rare species: the Yellow-headed Blackbird.

References

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Orians, G.H. 1985 *Blackbirds of the Americas*. University of Washington Press, Seattle.

Location

Iona Island Regional Park Richmond British Columbia, Canada

Iona Island lies within the Fraser River delta in south-western British Columbia. It is within the Municipality of Richmond, a member municipality of the MetroVancouver Regional District (MVRD). The estuary of this great river, and in particular its delta area, are internationally significant fish and bird habitat (Butler and Campbell, 1987; Fraser Basin Council 2010).

The Problem

The island is connected to Sea Island; home of Vancouver International Airport, by a causeway and since 1961 has been home to a sewage treatment plant that services much of the surrounding urban area. In 1987, much of Iona Island was given to the MVRD for development as a regional park. At West Iona beach, the main parking and use area of the park, two groundwater-fed freshwater marshes had developed from unused sewage lagoons. These became popular birding sites.

When one of these ponds was filled with material dredged from the north arm of the Fraser River, important bird habitat and birding opportunities were lost. At the time, an impending expansion of Vancouver International Airport would have destroyed important Yellow-headed Blackbird (*Xanthocephalus Xanthocephalus*) habitat. This was the only documented breeding habitat for this species in the Fraser River Delta. Although numerous elsewhere in North America, this bird has restricted habitat and was uncommon in coastal British Columbia (Butler and Campbell, 1987, Campbell et al. 2001).

The Solution

Project Goals

The restoration plan sought to restore a freshwater marsh on the recently filled site and enhance the adjacent freshwater marsh within the newly created Iona Island Regional Park. The intention was to maximize general avian diversity and provide replacement habitat for the Yellow-headed Blackbird. A secondary intention was to provide a trail system including a boardwalk for controlled public access and interpretive facilities.

The MVRD local area park planner, the author and members of the Vancouver Natural History Society (VNHS) recognized that restoring and enhancing this disturbed site would change a sterile filled site into highly productive bird habitat. In 1990 a grant application was made to Environment Canada for a total of $321,470. Of this, the Canadian federal government would pay $139,853, the MVRD regional park system $145,635 and the remaining $35,982 would be in kind contributions of unpaid consultants and volunteers. The grant application was made through the VNHS, while the MVRD parks planner assisted in getting the necessary regulatory approvals.

Restoration Design and Implementation
The consultant team reasoned that since a groundwater fed wetland had persisted on the site for many years, establishing the same topography that had supported the original wetland would tap into the original groundwater source. However, there was a possibility that compaction brought about by filling and excavation by heavy equipment might have caused compaction and reduced groundwater flows. The restored pond was joined by a culvert to the undisturbed pond for an additional water source. This allowed the team to predict winter and spring water levels from historic data, and to establish a moisture gradient to guide the re-vegetation plan. The aquatic ecologist conducted a transect of McDonald Slough, a nearby marsh, to establish the relative locations and elevations of emergent marsh vegetation. Soil fertility, pH and nutrient levels between the slough and the restoration site were tested to ensure that these matched.

The site analysis revealed that the wetland would be used by marsh habitat passerines, raptors, waterfowl and shorebirds. The area around the perimeter of the marsh was planned as an "old field" type of habitat, i.e. an open grassy meadow with dispersed shrubs and small trees intended to attract passerines and raptors and increase the site avian diversity.

The species/habitat model for the Yellow-headed Blackbird showed that the bird nests exclusively in marshes, in Hardstem bulrush (*Scipus acutis*) adjacent to open water. It will not nest within a 45 degree angle of influence of a tree or promontory (Orians, 1985). Males are polygamous and occupy territories in the center of a marsh, with water depths of 2 to 4 feet, pushing smaller redwing blackbirds to the peripheries (Ibid, Ehrlich et al., 1988). This simple, descriptive species/habitat model was used to set the requirements of the nesting sites for the Yellow-headed Blackbird.

Inevitably, the model led to an examination of requirements to establish Hardstem bulrush. Transects of McDonald Slough revealed that Hardstem bulrush will sprout from a maximum depth of about 2 feet. Cattails need to be wet or inundated during initial growth but will tolerate drier conditions later in the growing season. In general, emergent vegetation positions itself along a moisture regime from wetter to dryer, accounting for seasonal depth fluctuations. The pond bottom was contoured and planted to produce the necessary growing conditions for the emergent vegetation, and to limit its growth where open water was required.

The consultant landscape architect developed pond construction and grading drawings and the pond was excavated in the summer of 1992. The civil engineer from the GVRD Parks took on project administration, hiring consultants and contractors and supervising all work.

The pond area on Sea Island served as a plant donor site while McDonald Slough served as the representative ecosystem type. Because the Sea Island ponds were about to be destroyed by the airport expansion, removing plants was straight-forward, whereas environmental approvals would have been required to take plants from McDonald Slough. Further, the regulatory agencies would have sought assurance that the donor marsh would be restored and that the plants removed would prosper in the restoration site.

Fill from the excavation of the restored pond was used to create two nesting islands in the existing pond. In a creative cost-saving measure, the civil engineer used large portable pumps to lower the water level in the existing pond to build a causeway to the nesting islands and place fill using conventional earth moving equipment. When the water levels were allowed to return to normal, the causeways were inundated and leaving only the new nesting islands visible above the pond surface.

In late summer of 1992 the landscape architect developed a planting plan using the recommendations of the aquatic ecologist. Emergent vegetation was planted in the fall by MVRD staff using donor material from Sea Island ponds.

Project evaluation

The site was monitored for three years after completion. All the emergent plants throve in their intended locations and did not expand into deeper water. In the Spring of 1993, their Sea Island habitat having been destroyed, Yellow-headed Blackbirds moved into the restored pond. In the summer of 1995, eleven Yellow-headed Blackbird nest and 54 eggs were recorded in the restored pond. Yellow-headed Blackbirds continue to occupy the site. At the same time general avian diversity increased dramatically in the five years after the restoration was implemented.

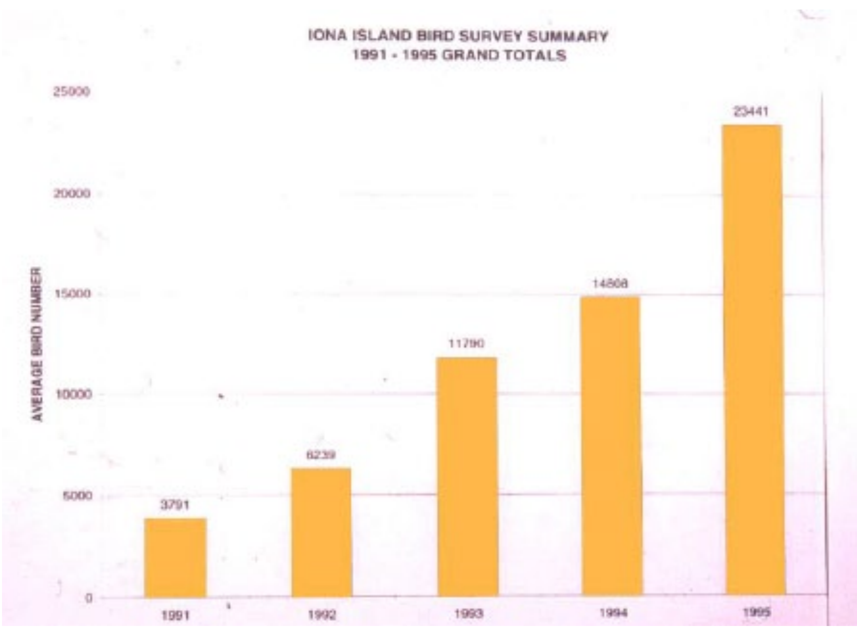

Table 1. Increase in numbers of birds sighted after marsh restoration

Two exotic species, Scotch Broom (*Cyticus scoparius)* and Purple loosestrife (*Lythrum salicaria)* invaded the site. Scotch Broom colonized the old field area around the pond, and the loosestrife spread throughout the cattail areas of the marsh. In 1998 volunteers cut and removed the broom that was shading out native shrub species. This was followed by several other smaller volunteer broom removals. While still present on the site, the broom is now under control. In 1996 the landscape architect introduced three biological controls of the loosestrife. Although

	slow to establish they have now controlled the loosestrife in the restored pond. In the larger existing pond they have not established sufficiently to control the loosestrife. Scientists working on the biological control of loosestrife believe the low slope of the restored pond allows a root eating weevil to establish and destroy the loosestrife. In the existing pond the steeper slope means the roots of the emergent vegetation are too wet for the biological control to establish. With the exception of the biological control project, the pond has been left to succession and has required little maintenance and management. The MVRD parks staff believed that even controlled human access would reduce bird usage of the site, and cancelled the proposed trail, boardwalk and interpretation, while allowing uncontrolled access. The real losses and benefits of this action are uncertain. This case study shows that even disturbed and highly used urban-fringe habitats can sustain significant biodiversity. The approach demonstrates the benefits of ecological modeling in restorations, as well as the risks of invasive plants and the effectiveness of biological controls on purple loosestrife. Restoration is not an exact science and should be treated as an experiment. Every restoration should be monitored so that mid-course corrections can be made and so that the successes and failures of the restoration can be used to improve future restoration projects. (see Special Topics 4 section 4.0) **Benefits:** Increased biodiversity (general biodiversity and rare species) and recreational opportunities (birding, wildlife photography.)

Biodiversity and Ecosystem Services Derived from Iona Island Wetland Restoration					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, L**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	Restored wetland	Groundwater flows to maintain wetland.
	Habitat for Native species	X	H	Restored wetland and the surrounding 'Old Field' habitat.	Maintain these two habitat types. Especially, continue to control the invasive plants on the site.
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M The wetland is small and does not have the high values of a peat bog.	Wetland	Maintain the wetland
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
	Maintain or increase pollination				

Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity	X	M	Wetland	Maintain the wetland
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation	X	M	Wetland and adjacent Old Field Habitat	Maintain access to the wetland and surrounding area for birders.
	Aesthetic appreciation	X	H	Landscapes with water have a higher aesthetic preference than those without.	Maintain the wetland and view to the surrounding river and ocean.

Figure 1. Yellow-headed Blackbird (*Xanthocephalus Xanthocephalus*),

Figure 2. Restored Wetland, Iona Island Regional Park

5.2.4 Southeast False Creek Sustainable Community, Vancouver B.C.

Project type: Urban waterfront community
Southeast False Creek Sustainable Community (SEFC)
Project Description Today SEFC is a developing sustainable, mixed use community on a former 'brownfield' site in the city of Vancouver, Canada. This case study evaluates the first phase of development, which occupies 7 hectares and has a buildout density of 157 dwellings/hectare or 64 dwellings/acre (gross). This phase is 100% complete with approximately 1,100 dwellings constructed. We evaluated the ecosystem services created by implementing sustainability best practices in the design of the Southeast False Creek community and procedures that led to those increased benefits. **References** City of Vancouver. 2007. Southeast False Creek Official Development Plan. Available at https://vancouver.ca/docs/sefc/official-development-plan.pdf City of Vancouver 2013. SEFC https://vancouver.ca/home-property-development/southeast-false-creek.aspx The Challenge Series, Millennium Water: The Southeast False Creek Olympic Village, Vancouver Canada-A story of leading-edge sustainable development. Roger Bayley Inc. Available at : http://www.thechallengeseries.ca Margot Long, Personal Communication **Location** Southeast False Creek is a new, 32 hectare, urban community on the southern edge of a tidal basin known as False Creek in the Central Business District in the City of Vancouver Canada. The City of Vancouver is located on Canada's West Coast and is part of the Metro Vancouver metropolitan area, which has a population of approximately 2.5 million residents. Vancouver was host to the 2010 Winter Olympics and has repeatedly been ranked among the world's most livable cities. Part of the southeast False Creek Community was utilized as the athletes "Olympic Village" during the 2010 Olympics (City of Vancouver 2007).

Figure 1. Location Plan, City of Vancouver and SEFC Sustainable Community

Figure 2. Overview of the Southeast False Creek Community showing the rooftop gardens, continuous waterfront walkway, with Hinge Park the community garden and the habitat island in the upper portion of the photo.

Figure 3. Habitat Island is accessible at low tide. (All photos, courtesy of PWL Ltd.).

The Problem

Site History

Prior to European settlement the shores of False Creek were covered with old growth forest inhabited by a diverse array of organisms, including large carnivores such as bears, cougars, and wolves. The tidal basin would have supported abundant seabird and marine life and provided rich sustenance for the aboriginal people. In the late 1800's sawmills and shingle mills were constructed here to serve the needs of the expanding city. The 1930 city plan by St. Louis planner Harland Bartholomew zoned the area for heavy industry. Subsequently, industries such as shipbuilding and cable making occupied the shores of False Creek and continued until after the World War II. Gradually, industry on the site declined and in 1970 much of False Creek was rezoned for housing and parks (City of Vancouver 2013).

Influence of Policy

Vancouver has a number of regional and local planning policies that have influenced this neighbourhood's planning and design. At the regional scale, the Provincial Agricultural Land Reserve restricts the development of Agricultural land. The regional water supply system sets aside 144,557 acres of forested watershed from human intrusion to protect thee lakes that are the region's source of potable water. These set aside areas act as urban containment boundaries restricting urban sprawl and promoting increased density.

In the 1960's the City of Vancouver began promoting residential density in the downtown core. Vancouver has approximately 45,000 residents living on 504 acres in its downtown west end and approximately 500 new residents a year are added to the downtown core. The provision of public access by means of waterfront promenades is also a long-standing tradition in Vancouver, as the provision of social housing. Twenty percent of the housing units in the SEFC will be subsidized housing for low income households. The city also supports development that facilitates biking and walking and reduces the use of automobiles.

After years of consultation and planning the SEFC Official Development Plan by law was enacted in July of 2005. The community is still under construction although the public realm is substantially complete. When completed this mixed-use pedestrian and transit-oriented community will contain more than 1.5 million square feet of built space and house between 11,000 and 13,000 people.

SEFC was the last the last large tract of available waterfront land adjacent to the city's downtown peninsula. Both the past industrial uses and the City works yard had left the site in a contaminated condition. Its vision was to create "a place where people, live, work, play, and learn in a neighbourhood designed to maintain and balance the highest possible levels of social equity, livability, ecological health and economic prosperity" (The Challenge Series, (2) Planning + Olympics p.13).

The Solution
An innovative city-developer relationship enabled this development. The city owned more than 20 hectares of the 32 hectare site (City of Vancouver 2007). Because so much of the site was city-owned, the city played a lead role in early planning and policy development. A major interdisciplinary design charrette was held in 1996 to help establish the vision and early urban form concepts for this development.

After passing the official development plan in 2005, the city put out a call for developer/consultant teams to complete the design through construction of Phase 1 of the development, the 2010 Olympic Village. Landscape Architects played a key role in the planning, design and implementation of the development parcels, public realm, and parks. Each of 10 development parcels in Phase 1 had a consultant team with landscape architects on every team. PWL Partnership consulted on the Master Plan, Official Community Plan, authored the Public Realm Plan, and designed Hinge Park, the waterfront and the all streets (personal communication Margot Long).

The consultants working on the project did not start this project with ecosystem services as targets. Their intention was to meet the stated goals and vision of the City of Vancouver (Ibid). The sustainability initiatives that were implemented led to SEFC becoming the first Leadership in Energy and Environmental Design (LEED) certified Gold neighbourhood in Canada (The Challenge series 01). LEED is a voluntary certification system for projects seeking to meet environmental performance standards and is administered by the Green Building Council in Canada (The Challenge series 01).

The sustainability initiatives include:

- LEED Platinum neighborhood (certified 2010): high density, complete with excellent connectivity to mixed use commercial and civic center, transit service, and walkability.
- Walkable neighborhood: fine grained network of on-street and off-street sidewalks and paths and narrow, pedestrian friendly streets.
- Target of 60% of trips to be alternate mode (walking, biking, transit, pedestrian/bike ferry).
- Green buildings and sustainable landscapes mandated (One Net Zero seniors housing; One LEED Platinum Community Centre; balance LEED Gold buildings/sites).
- Heat & cooling and systems: district heating using sanitary sewer heat recovery supplemented with horizontal groundsource loop, waste hot water heat recovery, solar hot water and passive solar gain.
- 50% of roof area to be green roofs both intensive and extensive.
- On-site stormwater management (green roofs, infiltration galleries in streets and around some buildings, all stormwater detained and filtered in stormwater wetlands and/or bioswales).
- Created a habitat island in False Creek.
- A comprehensive tree planting plan and program with innovative tree planting standards, including

extensive use of tree cells alongside streets and other paved areas and use of drought tolerant or native plants is encouraged.

- Extensive use of native plant and/or drought tolerant plants to reduce the water demand.
- High efficiency irrigation system (drip irrigation) for ornamental landscapes in specific applications.
- Storage and use of storm water for irrigation.
- Herbicide and pesticide use is not supported.
- Urban food program on intensive green roofs.
- Community Garden supports urban agriculture
- By reusing existing pavement as sub-base the embodied energy costs of the project were reduced and land filling was averted.
- One-third of the site, 26 acres, is public parks, including a fully public waterfront greenway, a park also serving as a stormwater wetland, and a created habitat island.
- All stormwater is channeled through the stormwater wetland or a bioswale before it enters False Creek, an ocean inlet.

Benefits:

Habitats and biological diversity.

There are eight different, habitat types on this site. Each supports a different set of species on the site and increases the site's overall biodiversity. The Mixed Forest that is found on a man-made habitat island replaces poor habitat with high quality diverse habitat at a ratio of 2:1. This island was required as part of a habitat compensation program. The Shore Zone Habitat also added to the required compensation (personal communication Margot Long). In addition, there is Old Field Habitat which is a highly productive ecosystem type especially for song-birds and their predators. Other habitat types include Street Trees, Hedgerow, Freshwater Wetland, Riparian and Meadow. The different habitats not only function individually: research has shown that certain habitat assemblages such as forest and shoreline or old field, meadow and wetland are particularly productive when taken together since they contain both breeding and feeding habitat for a wide range of species. As a sustainable community there are significant areas that are vegetated. Herring spawned in False Creek for the first time in 80 years on the banks of the new habitat island. In 2009 a Grey whale entered the Creek. Five species of juvenile salmon are now found in False Creek.

Figure 3. Location of different habitats and the cultural landscape in SEFC.

Large areas of the parkland and foreshore are predominantly native plant material, many of which were used and still are by the First Nations populations of the area.

The Cultural Landscape is comprised of the courtyards, plazas, roof decks, and green roofs of the building sites. While these landscapes do not provide significant habitat values, the many cultural ecosystem services of the site are due to the design of these areas which provide flexible use, promote social interaction and provide a sense of site and regional identity. The ornamental planting occurs predominantly on the development parcels, and green roofs. Native and non-native lawns provide places for people to play, gather, and recreate. Areas of urban agriculture are provided in a community garden, and on roof tops which directly support the provision of cultivated food whereas the native planted areas support the provision of food indirectly through providing habitat for pollinators and support for the aquatic food chain.

A number of best practices that influence water flow. This is critical in Vancouver, where the average rain fall is 1200 mm of rain. All storm water from the streets is collected in a bio-swale and purified in a wetland before it goes into the ocean. Cleaner water collected from roof tops is stored in cisterns in underground parking garages and used for toilet flushing and irrigation of the roof top gardens, urban agriculture areas and the rest of the cultural landscape. Throughout the project, the water flows provide much of the landscape character. The storm water is transformed into landscape features providing green streets, rain gardens, and rain channels.

Also critical in the built environment was the new approach to street tree planting. Typically new street trees in Vancouver over the past 20 years have been planted with an average of 1.8m^2 of growing medium. The city estimates the trees will survive average of 13 years and reach a minimal tree canopy. In the SEFC village, structural soil cells were utilized to achieve an average of 19.6 m^2 of growing medium which is more than 10 times that which is usually provided. This will provide adequate growing medium to support a street tree for a 50 year life span, in an urban setting, dramatically increasing the carbon that is sequestered and oxygen generated. It is estimated that, when mature, the street trees on site will provide $20,536 annually in ecosystems services. And over this time period they will sequester 271,800 kilogram of carbon (personal communication Margot Long).

The site design and planning was intended to provide flexibility of use and promote walkability through the incorporation of public pedestrian circulation into and through the private open spaces of the individual developments. This makes the site more permeable and provides car-free pedestrian walkways. The individual spaces within the site were designed to meet the needs of anyone at any time. This has worked to foster a high intensity of use by people of all ages.

Conclusion

In evaluating this site we have reached a number of conclusions:
Such post-industrial, high density urban sites are generally considered to support little biodiversity and ecosystems services. The post occupancy evaluation of this site has shown that site planning and design may make a significant contribution to both ecosystems services and biological diversity.

The sustainability best practices did support biological diversity and multiple ecosystem services. Most notable was the wide range of cultural ecosystem services supported by the site design. A key finding is that while the good ecological design may support provisioning and regulating ecosystem services, site planning and design that responds to the basic needs of people can contribute more to cultural ecosystem services than most natural sites of equivalent size.

In future research, establishment of baseline inventories and more post-construction monitoring would support more detailed measurement of biodiversity and ecosystem services in urban development.

Biodiversity and Ecosystem Services Derived from SEFC Community and Open Space					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, L**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	Bioswale and wetland	Continue to cleanse the urban runoff before it enters False Creek.
	Habitat for Native species	X	H	Maintain the diverse habitat types of the site.	Habitat types
Provisioning Services					
	Food	X	L	Rooftop Gardens and the Community Garden	Maintain urban agriculture.
	Raw Materials	X	L	Native plants provide resources for First Nations	Maintain the high proportion of native plants.
	Fresh water	X	H	Rooftop capture and storage for irrigation	Maintain built infrastructure.
	Medicinal Resources			Native Plants Provide resources for First Nations	Maintain native plants.
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Woody plants, and wetlands sequester significant carbon.	Maintain site vegetative cover of all types.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)	X	L	Street trees uptake gaseous and particulate pollutants and all plants release oxygen.	Maintain street trees
	Pollution Mitigation (Water)	X	M	All surface runoff is cleansed in bioswales and the wetland before being released into False Creek.	Retain and restore bioswales as needed.
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	M	Since the neighbourhood is heated with heat extracted from sewage, Co2 release is greatly	Maintain community heating system.

				reduced.	
	Maintain or increase pollination	X	M	Native plantings provide habitat for native pollinators.	Maintain native plants and pollinator habitat.
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation	X	H	On site irrigation system eliminates effect of summer drought on plants.	Continue to irrigate with collected precipitation.
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				.
	Reduced Erosion				
Supporting Services					
	Primary Productivity	X	L	The dramatic increase in vegetative cover of the site will result in increased biomass production.	Maintain site vegetation of all types.
	Preservation and generation of soils	X		In many of the plantings, leaf litter will provide organic matter and nitrogen cycling that will increase soil fertility and organic matter over time.	Allow leaf litter in old field, forest riparian and wetland habitat to decay in place.
	Water Cycling	X	M	Precipitation on rooftops is cycled to irrigation and toilet flushing.	Maintain
Cultural Services					
	Social Cohesion	X	M	Site is highly used by a wide demographic.	Anecdotal on-site observations suggest

					that this is a result of the site plan and design.
	Sense of identity				
	Mental and physical well-being	X	H	Significant access to urban nature will give these benefits.	Maintain site plan and design.
	Recreation	X	H	Numerous opportunities for cycling walking kayaking, park use and socializing exist in the public realm.	Maintain site plan and design.
	Aesthetic appreciation	X	H	Aesthetically attractive community with access to water views.	Maintain
	Tourism	X	M	Vancouver is experiencing increased bike tourism. The public seawall is an important destination for cyclists in the city.	Maintain public access to sea wall walkway.

5.2.5 Fisherman's Wharf Park and Rain Garden

Project type: Rain Garden/Urban Park

Fisherman's Wharf Park, and Rain Garden, Victoria British Columbia

Project Description

Location

Victoria, British Columbia is located on the southern tip of Vancouver Island approximately 60 miles off Canada's Pacific coast. This city of 345,000 people is a popular tourist destination and retirement community, in part, due to its sunny climate that is characterized by distinct wet and dry seasons. Approximately two-thirds of annual precipitation occurs in the period from November to February and summers are very dry. Annual precipitation is 62 inches.

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The problem

The Landscape Architecture firm of Murdoch de Greeff Inc. in collaboration with KWL Engineering was initially asked by the City of Victoria to develop a plan to daylight a large storm drain to create a stream running through the Park and emptying into Victoria Harbour.

Roughly 40% of the park area was a marine estuary until it was filled in the 1950's. At that time the stream was extended to the new marine edge in a storm drain that was buried under 6 m of fill. The outlet of the pipe is below the high tide level and is inundated with sea water every day. A baffle at the end of the pipe limits salt water movement into the pipe. Soil testing also revealed the presence of contaminated material at depths great than about 3 m in various areas of the park.

The Solution

Site analysis, by the landscape architects, revealed that due to the existing elevations of the stormwater drains, the new stream, within the park, would be at the bottom of a deep and shady ravine and would have little to no water cleansing effect. In fact, if the baffles were removed at the end of the pipe, the stream would become marine habitat. They therefore proposed to the city that the stormwater flows from smaller catchment areas surrounding the park (with shallower storm drains) be directed to a large rain garden within the park closer to the surface.

This solution allowed day lighting and treatment of at least some of the watershed's runoff before it entered the fish bearing water of the harbor. A greater percentage of the park area was retained for typical urban park uses without the need for deep excavation and risk of uncovering contaminated material and removal and disposal of soil from the site.

The new rain garden, installed in 2012, intercepts two storm drains at roughly 3 m depth and day lights their flows into the park rain garden. This rain garden treats all of the rainwater runoff from two catchment areas adjacent to the park, totaling 14,250 m^2 (or 153,386 square feet) of impervious surfaces comprised of roads and buildings. The treated stormwater is estimated to equal approximately 8,500 cubic meters or 2,290,000 US gallons annually. The rain garden will hold standing water only immediately after rainfall events (approximately 48-72 hours) and will largely be dry in the summer.

Vegetation in the bottom of the rain garden consists of *Juncus effusus (*Common Rush*), Myrica gale* (Sweet Gale) and Red Osier Dogwood (*Corus stolonifera*) that were selected to handle these ranges of flood and drought and to remain attractive throughout the year. Fill from the excavation of the rain garden was deposited on site to form berms surrounding the rain garden.

Other site features include plantings of native and site adaptive non-native plant species, and extended "Historic Shoreline Wall" retaining wall that doubles as a sitting wall, natural play spaces, a large unprogrammed community lawn, a contemplative garden, paths and walkways and a location for the future placement of public art.

Figure 1. Overview of Fisherman's Wharf Park Prior to the redesign
(All figures courtesy of Murdoch de Greeff Inc.).

Figure 2. Catchment area draining to the park

Figure 3. Proposal to intercept runoff from two adjacent catchment areas

Figure 4. Landscape Concept Proposal

Figure 5. Preliminary Park Plan

Figure 6. Landscape plan with section through park and rain garden

Figure 7. Plan sub-area showing another section of the park

Figure 8. Detailed design of the rain garden

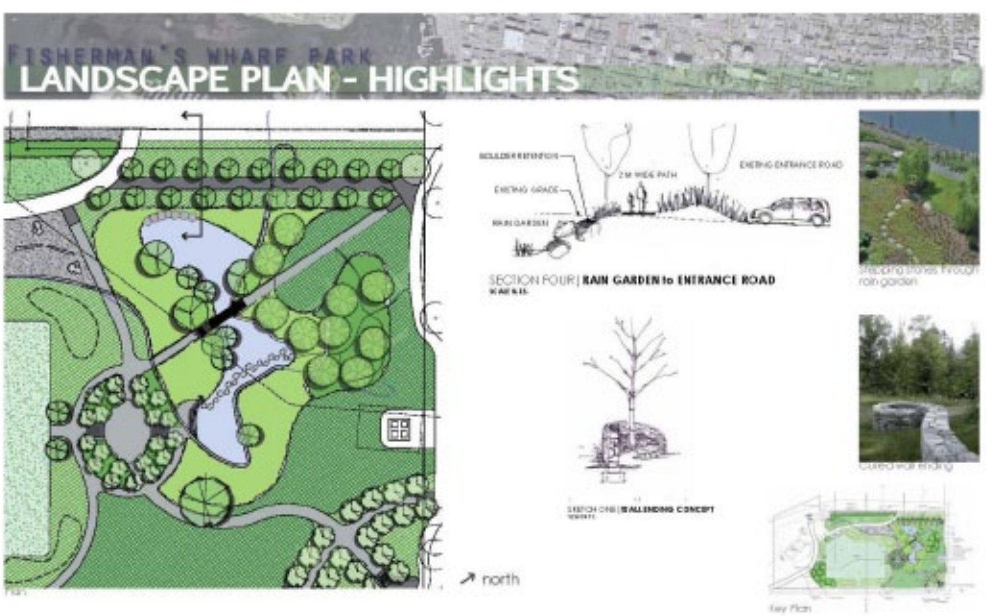

Figure 9. Additional section through the rain garden and stone wall detail

Biodiversity and Ecosystem Services Derived from Fisherman's Wharf Park					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study High, H Moderate, M Low, L**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Biodiversity Maintain or increase	X	M	Native plantings support increased bird and insect populations and the rain garden will support aquatic life in the harbour.	Freshwater flows.
	Habitat for wild species				
	Maintain or increase pollination				
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	The rain garden and park plantings will sequester more carbon than did the lawns that formerly comprised much of the park's area. In addition, parks have been shown to sequester carbon (Jo, 2002; Makhelouf, 2009; Kordowski and Kuttler, 2010; Davies et al., 2011; Paoletti et al., 2011).	Plant growth, especially trees
	Moderation of Extreme Events				
	Pollution Mitigation (Air)	X	M	Parks have been shown to reduce particulate and gaseous air pollutants (Beckett et al., 2000; McDonald et	Plant growth, especially trees

				al., 2007; Paoletti et al., 2011; Tallis et al., 2011; Yin et al., 2011; Jim and Chen, 2008; Makhelouf, 2009; Paoletti et al., 2011; Yin et al., 2011).	
	Pollution Mitigation (Water)	X	M	The rain garden will capture harmful particulate pollutants from the surrounding urban catchment area that previously went untreated.	Plant growth and stormwater infiltration
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	L	See pollution mitigation (air) above	Maintain park vegetation especially trees.
	Moderation of weather extremes and its impacts				
Hazard Regulation					
	Reduction in Landslide potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity (NPP)	X	L	The rain garden and surrounding landscape increase NPP over the previously existing condition.	Plant growth
	Preservation and generation of				

	soils				
	Nutrient Cycling				
	Water Cycling				
	Maintenance of genetic diversity			New habitats support native and non-native biodiversity.	
Cultural Services					
	Social Cohesion	X	M	Several studies have shown that parks moderately support Social cohesion (Fan and Chen , 2011;Peters, 2010;Peters Elands, and Buijs, 2010; Ravenscrofy and Markwell, 2000; and Seeland Duberndorfer and Hansmann, 2009).	Maintain the park and its surrounding context. Fisherman's Wharf is an important draw to the park.
	Sense of Identity				
	Mental and physical well-being	X	M	Numerous studies have shown that urban green space contributes to mental and physical well-being (http://www.nrpa.org/uploadedFiles/nrpa.org/Publications_and_Research/Research/Papers/MingKuo-Summary.PDF).	Maintain the park.
	Recreation	X	M	Parks support a variety of recreational opportunities. (Weber, 2010; Tinsley, Tinsley and Croskeys 2002).	Maintain the park.
	Tourism	X	L	Research has shown that urban parks contribute to tourism (Chaudhry and Tewari, 2010; Liaghati et al. 2010; Villella et al. 2006; Wong and Domroes, 2005).	The site location near the Victoria Parliament buildings and the attractions of the Victoria Inner Harbour and Fisherman's Wharf mean that the park will be frequented by tourists.

5.3 Ecosystem Services Case Study Briefs

The following 27 case studies are existing case studies that we have researched and re- interpreted using ecosystem services. Each of the chosen case studies attempted to meet some environmental or sustainability goals. Like the earlier Southeast False Community Creek case study, (see section 5.2.4) these projects involved using best practices to achieve their goals.

The following case studies have identified the ecosystem services that were positively impacted though these projects. It became apparent to us that in some cases a greater range of ecosystem services might have been maintained or enhanced, without greater cost, if they had been considered in the design and planning of that project.

5.3.1

5.3.1.1 Case Study Brief 1, Alex Wilson Community Garden

Project type: Community Garden

Project Title: Alex Wilson Community Garden

Project Description

A public participatory process led to the creation of a community Garden in Toronto that produces multiple ecosystem benefits.

Reference

Irvine, S., L. Johnson, and K. Peters. 1999. Community gardens and sustainable land use planning: a case-study of the Alex Wilson Community Garden. Local Environment 4(1), 33 – 46

Location

The Alex Wilson Community Garden is located in Central Toronto, Ontario, Canada.

The Problem

In his book *The Culture of Nature*, horticulturalist, journalist and social activist Alex Wilson concludes that we "need to gain a sense of how our constructed environment connects to the natural one surrounding it" so that we can "be mobilized to restore nature and assure it, and ourselves, a future" (quoted in Irvine et al 1999, p. 34). The Alex Wilson Community Garden does this by linking an urban community with its wide variety of needs to nature.

The Solution

The City of Toronto and the Alex Wilson Community Garden planning committee engaged a diverse group of stakeholders and factored long term economic, community and environmental conditions and constraints into the garden design. The winning design (chosen from 65 entries) included key features of southern Ontario landscape: lake-shore, agricultural, and woodland landscapes. By highlighting the natural beauty of southern Ontario and landscaping with native species, the design promotes the natural history of the area. The garden produces food for low income residents of the neighborhood, functioning as a meaningful, naturalized urban space.

Benefits:

- Provides food for low income residents as well as restaurants
- Maintains native plant species
- Promotes the natural history of the region
- Reconnects urban Torontonians with nature

Biodiversity and Ecosystem Services Derived from Alex Wilson Community Garden					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity				
	Habitat for Native species	x	M	The landscaping around the community garden was planted with native species.	Native vegetation is maintained in the garden.
Provisioning Services					
	Food	x	H	Food is produced in the garden for low income residents and for local restaurants	Soil fertility, garden space in an urban area
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	x	L	Crops and landscape vegetation sequester carbon	Uptake and storage of carbon by vegetation and soil.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	x	L	Vegetation surrounding the garden would reduce particulate pollution from	Trees filter air and create shade

				traffic and maintain shade	
Pollination	Maintain or increase pollination	x	L	Native plants and crops provide habitat for pollinators	Flowering plants provide pollen and nectar for foraging pollinators
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction	x	L	The garden's landscape includes a row of trees sheltering the garden from a noisy alley way.	Trees slightly block noise from garden and provide a psychological barrier.
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity	x	L	Landscaping plants and food crops provide primary productivity	Plant growth through photosynthesis
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	x	M	The garden absorbs rain water and runoff, allowing for water table recharge	Reducing the amount of impermeable surface area in a city
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and	x	H	The garden	Garden space within

	physical well-being			provides nutrition as well as learning and nature-experience opportunities.	an urban environment
	Recreation				
	Tourism				

5.3.1.2 Case Study Brief 2, Avalon Park and Preserve

Project type: Parks

Avalon Park and Preserve

Project Description

A former residential site was redeveloped as a memorial garden surrounded by a series of gardens that reference the regional landscape of northern Long Island, New York.

Reference

Andropogon Associates, Ltd. 2001. Avalon Park and Preserve. Landscape Architecture Foundation Case Study series. Available at: http://www.lafoundation.org/research/landscape-performance-series/case-studies/case-study/392/

Location

Avalon Park and Preserve is a seven acre memorial garden and 76 acre preserve in Stony Brook, New York.

The Problem

The challenge was to turn abandoned residential/agricultural land into an indigenous plant garden, wildlife habitat and park.

The Solution

Invasive plants were removed and replaced with native trees, shrubs, ferns, and low herbs. The planting plan followed ecological relationships between plants and historical plant distribution patterns in the area. Agricultural land converted to wildflower meadows now provides bird and small mammal habitat. Designers included a vegetated swale to improve water quality in a eutrophied pond, and constructed wetland habitat to support amphibian species. Wooden footpaths enable pedestrian viewing without disturbing wildlife habitat. The park is now frequently used as a therapeutic garden and as an environmental education site for elementary and high school students.

Benefits:

- Abundance of identified bird species, including 11 species from the Audubon High Priority Watch list and seven species with populations of regional significance, increased by 35%.
- Diversity index for native plants more than doubled.
- Reduced eutrophication in a pond and constructed wetlands to support amphibian species.
- Provides garden therapy for approximately 129,600 annual visitors. 93% of visitors surveyed claim that Avalon had a positive effect on their mood; 51% experienced some form of stress reduction.
- Provides educational opportunities for 135 school-aged children and teens and approximately 1,500 local residents annually.
- Provides a place for physical activity: 77% of visitors interviewed reported walking, hiking, running or jogging.

Biodiversity and Ecosystem Services Derived from Avalon Park					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	35% increase in identified bird species; wetland habitat provided for amphibians; Diversity index for native plants more than doubled.	Provision of songbird and wetland habitat and native plants
	Habitat for Native species	X	H	Wetland and woodland habitat restored	Structural habitat and water quality
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Carbon storage was not discussed, although it would have been improved through wetland construction and plantings.	Carbon storage in wetlands.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	M	Nutrient removal was not quantified, but water quality in a pond was improved.	Nutrient cycling and water filtration.
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase				

	pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being	X	H	Provides educational opportunities for 135 school children and youth and 1500 community members each year. Provides a relaxing space for visitors.	Aesthetics, experience of nature.
	Recreation	X	H	Provides a space for walking, hiking, jogging.	Physical space, trails.
	Aesthetic appreciation				
	Tourism				

5.3.1.3 Case Study Brief 3, Beijing Master Plan

Project type: Urban Planning
Beijing Master Plan

Project Description
The case study documents a comprehensive urban plan for Beijing, China.

Reference
Li, F., D. Hu, X Liu, R. Wang, W. Yang, and J. Paulussen. 2008. Comprehensive urban planning and management at multiple scales based on ecological principles: a case study in Beijing, China. International Journal of Sustainable Development and World Ecology 15, 524 – 533

Location
The study included Beijing, China at various spatial scales ranging from regional (Beijing-Tianjin agglomeration and Hebei Province) to selected areas within districts.

The Problem
Global population growth is driving rapid urban development. When urban areas expand without careful planning, ecosystem services are sacrificed. Beijing has been urbanizing rapidly since 1978 and continues to be so. At the time of this research, Beijing faced serious water and energy shortages, poor air quality and urban sprawl.

The Solution
The Beijing Municipal Institute of City Planning and Design commissioned the authors to develop a comprehensive ecological planning proposal for Beijing. Goals included:

- Completing the "Green Olympic City": development of Olympic park and related infrastructure by 2008
- "Modern International City" by 2020
- "Sustainable City" over the long term, including a "green sustainable ecosystem", connected green space, water and built areas.

The authors included biodiversity and ecosystem services among eight design principles used in revisions to the Beijing Master Plan. At the regional and administrative level, development needs of the neighboring towns and cities needed to be harmonized. Beijing's spatial development pattern was addressed, and an ecological corridor system was proposed for the inner city. The proposal included restoring the canal and river systems of the historic old city district and improving access for pedestrians and bicycles.

Benefits:

- Restoration of many of the cultural attributes of historic Beijing
- Restoration of waterways
- Reduce habitat loss and fragmentation
- Improve air quality by reducing motorized traffic

Biodiversity and Ecosystem Services Derived from Beijing Master Plan					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study** **H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X	M	Reduce urban sprawl and ensure development continues in a way that maintains habitat corridors	Connected green space and habitat
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water	X	H	Restore canal system in old city	Hydrologic connectivity
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage				
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					

	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity	X	H	Restore old city and cultural land marks	Maintain heritage neighbourhoods
	Mental and physical well-being				
	Recreation				
	Aesthetic appreciation				
	Tourism	X	H	Prepared Beijing for the 2008 Olympics	Maintain plan for wayfinding and pedestrian circulation

5.3.1.4 Case Study Brief 4, Beijing Urban Wetland Planning

Project type: Water treatment and regulation by wetlands, Ecosystem Services in Urban Planning

Beijing Urban Wetland Planning

Project Description
The project presents a plan for a large number of wetland restoration projects that are classified according to the ecosystem services they are designed to contribute.

Reference
Jia, H., H. Ma, and M. Wei. 2011. Urban wetland planning: A case study in the Beijing central region. Ecological Complexity 8, 213 – 221

Location
This case study focused on urban wetland planning in the central region of Beijing, China. The region is 1845 km^2 and is bordered by the Liangshui River (south), the Nansha River (north), Yongding River (west), and the Wenyu River (east).

The Problem
Urban wetland planning lags behind many other aspects of urban ecosystem planning. The authors propose methods for including wetlands in urban master plans, and use Beijing as a case study illustrating their points.

The Solution
In the proposed methodology, urban wetlands are classified by their major ecosystem services according to the city master planning, and are built into the city plan. The method includes three steps:
1. Identify the important services of each planned wetland
2. Determine the area requirements for each type of wetland
3. Estimate the water requirements for each wetland

Authors developed and used mathematical functions to estimate water depth requirements for habitat, recreation, or pollutant dilution efficacy.
In the Beijing case study, eleven water purification wetlands were planned to augment services of waste water treatment plants. Flood control wetlands were designed for 200 year floods, including drainage river wetlands (total of 3991 ha) and flood detention wetlands (total of 1075 ha). Thirty-five scenic lakes and three historical scenic rivers were included in the plan. A total of 5775 ha of urban wetlands of all types were planned.

Benefits:
- Water purification
- Flood control
- Biodiversity habitat
- Microclimate regulation
- Groundwater recharge
- Cultural and aesthetic values

Biodiversity and Ecosystem Services Derived from Beijing Urban Wetland Planning					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X		Biodiversity was not a major focus of the study, though the authors do mention positive impacts through provision of wetland habitat.	Improved habitat connectivity and wetland habitat.
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water	X	H	Improve surface water storage and ground water recharge.	Hydrologic connectivity
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	H	Not discussed by authors, but carbon sequestration by wetlands is high.	Uptake of carbon by wetland plants through photosynthesis and carbon storage in wetland substrate.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	H	Wetlands are proposed as secondary or tertiary water treatment to a very large extent	Hydraulic residence time, water filtration by plants and microbial decomposition.
	Pollution Mitigation (Soil)				

	Local Climate and Air Quality regulation	X	M	Urban heat-island effect would be reduced by wetlands	Reduction in paved surfaces, climatic regulation by wetlands
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	H	The case study planned for wetland control of up to a 200 year flood event	Drainage rivers and flood water detention in wetlands
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment	X	H	Wetlands are proposed as secondary or tertiary water treatment to a very large extent	Hydraulic residence time, water filtration by plants and microbial decomposition.
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	H	Surface water storage and ground water recharge would be improved	Storage and drainage of water through wetlands
Cultural Services					
	Social Cohesion				
	Sense of identity	X	H	The master plan would make Beijing a more "liveable" city.	Access to natural areas
	Mental and physical well-being	X	H	Improve access to green space for urban Beijing citizens	Access to natural areas

	Recreation				
	Aesthetic appreciation				
	Tourism				

5.3.1.5 Case Study Brief 5, Campus RainWorks Challenge Winner: Illinois Institute of Technology

Project type: Green Infrastructure

Project Title: 2012 Campus RainWorks Challenge Winner: Illinois Institute of Technology

Project Description

This case study presents the winning design for a green infrastructure competition. Entries were intended to show how stormwater impacts could be reduced.

Reference

US Environmental Protection Agency. 2012. US Environmental Protection Agency 2012 Campus RainWorks Challenge Winner: Illinois Institute of Technology, 1st Prize, Small institution. Available at: http://water.epa.gov/infrastructure/greeninfrastructure/upload/Summary-for-Illinois-Inst-of-Technology.pdf

Location

Illinois Institute of Technology, Chicago, Illinois.

The Problem

The EPA created the Campus RainWorks competition to inspire students to design green infrastructure systems that mitigate urban stormwater impacts.

The Solution

The winning design for 2012 in the small institution category came from the Illinois Institution of Technology. The design proposes turning a service lane into a pedestrian thoroughfare that connects multiple green spaces, including three water gardens to capture and an underground cistern to store runoff for non-potable reuse. Public education displays with information about storm water management are included in the design. Estimates suggest that this design would reduce runoff by 70 – 80 percent and reduce campus water requirements by three million gallons annually.

Benefits:

- Reduces storm water runoff by 70 – 80 percent
- Reduces campus water requirements by three million gallons annually
- Provides public education regarding stormwater management
- Would reduce water pollution carried by runoff into local waterways

Biodiversity and Ecosystem Services Derived from Campus RainWorks					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species				
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water	X	H	Runoff stored for non-potable uses saves 3 million gallons per year	Water collected by infiltration through water gardens and stored in a cistern
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage				
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	M	Reduced runoff would reduce pollution inputs to nearby waterways	Runoff infiltrates through water gardens
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					

	Reduction in Landslide Potential				
	Reduced Flooding	X	M	Runoff is 70 – 80 percent reduced	Reduction in impervious surfaces / enhanced infiltration and water storage
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity	X	L	Vegetation in green areas provide some primary productivity.	Plant growth through photosynthesis
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	M	The design acts as an artificial water cycle, capturing and storing runoff for use.	Restored infiltration in water gardens
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being	X	M	Provides public education regarding stormwater management	
	Recreation				
	Tourism				

5.3.1.6 Case Study Brief 6, Cheonggyecheon Stream Restoration

Project type: Aquatic Ecosystem Restoration, Park

Cheonggyecheon Stream Restoration

Project Description

This urban ecological restoration project demolished urban infrastructure to restore fish populations.

Reference

SeoAhn Total Restoration. 2005. Cheonggyecheon Stream Restoration Project.
Landscape Architecture Foundation Case Study Series. Available at:
http://www.lafoundation.org/research/landscape-performance-series/case-studies/case-study/382/ Last Accessed 29 May 2013

Location

Cheonggyecheon stream restoration and park occupies approximately 100 acres in urban Seoul, South Korea.

The Problem

The City of Seoul is transitioning to a more ecologically-friendly development paradigm. This project demolished an elevated freeway, and restored a previously culverted section of Cheonggyecheon Stream.

The Solution

A 3.6 mile green corridor for pedestrians, cyclists, and wildlife was created by demolishing an elevated freeway and daylighting a section of Cheoggyencheon stream. This project restored connections between waterways, and included a fish spawning ground where the Cheonggyecheon meets the Jungnangcheon River. A variety of wetland habitats for fish, amphibians, insects, and birds were created in 29 different locations. Concrete from the demolished highway was re-used to create terraced vertical walls which provide access to pedestrians at different water levels. The project increased the value of properties within 50 m of the site by 30 – 50%, increased the number of businesses in the area by 3.5% and attracts an average of 64,000 visitors daily.

Benefits:

- Provides protection for up to a 200-year flood (flow rate of 118 mm/hr)
- Increased biodiversity by 639%: plant species went from 62 to 308, fish from four to 25, birds from six to 36, aquatic invertebrates from five to 53, insects from 15 to 192, mammals from two to four and amphibians from four to eight.
- Reduces urban heat island effect by 3.3°C to 5.9°C.
- Reduced particulate air pollution by 35%.
- Contributed to a 15.1% increase in bus ridership and 3.3% increase in subway ridership.
- The project is thought to have contributed to the higher business growth experienced in the Cheoggyecheon area compared to the rest of Seoul
- Attracts an average of 64,000 visitors per day, including 1,408 foreign tourists.

Biodiversity and Ecosystem Services Derived from Cheonggyecheon Stream Restoration					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	Biodiversity increased by 639% overall.	Wetland habitats for a wide variety of taxa were created as a result of this project.
	Habitat for Native species	X	H	Wetland and stream habitat was created.	Structural habitat and water quality
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Carbon storage was not discussed, though would have been improved through wetland construction and plantings.	Uptake of carbon by wetland plants through photosynthesis and long term storage in wetland substrates.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)	X	M	Particulates were reduced by 35%	Reduction in traffic and increased filtration by plants.
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	H	Reduces urban heat island effect by 3.3 to 5.9° C.	Improved air flow, reduction in paved surfaces, increase in vegetation
Pollination	Maintain or increase pollination				

Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	H	Protection for up to a 200 year flood	Reduction in impervious surfaces, increase in stream and wetland area
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being	X	H	Encourages pedestrianism	Provides pedestrian access
	Recreation	X	H	Attracts 64,000 visitors per day	Space to walk and view nature
	Aesthetic appreciation				
	Tourism	X	H	Attracts 64,000 visitors daily, including foreign tourists. The area experienced greater economic growth than the rest of Seoul.	Aesthetics, experience of nature.

5.3.1.7 Case Study Brief 7, Phytoremediation of a pond contaminated by the Chernobyl nuclear disaster

Project type: Bioremediation

Phytoremediation of a pond contaminated by the Chernobyl nuclear disaster

Project Description
This project used bioremediation to reduce radioactive contaminated in water.

Reference
Chhotu, D.J. and M.H. Fulekar. 2009. Phytoremediation of heavy metals: Recent techniques. African Journal of Biotechnology 8(6), 921 – 928.

Location
Chernobyl, Ukraine.

The Problem
The Chernobyl nuclear disaster contaminated a large area of land and ponds with radionuclides.

The Solution
In one of a number of bioremediation efforts, sunflowers were planted as a demonstration of phytoremediation in a contaminated pond. After two weeks, concentrations of radioactive cesium-137 and strontium-90 in the sunflowers were 8000 times that of the water. The concentration of radionuclides on the pond was reduced by 90%. Contaminated plants were safely disposed.

Benefits:

- Soil remediation
- Reduce impacts of an prevent further health impacts from the Chernobyl disaster
- Reduced erosion

Biodiversity and Ecosystem Services Derived from Chernobyl Phytoremediation

Biodiversity and Ecosystem Services			Relative Increase or proportion within this case study H, M, Low	Sustainability Feature	Ecological Function or Process to be Protected
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species				
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal				

	Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage				
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	H	90% of radionuclides were removed from pond water after 2 weeks	Uptake of radionuclides by sunflowers through roots
	Pollution Mitigation (Soil)	X	M	Authors did not comment on soil remediation, though this would also have been accomplished.	Uptake of radionuclides by sunflowers through roots
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion	X	M	Sunflowers replanted in succession during remediation help keep soil in place.	Sunflower roots stabilize soil.
Supporting Services					
	Primary Productivity				

	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being	X	H	Reduction in ambient radionuclides is extremely beneficial in preventing further health impacts.	Removal of dangerous compounds by plants.
	Recreation				
	Aesthetic appreciation				
	Tourism				

5.3.1.8 Case Study Brief 8, Columbia, Missouri Treatment Wetlands

Project type: Water treatment and regulation by wetlands, Bioremediation

Project Title: Columbia, Missouri treatment wetlands

Project Description

This case study documents the used of restored wetlands to reduce downstream biological oxygen demand (BOD). By reducing BOD more oxygen will be available for aquatic species.

Reference

Kadlec, R.H., C. Cuvellier, and T. Stober. 2010. Performance of the Columbia Missouri treatment wetland. Ecological Engineering 36(5), 672 – 684

Location

The wetlands were developed in Columbia, Missouri, USA.

The Problem

Secondary treatment was needed to augment the quality of water exiting an existing activated sludge treatment plant. The treatment plant had exceeded its capacity, and was failing to meet water quality standards in four of 12 months of the year.

The Solution

A marsh ecosystem was designed in 1990-91 to help control biochemical oxygen demand (BOD) and total suspended solids (TSS). The complex includes three wetland units, the first with eight cells, the second with four cells and the third with six cells for a total of 37 ha. Cattails (*Typha latifolia*) were planted in each cell. The wetland has been successful in reducing BOD to the required level and TSS below the required level. Treated water discharged from the treatment wetlands supplies wetlands in a conservation area, reducing demands on the Missouri River. The conservation area is used for a wide variety of recreational activities.

Benefits:

- Provides secondary water treatment to municipal sewage
- Provides fresh water input to conservation area which provides recreational benefits
- Carbon sequestration is not discussed, but is a major benefit of wetlands

Biodiversity and Ecosystem Services Derived from Columbia, Missouri treatment wetlands					
Biodiversity and Ecosystem Services			Relative Increase or proportion within this case study H, M, Low	Sustainability Feature	Ecological Function or Process to be Protected
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species				
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water	X	H	Provides fresh water to a conservation area and reduces water demands on Columbia River	Wetlands treat waste water by settling of pollutants, adhesion to plant surfaces, and microbial decomposition.
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage				
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or				

	increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment	X	H	Wetlands reduce BOD and TSS to guideline levels or better.	Wetlands treat waste water by settling of pollutants, adhesion to plant surfaces, and microbial decomposition.
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling	X	M		Cattails take up Carbon, phosphorous and Nitrogen
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation	X	M	The recreational benefits are indirect through provision of water to a recreational area.	Wetlands treat waste water by settling of pollutants, adhesion to plant surfaces,

					and microbial decomposition.
	Tourism				

5.3.1.9 Case Study Brief 9, Sonoran Desert Preserve

Project type: Ecosystem Services in Urban Planning, Preserves

Sonoran Desert Preserve

Project Description

The case study presents the results of a multi - stakeholder planning process to preserve the desert ecosystem around Phoenix Arizona.

Reference

Ewan, J., R.F. Ewan, J. Burke. 2004. Building ecology into the planning continuum: case study of desert land preservation in Phoenix, Arizona (USA). Landscape and Urban Planning 68(2004), 53 – 57

Location

The study focuses on the North Phoenix Area, Arizona, USA.

The Problem

As of the year 2000, Phoenix was the sixth largest city in the USA, and had been growing about 3.5 times faster than the average US annual growth rate since 1990. Population growth, gravel mining and grazing pressure are threatening the natural Sonoran desert landscape in the North Phoenix Area. Traditionally, land-use planning was driven by economic considerations, with the desert environment viewed as a constraint to development (i.e. aridity and flash flood risks).

The Solution

The Sonoran Desert Preservation plan was developed in consultation with a wide variety of stakeholders. The plan focused on preserving both ecosystem processes and scenic quality of the desert, including: habitat connectivity, hydrologic processes, sensitive plant communities, geologic features and archaeological sites. Preserved tracts of desert were designed with buffers where development transitioned from low to high intensity further away from the preserve.

Three alternatives were considered for the Sonoran desert preserve: Concentrated (preserve is in one large parcel); Semi-concentrated (mostly one large parcel, but also some dispersed open space throughout developed areas); Dispersed (preserve is completely integrated into developed areas). The Concentrated design was preferred by 61% of stakeholders, with the semi-concentrated second with 33%. Due to the high degree of public support and collaborative planning process, this plan has been implemented, with 985 ha already purchased and another 380 ha in process of being purchased as of the publication of this article (2004).

Benefits:

- Micro-climate regulation
- Hydrologic connectivity
- Habitat for wildlife
- Cultural ecosystem services

Biodiversity and Ecosystem Services Derived from Sonoran Desert Preserve					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X	H	The three design options provided varying levels of habitat quality for wildlife species.	Structural habitat connectivity
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage				
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	M	Climate regulation differed between different design options.	Shade provided by vegetation
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in				

	Landslide Potential				
	Reduced Flooding	X	H	Maintaining natural hydrologic conditions allows for the regular flash flood cycles without developing in high risk areas.	Natural drainage patterns and watersheds maintained.
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity	X	H	Archaeologically sensitive areas protected.	
	Mental and physical well-being	X	H	Scenic nature of the desert maintained.	Natural aesthetics
	Recreation				
	Aesthetic appreciation				
	Tourism				

5.3.1.10 Case Study Brief 10, Ecosystem Service trade-offs in the urban region of Leipzig-Halle, Germany

Project type: Assessment of Ecosystem Services/ Landscape Planning

Ecosystem Service trade-offs in urban region: Leipzig-Halle region, Germany

Project Description

This was a landscape assessment and planning exercise that evaluated the tradeoffs of different land uses.

Reference

Haase, D., N. Schwarz, M. Strohback, F. Kroll, and R. Seppelt. 2012. Synergies, trade-offs, and losses of ecosystem services in urban regions: an integrated multiscale framework applied to the Leipzig-Halle region, Germany. *Ecology and Society* 17(3), 22

Location

This study examined ecosystem service trade-offs in the rural-urban region of Leipzig-Halle, in eastern Germany.

The Problem

Trade-offs between ecosystem services as a result of urban development should be assessed. The authors used spatial modeling to assess trade-offs between five ecosystem services in the Leipzig-Halle region, which has seen restoration of former mine sites, and land-use changes from agriculture to residential developments.

The Solution

The authors used spatial modeling to determine tradeoffs between five ecosystem services between 1990 and 2006. Results show a trade-off between agricultural food production and recreation in grassland areas and synergies between above-ground carbon storage and biodiversity potential. Above-ground carbon storage increased in areas that went from treeless agricultural fields to residential areas and with the afforestation of former mine sites.

Benefits:

- Flood risk mitigation
- Recreation potential
- Biodiversity potential
- Food supply
- Above-ground carbon storage

Biodiversity and Ecosystem Services Derived from The Leipzig-Halle Ecosystem Services Assessment					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X	H	Afforestation of old mine sites and conversion of treeless agricultural fields to treed residential areas improved habitat for birds.	Nesting and foraging habitat provided for birds by trees.
Provisioning Services					
	Food	X	H	The authors model the impacts of different development densities on agricultural production.	Reducing land conversion in the form of urban sprawl preserves agricultural land.
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	H	Reducing urban sprawl in favour of high density development maintains higher carbon storage capacity.	Maintaining available land-base for carbon sequestration
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				

	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	h	Flood risks were higher under the higher density development scenario.	High density development reduces subsurface water storage more than sprawling development, and increases the number of people in flood prone areas.
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation	X	M	Recreational benefits were highest when grassland	Grassland provides recreational space

				area was maximized.	
	Aesthetic appreciation				
	Tourism				

5.3.1.11 Case Study Brief 11, Masdar City, Abu Dhabi Urban Planning.

Project type: Park, Ecosystem Services in Urban Planning, Assessment of Ecosystem Services

Trade-offs in ecosystem services during urban planning: Masdar City case study

Project Description
The authors used a geographical information system in urban planning to maintain ecosystem services.

Reference
Gret-Regamey, A., E. Celio, T.M. Klein, & U.W. Hayek. 2013. Understanding ecosystem services trade-offs with interactive procedural modeling for sustainable urban planning. *Landscape and Urban Planning* 109(2013), 107-116.

Location
The authors use Masdar City in Abu Dhabi, United Arab Emirates, to illustrate their methods. Near Abu Dhabi, Masdar City will be 650 ha with approximately 135 people per ha.

The Problem
Maintaining and enhancing certain ecosystem services in an urban planning context can come at the expense of other ecosystem services. Understanding and explicitly considering these trade-offs in urban planning is extremely difficult.

The Solution
The authors developed a GIS-based 3D visualization tool to help stakeholders and decision-makers incorporate ecosystem service trade-offs in urban planning. The tool uses interactive slider-bars that allow users to explore trade-offs in ecosystem services between different urban designs.

Masdar City is a new zero-emissions city planned near Abu Dhabi.
The case study focuses on "Linear Park", a 2.5 ha park that will be located in the core of Masdar. The authors proposed three design options for the park, differing primarily on vegetation characteristics. Design options were called Indigenous, Mixed, and Mediterranean. While the Mixed and Mediterranean designs provided the greatest climate regulation and habitat, the Indigenous design conserved the most water.

Benefits:
- Micro-climate regulation
- Habitat for wildlife
- Cultural ecosystem services

Biodiversity and Ecosystem Services Derived from Masdar City Urban Planning					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study** **H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X	L	The three design options provided varying levels of habitat quality for wildlife species.	Structural habitat
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water	X	L	Different design options had differing water requirements.	Planting indigenous xerophytic vegetation reduced water demands.
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage				
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	M	Climate regulation differed between different design options.	Shade provided by vegetation
Pollination	Maintain or increase				

	pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being	X	H	Access to a natural area in an extremely urbanized region	Access to natural areas
	Recreation	X	H	Park provides an area for outdoor recreation.	Access to natural areas
	Aesthetic appreciation				
	Tourism				

5.3.1.12 Case Study Brief 12, The Clarence River Fish Passage

Project type: Aquatic Ecosystem Restoration

Fish passage and tidal flow restoration in the Clarence river estuary

Project Description
A culvert was inserted thorough a causeway to re-establish tidal exchange and fish passage.

Reference
Nellemann, C.E. & Corcoran. 2010. Dead Planet, Living Planet – Biodiversity and ecosystem restoration for sustainable development. A Rapid response assessment. United Nationes Environment Programme, GRID-Arendal. www.grida.no (p. 30).

Location
Clarence River estuary, on the east coast of Australia.

The Problem
A causeway, initially built in the 1920s, prevented tidal flow from entering the Clarence river estuary. The causeway was a barrier to fish passage and prevented marine species from accessing important nursery habitat (i.e. seagrass beds and side channels). Sediment accumulated against the causeway, causing algal blooms and raising water temperatures, killing remaining seagrass beds.

The Solution
A doublecell box culvert was installed to reestablish tidal exchange and enable fish passage. Nutrient and dissolved oxygen levels are returning to normal and wading birds have returned. Temperature extremes have been eliminated, allowing seagrass beds to regenerate. Numerous fish species have benefited, and recreational anglers have begun using the area.

Benefits:

- Biodiversity: habitat for fish and other aquatic species as well as birds has been restored
- Recreational angling opportunities have been restored
- The restored estuary will be better able to buffer storm and flood events

Biodiversity and Ecosystem Services Derived from the Clarrence River Fish Passage					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	Fish and birds have returned to the estuary since restoration.	Fish passage; spawning and rearing habitat. Perches and foraging areas for birds.
	Habitat for Native species	X	H	Fish and bird habitat has been restored.	Reconnecting the marine and estuary habitat has provided habitat for fish and birds and has allowed seagrass beds to begin regenerating.
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	H	Estuaries play an important role in sequestering carbon.	Carbon uptake and storage by seagrass
	Moderation of Extreme Weather events.	X	H	Estuaries buffer storm events.	Estuaries provide a larger area to buffer storm surges. Vegetation protects coast.
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	H	Reduced sedimentation and improved circulation has improved water quality.	Reduced sedimentation has increased water circulation and depth and reduced biological oxygen demand.
	Pollution				

	Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	H	Estuaries buffer flood events.	Estuaries provide a larger area to buffer flood levels.
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity	X	H	Seagrass beds are among the most productive ecosystems on the planet.	Uptake growth of seagrass through photosynthesis
	Preservation and generation of soils				
	Nutrient Cycling	X	H	Seagras beds and estuaries in general are an important link in nutrient cycling: this is where nutrient exchange between river and marine environments occur.	Physical exchange of waters bearing nutrients between river and marine environment
	Water Cycling	X	H	Water cycling between marine and river environments occurs in estuaries.	Physical exchange of waters between river and marine environment
Cultural Services					
	Social Cohesion				

	Sense of identity				
	Mental and physical well-being				
	Recreation	X	H	Restored fish and bird populations provide recreational angling and bird watching opportunities; restored estuary is a place to go boating.	Fish and bird habitat (seagrass beds, fish passage, native vegetation). Connection between marine and fresh water ecosystems.
	Aesthetic appreciation				
	Tourism	X	H	Restored fish and bird populations provide recreational angling and bird watching opportunities; restored estuary is a place to go boating.	Fish and bird habitat (seagrass beds, fish passage, native vegetation). Connection between marine and fresh water ecosystems.

5.3.1.13 Case Study Brief 13, Gary Comer Youth Center

Project type: Green roof / Urban Agriculture

Gary Comer Youth Center

Project Description
This is an architectural project that incorporates urban agriculture on a green roof.

Reference
Hoerr Schauldt Landscape Architects. 2006. Gary Comer Youth Center. Landscape Architecture Foundation Landscape Performance Series Case studies. Available at: http://www.lafoundation.org/research/landscape-performance-series/case-studies/case-study/384/ Last accessed: 29 May 2013

Location
The Gary Comer Youth Center is located on a 8,160 square foot site on Chicago's southside.

The Problem
The challenge was to develop urban agriculture in a highly urbanized area with a climate that varies widely between seasons.

The Solution
An 8,160 square foot green roof was created with soil depth of 18 to 24 inches to allow for food production and drainage. The green roof buffers Chicago's temperature extremes: temperatures remain 20 – 30° F warmer in the winter and 10° F cooler in the summer. The roof includes six large light wells which provide solar lighting to the gymnasium and café below.

Benefits:

- Produces 1,000 lbs of fruits and vegetables each year. This feeds 175 children at the center daily, is used at four local restaurants, and sold at a farmers market.
- Extreme temperatures are buffered: temperatures on the roof remain 20 – 30° F warmer in the winter and 10° F cooler in the summer.
- Saves $250 in annual heating and cooling costs compared to a traditional roof.
- Provides educational opportunities for around 600 students and community members.

Biodiversity and Ecosystem Services Derived from The Gary Comer Youth Center

Biodiversity and Ecosystem Services			Relative Increase or proportion within this case study H, M, Low	Sustainability Feature	Ecological Function or Process to be Protected
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	x	L	The green roof provides habitat for native birds and pollinators.	Vegetation provides perches and foraging.
Provisioning Services					
	Food	x	H	1,000 lbs. of fruits and vegetables are produced each year	Soil quality, drainage, nutrient cycling.
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	x	M	Energy use is reduced by $250 per year in the building. Vegetation sequesters some carbon.	Buffers extreme temperatures and insulated the building. Plant growth sequesters carbon.
	Moderation of Extreme Weather events.				
	Pollution Mitigation				

	(Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	M	The project buffers temperature extremes: 20° F to 30° F warmer in winter and 10° F cooler in summer.	Green roof reflects heat and controls microclimate.
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	L	Instead of running off of an impermeable roof, water filters into the soil and irrigates crops.	Provides a permeable surface for drainage and vegetation to take up rain water
Cultural Services					
	Social Cohesion				
	Sense of				

	identity				
	Mental and physical well-being	X	H	Provides food and educational opportunities for children and community members.	
	Recreation				
	Aesthetic appreciation				
	Tourism				

5.3.1.14 Case Study Brief 14, The Gladstone Hotel Green Roof

Project type: Green Roof

Project Title: Gladstone Hotel Green Roof

Project Description

The Gladstone Hotel in Toronto, Canada is retrofitted with a green roof for multiple ecosystem service benefits.

Reference

City of Toronto. 2011. ECOroof Case Study: Gladstone Hotel.
Available at: http://www.toronto.ca/livegreen/downloads/ecoroof_gladstone.pdf Last Accessed: 10 June 2013

Location

Central Toronto, Ontario, Canada.

The Problem

The historic Gladstone Hotel, originally built in 1889, and restored in 2000 was voted one of National Geographic's Traveler Stay Guide's most loved hotels. When the hotel's steep roof was repaired to meet modern building codes, a storm water runoff problem resulted, flooding the basement and kitchen during each mid to heavy rain fall.

The Solution

A green roof was installed to manage storm water runoff and to make the hotel more efficient. The 540 m^2 roof diverts 264,585 L of runoff from the municipal storm drain system each year and saves 31,131 Gigajoules of natural gas-fired energy. The roof reduces GHG emissions by 59 Kg each year by diverting storm water alone.

Benefits:

- Resolved storm water runoff problem
- Improves energy efficiency
- Reduces GHG emissions
- Improves air quality
- Provides habitat for birds
- Buffers temperature extremes

Biodiversity and Ecosystem Services Derived from The Gladstone Hotel Green Roof					
Biodiversity and Ecosystem Services			Relative Increase or proportion within this case study H, M, Low	Sustainability Feature	Ecological Function or Process to be Protected
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X	L	The roof provides some habitat for birds.	Vegetation on the roof provides nesting and foraging habitat.
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	L	Vegetation on the roof will sequester some carbon.	Uptake and storage of carbon by vegetation and soil.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)	X	L	Vegetation on the roof provides some air filtering benefits.	Vegetation filters out some particulate pollution and toxins
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	M	Green roof buffers temperature extremes.	Vegetation insulates the hotel
Pollination	Maintain or increase pollination				
Hazard					

Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	H	Eliminated flooding inside the hotel.	Vegetation absorbs water and slows flow of runoff
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity	X	L	Green roof vegetation provides some primary productivity .	Plant growth through photosynthesis
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	M	The garden would absorb rain water and runoff, allowing for water table recharge.	Reducing the amount of impermeable surface area in a city
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation				
	Tourism	X	H	The restored hotel made National Geographic's "most loved hotels" list.	

5.3.1.15 Case Study Brief 15, The Golden Horn Estuary Restoration

Project type: Aquatic Ecosystem Restoration

Golden Horn Estuary Restoration

Project Description
This is a large urban redevelopment and ecosystem restoration project in Istanbul Turkey.

Reference
Nellemann, C.E. and Corcoran. 2010. Dead Planet, Living Planet – Biodiversity and ecosystem restoration for sustainable development. A Rapid response assessment. United Nations Environment Programme, GRID-Arendal. www.grida.no (p. 45).

Location
The project restored the Golden Horn Estuary, Istanbul, Turkey.

The Problem
Unchecked industrial development in Istanbul resulted in major damage to local water resources. Industrial wastes created anoxic sediments which lead to fisheries collapse, poor water clarity, and strong hydrogen sulfide odors.

The Solution
This project took place over two decades. Industries were relocated and waste water infrastructure was developed. Anoxic sediments were dredged and removed from the estuary, and a bridge that impeded water circulation was removed. Cultural and social facilities were created.

Benefits:

- Biodiversity: aquatic organisms once again inhabit the estuary
- Local fisheries have begun to reestablish
- Tourism has benefited
- Istanbul has regained a lost sense of cultural identity

Biodiversity and Ecosystem Services Derived from The Golden Horn Estuary Restoration

Biodiversity and Ecosystem Services			Relative Increase or proportion within this case study H, M, Low	Sustainability Feature	Ecological Function or Process to be Protected
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X	H	Habitat for fish and other aquatic species has been restored.	Water quality
Provisioning					

Services					
	Food	X	M	Fisheries are beginning to reestablish in the estuary	Water quality and fish habitat
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage				
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	H	Anoxic sediments were removed as was a bridge impeding circulation.	Water circulation, reduced industrial effluent.
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					

	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being	X	H	Improved water quality and reduction in undesirable odors has restored a sense of pride in the Golden Horn estuary.	Improvements in water quality, reduction in negative odors
	Recreation				
	Aesthetic appreciation				
	Tourism	X	L	The restoration project has made some positive contributions to tourism.	Water quality, reduction in negative odors

5.3.1.16 Case Study Brief 16, High Desert Community

Project type: Including ecosystem services in urban planning

High Desert Community

Project Description
A low impact desert community is designed around existing landscape features.

Reference
Design Workshop Inc. 2010. High Desert Community. Landscape Architecture Series Landscape Performance Series Case Studies.
Available at: http://www.lafoundation.org/?page_id=403&template_id=31&preview=true Last Accessed: 29 May 2013

Location
High desert community is a 1,067 acre residential development planned near Albuquerque, New Mexico. Expected completion date is 2030.

The Problem
The challenge was to design a low-impact residential community in an ecologically sensitive area. Objectives included: maintaining viewscapes, managing stormwater runoff, minimizing habitat fragmentation.

The Solution
The community was designed around natural landscape features. The development plan conserved stormwater and existing hydraulic paths. Habitat fragmentation was minimized by maintaining multifunctional open spaces and wildlife corridors. The design includes locally-sourced materials, permeable surfaces, native vegetation and natural hydraulic recycling.

Benefits:
- Maintains 50% of original ecotype
- Saves up to 28.7 million gallons of water per year
- Maintains 7 acres more critical breeding habitat for Peregrine Falcon and Gray Vireo than traditional community design
- Increased carbon sequestration by 170,160 tons by restoring twice the vegetation displaced by all areas of disturbance during development
- Uses decomposed-granite mulch instead of traditional wood chip mulch: this preserves 15,230 trees per year, and saves up to 100,000 gallons of fuel and 617,600 tons of carbon emissions over ten years.

Biodiversity and Ecosystem Services Derived from High Desert Community					
Biodiversity and Ecosystem Services			Relative Increase or proportion within this case study H, M, Low	Sustainability Feature	Ecological Function or Process to be Protected
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X	H	Maintains and restores breeding bird habitat	Breeding habitat
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water	X	H	Conserves 28.7 million gallons of water per year: this community will use 80% less than allocated by municipal water allowances.	Improved infiltration and water recycling
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	H	Doubles the volume of vegetation from pre- to post-development which increases carbon sequestration by 170,160 tons. Uses granite mulch instead of wood-chips, saving 15,230 trees per year and reducing carbon emissions by 617,600 tons over ten years.	Carbon uptake by vegetation.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution				

	Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	M	The community design reduces impermeable surfaces and enhances infiltration and hydraulic recycling.	Infiltration and recycling of surface waters
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation	X	H	Uses 80% less water than municipal allowance. Enhances infiltration and hydraulic recycling	Infiltration and recycling of surface waters
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	H	Community design enhances infiltration and hydraulic recycling.	Permeable surfaces facilitate infiltration
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation				

	Aesthetic appreciation	X	H	Aesthetic experience of nature.	Viewscapes are maintained for residents.
	Tourism				

5.3.1.17 Case Study Brief 17 Assessment of Ecosystem Services Under Alternative Growth Scenarios

Project type: Assessment of Ecosystem Services

Country wide planning: Assessing Different Growth Scenarios

Project Description
For all of Great Britain the authors examine the ecosystem services effects of projected population increases and different density scenarios.

Reference
Eigenbrod, F., V.A. Bell, H.N. Davies, A. Heinemeyer, P.R. Armsworth, & K.J. Gaston. 2011. The impact of projected increases in urbanization on ecosystem services. *Proceedings of the Royal Society B* 278, 3201 – 3208

Location
This study incorporated all of Britain.

The Problem
Urbanization will probably be the main driver of land-use change in Europe. This will alter ecosystem services and their beneficiaries with uncertain consequences.

The Solution
The authors model anticipated land-use changes in Britain due to projected population increases by 2031, and how these changes would affect flood mitigation, agricultural production and carbon storage. Two development scenarios, bookending the range of probable growth rates for Britain, were analyzed. One scenario assumes continued urban sprawl, while the other favours high density development which minimizes land-use change.

Results suggest that the impacts on flood mitigation are higher under the high density scenario, while impacts on agricultural production and carbon storage are more severe under the urban sprawl scenario. The difference in flood impacts are attributable to the higher number of people that would live in areas projected to see increased flood risk under the high density scenario, and the greater reduction in subsurface water storage caused by high density housing. Conversely, the sprawl scenario results in more overall land conversion, reducing the capacity for agricultural production and carbon storage.

Benefits:
- Flood control
- Agricultural production
- Carbon storage

Biodiversity and Ecosystem Services Derived from Alternative Growth Scenarios					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study** **H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species				
Provisioning Services					
	Food	X	H	The authors model the impacts of different development densities on agricultural production.	Reducing land conversion in the form of urban sprawl preserves agricultural land.
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	H	Reducing urban sprawl in favour of high density development maintains higher carbon storage capacity.	Maintaining available land-base for carbon sequestration
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or				

	increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	H	Flood risks were higher under the higher density development scenario.	High density development reduces subsurface water storage more than sprawling development, and increases the number of people in flood prone areas.
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation				
	Aesthetic appreciation				
	Tourism				

5.3.1.18 Case Study Brief 18, Restoration of limestone forests in Phuc Sen in Northwestern Vietnam

Project type: Ecological Restoration of Forests

Restoration of limestone forests in Phuc Sen in Northwestern Vietnam

Project Description

This project restored communally managed forests in Son La District, Northwestern Vietnam.

Reference

Nellemann, C.E. and Corcoran. 2010. Dead Planet, Living Planet – Biodiversity and ecosystem restoration for sustainable development. A Rapid response assessment. United Nations Environment Programme, GRID-Arendal. www.grida.no (p. 27).

Location

This project restored communally managed forests in Son La District, Northwestern Vietnam.

The Problem

Forests, traditionally managed by ethnic communities, were degraded by harvest by government and local villages. The affected forests grew on steep karst slopes, and played an important role in hydrologic cycling by reducing runoff and storing moisture in the soil during the dry season. Ethnic communities that traditionally manage these forests wished to restore hydrologic cycling as well as the aesthetic value of the forest.

The Solution

Twelve ethnic communities collaborated and planted indigenous trees in their traditional forested lands. Natural regeneration was allowed to occur. Reforestation restored spring flows which irrigate rice fields. The restored forests also provide habitat for native mammal species, including five endemics and 26 rare species.

Benefits:

- Restored a spring used to water rice fields
- Restored traditional management by ethnic communities
- Restored habitat for native mammal species
- Restored diversity of mammal species

Biodiversity and Ecosystem Services Derived from Restoration of limestone forests					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	Five endemic and 26 rare species have returned.	Structural (forest) habitat for mammals.
	Habitat for Native species	X	H	Forested habitat was restored.	Structural habitat.
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water	X	H	Spring used to irrigate rice fields was restored.	Hydrologic cycling: runoff reduced and infiltration increased by forest restoration.
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Restored forests sequester carbon.	Uptake of carbon by vegetation.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	M	Restored forests would provide shade and absorb heat.	Shade provided by forest stands and absorption of heat.
Pollination	Maintain or increase pollination				

Hazard Regulation					
	Reduction in Landslide Potential	X	H	Restored forest plays an important role in stabilizing karst slopes.	Tree roots stabilize steep slopes
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion	X	H	Restored forest plays an important role in stabilizing karst slopes.	Tree roots stabilize steep slopes
Supporting Services					
	Primary Productivity	X	M	Restored forests provide primary productivity.	Photosynthesis by vegetation
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	H	Restored forests restored hydrologic functions.	Tree roots stabilize karst slopes and facilitate drainage
Cultural Services					
	Social Cohesion	X	H	This work was a collaboration between 12 ethnic communities.	
	Sense of identity	X	H	Ethnic community values forest for aesthetics as well as water supply. Management by ethnic communities also restored.	Forest aesthetics
	Mental and physical well-being				
	Recreation				
	Aesthetic appreciation	X	H	Ethnic community values forest for aesthetics as well as water supply. Management by ethnic communities also restored.	Forest aesthetics

	Tourism				

5.3.1.19 Case Study Brief 19, The Maloti-Drakensberg Transfrontier Project

Project type: Preserve, Terrestrial Ecosystem Restoration

Maloti-Drakensberg Transfrontier Project

Project Description

The project combined landscape management and payment for ecosystem services to maintain and enhance ecosystem services.

References

Mander, M., J. Blignaut, R. Schulze, M. Horan, C. Dickens, K. van Niekerk, K. Mavundla, I. Mahlangu, A. Wilson, and M. McKenzie. An Ecosystem Services trading model for the Mweni/Cathedral Peak and Eastern Cape Drakensberg Areas. International Resources Institute Report no. IR 281. Available at: http://www.futureworks.co.za/PES%20FINAL%20REPORT%206%20MARCH%2008.pdf

Location

The project took place in the Maloti Drakensberg mountains and watersheds at the South Africa – Lesotho border.

The Problem

The Maloti Drakensberg Transfrontier Project sought a strategy to develop incentives for land users in the region to maintain and enhance ecosystem services. Important services include providing 25% of South Africa's freshwater, the mountains are a World Heritage site of biodiversity and cultural significance, and a site with significant ecotourism opportunities.

The Solution

The project team used modeling to identify grassland management patterns that maximize water recharge, sediment reduction and carbon sequestration. An institutional framework for payment for ecosystem services (maintaining grassland cover) was developed including capacity building with stakeholders. An economic model was used to estimate the value of each ecosystem service. South Africa's Department of Water Affairs and Forestry was identified as the main beneficiary and therefore the most appropriate funder of a payment for ecosystem services scheme. Raw Water Charges were chosen as a vehicle that the Department of Water Affairs and Forestry can use to generate payments to land managers in the region for managing grassland habitat. Strategic partnerships with other beneficiaries must be developed to secure additional funds for payments (ie carbon and biodiversity trading).

Benefits:

- Maintenance of a critical watershed that provides 25% of South Africa's water supply
- Maintaining habitat for wildlife including 11 endemic mammal species and 32 endemic bird species
- Carbon sequestration
- Soil formation
- Sedimentation prevention
- Ecotourism and cultural monuments: the area is a UNESCO World Heritage site
- Subsistence harvesting of food and structural materials

Biodiversity and Ecosystem Services Derived from The Maloti-Drakensberg Transfrontier Project					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	The region supports many endemic species including 11 mammals and 32 birds. The region is one of the eight centers of reptile and amphibian diversity in southern Africa.	Structural habitat for wildlife.
	Habitat for Native species	X	H	Grasslands provide habitat for biodiversity.	Grassland habitat
Provisioning Services					
	Food	X	M	Wild foods and medicines are provided by the ecosystems.	Vegetation cover and availability
	Raw Materials	X	M	Grasslands are harvested to provide thatch for roofs.	Maintaining grassland cover.
	Fresh water	X	H	This region is South Africa's most important water supply area, contributing 8000 million m3 in mean annual runoff.	Maintaining watershed connectivity, drainage and recharge.
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Carbon is taken up by growing plants. In the Drakensberg region most carbon is stored in the soil.	Vegetation cover and soil conservation.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				

	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility	X	M	Vegetation cover maintains soil formation processes.	Vegetation keeps soil in place and contributes nutrients to soil formation processes.
	Reduced Erosion	X	H	Vegetation cover prevents erosion. This reduces siltation in the river systems.	Maintain vegetation cover.
Supporting Services					
	Primary Productivity	X	M	Grasslands provide some primary productivity	Photosynthesis by vegetation
	Preservation and generation of soils	X	M	Vegetation cover maintains soil formation processes.	Vegetation keeps soil in place and contributes nutrients to soil formation processes.
	Nutrient Cycling				
	Water Cycling	X	H	Drainage and hydrologic connectivity is maintained	Vegetation and soil quality and ecosystem connectivity.
Cultural Services					
	Social Cohesion				
	Sense of	X	H	As a UNESCO world	Maintaining

	identity			heritage site, the region is something to be proud of.	ecosystem connectivity and cultural sites.
	Mental and physical well-being				
	Recreation				
	Aesthetic appreciation				
	Tourism	X	H	This is a UNESCO world heritage site for both biodiversity and cultural heritage.	Bird watching, other wildlife viewing, cultural monuments.

5.3.1.20 Case Study Brief 20, Rock Creek and Ignacio Creek stream restoration

Project type: Riparian Corridors, Aquatic Ecosystem restoration

Project Title: Rock Creek and Ignacio Creek stream restoration

Project Description
Restoration of native riparian vegetation improved stream quality

Reference
Biohabitats Inc. Rock Creek III, IV & V and Ignacio Creek Stream Restoration Design – Build. La Plata County, Colorado. Available at: http://www.biohabitats.com/wp-content/uploads/RockCreekIgnacioCreek.pdf Last Accessed 9 June 2013.

Location
This project took place on Rock Creek in La Plata County, southwestern Colorado, USA.

The Problem
Over-grazing resulted in severe bank erosion on Rock Creek.

The Solution
The stream bank was stabilized with re-grading and creation of riparian habitat. Native riparian species such as willows and cottonwoods were planted. Riffle and pool habitat was created using coarse substrates and large woody debris.

Benefits:
- Improved water quality and reduced soil losses by reducing erosion
- Improved fish and wildlife habitat
- Enhanced Carbon Sequestration

Biodiversity and Ecosystem Services Derived from Rock Creek and Ignacio Creek stream restoration					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	M	Habitat was restored for fish and other aquatic species. Riparian vegetation provides habitat for terrestrial species.	Water quality and structural habitat.
	Habitat for Native species	X	M	Riparian vegetation provides habitat for birds, amphibians and mammals; water quality was improved for fish.	Native riparian vegetation, reduced erosion and improved water quality.
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	L	Riparian vegetation sequesters carbon and stabilizes soil, improving carbon storage.	Uptake and storage of carbon by vegetation and soil.
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	H	Riparian vegetation prevents soil erosion into streams, reducing nutrient enrichment, sedimentation and turbidity.	Riparian vegetation stabilizes banks and retains soil.
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or				

	increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential	X	M	Riparian vegetation stabilizes banks and reduces risk of small landslides and slumps.	Roots of riparian vegetation stabilize banks.
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion	X	H	Riparian vegetation stabilizes banks and reduces erosion.	Roots of riparian vegetation stabilize banks.
Supporting Services					
	Primary Productivity	X	L	Riparian vegetation adds to primary productivity	Plant growth through photosynthesis
	Preservation and generation of soils	X	M	Riparian vegetation prevents soil loss	Stabilization of banks by tree roots
	Nutrient Cycling				
	Water Cycling	X	L	Drainage and water recharged is enhanced by riparian vegetation	Vegetation intercepts rain and runoff, enhancing drainage into soil.
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation				
	Tourism				

5.3.1.21 Case Study Brief 21, Tanzanian Agro-forestry Restoration

Project type: Silviculture/Forestry, Terrestrial Ecosystem Restoration

Regenerating woodlands: Tanzania's HASHI project

Project Description
This is an agro-forestry restoration project in Tanzania

Reference:
http://www.equatorinitiative.org/images/stories/winners/83/casestudy/case_1348161099.pdf Also in Nellemann, C.E. and Corcoran. 2010. Dead Planet, Living Planet – Biodiversity and ecosystem restoration for sustainable development. A Rapid response assessment. United Nations Environment Programme, GRID-Arendal. www.grida.no (p. 27).

Location
Shinyanga Region south of Lake Victoria, Tanzania.

The Problem
Woodlands were removed to eradicate tsetse fly, create cropland, and accommodate population growth. Removing the woodlands caused desertification: the Shinyanga Region came to be known as the "Desert of Tanzania".

The Solution
The HASHI project restored vegetation in the Shinyaga Region by re-instating an ancient pastoral management system. Under this management system, pastures are broken up into communally managed enclosures called Ngitili. Ngitili included both pastures and woodlots. Resource use in Nigitili (ie grazing and silviculture) is rotated to maintain vegetation cover. Between 1986 and 2004 Ngitili were restored from 600 ha to 350,000 ha.

Benefits:
- Improved household diets and income in Shinyaga region
- Reduced desertification
- Restored native biodiversity: trees, shrubs and grasses as well as birds and mammals
- Restored indigenous resource management practices

Biodiversity and Ecosystem Services Derived from The Tanzania's HASHI project

Biodiversity and Ecosystem Services			Relative Increase or proportion within this case study H, M, Low	Sustainability Feature	Ecological Function or Process to be Protected
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	Restored vegetation, bird, and mammal diversity	Maintains vegetation, and structural habitat
	Habitat for	X	H	Restored woodlands	Structural habitat.

	Native species			provide habitat for biodiversity.	
Provisioning Services					
	Food	X	H	Maintains high quality grazing for cattle.	Soil nutrients and moisture; no over-use
	Raw Materials	X	H	Restored woodlots are sustainably used for timber.	Soil nutrients and moisture
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Restored woodlots sequester carbon.	Uptake of carbon by trees during photosynthesis
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of	X	H	Soil conditions were	Vegetation

	Soil Fertility			restored and are maintained by management through Ngitili.	maintains soil nutrients and moisture preventing desertification.
	Reduced Erosion	X	H	Soil is stabilized by vegetation and management through Ngitili	Vegetation maintains soil nutrients and moisture preventing desertification.
Supporting Services					
	Primary Productivity	X	M	Restored woodlots provide primary productivity.	Photosynthesis by trees
	Preservation and generation of soils	X	H	Soil formation is maintained by careful vegetation management.	Vegetation returns nutrients to soil through leaf litter.
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity	X	H	Indigenous management practices were restored.	Indigenous management structure.
	Mental and physical well-being	X	H	Crop and timber-based livelihoods were restored.	Pasture and woodlot regeneration.
	Recreation				
	Aesthetic appreciation				
	Tourism				

5.3.1.22 Case Study Brief 22, Sustainable Community Design

Project type: Street Trees / Urban Forests, Urban Design

The Avenue

Project Description
Planning and design of a low impact transit- oriented community.

Reference
Sasaki Associates Inc. 2011. The Avenue. Landscape Architecture Foundation Landscape Performance Series Case Studies. Available at: http://www.lafoundation.org/research/landscape-performance-series/case-studies/case-study/491/ Last accessed 29 May 2013

Location
The Avenue is a 3.5 acre site in downtown Washington DC bordered by George Washington University (south), the Foggy Bottom-GWU Metro Station and GWU Hospital (east), and Pensylvania Avenue (north).

The Problem
The challenge was to design a transit-oriented residential development, improve stormwater management and offer an outdoor experience in urban Washington DC. The design had to account for the fact that the site is above a five-level underground parkade, that the public entrance is about 15 feet lower than the courtyard, and that surrounding buildings would limit light available for vegetation.

The Solution
Landscape architects worked with engineers to design a structure that allowed large trees to be planted above the parkade. A long, gently sloped ramp was built to allow access to the courtyard. The residential property was split into two buildings connected by a two story lobby: 120 feet shorter than the residential buildings, the lobby allows more natural light into the courtyard.

Benefits:

- Diverts and reuses 76,000 gallons of stormwater runoff, eliminating the use of potable water in the landscape: native and drought-tolerant plants and efficient irrigation reduces the water needs by 62%
- Green and light-coloured roofs on residential buildings reduce summer rooftop temperatures by 40 F compared to conventional black roofs
- Will sequester over 12,000 lbs. of carbon per year once trees are fully mature
- Will create about 24,000 square feet of shade once trees mature
- Provides a relaxing place for visitors (visitors appear to spend an average of 21 minutes in the courtyard)
- Contributes $11.5 million in tax revenue each year from commercial office space, retail, and residential units.

Biodiversity and Ecosystem Services Derived from The Avenue Community					
Biodiversity and Ecosystem Services			Relative Increase or proportion within this case study H, M, Low	Sustainability Feature	Ecological Function or Process to be Protected
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X	L	Vegetation will provide some habitat.	Structural habitat
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Will sequester 12,000 lbs. of carbon per year once trees mature.	Carbon sequestration by vegetation
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	H	Green and light-coloured roofs reduce temperature by 40 F compared to traditional black roofs	Reflection of light by planted and light surfaces
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide				

	Potential				
	Reduced Flooding				
	Noise Reduction	X	L	Trees will buffer the area from some of the street noise.	Physical buffering of sound by trees
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity	X	L	Trees and other vegetation will provide some primary productivity.	Photosynthesis by trees
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	H	76,000 gallons of stormwater runoff is diverted and re-used for irrigation. No potable water is used as a result.	
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being	X	H	Provides green space for residents and office workers.	Green space in an urban environment
	Recreation	X	H	90 individuals were observed using the area for outdoor dining during the summer months.	Green space in an urban environment
	Aesthetic appreciation				
	Tourism				

5.3.1.23 Case Study Brief 23, Thornton Creek Water Quality Channel

Project type: Integrated Storm Water Management Plans and Aquatic Ecosystem Restoration

Thornton Creek Water Quality Channel

Project Description

The project is a redevelopment of a parking lot that reduced impervious surfaces, improved water quality and increased urban open space.

Reference

SvR Design Company. 2009. Thornton Creek Water Quality Channel. Landscape Architecture Foundation, Landscape Performance Series. Available at: http://www.lafoundation.org/research/landscape-performance-series/case-studies/case-study/137/ Last Accessed 12 June 2013

Location

Thornton Creek is a salmon-bearing stream in Seattle Washington. The project dealt with runoff from 680 acres of urban area.

The Problem

Runoff from 680 acres of urban Seattle was being piped directly into salmon-bearing Thornton Creek. The challenge was to improve the quality of water flowing into the creek in order to protect salmonid habitat.

The Solution

Designers created an open, planted channel to treat water flowing from the pipe. The channel is tiered, with the Upper Cascade Swale collecting runoff from 20 acres and the Lower Channel receiving runoff from the remaining area through the pipe. The design handles deeper flows than in a traditional bioswale by using densely vegetated terraces at least 30 feet wide. The channel alignment will be allowed to evolve over time. The project contributes green, public open space to the neighborhood.

Benefits:

- 78% reduction in impervious surfaces
- Removes 40 – 80% of total suspended solids from 91% of the average annual volume of stormwater runoff
- Increased open space by around 50% in the Northgate Urban Center
- Created native bird and plant habitat
- Provides a relaxing place for visitors (visitors appear to spend an average of 21 minutes in the courtyard)
- Catalyzed $200 million in adjacent private residential and commercial development.
- Added 2.7 acres of urban open space

Biodiversity and Ecosystem Services Derived from Thornton Creek Water Quality Channel					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	x	M	Improves water quality for salmonids; Provides habitat for native birds and plants in urban Northgate.	Filtration of water by plants; structural habitat.
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	L	Planted vegetation sequesters carbon.	Uptake of carbon by vegetation
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	M - H	Removes 40 to 80% of TSS from 91% of average annual runoff.	Filtration of water by plants
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					

	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment	X	H	Removes 40 to 80% of TSS from 91% of average annual runoff.	Filtration of water by plants
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity	X	L	Planted vegetation provides some primary productivity	Uptake of carbon by plants
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	H	Improves drainage and ground water recharge.	Reduction in impervious surfaces
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being	X	H	Provides greenspace in urban Northgate; provides pedestrian links between neighborhoods.	
	Recreation				
	Aesthetic appreciation				
	Tourism				

5.3.1.24 Case Study Brief 24, Tainjin Qiaoyuan Park TianjinChina

Project type: Park, Water Treatment and/or Regulation by Wetlands

Tianjin Qiaoyuan Park: The Adaptation Palettes

Project Description

A large park in Tianjin China includes aspects of landscape rehabilitation that contribute to ecosystem services.

Reference

Turenscape. 2008. Tianjin Qiaoyuan Park: The Adaptation Palettes. Landscape Architecture Foundation, Landscape Performance Series. Available at: http://www.lafoundation.org/research/landscape-performance-series/case-studies/case-study/425/ Last Accessed 12 June 2013

Location

Tianjin Qiaoyuan Park is a 54 acre park in Tianjin, China.

The Problem

The challenge was to restore ecosystem functions to a garbage dump surrounded by slumps and highways. The site was contaminated and had poor drainage. Historically, the site was a wetland, and the municipal government wanted it turned into a low-maintenance park.

The Solution

Instead of trying to restore to a historic natural state, ecosystem functions were re-established and natural succession was allowed to occur. Practitioners removed garbage and carved out 21 ponds of varying sizes and elevations. Seasonal rain washes the soil, feeds ponds and wetlands and recharges groundwater. Ground cover and wetland plants were sown and rich patches of vegetation established in response to water level fluctuations. Paths and viewing platforms were built for visitors.

Benefits:

- Reduced soil alkalinity
- Increased the number of plant species from five to 58 immediately, and to 96 within two years.
- Sequesters approximately 539 tons of carbon
- Reduces noise from 70 dB to 50dB
- Provides access to green space for 20,000 nearby residents. The park is visited by 350,000 people each year: 50% are seniors, 40% are children.
- Provides educational opportunities for approximately 500 children from nearby schools
- Improves ecological awareness of park visitors

Biodiversity and Ecosystem Services Derived from Tianjin Qiaoyuan Park					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	Increased plant species richness from 5 to 96 over two years. Waterfowl and mammal species have now also been observed on the site.	Increase in plant species diversity, provides wildlife habitat.
	Habitat for Native species				
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	H	Sequesters around 539 tons of carbon.	Vegetation takes up carbon from the atmosphere
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)	X	H	Contaminated soil is "washed" by rain.	Filtration of contaminants by wetlands
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard Regulation					
	Reduction in Landslide				

	Potential				
	Reduced Flooding				
	Noise Reduction	X	M	Reduces noise from 70 dB to 50 dB.	Buffering of urban noise by vegetation
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment	X	H	Wetlands treat wastewater.	Reduction in soil alkalinity and salinity by plant uptake
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	H	Ponds and wetlands were created which store and purify water.	Water filtration and drainage in wetlands
Cultural Services					
	Social Cohesion				
	Sense of identity	X	H	Provides educational opportunites to 500 children from nearby schools and increases environmental awareness among 83% of visitors.	Restores nature within an urban area.
	Mental and physical well-being	X	H	Provides greenspace for 20,000 nearby residents.	Restores nature within an urban area.
	Recreation	X	H	Park is visited by 350,000 people per year: 50% seniors and 40% children.	Restores nature within an urban area.
	Aesthetic appreciation	X	H	Park is visited by 350,000 people per year: 50% seniors and 40% children.	Provides an aesthetic experience of nature within an urban area.
	Tourism				

5.3.1.25 Case Study Brief 25, The Trinity River Restoration

Project type: Riparian / Aquatic Ecosystem Restoration

Project Title: Trinity River Restoration

Project Description
A river restoration project in California restores ecosystem services.

Reference
Griggs, T.F. 2009. California Riparian Habitat Restoration Handbook. Appendix 2: Case Study #3: Restoration on the Trinity River: Berm Removal.
Available at:
http://www.conservation.ca.gov/dlrp/watershedportal/InformationResources/Documents/Restoration_Handbook_Final_Dec09.pdf Last accessed: 11 June 2013

Location
Trinity River, northwestern California, U.S.A.

The Problem
The Trinity River Diversion shifted the river from highly variable flows (up to 70,000 cfs) to a constant flow of 100 to 150 cfs. As a result, sediment accumulated in berms, isolating the river from its floodplain. Flows were too low to maintain fish habitat and ground water recharge.

The Solution
Berms were mechanically removed, and coarse substrate was added to improve fish habitat. Variable flows were restored and native riparian vegetation was planted to stabilize critical areas on the banks and prevent sedimentation.

Benefits:
- Restored habitat for fish and wildlife
- Restored native riparian vegetation
- Improved water quality by reducing sedimentation and restoring variable flows
- Improved ground water recharge

Biodiversity and Ecosystem Services Derived from the Trinity River Restoration					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study** **H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	Aquatic and riparian habitat was restored for fish and wildlife.	Structural habitat, water flows and quality
	Habitat for Native species	X	H	Water flow and quality and river substrate restored for fish and other aquatic species; riparian habitat restored for terrestrial species.	Variable flows; structural habitat
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	M	Planted and naturally recolonizing vegetation will sequester and store carbon .	Uptake of carbon from the atmosphere through photosynthesis
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)	X	H	Sedimentation is reduced by restoration of riparian vegetation.	Tree roots stabilize banks
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase				

	pollination				
Hazard Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion	X	H	Riparian vegetation prevents soil erosion.	Tree roots stabilize banks
Supporting Services					
	Primary Productivity	X	M	Riparian vegetation provide some primary productivity.	Plant growth through photosynthesis
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	M	Ground water recharge was restored.	Variable flows restored, and infiltration and drainage improved by riparian vegetation
Cultural Services					
	Social Cohesion				
	Sense of identity				
	Mental and physical well-being				
	Recreation				
	Tourism				

5.3.1.26 Case Study Brief 26, Szeged Hungary GIS mapping

Project type: GIS mapping of sensitive areas for planning, Assessment of Ecosystem Service

Urban Ecology: Case Study in Szeged, Hungary

Project Description

GIS Mapping is used to demonstrate loss of ecosystem services. There is potential to incorporate the methods used onto into urban planning to enhance ecosystemservices.

Reference

Mucsi, L. Urban Ecology: Case Study in Szeged. Available at: http://www.geo.u-szeged.hu/web/sites/default/files/publikaciok/ML/41.pdf Last accessed 23 May 2013

Location

The study is of the City of Szeged, Hungary.

The Problem

Szeged is a historic Hungarian city located on the banks of the Tisza river. The city was destroyed during a flood in 1879. The author uses GIS to illustrate how re-development over the years had changed the ecosystem services in the city.

The Solution

Using data from a variety of sources, the author uses GIS to show how the City of Szeged has re-developed since the flood of 1879. Losses of urban green space have resulted from a transition from garden homes to higher density urban development. Changes to the hydrological system, reduction in urban forest, and a segmented pattern of natural areas is evident. The methods are useful for future urban-ecology planning efforts.

Benefits:

- Flood control and hydrological connectivity
- Local climate regulation and air quality improvements
- Maintaining cultural landmarks

Biodiversity and Ecosystem Services Derived from Szeged, Hungary GIS mapping					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study** **H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)				
	Habitat for Native species	X		GIS could be used to plan areas of forests to be preserved in urban areas.	Structural habitat connectivity
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage				
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation	X	M	GIS could be used to plan where green spaces should be maintained to provide shade and improve air quality.	Shade and filtration of pollutants provided by vegetation.
Pollination	Maintain or increase pollination				
Hazard					

Regulation					
	Reduction in Landslide Potential				
	Reduced Flooding	X	H	GIS could be used to preserve natural hydrologic features and plan to buffer flooding events.	Natural drainage patterns and watersheds maintained.
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion				
Supporting Services					
	Primary Productivity				
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling				
Cultural Services					
	Social Cohesion				
	Sense of identity	X	H	GIS could be used to plan development in way that ensures culturally significant areas are preserved.	
	Mental and physical well-being	X	H	GIS could be used to plan to preserve tracts of natural forests to provide urban greenspace.	Natural aesthetics
	Recreation				
	Aesthetic appreciation				
	Tourism				

5.3.1.27 Case Study Brief 27, The Yellowstone to Yukon Project.

Project type: Terrestrial Planning for Environmental Corridors

Project Title: Yellowstone to Yukon

Project Description
The Y2Y project is a proposal to create corridors for wildlife movement at a continental scale.

Reference
Yellowstone to Yukon (Y2Y) initiative website: www.y2y.net Last Accessed 4 June 2013.

Location
The Yellowstone to Yukon initiative would preserve a major wildlife corridor reaching from Yellowstone National Park, Wyoming, USA to the Yukon Territory, Canada.

The Problem
Human development across the globe has fragmented Mountain ecosystems. In many cases, this has resulted in extinction and endangerment of native species. The corridor between Yellowstone National Park and the Yukon Territory is the last remaining intact mountain ecosystem in the world.

The Solution
Established by conservationists and scientists in 1997, the vision of Y2Y is to maintain ecosystem connectivity in this region. The initiative uses the territorial needs of Grizzly bears, fish, and birds as umbrella species / species groups: the required territories of these species covers the territorial needs of all species in the region. The Y2Y organization unifies a wide variety of conservation groups to streamline conservation efforts in the region and ultimately to contribute to protecting the whole ecosystem and its functions.

Benefits:
- Provides widely connected habitat for native species
- Preserving forested ecosystems in mountainous regions would maintain carbon sequestration, landslide / erosion prevention, and water cycling
- Would provide excellent wildlife viewing opportunities
- Unites conservationist across North America

Biodiversity and Ecosystem Services Derived from The Y2Y Project					
Biodiversity and Ecosystem Services			**Relative Increase or proportion within this case study H, M, Low**	**Sustainability Feature**	**Ecological Function or Process to be Protected**
Biodiversity	Maintain or increase biodiversity (includes genetic diversity)	X	H	With the goal of protecting a large tract of North America, Y2Y hopes to protect habitat for all native biodiversity.	Large interconnected protected corridor
	Habitat for Native species	X	H	With the goal of protecting a large tract of North America, Y2Y hopes to protect habitat for all native biodiversity.	Large interconnected protected corridor
Provisioning Services					
	Food				
	Raw Materials				
	Fresh water				
	Medicinal Resources				
Regulating Services					
Climate and Atmosphere	Carbon sequestration and storage	X	H	Protecting large tracts of forested habitat maintains carbon sequestration.	Protecting an maintaining forest growth and regeneration
	Moderation of Extreme Weather events.				
	Pollution Mitigation (Air)				
	Pollution Mitigation (Water)				
	Pollution Mitigation (Soil)				
	Local Climate and Air Quality regulation				
Pollination	Maintain or increase pollination				
Hazard					

Regulation					
	Reduction in Landslide Potential	X	H	Protecting forested mountain ecosystems reduces the risk of landslides.	Tree roots stabilize steep slopes.
	Reduced Flooding				
	Noise Reduction				
	Disease and pest Regulation				
Water	Seasonal drought mitigation				
	Waste-water Treatment				
Soil	Maintenance of Soil Fertility				
	Reduced Erosion	X	H	Protecting forested mountain ecosystems reduces run-off and erosion.	Tree roots stabilize mountain slopes.
Supporting Services					
	Primary Productivity	X	H	Large tracts of forest ecosystems which have high primary productivity would be maintained.	Plant growth through photosynthesis.
	Preservation and generation of soils				
	Nutrient Cycling				
	Water Cycling	X	H	By protecting mountainous forest ecosystems, Y2Y would protect a large number of watersheds by maintaining drainage and preventing soil loss and runoff.	Trees stabilize mountain slopes, intercept rain fall, and enhance drainage, maintaining water tables.
Cultural Services					
	Social Cohesion	X	M	Fosters cohesion between numerous conservation groups working towards the same goals.	
	Sense of identity				
	Mental and physical well-being				
	Recreation	X	H	Would provide many wildlife viewing opportunities	Maintains large wildlife corridor.

	Tourism	x	H	Would provide many wildlife viewing ecotourism opportunities.	Maintains large wildlife corridor

Figure 13: Case Studies: Supporting Research

Biodiversity and Ecosystem Services provided by Ecosystem Types			
Category	**Service**	**Ecosystem**	**References**
Biodiversity	Maintain or increase Biodiversity	Urban Parks	Chamberlain et al., 2007
			de Toledo et al., 2011
			Fitzsimons et al., 2011
			Garden et al., 2010
			Khera et al., 2009
			Koh and Sodhi, 2004
			Matteson and Langellotto, 2010
			Platt and Lill, 2006
			Tonietto et al., 2011
		Agriculture	Clergue et al., 2005
		Forest	Martinez et al., 2009 Krieger,2001 Peres, 2001
		Grassland	Sala and Paruelo, 1997
		Lake	Holmlund and Hammer, 1999
		River	Loomis et al., 1999
		Wetland	Pollock et al., 1998
			Do and Bennet, 2007
		Riparian Corridors	Ewing and Hodder, 1998
			Grillmayer, 2002
			Henry et al., 1999
			Naiman et al., 1993
			Naiman and Decamps, 1997
			Schuller et al., 2000
	Habitat for native species	Urban Parks	Angold et al., 2006
			Carbó-Ramírez and Zuria, 2011
			Hernandez et al., 2009
			Mahan and Connell, 2005
		Agriculture	Clergue et al., 2005
		Forest	Martinez et al., 2009
			Krieger, 2001
			Peres, 2001
		Grassland	Sala and Paruelo, 1997
		Lake	Holmlund and Hammer, 1999
		River	Loomis et al., 1999
		Wetland	Pollock et al., 1998
			Do and Bennet, 2007
		Riparian	Bowler et al., 2002
	Maintain or increase	Wild pollinators	Garibaldi et al., 2013
			Javorek et al., 2002

	pollination	Forests	Morandin and Winston, 2006
			Greenleaf and Kremen, 2006
		Riparian	Greenleaf and Kremen, 2006
Provisioning Services			
	Food	Grasslands	Sala and Paruelo, 1997
		Fish populations	Holmlund and Hammer, 1999
		Wildlife	Peres, 2001
	Raw Materials	Forest	Martinez et al., 2009
		Grassland	Sala and Paruelo, 1997
	Fresh water	Lake	Bolund and Hunammar, 1999
			Mitchell and Carson, 1989
		River	Mitchell and Carson, 1989
			Bharati, 2002
			Woessner, 2000
		Wetland	Zedler and Kercher, 2005
			Brauman et al., 2007
	Medicinal Resources	Forest	Cracraft and Grifo, 1996
			Caniago and Stephen, 1998
Regulating Services			
Climate and Atmosphere	Carbon sequestration and storage	Urban Parks	Jo, 2002
			Lam et al., 2005
			Paoletti et al., 2011
			Tallis et al., 2011
			Yang et al., 2005
		Estuary	Chmura et al., 2003
		Forest / urban trees	Bolund and Hunhammar, 1999
			Martinez et al., 2009
			Krieger, 2001
		Wetland	Chmura et al., 2003
			Zedler and Kercher, 2005
		Grassland	Sala and Paruelo, 1997
		Riparian	Hernandez et al., 2008
	Pollution Mitigation (Air)	Forest / urban trees	Bolund and Hunhammar, 1999
			Dobbs et al., 2011
			Krieger, 2001
			Oke et al., 1989
		Riparian	Dobbs et al., 2011
			Nowak et al., 2006
	Pollution Mitigation (Water)	Wetland	Zedler and Kercher, 2005
			Fisher and Acreman, 2004
		Riparian	Lovel and Sullivan, 2006

			Lee et al., 2003
			Vought et al., 1994
	Pollution Mitigation (Soil)	Forest	Dobbs et al., 2011
	Local Climate and Air Quality regulation	Urban Parks	Bowler et al., 2010
		Forest / urban trees	Bolund and Hunhammar, 1999
			Dobbs et al., 2011
			Krieger, 2001
			Oke et al., 1989
		Lake	Bolund and Hunhammar, 1999
		Grassland	Sala and Paruelo, 1997
	Moderation of weather extremes and its impacts	Forest / urban trees	Dobbs et al., 2011
		Riparian	Lowrance et al. 1985
Hazard Regulation			
	Flood attenuation	Wetland	Zedler and Kercher, 2005 Brauman et al., 2007
		Soils and low vegetation	Bolund and Hunammar, 1999
		Riparian	Cooke, 1997
			Forman, 1998
			Kim et al., 2006
	Reduction in landslide potential		
	Noise Control	Forest / urban trees	Bolund and Hunhammar, 1999 Dobbs et al., 2011
		Soils and low vegetation	Bolund and Hunhammar, 1999
	Disease and pest Regulation	Forest	Bianchi et al., 2006
			den Belder et al., 2002
		Riparian	Rein, 1999
			Ober and Hayes, 2008
			Zhang et al., 2007
Water	Seasonal drought mitigation	Lake	Brauman et al., 2007
		River	Brauman et al., 2007
		Wetland	Brauman et al., 2007
	Waste-water Treatment	Wetland	Bolund and Hunhammar, 1999
			Fisher and Acreman, 2005
			Zedler and Kercher, 2004

		River	Loomis et al., 1999
Soil	Maintenance of Soil Fertility	Forest	Dobbs et al., 2011
		Grassland	Sala and Paruelo, 1997
	Reduced erosion	Forest / urban trees	Bharati et al., 2002
			Krieger, 2001
			Lovel and Sullivan, 2006
			Lee et al., 2003b
			Mankin et al., 2009
			Parkyn et al., 2003
			Rein, 1999
			Vought et al., 1994
			Zaimes et al., 2004
Supporting Services			
	Primary Productivity	Estuary	Harding et al., 2002
		Forest	Norby et al., 2002
		Grassland	Scurlock et al., 2002
		Lake	Carpenter et al., 1987
		Wetland	Mitsch et al., 1991
		Riparian	Lowrance et al., 1985
	Preservation and generation of soils	Grassland	Sala and Paruelo, 1997
		Forest	Dobbs et al., 2011
		Riparian	Abernathy and Rutherford, 2000
			France, 2000
	Nutrient Cycling	Fish populations	Holmlund and Hammer, 1999
		Estuary	Chmura et al., 2003
		Forest	Dobbs et al., 2011
		Grassland	Sala and Paruelo, 1997
		Wetland	Chmura et al., 2003
			Fisher and Acreman, 2004
		Riparian	Hanson et al., 1994
	Water Cycling	Urban Parks	Pauleit and Duhme, 2000
			Zhang et al., 2012
		Forest	Martinez et al., 2009
			Krieger, 2001
			Dobbs et al., 2011
		Soils and low vegetation	Bolund and Hunhammar, 1999
		Wetland	Brauman et al., 2007
	Wild Species	Agriculture	Clergue et al., 2005

	Habitat	Forest	Martinez et al., 2009
			Krieger, 2001
			Peres, 2001
		Grassland	Sala and Paruelo, 1997
		Lake	Holmlund and Hammer, 1999
		River	Loomis et al., 1999
		Wetland	Pollock et al., 1998
			Do and Bennet,, 2007
	Maintenance of genetic diversity	Forest	Martinez et al., 2009
			Krieger, 2001
			Dobbs et al., 2011
		Grassland	Sala and Paruelo, 1997
Cultural Services			
	Social cohesion	Urban Parks	Coley et al., 1997
			Peters et al., 2010
			Ravenscroft and Markwell, 2000.
			Seeland et al., 2009
	Sense of identity	All Landscape types	Manzo and Perkins, 2006
			Proshansky et al., 1983
	Mental and physical well-being (Health)	Urban Parks	Babey et al., 2008
			Bell et al., 2008
			Boone-Heinonen et al., 2010
			Grahn and Stigsdotter, 2003
			Guite et al., 2006
			Hansmann et al., 2007
			Korpela et al., 2010.
			Maas et al., 2006
			Richardson et al., 2010
			Roemmich et al., 2006
			Takano et al., 2002
			Ward Thompson et al., 2012
			Wolch et al., 2011
		Biodiversity	Bolund and Hunhammar, 1999
		Forest / urban trees	Bolund and Hunhammar, 1999
		Lake	Bolund and Hunhammar, 1999
		All 'Natural' landscapes	Frumkin and Louv, 2007
			Kuo, 2010
	Recreation	Forest	Krieger, 2001
		Grassland	Saleh and Karwack, 1996
		Lakes	Mitchell and Carson, 1989

		Rivers	Mitchell and Carson, 1989
			Loomis et al., 1999
		wetland	Wall, 1998
	Tourism	Urban Parks	Chaudhry and Tewari,2010
			Deng, et al., 2010
			Wu et al., 2010.
		Forest	Krieger, 2001
		Grassland	Saleh and Karwack, 1996
		Lakes	Mitchell and Carson, 1989
		River	Mitchell and Carson 1989
		Wetland	Bacon, 1987
	Aesthetics/ Religious Spiritual	Natural Landscapes	Greeley, 1974
			Wuthnow, 1978

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Special Topics

Special Topic #1

Key Ideas about Ecosystem Services

1.0 Introduction

We discuss nine key ideas about ecosystem services that were discussed in Section 1 and five key ideas about ecosystem services, assessment and evaluation that were covered in in Section 2.

2.0 Key ideas About Ecosystem Services

1. Not all parts of nature are related to ecosystem services.

Ecosystems are the source of ecosystem services and not all of nature or the physical environment more broadly. Thus mineral deposits and even fossil fuels produced by ancient ecosystems are not considered part of the natural capital that leads to ecosystem services. (Although to deliberately include those ideas some people use different terms, such as environmental services or landscape services.) Water is considered part of the ecosystem services cascade because of its many interactions with living creatures and because of its central role in ecosystem processes. (Haines-Young and Potschin 2010)

2. Ecosystems generate multiple services and benefits.

Arctic tundra, tropical rainforest, and coral reefs are ecologically very different, but they are similar in that each generates multiple services and benefits for people. The services they generate can be local, like providing caribou or fish for local people. They can also be less tangible and distant in time or space. And some services, like the carbon taken from the atmosphere by all vegetation, might provide equal benefits for people in many different places far away (Perrings et al. 2011, Tallis and Polasky 2011).

3. Two 'identical' ecosystems can yield different services and benefits to people.

If one were to imagine two otherwise identical ecosystems, say a temperate forest, one near and one far from a city, they would produce different services and benefits. The forest near the city might filter water that is used for drinking, provide recreational opportunities, and provide construction lumber, firewood and edible berries. The forest distant from the city will filter water, provide wildlife habitat and potential views, and contain wood and berries. But if no people use them, then those aspects of the second forest are not providing services. However, both forests might equally extract carbon dioxide from the atmosphere, and thus influence global climate in ways that equally benefit people far away. When thinking of services, benefits and the values they provide, what is central is the extent to which people use them. (Luck et al. 2007)

4. Using one ecosystem services often results in a trade off, resulting in less of another service.

When one harvests crops, the original forest or grassland is cleared and many other services—water filtration, recreation, lumber or grazing land—are reduced or eliminated completely. Any situation in which one result is achieved with a simultaneous cost of some kind is called a trade-off.

However, good managers need to know what is traded-off. A major point is that people do not always understand what they trade off in the long-run for short term gains from using natural capital. There are four typical and challenging trade-offs involving ecosystem services. They are trade-offs in time, in space, among beneficiaries and between services (Reyers et al. 2010).

- Trade-offs in time mean that taking some advantages now may mean losing other advantages years later.
- Trade-offs in space refer to advantages that are taken at one scale which have costs at another, such as clearing Amazonian forests for local benefits which could result in costly weather and climate changes far away.
- Trade-offs among beneficiaries refer to some people obtaining the advantages while others pay the costs.
- Trade-offs among the services themselves occur when one kind of use, such as harvesting a forest for lumber, results in the loss of a different kind, like hunting or spiritual benefits.

Reaping the benefits of provisioning services often results in costs to regulating services (Reyers et al. 2010). Often, several trade-offs occur simultaneously (Perrings et al. 2010). For example, a forest cleared for lumber benefits a few land owners in the short term but might causes a loss of flood protection and thus damage to many other people far downstream some years later. Documenting all the trade-offs, the subtle changes in natural capital and services distant in time and space, and the tricky estimates of who gains and who loses and by how much, are among the difficulties in the study of ecosystem services.

5. Biodiversity is important but is not an ecosystem service.

'Biodiversity', meaning all features of the diversity of life, or more casually, the wildlife and living features of ecosystems, is a vital part of nature. Because it is important, it is often assumed to be an ecosystem service, but it is not specifically named in the classifications of ecosystem services. In the cascade diagram in Figure 2, biodiversity is understood to be part of the upper boxes, the structure and processes of ecosystems, separate from the ecosystem services. Figure 14 below is from the second chapter of the TEEB report (Elmquist et al. 2010) which considers the role of biodiversity in detail. It shows examples of relationships between biodiversity and several of ecosystem services it provides. The diversity of life is a crucial component of the ecosystem services story. It creates the flow of services that benefit people. But biodiversity itself is not an ecosystem service.

Figure 14: Examples of relationships between biodiversity and ecosystem services

COMPONENT OF BIODIVERSITY	EXAMPLES OF ECOSYSTEM SERVICES
Genetic variability	Medicinal Products
Population sizes & biomass	Food from crops & animals
Species assemblages, communities and structures	Habitat provision and recreation

COMPONENT OF BIODIVERSITY	EXAMPLES OF ECOSYSTEM SERVICES
Interactions between organisms and their abiotic environment	Water purification
Interactions between and among species and individuals	Pollination and biological control

The relationship among biodiversity, ecosystem services and conservation planning is given specific attention by 16 biodiversity scientists from the group DIVERSITAS (Perrings et al. 2011). DIVERSITAS examined the revised 2020 targets of the Convention on Biological Diversity (CBD). The 2020 targets are more specific than the 2010 ones, which were not realized. The authors recommend adopting and ecosystem services approach and provide guidelines to do so in their paper Ecosystem services, targets, and indicators for the conservation and sustainable use of biodiversity. They show how the CBD's five 2020 strategies and 20 new targets are related to ecosystem services. The authors state:

"An ecosystem services approach has four immediate implications for target setting and implementation. First, what and how much biodiversity should be targeted for conservation depends on what services are important. Second, the temporal and spatial scale of (biodiversity) targets depends on the temporal and spatial scale of the "production" and "distribution" of ecosystem services. Third, interdependencies between ecosystem services imply that there are interdependencies between targets. Fourth, implementation of interdependent targets should be coordinated and should include all agencies involved with the management of ecosystem services." p. 513.

Their analysis confirms the central relationship between biodiversity and ecosystem services, and that they are quite different.

6. The precise details of relationships among nature, services and benefits are not clear. Details often need to be understood.

The concept of ecosystem services is becoming well established, along with the idea that identifying those services and benefits will likely benefit society's planning and decision making. However, the details of exactly what natural processes generate which services, or how much of a service provides how much benefit is still not certain.. Additionally, methods for measuring ecosystem services are not yet standardized. A statement early in the TEEB summary report makes important points:

"The release of the Millennium Ecosystem Assessment (MA 2005a) helped foster use of the concept of ecosystem services by policy makers and the business community. However, progress in its practical application in land use planning and decision making has been slow (e.g., Daily et al. 2009, Naidoo et al. 2008).

This lack of progress stems not only from failures of markets and systems of economic analysis and accounting (notably GDP) to capture values of ecosystem services, but also from our limited understanding of: a) how different services are interlinked with each other and to the various components of ecosystem functioning and the role of biodiversity; b) how different human actions that affect ecosystems change the provision of ecosystem services; c) the potential trade-offs among services; d) the influence of differences in temporal and spatial scales on demand and supply of services; and e) what kind of governance and institutions are best able to ensure biodiversity conservation and the sustainable flow of ecosystem services in the long-term." (de Groot et al. 2010 p. 4)

These limitations and challenges are being addressed. But they are deep and will only be overcome gradually.

7. The concept of ecosystem services is entirely centered on people.

That ecosystem services perspective is anthropocentric. The idea of ecosystem services was developed to make clear that human actions taken for short term benefits often damage nature and decrease human benefits over the longer term or on a larger geographical scale. Nonetheless, one must realize that there are other aspects of the environment, which some people consider intrinsically valuable, which are not part of the ecosystem services approach. (Haines-Young and Potschin 2010).

8. There is a place for the importance of nature for its own sake.

The ecosystem services perspective does not deny—at all—that nature and living things can have merits that are separate from their utility to people. However, such merits are not part of ecosystem service calculations. It is possible, and often desirable, to consider the ecological importance of different species or habitats, in their own right. It might also be worthwhile to consider the 'intrinsic value' of species or ecosystems separately from their uses by people. However, such considerations would need to be done on a parallel and separate track from measures of natural capital or human benefits.

You might want to document other perspectives on value or importance, perhaps aspects of resilience or other ecological parameters. Other value perspectives can be calculated separately, and then used to complement economic approaches, if desired (Pascual et al. 2010).

Some people believe that some 'intrinsic' aspects of nature are captured in measures of ecosystem services. Specifically, some think that the 'existence value' of the Total Economic Value calculus includes intrinsic value. This is not correct. Existence value is, by definition, the value or merit people get from knowing that nature exists somewhere in an undamaged state. The existence values are not themselves intrinsic, outside or separate from people. This point is discussed further in Special Topic 3.3.

9. There is a worldwide trend towards increasing use of ideas of ecosystem services and natural capital.

In a sense, most of this document, and many of the papers quoted in it, describe trends in the field of ecosystem services. Nonetheless, some papers are specifically oriented to that task. Carpenter et al. (2009) described the state of ecosystem services science, reflecting on lessons learned from the Millennium Assessment, and made recommendation for future research. Searle and Cox (2009) interviewed multiple experts and summarized trends and key features of ecosystem services projects. Trends in ecosystem services research are described by Vihervaara, Rönkä and Walls (2010). Potschin and Haines-Young (2011a, 2011b) introduce a review of the field and its trends. Some of the trends within global organizations and governments are described by BSR (2012) and business related trends are described by Waage (2013). The United Kingdom Natural Capital Committee (2013) discusses current challenges and suggestions for measurement and valuation of ecosystem services.

International agencies like the International Finance Corporation (the section of the World Bank that funds private sector projects) require consideration of ecosystem services in their Performance Standards which apply to pre-project studies. The Equator Principles, adopted by over 75 international banks, also require IFC standards. The Convention on Biological Diversity always recognized the benefits of biodiversity to people. The CBD has revised its guidelines for 2020 to focus more on ecosystem services (Perrings et al. 2011). These international trends are matched by many guidelines and requirements at national, regional and municipal levels, as per the citations in the previous paragraph.

The big picture is simple. Considerations of ecosystem services are becoming the new norm: they are here to stay. There are textbooks and websites about ecosystem services. Conferences and organizations focus on ecosystem services. Multiple journals regularly produce articles about ecosystem services and some journals have 'ecosystem services' directly in their title (See the 'starting points' section of References and Resources for details on these resources.) The extent to which the ideas are used and how they will interact with other tools of environmental planning and government policy are still to be seen.

3.0 Key Ideas about Ecosystem Assessment and Valuation

Here we provide more details of the key ideas introduced in Section 2.

1. Economic development depends on nature; development in the future is often constrained by development in the present.

It is helpful to many audiences to think about ecosystem services in the slightly different language of 'development'. The United Nations' Millennium Assessment was very focused on development, by which they meant all activities--economic, social and political--that create changes to improve human well-being. We know that people are harvesting or using many ecosystem services and often plan to increase those activities in future. That is what 'economic development' often involves. The pursuit of ecosystem services is an explicit and legitimate part of the search for economic development.

The essential message from studies of ecosystem services is that economic development has already caused a decrease in ecosystem services. The Millennium Assessment showed that almost 60% of the world's ecosystem services are in decline. That means that the human well-being that depends upon those services is under threat. Habitat and regulatory services, which can be less visible and provide more diffuse and delayed benefits, are most threatened. Thus, uninformed development in the present can reduce options for development in future.

The message is that we do not face a simple trade-off between different things—perhaps exaggerated as jobs versus bunnies. It is not a case where one thing is economically desirable and the other is environmentally desirable but economically not relevant. What we really face is a trade-off between development now, for some people, and other development later, probably for other people. What we must explore is whether the short term benefits of development are really worth the longer term costs to development. We must also investigate who benefits and who pays, and where the benefits occur and where the costs occur. We need this information to make informed choices for the best results. Studies of ecosystem services help us plan and manage economic development.

The explicit relationship between economic development and ecosystem services is well expressed in the TEEB reports about local and national policy and their summary report about a green economy. A narrower case, about how ecosystem services can benefit individual businesses, is presented by Hanson et al. (2012), the World Business Council for Sustainable Development (2011), TEEB for business, and Grigg (undated).

2. It can be helpful, and often necessary, to think in terms of intermediate and final services.

In planning for ecosystem services it is often necessary to measure services and benefits. Measuring requires some precision. Some ecosystem services can yield multiple benefits, and the same benefit can come from different services: it is important not to double count services and benefits. One way to avoid errors is to distinguish between intermediate and final services. It is only the final services that yield direct benefits to people, and those are what one usually 'counts'. Some ecosystem services turn out to be intermediate services and others are final services and they must be distinguished in a project that is doing detailed measurements.

The topic of intermediate and final services is discussed specifically by Boyd and Banzhaf (2007) and in more detail in Special Topics 3.3)

3. Studies often need to distinguish nature and the natural sciences from human benefits and social sciences.

Detailed planning and management often requires local studies of services and benefits. In the ecosystem cascade diagram in Figure 15, the top three boxes (ecosystem structure, functions and services) are aspects of nature. They are usually studied by scientists and measured in biophysical units (cubic meters per second of river flow, number of ducks per hectare of habitat, tonnes of carbon stored in the soil). The last two boxes in the cascade, the benefits and the values obtained from them, are what people get from nature's services. They are determined by measures of 'utility' or 'satisfaction' in units of dollars or with other measures of importance. The major point is that scientific tools are usually most appropriate to explore the top three boxes and social science tools are more appropriate for the bottom two items. Knowing that helps to organize your field projects.

Boyd and Banzhaf (2007) make a similar point in a discussion about clarifying the definition for services, and the distinction between intermediate and final services. They provide the definition "Final ecosystem services are components of nature, directly enjoyed, consumed or used to yield human well-being." p. 619.) They then conclude ". . . this leads to measurement of units (for services) that are in fact biophysical, rather than social or economic in nature." Other quotations from their paper are found near the end of Special Topic 1.

4.0 Discussion

The key ideas from Section 1 come from the definitions and classifications of ecosystem services and the idea of ecosystem cascades. You can find resources for further study in the Starting Points for Further Study. The biweekly 'TEEBrief' provides constant update on events and trends related to ecosystem services as do many of the websites recommended in the Resource section.

The key ideas from Section 2 concern economic valuation, which is a field that gets much attention. Valuation methods help put ecosystem services into monetary terms, to make them clearer to people. There are cautions about using the ideas of economic valuation and it helps to know about them. But despite the cautions, economic evaluation has many merits. When carefully used, valuation is a helpful contribution to a repertoire of planning and management approaches. You can find further information about valuation in Special Topic 3

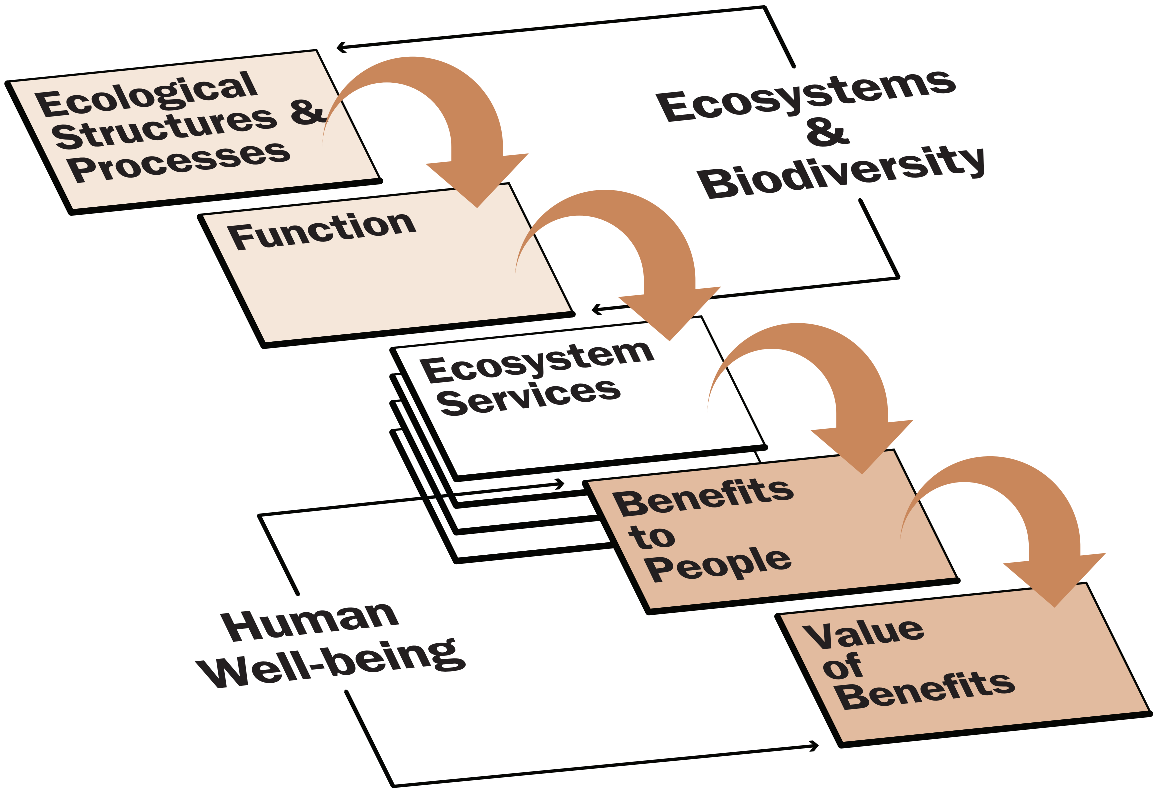

Figure 15: The ecosystem services cascade.

Special Topic #2

Comprehensive Approaches to Ecosystem Services

1.0 Using Ecosystem Services: Two Comprehensive 'Approaches' to Aid Society's Decision Makers

The idea of ecosystem services was introduced into management thinking to remedy an identified problem: nature has deteriorated due to human actions taken without understanding the negative long term consequences. Ecosystem services are a vehicle for longer term thinking and including more diffuse benefits into the planning system.

Hence, when some people think about the goal of ecosystem services, they have a big vision: to explicitly identify, measure, map, rank and otherwise include ecosystem services into a full range of human thinking, planning and decision making. The diagram in Figure 15 on the following page shows this kind of broad thinking about different aspects of ecosystem services within a social planning framework. The Figure shows that the framework includes assessment, identifying future change and stakeholder engagement. Ecosystem services can contribute to sustainable development, conservation of natural resources and the protection of nature and wildlife.

There are broad `approaches' to using ecosystem services that can approximate this kind of general vision with multiple steps. We distinguish two somewhat different approaches, and provide two examples of each, in the next pages:

- Ecosystem Assessment, as described by
    - The Millennium Ecosystem Assessment (MA), and later expanded by
    - The Economics of Ecosystems and Biodiversity (TEEB) project

- Geospatial mapping and ecological production functions, as exemplified by
    - The InVEST models, and
    - Other mapping methods that integrate with environmental planning.

The two assessment processes both systematically organize and describe many factors, from the conditions of natural resources to social policy options. The mapping approaches also organized scientific and social information to guide policy, but their central tools are maps and models. The two approaches overlap because they consider very similar data for similar purposes. We describe them separately because the assessment approaches, which are better known, have major differences from the mapping and modeling efforts. Their authors also describe them as separate approaches. They all can involve complex studies which could be time consuming and expensive.

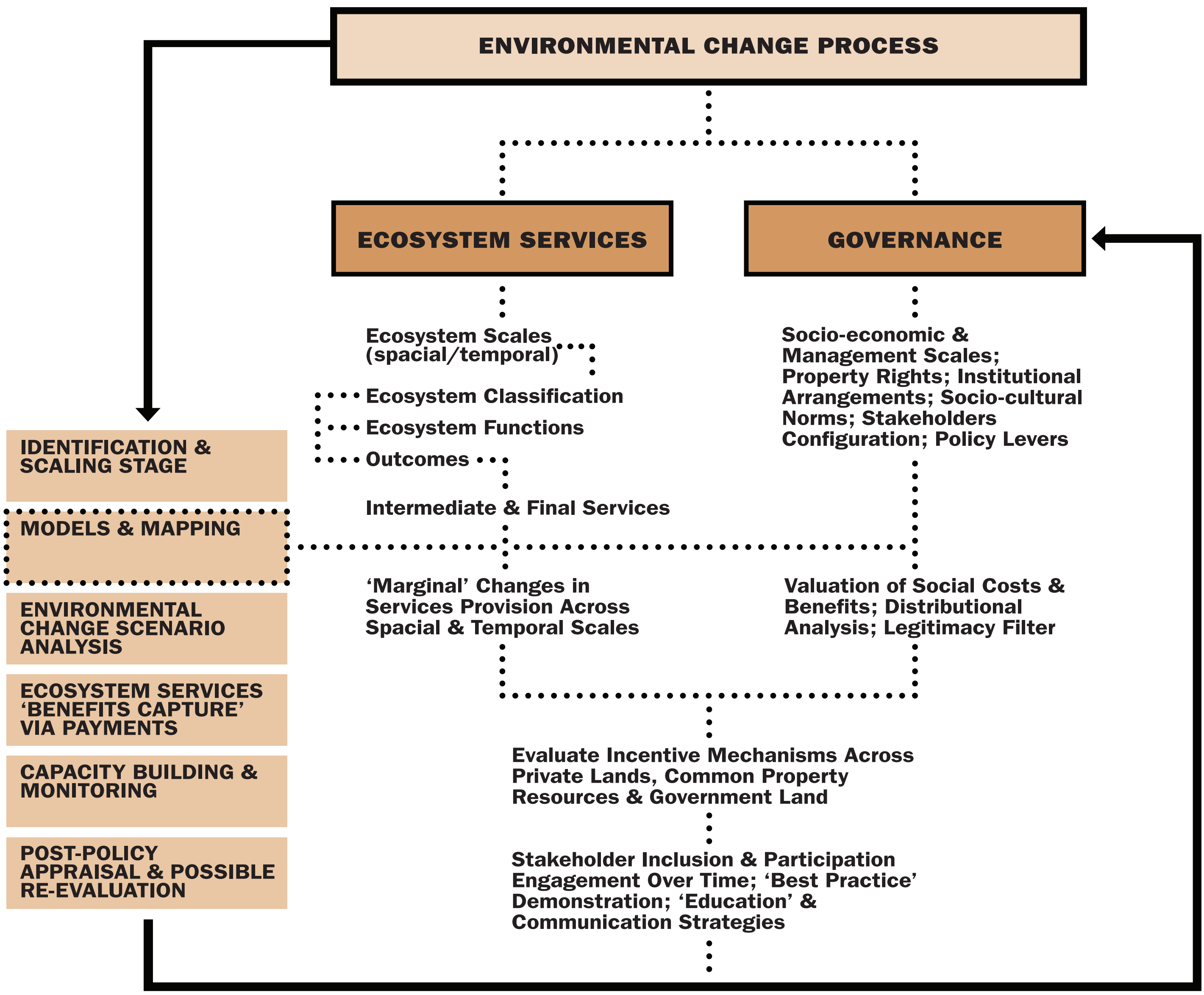

Figure 16: The 'ecosystem services framework'
(adapted from Turner and Daily 2008)

2.0 Ecosystem Assessment

2.1 The Benchmark of the Millennium Ecosystem Assessment

The Millennium Ecosystem Assessment (MA) was an effort, coordinated by the United Nations, to describe the state of the planet's resources. It was particularly concerned to identify changes to natural resources. Gathering data for the whole planet, and for many regional studies, took five years and the work of over 1300 people. The many volumes containing the results were released in 2005. They are available free from the Internet at Millennium Ecosystem Assessment.

One of the most important results was that 15 of 24 ecosystem services surveyed have been degraded over the past 50 years. Further, they found human efforts or negligence responsible for the decline of the ecosystem services that benefit people.

A major feature of the Millennium Assessment is that it discussed more than just 'natural resources.' It showed that nature offered other advantages that were as important to human well-being as fish and lumber, but were not often discussed. With the phrase 'ecosystem services', the MA embedded the idea that nature helps people. The regulation of river flow, the pollination of crops, and the creation of soils all benefit people. But if they are not discussed, described, and valued monetarily, then they might not be considered when people plan how to manage nature. The MA popularized the idea of ecosystem services that has become much better known since 2005.

The Millennium Ecosystem Assessment developed its own four part classification system to organize discussion of ecosystem services. That MA four part classification is now well known and widely used. It is described in more detail immediately below. As we show later, there are newer variations that might be more helpful at regional and local scales.

The Millennium Ecosystem Assessment established procedures that were shared publicly, so others could follow them. The free downloadable book by Ash et al. (2010) describes the MA assessment approach. The authors state clearly that their approach is not a fixed recipe but a series of ideas to be used as needed. However, their example and the shorter guidelines by Ragnanathan et al. (2008) offer a quite structured and comprehensive approach to ecosystem services.

Ash et al. 2010 describe three major stages in the Millennium Assessment process:

- The exploratory stage, involving initial scoping and communication with stakeholders,
- The design stage, which explores user needs and project planning steps, and
- The implementation stage, in which the data are gathered, analyzed and used for communication and governance

The three stages with some of their details are show in Figure 17, on the following page.

2.1.1 Steps in an Ecosystem Assessment Process

The Exploration and Design stages in Figure 17 are vital, but conceptually similar to other thoughtful environmental planning processes. We expand here upon the key items that are specific to the MA and its implementation stage. For more details refer to Ash et al. (2010) or Ragnanathan (2008).

1. Develop a conceptual model
2. Assess ecosystem services and human well-being
3. Determine drivers of change
4. Develop plausible futures
5. Develop response options

1. Develop a conceptual model

A conceptual model is an abstract model, often a diagram with boxes and arrows, which simplifies the main features of a situation and their relationships. Figure 16 on the previous page is a conceptual model. If creating a conceptual model is an early step, it generates communication about what could be important parts of the case and what are not. Technical staff can create models, but public stakeholders can be involved too. The model helps to guide what is studied, what the assessment's priorities are and who needs to be involved.

2. Assess ecosystem services and human well-being

The short title of this step belies its complexity and centrality to the process. This is the heart of 'ecosystem assessment'. 'Assess' means identify the current condition and the trends in the ecosystems and the services they provide. Since there are many ecosystems and services, at different scales and with different amounts of data available, this can be demanding work. Many biophysical indicators can measure the ecosystems and services.

Measures of human well-being can also vary and include aspects of health, nutrition and security. The economic value of services and benefits can be assessed. In recent years, assessing economic benefits has gained greater attention. In the MA itself, doing an economic valuation was desirable but 'not essential'. (Ash et al. 2010 p. 138). It is also important to identify the local, regional and global beneficiaries of different services. Different people often benefit in different ways at different geographical scales and also at different time scales.

3. Determine drivers of change

Assessment often finds that the quality of ecosystem services is changing, and often deteriorating. The next step is to identify the drivers behind the changes. This phase identifies the immediate forces of change (the direct drivers, such as water pollution) and also the broader processes that might lie behind immediate changes (the indirect drivers, such as population change or migration).

4. Develop plausible futures

The process forecasts what could happen if different management actions were taken. Creating 'scenarios' of the future summarizes many relevant influences, trends, and priorities. Scenarios are alternative, realistic 'futures': for example, a municipality might have a choice between continuing city-wide development as per status quo, or concentrating development on the south side of the city.

Regional maps and diagrams often display the projected results of different scenarios so that people can visualize the results. Then they can decide what to vote for or study further. Producing realistic future projections can be expensive and complicated, but the final maps or diagrams are often very easy for the public to understand and discuss.

5 Develop response options

This step generates options to address the challenges identified by the scenarios. If negative results seem likely from current trends, choices to avoid the problems can be created. Society can then make conscious choices among the available response options.

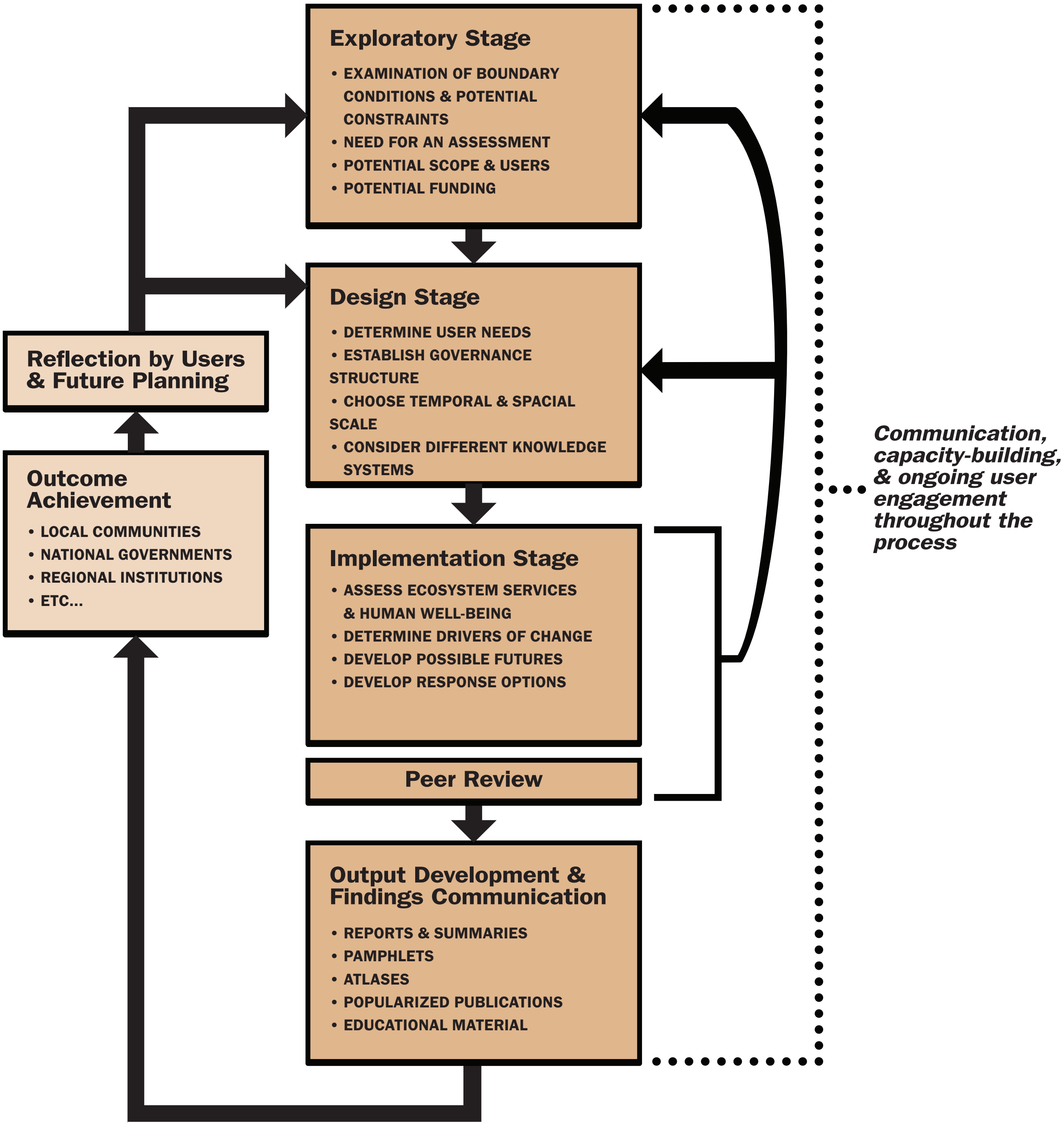

Figure 17 An overview of the Millennium Assessment process
(modified from Ash et al. 2010 p. 9)

2.1.2 The Millennium Ecosystem Assessment Classification of Ecosystem Service

An essential part of carrying out the MA process, and an element of step 2 above, is describing the ecosystem services themselves. The Millennium Assessment described all ecosystem services as belonging to one of four categories. Those four are listed in the table below.

The classification system includes multiple examples of specific services in each category, as shown in the chart below. This four part classification is very well known and widely used. It is discussed further, in comparison with classifications from two other programs (TEEB and CICES) below.

COMPONENT OF BIODIVERSITY	EXAMPLES OF ECOSYSTEM SERVICES
Provisioning Services	The goods and services harvested from ecosystems: lumber, crops, fish, water.
Regulating Services	the ways in which ecosystems adjust, influence and regulate resources and conditions which benefit people: water filtration, regulating weather and climate, erosion control, pollination of crops.
Supporting Services	the most fundamental supports provided for life and other functions, and the basis for the other three categories: photosynthesis, soil formation, nutrient cycling.
Cultural Services	The opportunities and resources provided which permit recreation, artistic appreciation, spiritual connections, educational and scientific use, etc.

2.2 The Economics of Ecosystems and Biodiversity (TEEB)

The Economics of Ecosystems and Biodiversity (TEEB) project is organized thorough several European governments and the United Nations. More than 500 professionals have contributed to the TEEB process. Its summary reports, which are still being produced (e.g. TEEB 2013), incorporate recent improvements in thinking about ecosystem assessments. Its title implies that its central concern is to include economic tools in ecosystem and biodiversity management. Like its predecessor, it uses an ecosystem assessment framework for planning and management.

TEEB recommends many procedures. They suggest that simple analyses can sometimes be all that is needed, but they provide much detail to support in depth studies. Most generally, TEEB describes a six-step approach "for providing some basic guidance on how to identify ecosystem service opportunities in ecosystem management" (TEEB 2013, p. 32.). They suggest "a stepwise approach helps navigate through the different assessment options available.

This approach is not a fixed recipe, but is intended to guide policy makers in designing their own processes for appraising and considering nature's benefits in their policy decisions:"

- (i) Specify and agree on the policy issue with stakeholders to avoid misunderstandings during decision making and implementation.
- (ii) Identify which ecosystem services are most relevant to the policy issue in order to focus analysis.
- (iii) Define the information needs to tackle your issue and select appropriate methods for assessment.
- (iv) Assess ecosystem services, expected changes in their availability and distribution.
- (v) Identify and appraise policy options based on your assessment.
- (vi) Assess impacts of policy options on different groups in your community. (TEEB 2010b, p. 7)

The major TEEB report, Kumar (2010), summarizes the science and economics underlying their approach. They provide details for implementing those six steps in three major reports customized for specific audiences: national and international policy makers, local and regional policy makers, and businesses. These documents give suggestions for identifying and measuring ecosystem services, beneficiaries of services and economic values. They explicitly identify policies and management approaches to protect and enhance ecosystem services. The TEEB program is still operating. More recently several guidance and summary reports have been released, specifically relating the TEEB approach to cities, oceans, the transition to a green economy, and water and wetlands.

Within the TEEB approach and essential to their assessments are two related technical advances, concerning ecosystem cascades and classification systems, which we describe next.

2.2.1 Ecosystem Service Cascades

Figure 18 below describes an ecosystem service cascade of influence. This diagram tries to encompass the whole 'pathway' from natural ecosystems to human well-being. This set of factors is central to the TEEB approach and is part of the 'TEEB conceptual framework' (see de Groot et al. 2010, p 17 and 21.).

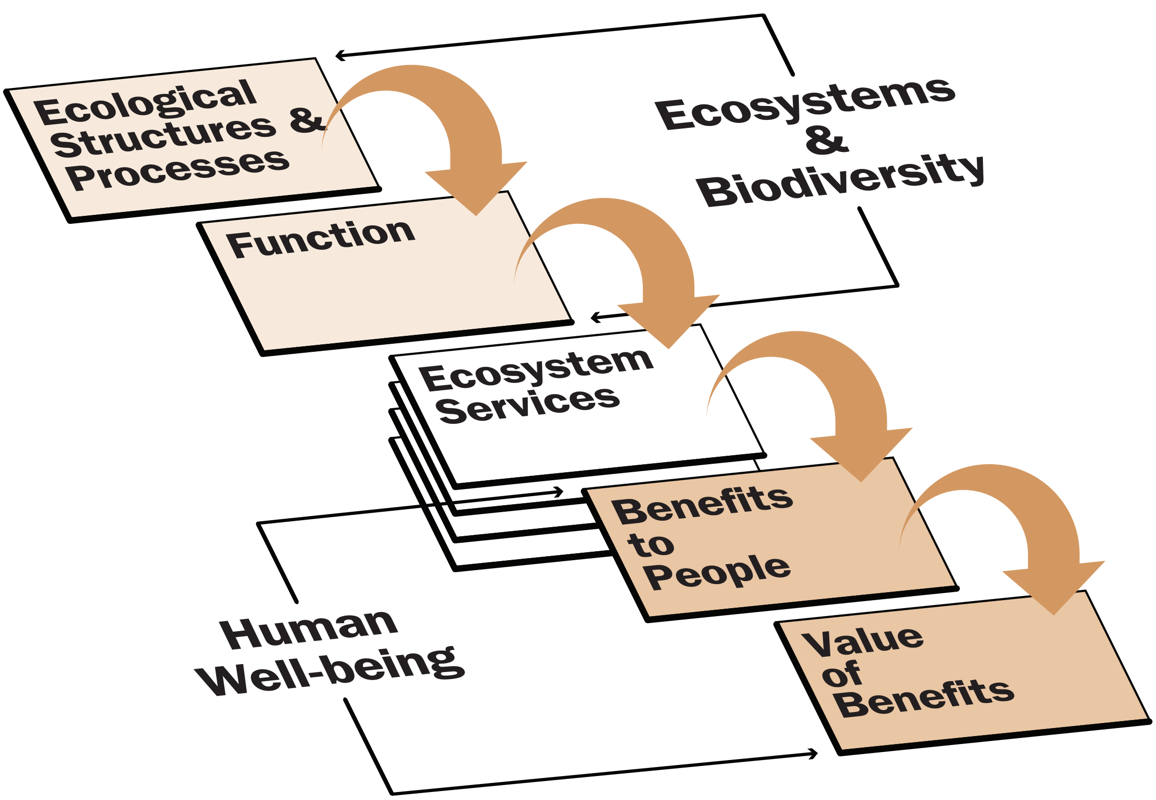

Figure 18: The ecosystem services cascade.

TEEB summarizes the relationships between ecosystems and the biodiversity they contain in the two boxes on the upper left. These features of ecosystems generate ecosystem services in the center. The services produce the features of human well-being, the two boxes of benefits and economic value on the right (adapted from Kumar 2010 p 17).

Similar models have been adopted elsewhere (e.g. Hester and Harrison 2010) and a cascade approach is central to the planning process of the ongoing Common International Classification of Ecosystem Services (Haines-Young and Potschin 2010b). The meanings of the five boxes in the pathway are described in Figure 19 below.

Figure 19: Brief definitions of the elements of the cascade, with examples based on water.

PATHWAY ELEMENT	MEANING	EXAMPLE
(1) Ecosystem structure or processes	Also referred to as 'natural capital', these are the physical features of natural ecosystems, e.g. the vegetation, wildlife and full range of natural variation (biodiversity), and the natural processes like photosynthesis, growth, predation, and the water cycle.	Volume of water and time patterns of infiltration and runoff of water across the landscape.
(2) Ecosystem functions	The functions are what the natural ecosystems accomplish that is useful to people in a given place. This is a somewhat narrower meaning of 'function' than ecologists sometimes use.	Runoff and infiltration that results in seasonal pattern of stream flows in a river that influences people.
(3) Ecosystem services	These are the subset of the whole ecosystem's functions that are useful to people: these are the results of ecosystem functions.	Regulation of flow of the river. Reduction of high water (floods) and low waters (droughts)
(4) Nature's benefits to people	The benefits are what people get from a service. Some people will get different benefits from the same service.	Sense of security from reduced flood risk; reduced insurance premiums; higher value of safer real estate

PATHWAY ELEMENT	MEANING	EXAMPLE
5 Value of benefits received	The specific value that people assign to the benefits they receive. Although monetary value can often be estimated, sometimes only a general non-monetary 'utility' or comparative ranking of worth can be identified	Measures of psychological well-being or cost savings or real estate prices

2.2.2 The TEEB and CICES Classification Systems

Since the MA was released in 2005, the four categories of its classification system have been much discussed. The TEEB project modified the four major classes of the MA system and changed some of the sub-categories (de Groot et al. 2010). The MA classification system is compared to two others in Figure 20. The process of revising the classification of ecosystem services continues beyond TEEB with funding from European governments. The Common International Classification of Ecosystem Services (CICES) project is underway, but the final results are not complete. The most recent (2013) version is included in Figure 20 on the following page.

Provisioning and Regulating Services are understood similarly in all three classifications. Provisioning Services are harvestable goods, such as crops or fish (Remember that the short title 'ecosystem services' refers to both good and services.). Regulating Services are processes, such as infiltration of rainfall, decomposition of wastes, and maintenance of weather and climate. Regulating Services influence the conditions and patterns of nature.

The general idea of Cultural Services is similar in each classification: this refers to experiences and opportunities for mental or spiritual engagement with nature, such as recreation, education, artistic and religious experiences. However specific ideas about the cultural category are contested. Understanding has evolved between MA to CICES and continues to do so (e.g. Chan et al. 2011).

Supporting Services in the Millennium Assessment referred to fundamental ecosystem processes, like soil formation and photosynthesis, considered so basic that they 'supported' regulating services. The corresponding TEEB classification is renamed Habitat Services and is composed of only two services: habitat and genetic resources. The other categories that made up supporting services, such as photosynthesis and soil formation, are no longer considered services. They now fall under ecosystem structure and function . The CICES classification carried the same reasoning farther and eliminated the Habitat category. Even habitat and genetic resources are considered part of 'natural capital' itself in CICES.

Most ecosystem services projects will have to choose a classification system to work with.

We prefer the TEEB system, and we used it to develop the ecosystem service matrix in the Case Study section of this document. The CICES process will eventually link the analysis of ecosystem services with European accounting systems (see Haines-Young and Potschin 2010b), which should make for a powerful integrated tool when it is finished. You can adopt what seems best for your projects.

More of the reasoning behind these classifications is outlined in the TEEB foundations documents by de Groot et al. (2010) and Elmqvist et al. (2010).

2.2.3 Major Ecosystem Service Assessment Projects

The largest ecosystem assessment process was the Millennium Ecosystem Assessment itself, which contained over 30 regional sub-assessments. Summaries of the MA's major results make up five volumes.

Two major ecosystem assessments have been done in Europe. One was completed by the Council of the European Academies Science Advisory Council

Millennium Ecosystem Assessment (MA 2005)	The Economics of Ecosystems & Biodiversity (TEEB 2010)	Common International Classification of Ecosystem Services (CICES 2013)	
PROVISIONING SERVICES			
Food	Food	Nutrition	Biomass
Fresh Water	Water		Water
Fibre	Raw Materials	Materials	Biomass
Genetic Resources	Genetic Resources		Water
Biochemicals, Natural Medicines & Pharmaceuticals	Medicinal Resources	Energy	Biomass-based Energy Sources
Ornamental Resources	Ornamental Resources		Mechanical Energy
Fuel			
REGULATING SERVICES			
Erosion Regulation	Maintenance of Soil Fertility (including soil formation) & Nutrient Cycling	Maintenance of Physical, Chemical, & Biological Conditions	Soil Formation & Composition
Climate Regulation	Erosion Prevention		Atmospheric Composition & Climate Regulation
Air Quality Regulation	Climate Regulation (including carbon sequestration)		Pest & Disease Control
Natural Hazard Regulation	Air Quality Regulation		Lifecycle Maintenance, Habitat & Gene Pool Protection
Pest Regulation	Moderation of Extreme Events		Water Conditions
Disease Regulation	Biological Control	Mediation of Flows	Mass Flows
Pollination	Pollination		Liquid Flows
Water Regulation	Regulation of Water Flows		Gaseous & Air Flows
Water Purification & Waste Treatment	Waste Treatment (especially water purification)	Mediation of Waste, Toxics, & Other Nuisances	Mediation of Biota
			Mediation by Ecosystems
SUPPORTING SERVICES			
Soil Formation	Lifecycle Maintenance	(Not part of CICES)	
Photosynthesis	Maintenance of Genetic Diversity (especially through gene pool protection)		
Primary Production			
Nutrient Cycling			
Water Cycling			
CULTURAL SERVICES			
Aesthetic Values	Aesthetic Information	Physical & Intellectual Interactions with Biota, Ecosystems, & land-/seascapes (environmental settings)	Physical & Experimental Interactions
Recreation & Eco-tourism	Opportunities for Recreation & Tourism		Intellectual & Representative Interactions
Inspiration	Inspiration for Culture, Art & Design	Spiritual, Symbolic & Other Interactions with Biota, Ecosystems, & land-/seascapes (environmental settings)	Spiritual and/or Emblematic
Knowledge Systems	Information for Cognitive Development		Other Cultural Outputs
Educational Values	Spiritual Experience		
Spiritual & Religious Values			
Cultural Diversity			
Cultural Heritage Values			

Figure 20: Comparison of different classifications of ecosystem services
(adapted from Kumar 2010 pp 39-40 and CICES 2013)

(EASAC) and summarizes features across Europe. The United Kingdom National Ecosystem Assessment (2011) reviews the status of ecosystem services in the United Kingdom. Both provide examples of the level of detail that can be involved in an ecosystem assessment. A related ecosystem services approach was developed in Europe by the RUBICODE project. TEEB (2013) recently summarized a number of assessments of water and wetlands from around the world.

There are also approaches for assessing specific ecosystem types. The International Union for the Conservation of Nature (Springate-Babinski, Allen and Darwall 2009) prepared a guide to 'integrated wetland assessment' with a comprehensive scope of topics and steps. The state of Victoria, Australia, completed an assessment of the ecosystem services of an arid watershed before the MA was published, using their own ecosystem assessment approach (Binning et al. 2001). The province of Alberta used an assessment approach for a regional wetland assessment that was based on the MA (Raudsepp-Hearne, Claesson and Kerr 2011). Exmoor National Park (2007) in England used an ecosystem services approach as a basis for park wide planning. A number of specific examples are described in the Examples and Case Studies sections.

3.0 Geospatial Mapping and Modeling

Geospatial mapping and modeling is another way to bring ecosystem services into planning and decision making. These efforts map ecosystem services and model the relationships of the services to biophysical processes and social benefits. Below we describe two approaches to mapping and modeling. The first emphasizes simulation models of ecological production functions and the second maps ecosystem service features on the landscape.

3.1 Map and Calculate Ecological Production Functions (InVEST)

Mathematical expressions describing the biophysical processes that create ecosystem services are called 'ecological production functions'. For example, the soil erosion that occurs at a location can be modeled as a function of slope, soil type, vegetation and rainfall at that location. With such a model, one could estimate changes in erosion likely to result from a new development, given soil type, slope, vegetation, and rainfall. Models can also estimate economic values of services at a specific location. The results can be used to map ecosystem services, values and other land use features in that location. These maps are powerful tools for planning and management. They can provide inputs to scenario planning and discussions about options.

The most comprehensive approach to modeling and mapping production functions is being undertaken by the Natural Capital Project. This is a large project run jointly by Stanford University, the World Wildlife Fund, Conservation International and the University of Minnesota. The Natural Capital Project has produced computer models for both terrestrial and marine habitats which are collectively called InVEST models (Integrated Valuation of Ecosystem Services and Tradeoffs).

The InVEST models first permit users to apply local information to the landscape attributes (the production functions) that apply to each separate ecosystem service. Twelve ecosystem service modules and biodiversity calculations are described by Karieva et al. (2011 p. 38). They can also apply economic valuation processes to those services. The modeling features are embedded in add-ons to ArcGIS software that are available free for use with the commercial ArcGIS program (the most recent versions are moving from ArcGIS to Windows based software.) Depending on the precision amount of the data used, such analyses can be done at two levels of detail, called Tier 1 and 2. The recent book by Kareiva et al. (2011) describes the approach in detail. Tallis and Polasky (2009) provide a shorter summary and Nelson et al. (2009) show the InVEST mapping process applied to the Willamette watershed in Oregon.

Other groups have also used simulation and production function modeling with ecosystem services. Open source examples include Artificial Intelligence for Ecosystem Services (ARIES), and the Multiscale Integrated Models of Ecosystem Services (MIMES). Nelson and Daily (2010) discuss modeling, ecosystem services and the features of major models. A technical introduction to ecological production functions is available from the National Academy of Science.

3.2 Mapping Ecosystem Services to Integrate with Environmental Planning

Ecosystems services can be included in regional planning by direct mapping. One can do so most formally with computer-based data integration, though task-specific mapping for management purposes is also common.

Geographical Information Systems (GIS) are computer based data systems that permit versatile electronic mapping. GIS is often described as creating multiple electronic 'layers' of different properties which are added upon a base map of a landscape. GIS is now very common in governmental and corporate planning facilities and is available for ecosystem services projects.

Turner, Georgiou and Fisher (2008) take this approach in a book (Valuing Ecosystem Services: The Case of Multi-functional Wetlands) designed to provide a model of how to work with ecosystem services. They identify a series of steps that identify different wetland types, the services they provide, calculate monetary values for them and then use those values in regional planning. Their planning process uses five layers related to wetlands (Turner, Georgiou and Fisher 2008, p 11) as described in Figure 21 below.

The book focuses on the fourth layer. Some members of their team applied the full mapping process to regional planning in Tanzania (Fisher et al. 2011).

Mapping ecosystem services is not always explicitly linked with GIS. Mapping more generally is a major step in planning and management with ecosystem services at regional scales. Naidoo and Ricketts (2006) and Burkhard et al. (2009) reviewed considerations related to mapping ecosystem valuations and landscape services. Petter et al. (2012) focus on mapping the ecosystem functions that generate services. A special issue of the journal Ecological Indicators collected many perspectives on mapping and landscape planning with ecosystem services.

Most studies use vegetation or habitat mapping units as proxies for ecosystem services. Extracting specific ecosystem services, which vary with how people use them, from their landscape origins, and mapping them is a challenging and contentious task (Paetzold, Warren and Maltby 2010). Hein et al.'s (2006) thoughtful consideration of scale, stakeholders and ecosystem services is relevant to that challenge. Because governance is location and scale specific, the ability to link ecosystem services to mapping tools is likely to continue to be a popular and practical approach.

There are several Examples and Case Studies described that are related to mapping ecosystem services.

Figure 21: Mapping layers integral to ecosystem services approach
(adapted from Turner, Georgiou and Fisher 2008, p. 11)

COMPONENT OF BIODIVERSITY	EXAMPLES OF ECOSYSTEM SERVICES
Governance layer	Formal and informal rights and agreements over resource management
Value layer	Valuation or evaluation studies
Benefits layer	Service flow, demographic and land use characteristics
Service flow layer	Production and land cover, topography
Service production layer	Biophysical conditions and processes

4.0 Discussion

How can work at the regional and municipal scale use the approaches described in this Special Topic? At first glance, the number of steps, the amount of data concerned, the quantity and variety of potential measures of ecosystems and services, and the many ways to analyze them seem quite daunting. The apparent budget and time commitments implied by the size of example projects can seem beyond the scope of many local participants. Those observations are correct. It would not be possible for many cities or citizen groups to undertake tasks like many of these big projects.

On the other hand, the six steps of the TEEB process are logical and simple. The MA and TEEB guidelines explicitly say that they are flexible and applicable at different scales. The InVEST models are regionally focused and have simple versions which require limited data. There are examples available on MA and TEEB websites of local and municipal projects. Many local organizations have access to mapping facilities. These major approaches can have applications for local practitioners. How can one best build upon them? We have several suggestions.

4.1 Be aware of major approaches to this work

These major studies are models and benchmarks for other work. Even if you do not follow their procedures directly, the language of the field, the classification systems people use and the policy options that other people discuss probably build on these foundations. Although the MA is the most famous, it helps to know how the field has evolved since it was completed. Alternatives like TEEB and InVEST differ from it and may be more appropriate for you. Examining documents related to MA, TEEB, InVEST or the other mapping procedures provides a background to the choices you will make. The links mentioned in Section 2, in this Special Topic, and in the Examples section can provide a sound start. Then you can build a project to suit your needs.

4.2 Use frameworks like MA and TEEB as guidelines rather than strict recipes

It is unlikely that you will undertake a project as large as the big assessment projects. But their basic steps are planning processes that can apply at local scales. TEEB's six steps are a simple starting point for many local projects. The Cities manual describes assessment procedures as do the other TEEB guidelines (TEEB 2011, 2010a,2010b), and Ragnanathan et al. (2008) does also. Mapping and planning projects like Chan et al. (2006), Nelson et al. (2009) and Fisher et al. (2011) provide examples that you can build upon, even if you do not follow their details. Landsberg et al. (2011) integrate ecosystem services assessment with environmental impact assessment, which you might want to do. You can use their examples when they help you. Special Topic 3 describes three major tasks from within the large approaches that stand on their own and which might be useful to you.

4.3 With an inspired interest, you can incorporate natural capital and ecosystem services in other professional practices

The Millennium Assessment inspired many subsequent projects and much interest in ecosystem services. You can build on this enthusiasm without using their processes directly. You could add natural capital and ecosystem services, as new elements within your existing professional practices. For example, if you already work preserving water quality, you can add a broader dimension with attention to the ecosystem services related to water. Are you already protecting all water related services, or just some? What could you do to protect more services and add more benefits for people in your watershed? You can phase in more such work gradually as you and your colleagues become more familiar with new practices. Special Topic 2 describes established professional tools which support ecosystem services which you could add to your current practices.

Special Topic #3

Common Tasks Used with Ecosystem Services

1.0 Introduction

Section 3 discusses comprehensive approaches to study ecosystem services. Established approaches like the Millennium Assessment and production function mapping incorporate many steps, which we call 'tasks' here for simplicity. Three tasks commonly used in ecosystem services work are described here:

- Classification of Services and Benefits
- Economic Valuation Studies
- Payments for Ecosystem Services

Each task is worth using. The first two are major tasks in most assessment processes. The third is more specific, and is an increasingly popular mechanism to sustain ecosystem services. Each task can be carried out using different techniques. This discussion can help you decide whether to use one or more of these tasks on a project.

.

2.0 Classification of Services and Benefits

The most common classification systems for ecosystem services are those of the Millennium Assessment and TEEB, outlined in Special Topic 2. Other kinds of classification might be more appropriate for specific purposes. We discuss several alternatives that can complement the major systems. Although the sources cited in the text below all provide further information, the papers by Fisher, Turner and Morling (2009) and Haines-Young and Potschin (2009) are good overviews of alternative classifications.

2.1 Intermediate and final services

It is important to distinguish intermediate from final services. One must avoid 'double counting' of different inputs when estimating the total value of an output. For example, the total value of an automobile is its final price. That price includes the cost of the steel, plastic, labour and the other inputs that went into creating the vehicle. One does not count the price of those 'intermediate products' in addition to the 'final product'. It would be an error to add the cost of the steel, labour and other inputs to the final price, to calculate the total value, since they are already included in the price.

The potential for double counting exists in dealing with ecosystem services if one counted the value of water filtration separately and in addition to the value of the final drinking water. Turner, Georgiou and Fisher (2008) discuss the issue of double counting in valuation. There is potential for difficulties since prices are often not available, and we often deal only with the names of different services and benefits. Building on Figure 22, they make specific distinctions:

". . . we designate services to be either intermediate or final with human welfare benefits flowing from these final services. . . . In accounting systems, valuation exercises and policy decisions we are most often concerned with benefits, and therefore a more transparent method for evaluation is simply to consider the system in terms of intermediate services, final services and benefits. Given this schema we know only to add up, value or weigh the benefits for comparison." (Turner, Georgiou and Fisher 2008, p. 6-7, italics in original)

The issue of intermediate and final services is built into recent assessments. The United Kingdom National Assessment explicitly includes intermediate and final services in its conceptual framework (Mace et al. 2011). The TEEB system does so too, although more indirectly, in two ways. Most of what were called 'supporting services' in the MA classification are removed from what TEEB renamed 'habitat services'. The former supporting services were effectively intermediate services which are now considered part of the 'ecosystem functions'.

However the issue of intermediate and final services remains tricky. As Turner, Georgiou and Fisher (2008) and Boyd and Banzhaf (2007) point out, some things can be intermediate services in one context and final services in another. You must think things through case by case.

In addition to intermediate and final services, other alternative classifications have been described (Costanza 2008, Wallace 2008, Turner, Georgiou and Fisher 2008, and Fisher, Turner and Morling, 2009). Next, we explore their points about spatial characteristics, excludability and rivalness, and equity and human welfare.

2.2 Spatial Characteristics

Turner, Georgiou and Fisher's (2008) wetland analysis suggested that the spatial characteristics of ecosystem services could be used to classify them. They suggest that such a system:

"…might involve categories that describe relationships between service production and where the benefits are realized. Such a classification might include characteristics such as:

- *in situ*—where the services are provided and the benefits are realized in the same location
- *omnidirectional*—where the services are provided in one location, but benefit the surrounding landscape without directional bias;
- *directional*—where the service provision benefits a specific location due to the flow direction.

A classification scheme as such could also use scale qualifiers, such as local omnidirectional (e.g. pollination), and regional direction (flood protection)." (p. 8)

They offer the European Union's Water Framework Directive, which mandates river basin planning and data compilation, as a case that is "incorporating spatio-temporal characteristics of a natural system into policy solutions." (p. 8) While river basin planning is a is a rational biophysical approach, it is hardly new or specific to ecosystem services. Nonetheless, spatial and mapping systems do seem very relevant to ecosystem services contexts.

Costanza (2008) offers two alternative classifications, one based upon spatial characteristics. (The second, concerning equity, follows immediately below). He suggests five major spatial categories:

- Global non-proximal (does not depend on proximity)
- Local proximal (depends on proximity)
- Directional flow related—flow from point of production to point of use
- Directional flow related—in situ (point of use)
- User movement related: flow of people to unique natural features

Costanza felt that the kinds of ecosystem services identified in other classification systems could be reconsidered spatially: he placed all 17 ecosystem services from his own earlier functional classification into one of these five spatial categories (Costanza 2008, Table 1).

In his rebuttal to Costanza's suggestions, Wallace (2008. p. 354) notes: "Consequently, of the two alternative classification systems proposed by Costanza, that relating to spatial scales is a useful list of issues to bear in mind when establishing goals, but it is not a classification system for ecosystem services."

Regardless of whether the spatial characteristics make a classification system, it seems that Turner, Georgiou and Fisher and Costanza's suggestions could be helpful in many situations, particularly when thinking about mapping services.

2.3 Excludability and Rivalness

In his dispute with Wallace, Costanza (2008, p. 351) offered a second alternate classification system:

"Another way to classify ecosystem services is according to their 'excludability and rivalness' status. Table 2 (below) arrays these two characteristics against each other in a matrix that leads to four categories of goods and services. Goods and services are 'excludable' to the degree that individuals can be excluded from benefiting from them. Most privately owned, marketed goods and services are relatively easily excludable... Goods and services are 'rival' to the degree that one person's benefiting from them interferes with or is rival with another's benefiting from them." (p. 351)

Neither category is absolute. There is a range of both rivalness and excludability. (Fisher, Turner and Morling (2009).

Fisher, Turner and Morling (2009) also consider excludability and rivalness. They conclude ". . . the complexity of understanding how ecosystem services and their benefits fit into the public–private goods space, is not just a function of the ecosystem dynamics, but also in the social systems that interface with these goods and services" (p. 647). Thus, ways of organizing these services could be important for you if your work addresses such social interactions. (More details on the Wallace and Costanza debate are found in Special Topic 1.)

Figure 23: Excludability and rivalness of ecosystem services
(adapted from Costanza 2008)

	EXLUDABLE	NON-EXCLUDABLE
RIVAL	Market goods and services (most provisioning services)	Open access resources (some provisioning services)
NON-RIVAL	Club goods (some recreation services)	Public goods and services (most regulatory and cultural services)

2.4 Human well-being

Wallace (2007) points out that most classifications do not distinguish the 'means' from the 'ends' of the items at hand. He makes a vigourous case for considering human well-being, related target 'end-states' (which he calls 'values') and distribution of benefits in ecosystems services planning (the ends). He recommends including such matters in the basic classification system. A shortened version of his suggested classification system is in Figure 24 on the following page. Fisher, Turner and Morling (2009) think human well-being is an important concern and that Wallace's classification scheme is a potential resource in that context.

2.5 Cultural services, benefits and values

Debate about clarifying the 'cultural services' category continues. Some observe that cultural services named in the Millennium Assessment, such as recreation, education and aesthetic services, are important, but do not fit the idea of 'services' like the other categories. Fisher, Turner and Morling (2009, p. 644) summarize: "cultural services which (are not services but) we see as very valuable benefits derived from ecosystems and services." Schaich, Bieling and Plieninger (2010) compare cultural services and the different but related concept of cultural landscapes. Hernández-Morcillo, Plieninger & Bieling (2013) describe many different indicators used with cultural ecosystem services and the assumptions and classifications which went with them.

Chan and colleagues (2011, 2012) review some of the challenges associated with cultural services, and provide an alternative approach: "Here we define cultural services inclusively as ecosystem's contribution to the nonmaterial benefits (e.g. capabilities and experiences) that arise from human-ecosystem relationships." 2011 p. 206, italics in original). The authors distinguish a variety of related benefits, and 14 kinds of use and non-use values. Cultural services

are challenging but important and these authors' ideas can provide insights if your project needs to explore these topics.

The different classification alternatives just discussed, and the differences in major systems like MA and TEEB, can sometimes seem confusing. But it is important to know that alternative approaches exist, so one can apply what is best suited to one's own situation. The TEEB classification (like the MA before it) is simple, widespread and can be a helpful starting place for audiences. It is likely to be helpful for most communication and education purposes and early steps of management and planning. The other classifications are likely best for specific purposes and contexts.

Figure 24: Proposed classification of ecosystem services and links to human values, ecosystem processes, and natural assets (Adapted from Wallace 2007, Table 3)

<table>
<tr><th>CATEGORY OF HUMAN VALUES</th><th>ECOSYSTEM SERVICES EXPERIENCED AT THE INDIVIDUAL HUMAN LEVEL</th><th>EXAMPLES OF PROCESSES & ASSETS THAT NEED TO BE MANAGED TO DELIVER ECOSYSTEM SERVICES</th></tr>
<tr><td>Adequate resources</td><td>Food, oxygen</td><td rowspan="4">Ecosystem processes:

Biological regulation
Disturbance regimes, including wildfires, cyclones, flooding
Soil formation, Etc.

Biotic and abiotic elements:

Biodiversity assets
Water assets, Etc.</td></tr>
<tr><td>Protection from predators/disease/ parasites</td><td>Protection from predation</td></tr>
<tr><td>Benign physical and chemical environment</td><td>Benign environmental regimes of temperature, moisture, light.</td></tr>
<tr><td>Socio-cultural fulfillment</td><td>Access to resources for: spiritual/philosophical contentment</td></tr>
</table>

2.6 Cultural services, benefits and values

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3.0 Economic Valuation Studies

'Assess ecosystem services and human well-being' is the second step in the implementation stage of the Millennium Ecosystem Assessment process, described in Section 2. Such assessment includes describing the services, ranking their relative importance, identifying their beneficiaries and assigning economic values where appropriate. The TEEB process emphasizes economic evaluation, which is a very substantial task. Valuation attracts a great deal of attention and discussion within the world of ecosystem services. Haines-Young and Potchin (2009) report "it is the valuation issue which is now driving the field forwards" (p. 43.)

Recall that the idea of ecosystem services was invented to better include nature into public decision making. Without a price, water, air and other services are hard to compare to traditional topics like jobs and return on investment. Hence, there are many efforts to calculate 'surrogate monetary values' for ecosystem services that do not have prices in the marketplace. Such valuation studies provide a means to include ecosystem services in public discussion. Monetary values are not the only way to do that, but they are one important approach. Here we describe the main features of economic valuation.

We address two major ideas:

- Economic valuation and Total Economic Value
- The relationship of economic valuation to other kinds of 'value'

3.1 Economic Valuation

Valuation comes from the field of economics. Economic value is the comparative importance, worth, or relative utility of something to a person. Therefore, within economics the term 'value' means 'economic worth' or 'price' when goods are available in a marketplace. There are multiple other meanings of the term 'value' that can be relevant to ecosystem services-for example the term also can mean 'aesthetic standards', 'moral principles', or 'ecological importance'. Unfortunately, other meanings of 'value' are sometimes discussed in valuation literature and the authors do not always distinguish what kind of 'value' they are discussing. Readers must watch out for those ambiguities.

Trying to measure the economic value of things that do not always have market prices, requires special efforts. Economists have set up a framework to help. They identify five different kinds of economic value that nature can provide to people, within two categories. The framework is called Total Economic Value or TEV. TEV sets up a hierarchical classification system (Figure 25).

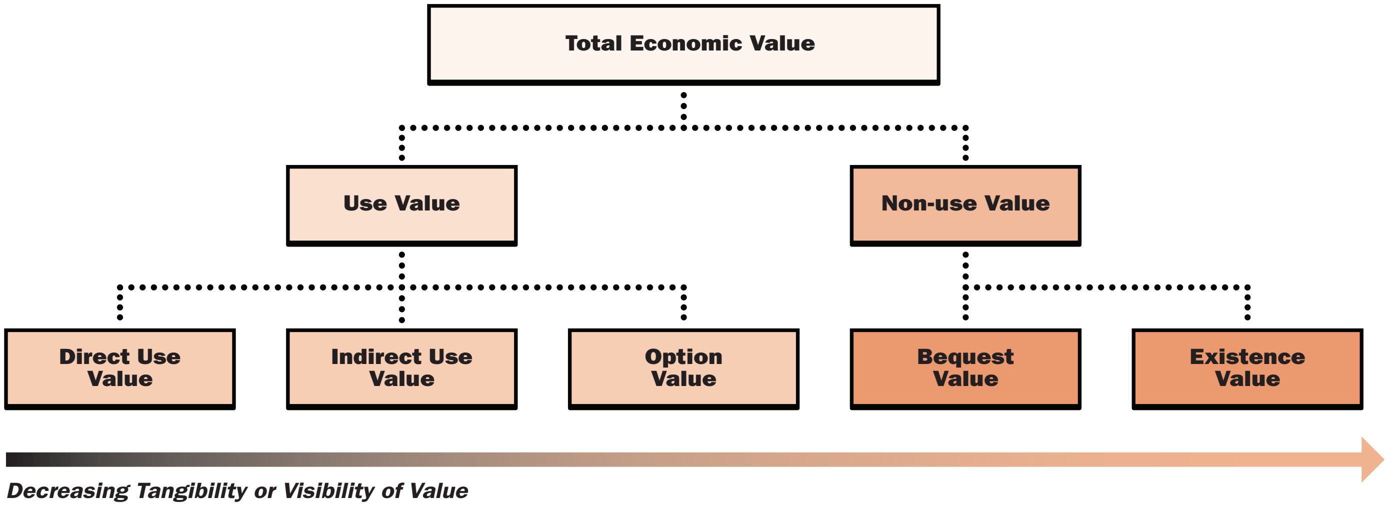

Figure 25: The Total Economic Value categories that could apply to a resource
(Adapted from DEFRA 2007)

Use value refers to value obtained by using something. Direct use value refers to the value that people obtain from using a resource directly, for example by harvest or for recreation. Some direct use resources, such as water or forms of recreation, do not usually have purchase prices.

Indirect use values support direct use. The decomposition of wastes, for example, can indirectly benefit a direct use, the consumption of clean water. Option value represents that economic value assigned to the value of maintaining a resource for future use. Indirect and option use values rarely have prices and their value is tricky to estimate.

The two boxes of the non-use category capture the value that comes from knowing resources are available. Existence value is the value people assign to something simply because it exists, without having any other use. For example, it is important for some people that wilderness exists somewhere, or that tigers live in a forest far away, even if that person never sees the resource in question. Bequest value refers to benefits expected for future generations. These two categories are also challenging to evaluate.

Pearce et al. (2006) comment on why it helps to distinguish between the use and non-use components of TEV:

"... in practice, it is usually not possible to disaggregate individual types of non-uses value, nor is it usually relevant to a decision to secure that breakdown. But differentiating use and non-use values is important because the latter can be large relative to the former, especially when the good in question has few substitutes and is widely valued. In addition, non-use value remains controversial in some decision-making contexts, so it is important to separate it out for presentational and strategic reasons." (p. 86)

TEV provides a framework within which to estimate resource values. Hein and colleagues (2006) provided a thoughtful framework for integrating TEV with ecosystem services assessment. Figure 26 summarizes their ideas. Two key points are worth pointing out. Step 3 indicates that one can use multiple methods for a single valuation project. This is appropriate since a given location or landscape is likely to have multiple services which might require more than one measure each.

Steps 3 and 4 indicate that both monetary and 'other' indicators can be used and combined as needed. This is an important point: all of these methods are economic, but not all economic measures use money. Non-econo-

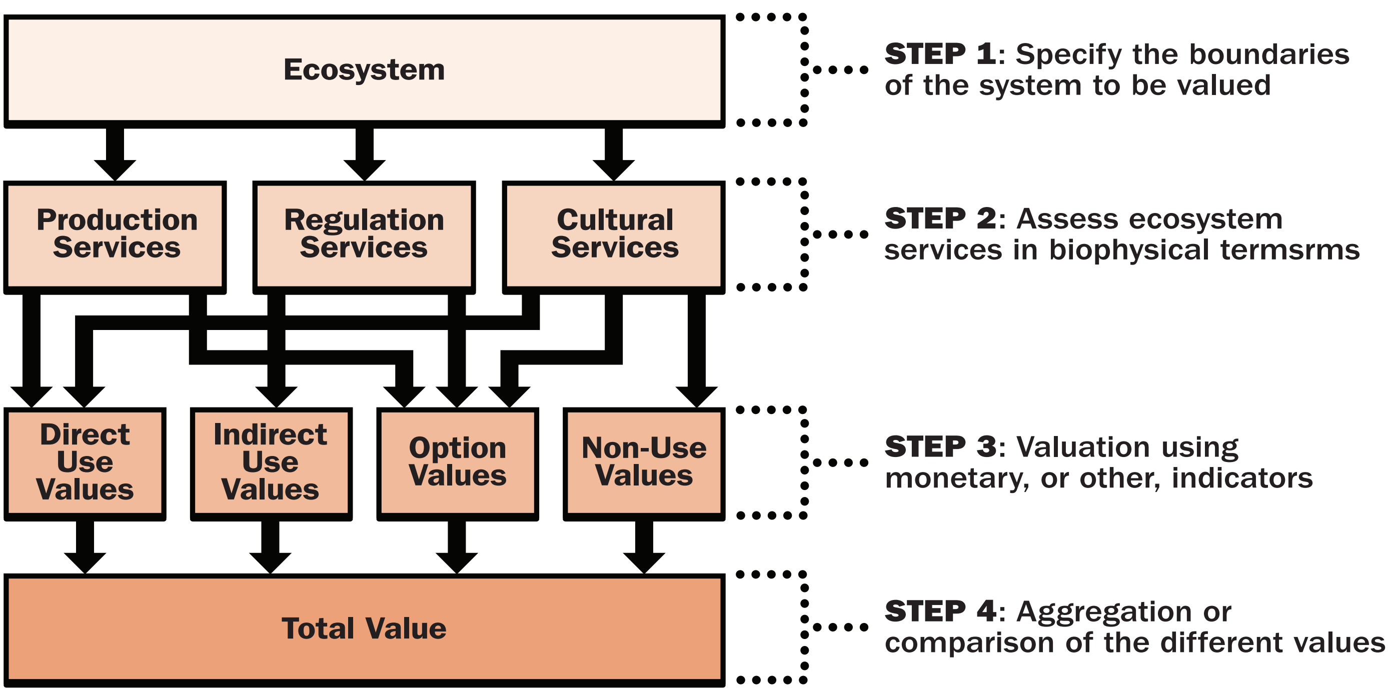

Figure 26: The ecosystem valuation framework.
(Adapted from from Hein et al. 2006)

mists often think that 'economic' and 'monetary' are synonyms, which is not the case. Monetary measures are a subset of economic measures. This framework can help you plan and can help simplify an assessment project. The detailed evaluation techniques named below can fit within this model.

Most economic valuation methods were developed before ecosystem services were considered important, and were not designed for them (see Freeman 2003, Adamowitz 2004, Pearce, Atkinson and Mourato 2006). Important discussions of valuation techniques applied to ecosystem services are provided by the National Research Council (2004), Pagiola, von Ritter and Bishop (2004), DEFRA (2007), Environmental Protection Agency Science Advisory Board (2007), Turner, Georgiou and Fisher (2008), Haines-Young and Potschin (2009) and Pascual et al. (2010).

Valuation methods are classified differently by different sources. Young (2005) identifies 17 non-market methods of water valuation. However Taylor and Kennedy (2008) report that eight of those methods are used most often. Pagiloa et al. 2004 describe eight main valuation approaches for ecosystem services. Haines-Young and Potschin (2009) expand Pagiola et al's list to ten. Turner, Georgiou and Fisher (2008) list nine. However, with minor variations, they address the same ideas. Figure 27 builds on those sources and identifies four different kinds of method and briefly describes ten major techniques.

Figure 27: Major features of common economic valuation methods

KIND OF METHOD	TITLE OF METHOD	DESCRIPTION
Market based methods	Prices	While the emphasis is on non-market methods, sometimes market information can be used. Some products (crops, lumber, bottled water) do have prices in some markets and these can be used for some estimates or to contribute to an overall value. For example, if wild rice is harvested from a wetland, the value of sales can be one element of the total value of the wetland.
	Replacement cost	Using known market costs of other goods or services can be used for some calculations. For example, one estimate of the worth of the filtration services of a forested watershed could be the cost of building a water filtration plant to replace them. There are known costs of such infrastructure. Often used as part of a comparison between typical 'grey' infrastructure and alternate 'green' infrastructure.

KIND OF METHOD	TITLE OF METHOD	DESCRIPTION
Market based methods	Production function	Takes data for industrial or agricultural inputs and outputs, often with statistical analysis, to estimate how much an ecosystem service contributes to a product or to enhancing productivity.
Non-market based methods: Revealed Preference		Estimates financial worth by studying peoples' actions and what they 'reveal'. Market-based methods are often considered to be revealed preference methods also.
	Travel cost	This technique estimates recreational value of a service (e.g. lake) by estimating the travel and related costs to visit and use it.
	Hedonic pricing	Estimates the value of an environmental attribute by inferring how it influences the demand for a marketed commodity. For example by calculating how much house prices rise when they are closer to a park gives an estimate for the value of the park.
Non-market based methods: Stated Preference		Asking people to 'state' their preferences without them actually having to pay or act on their stated preferences.
	Contingent valuation	This technique involves asking how much people would be willing to pay to preserve a wetland, landscape view, etc. This is a controversial valuation method
	Choice experiment	People are given hypothetical choices between different actions/expenses in hypothetical scenarios described to them.

KIND OF METHOD	TITLE OF METHOD	DESCRIPTION
Non-monetary methods		Although these methods are a form of stated preference methods, they differ in not involving monetary calculations, thus they can involve comparisons of quite different topics (landscape beauty or spiritual meaning) for which people cannot estimate a monetary worth. Includes 'multiple attribute' choice methods.
	Contingent ranking	People rank the order or otherwise weight or score the importance of different services.
	Group valuation	A variety of participatory or deliberative techniques in which groups of people review and rank or select choices.
Other methods	Benefits transfer	Using economic values calculated at one site, using any of the methods described here, and applying those estimates, with modifications, to a geographically different location. For example, taking estimated values of wetland services in Maryland and applying them to a wetland in California, with some 'adjustment' to accommodate different local conditions.

The main methods that you might hear about as you explore ecosystem assessments are briefly described in Figure 27. However, the methods are not equally well regarded. Although they all have limitations, contingent valuation and benefits transfer are the most commonly challenged as potentially unreliable (National Research Council 2004).

Most ecosystem assessments use estimates of monetary value. However there are non-monetary methods. Non-monetary methods (see Pereira et al. 2005, Raymond et al. 2009, Bryan et al. 2010, Martin-Lopez et al. 2012) are gaining in popularity (although they are still less widely used than monetary methods) because the monetary approaches are often seen as insufficiently inclusive. Non-monetary approaches involve ranking or weighting, which permits people to compare quite different categories (e.g. flood protection to landscape beauty).

Economic valuation studies of ecosystem services include those of: landscapes near Vancouver (Wilson 2010) and Toronto (Molnar et al. 2012a), nearshore aquatic habitats near Vancouver (Molnar et al. 2012b), the region of Puget Sound near Seattle (Batker et al. 2008), wetlands in Wisconsin (Earth Economics 2012), wetlands in Alberta (Wang et al. 2011), and forest ecosystem services in China (Niu et al. 2012). There are additional details among the Examples and Case Studies.

Valuation might be just one of several tasks in an ecosystem assessment, but it is also a task that can stand alone as a worthwhile effort . For readers whose projects do not require the complexity of a full economic evaluation, some non-monetary methods can be helpful and simple on their own. The Examples reported here describe non-monetary descriptive rankings of some characteristics.

3.2 Economic value and other kinds of 'value'

While economic valuation helps deal with benefits to people, it is not the only relevant approach. Four points related to other kinds of value are worth clarifying:

- Different categories of value can be addressed with methods appropriate to each,
- Different kinds of value can be compared or combined with multi-criteria decision making
- Economic valuation assesses specific uses of nature and does not attempt to provide an overall measure of the value of nature
- The economic category `existence value' does not measure intrinsic value.

In the economic studies discussed in this section, `value' means `economic worth' or `utility'. In other contexts `value' can also refer to importance or worth of other kinds. One is biophysical or ecological importance, such as an ecological process which is valuable (important) in maintaining an ecological community. Within the TEEB process, Pascual et al. (2010) distinguish two major biophysical values which complement economic ones and can be assessed in parallel with them. They call them `insurance', referring to protection or maintenance of an ecosystem, and `consumption,' referring to the energy or materials generated by a natural system. The point Pascual et al. make is that economic and biophysical approaches are addressed differently. They provide a framework for separating and discussing those other values, in parallel with economic ones.

Economists also recognize that multiple perspectives are necessary:

"No one would suggest that economic values should rule the day. Economic valuation measures are only one component of the criteria available for evaluating policy. Correctly interpreting what economic value measures mean does not require exclusive reliance on the results from such calculations." (Bockstael et al. 2000. On Measuring Economic Values for Nature. p.1389 (italics in original))

If one is going to deal with more than economic criteria, how does one do so? The formal title for using different kinds of criteria (as compared to only one—usually money), is `multiple criteria decision analysis' or MCDA. It is a popular topic among those who want to include non-monetary considerations, to include stakeholders more actively, or to use understandable and non-mathematical approaches. The DEFRA (2007) review provides a good synthesis of economic analysis and multicriteria decision making approaches. There is more discussion of decision making processes in Section 4 and Special Topic 5.

Some critics assume that economic valuation studies put a monetary or dollar value on water, the environment or nature itself. Taking such steps is often considered foolish or unethical. These assumptions represent misunderstandings. It is helpful to consider one economist's clarifications, which he felt important enough to mention in the first paragraph of a book describing economic valuation:

"(This book's) subject is exclusively the way in which economists seek to `measure preferences' for improvements in environmental quality and natural assets, or against their deterioration. `Measuring preferences' is a clumsy phrase, but at least it tells us what economic valuation is. Phrases such as `valuing the environment' (which I am as guilty of using as the next person) are really very misleading. Economists do not `value the environment'. They observe that individuals have preferences for improvements in the environment and that those preferences are held with varying degrees of intensity. For over a hundred years there has been a highly developed science within economics for measuring this intensity of preference. Its practice is known as cost-benefit analysis (or, more logically in the USA as benefit-cost analysis, the hyphen also serving as a `minus' sign). Perhaps because of the confusing terminology, many non-economists get rather upset at this idea of `valuing' environmental assets in monetary terms. I hope this little book will help persuade them that nothing evil is afoot." (Pearce, D. 1993. Economic values and the natural world p. ix)

Another point concerning valuation is worth clarifying. The existence value category does not measure the intrinsic value of nature. However, existence value, and other components of Total Economic Value, can have a relationship to intrinsic value. Resource economists Pearce et al. (2006) comment on this point:

"…critics…sometimes reject the notion that individual preferences should be the yardstick of 'value' preferring instead to speak of the intrinsic value of environmental assets, especially living assets. How is TEV related to the notion of intrinsic value? Intrinsic value is often regarded as being a value that resides "in" the asset in question, and especially environmental assets, but which is independent of human preferences. By definition, TEV relates to the preferences of individual human beings, so that if intrinsic value is defined to be independent of those preferences, TEV cannot encompass intrinsic values. However, notions of intrinsic value may well influence WTP (willingness to pay) and stated preference valuation techniques are particularly useful in eliciting such influences. . . .TEV cannot embrace a measure of intrinsic value, but (stated preference methods do) help to make the motivations for WTP explicit, and those motivations may well involve a concern 'on behalf' of the object being valued." (p. 87)

These perspectives on other kinds of value can help you balance the very strong emphasis on economic value in some work with ecosystem services.

4.0 Payments for Ecosystem Services (PES)

Once it is clear that nature contributes important services for people, and that the beneficiaries are often distant in space or time from the services, the question can arise: how do the beneficiaries guarantee the supply of their services? How can city people make sure that someone upstream does not clear their forest, to sell the wood, and thereby yield erosion and spoiled water quality downstream? One answer is to give the landowners upstream cash payments so they do not log their land. Such efforts are called Payments for Ecosystem Services or Payments for Environmental Services, both with the acronym PES.

Ferraro (2011) provides reasons for the increasing popularity of PES projects, from several standpoints:

- In developed nations PES is popular because it complements the trend to redirect agricultural subsidies towards more general public benefits and conservation projects
- In low and middle income regions, PES are supported for four reasons
- Weak local institutions make other kinds of environmental regulation difficult
- Governments prefer subsidies over direct regulations and are becoming more willing to apply standards of performance, which are effective with subsidies
- Donors and governments believe PES can help achieve both biodiversity and poverty alleviation goals.
- Donors and governments also believe PES projects can become self-financing and need only short term investments to get them underway.

Payments are appropriate where it is possible to identify a clear group of beneficiaries and an equally clear and separate group who control the ecosystem services. Governments or large NGOs often act on behalf of large numbers of beneficiaries. That is, the government represents citizens, many of whom benefit from ecosystem services. Sometimes large NGOs represent environmentally concerned citizens, or operate with financial funding from governments from other countries.

Wunder (2008), a leader in working with PES "currently exist(s) for four environmental service types: carbon, watersheds, biodiversity and landscape beauty" (p. 1). Potential PES recipients are those who control lands which influence water quality, store carbon, harbour wildlife or sustain attractive landscapes. Such conditions often apply to agricultural producers, rural landowners and villagers or indigenous peoples, whose land use could threaten the loss of those services. Payments provide and incentive to maintain or restore ecosystem services. Some PES programs are very concerned with maintaining the livelihoods of the producers of the services as well as with maintaining the ecosystem services. They sometimes emphasize that role by calling themselves 'pro-poor' PES (see Gouyon 2003, Duraiappah 2007 and Huberman 2009)

It is often simpler to identify both beneficiaries and providers of services related water supply and quality than for other services. Key guidelines for watershed PES projects are described by the Food and Agriculture Organization (2004) and Smith, de Groot and Bergkamp (2006). Bennett (2013) provides a state-of-the-art perspective on watershed payments worldwide, which include both PES programs and other market based mechanisms for managing watersheds and water quality. Porras, Alyward and Dengel (2013) address monitoring of watershed PES, a practice that usually forces consideration of a full range of management issues.

The fact that plants take carbon dioxide from the atmosphere is a service to humans who put excess carbon dioxide into the atmosphere. Land owners in many places can be paid to encourage carbon sequestration, or to keep wood and biomass from being burned, returning carbon to the atmosphere. Because there are large fees available for carbon storage to compensate for carbon dioxide released by industrial activity, substantial 'carbon markets' are developing. The World Bank summarized the markets and trends (Kossoy and Guigon 2012), showing the strong business and policy orientation of the whole field. The United Nations' Reduced Emissions from Reforestation and Land Degradation (REDD) program is more directly connected with implementing storage programs. It is built mostly around payments for carbon sequestration associated with protecting or regrowing forests and improving disturbed land. The REDD monitor organization and the Ecosystem Marketplace discuss both the positive and negative features of carbon markets, including many fraudulent carbon market schemes.

Biodiversity is the prime concern of many NGO and government organizations and many support PES programs (e.g. World Wildlife Fund 2006). However plants and animals live in watersheds, and preserving and regrowing forests for carbon also retains habitat. So biodiversity programs are often strongly related to watershed and carbon PES programs, and these projects often have multiple targets. The website of the Convention on Biological Diversity shows these overlaps, listing many different payment for services programs around the world.

Wunder (2008) mentions payments for landscape beauty, but this topic is much less developed, and less well defined, than the other three just mentioned. One review (Landell-Mills and Porras 2002, Ch 6) of payments for landscape beauty addressed 51 cases, all of them ecotourism efforts. Jindal and Kerr (2007) also discuss protection of attractive landscapes and seascapes, assuming that national and regional parks are set up dominantly for those purposes. Morrison and Aubrey (2010) point out that payments for landscape beauty mostly preserve the cultural services of tourism, recreation, spiritual and religious value. The PES goal is usually avoiding deforestation or other visually distracting actions, or restoring unsightly areas. Such efforts overlap with, and have very similar results as, efforts intended for watershed, carbon or biodiversity protection.

The special case of agriculture and agricultural producers is addressed by Kroeger and Casey (2007), Pretty (2008), Claassen, Cattaneo and Johansson (2008) and Yang et al. (2009). The goals for protecting specific ecosystem services are similar to those discussed above, although projects are designed for the agricultural context (FAO 2007, Lipper et al. 2009, Power 2010, Tarek 2010, Rapidel et al. 2011). The Food and Agriculture Agency (FAO 2011) makes an important case for linking payments for ecosystem services with payments for food security and sustainable agriculture.

How much should one pay people to keep native grassland intact to increase carbon sequestration, or to maintain wetlands so ducks can breed there? The economic valuation tools discussed above come into play to help answer that question, as do other matters of law and policy. PES are explicitly addressed in the TEEB (2010, 2011) reports for local and national policy.

Wunder (2011) created a definition and list of essential PES criteria, building on earlier definitions (see Wunder 2005 and Engel, Pagiola and Wunder 2008). He summarizes:

To work effectively, a Payment for Ecosystem Service process must be:

1. A voluntary transaction – to a variable extent on the buyer side; to a full extent on provider side
2. A well-defined environmental service (ES) or a land-use proxy, or some bundle thereof
3. Be "bought" by a (minimum one) ES buyer – which can be a public entity
4. From a (minimum one) ES provider or a community
5. If and only if the ES provider continuously secures ES provision – i.e. conditionality has to be present to some extent in design and function (Wunder 2011, p 9)

Greiber (2009) points out that while private contracts can work for PES projects, such arrangements are usually only possible at the local scale. For PES to be practical, larger scales are usually needed. He notes that since most PES projects are regional or national in scope, and involve substantial complexities, they require regional or national legislation to support them. Greiber (2009) concludes "an appropriate legislative framework which regulates public PES schemes has the potential to stimulate the development of trustworthy markets and to ensure good governance" (p. xiii). He points out that both property rights and public institutions must be reliable and effective.

Wunder's list of effectiveness criteria and Greiber's comments on legal complexity both provide insight into many of the challenges involved in getting PES projects to work well. There are both administrative and legal challenges to:

- Identifying who has services to offer and making the arrangements,
- Identifying who has revenues to provide and making the arrangements,
- Confirming who will provide the work needed,
- Maintaining land in an appropriate condition over time,
- Monitoring the provision of services,

- Maintaining payments over time.

Several large organizations provide guidance concerning PES programs. Landell-Mills and Porras (2002) prepared a detailed summary of PES for the International Institute for Environment and Development. Helpful outlines of the basic steps for starting PES plans are offered by the United Nations Environment Program (Katoomba Group 2008, 2010). The International Union for the Conservation of Nature has provided both a general introduction (Huberman 2008) and an extensive discussion of the legal and organization background to PES efforts (Greiber 2009). The United Nations' Food and Agriculture Organization (Lipper and Neves 2011, FAO 2011), discuss the applicability and experiences of PES programs and agricultural systems. The United Nations' Reduced Emissions from Reforestation and Land Degradation (REDD) program is built around payments for carbon sequestration, among other goals (IUCN-UNEP 2007). Many REDD projects and similar biodiversity protection projects are described by the Climate, Community and Biodiversity Alliance. Morrison and Aubrey (2010) summarize guidance from the World Wildlife Fund, prioritizing biodiversity and rural development.

Despite their great appeal to many people, PES projects have substantial challenges and drawbacks. The guidelines in the previous paragraph were prepared with the awareness of difficulties and include suggestions for making projects successful. Many reviews describe challenges and suggest improvements, including Gouyon (2003), Porras, Greig-Gran and Neves (2008), Engel, Pagiola & Wunder (2008), Arriagado and Perrins (2009), Farley and Costanza (2010), Pirard and Bille (2010), Ferraro (2008, 2011) and Kronenberg and Hubacek (2013). The debate between Redford and Adams (2009), Skroch and Lopez-Hoffman (2009) and Adams and Redford (2009) illuminates many worthwhile points.

Payments for services are just one market based mechanism and they can be used to complement others. Special Topic 5 discusses a range of market based topics.

5.0 Discussion

Three tasks are described in this Special Topic—classification, economic evaluation and payments for services. The first two are early components of ecosystem assessment projects and the third is a market mechanism for implementing ecosystem services. They are often carried out alone, rather than as part of a larger assessment project. You might want to use one of them in a project.

The classification methods can help you organize your project. The MA and TEEB classifications describe functions. That step is helpful for most people. But if you have a special interest in a tricky landscape or there are complex local social issues, then the spatial and human equity classifications discussed here might support your job.

Economic valuation is a large part of ecosystem services work. Some projects (e.g. Seattle and Vancouver) are solely directed to using economic values to protect natural capital. You can use any of the many valuation methods in your work.. Or, your projects might not need to include monetary measures at all. Simple ranking and preference steps might offer the information you need. Even if you do not use valuation at all, it helps to know the general approaches since so many people talk about them.

Payments for ecosystem services are attractive as simple and transparent methods to encourage protection of natural capital. They also have legal and administrative complexities that might make them difficult to use. If you can manage the challenges, such methods might work for you.

References mentioned in the text, in the Resources List and some of the Examples and Case Studies can help you pursue these ideas further.

Special Topic #4

Integrating Ecosystem Services with Environmental Planning and Management

1.0 Introduction

This Special Topic focuses on integrating ideas of ecosystem services and natural capital with environmental planning and management of urban landscapes. The major assessment and mapping approaches are often large and expensive. People working at the urban landscape scale will often be interested in more specific tasks and local environmental action. That is, instead of a complete ecosystem assessment, they might want to make a particular improvement, change a program or modify a regulation using ecosystem services as a contributing idea. This Special Topic introduces practical resources that you can integrate with an ecosystem services perspective.

We organize the ideas here around three fields, topics or professional perspectives:

- Multifunctional landscapes,
- Sustainable ecosystems, and
- Ecological restoration.

Each of these three fields originated before, and separately from, ideas about ecosystem services. They are about managing the natural environment and natural resources, and their approaches preserve natural capital and ecosystem services. To some extent, these fields overlap with each other. Since these fields have already worked out a number of management guidelines, tools and approaches, working with their goals and techniques can be very helpful in protecting ecosystem services.

In recent years, the perspective of ecosystem services has been absorbed within these three fields. However, ecosystem services are relatively new ideas, and not all of the literature of these fields uses the ideas explicitly or frequently. We will look at the basic approach of each field, and identify guidelines and tools from each that might help practitioners at the urban landscape scale.

2.0 Multifunctional Landscapes

2.1 Background Perspectives

Landscape architecture, landscape ecology, geography, municipal planning and related fields often use a concept called the 'multifunctional landscape'. The idea refers to a culturally modified landscape—a place where people live and work—which nonetheless possesses a variety of natural processes. It could be rural, agricultural, even urban, or contain all those and other land uses. Within the multifunctional landscape, natural processes take place, maintaining many natural functions and biodiversity. Planners and land managers deliberately try to maintain or to create natural features within the landscape, for example riparian corridors, areas of forest, and wetlands, so that it really will be ecologically multifunctional.

"Sustainable multifunctional landscapes are landscapes created and managed to integrate human production and landscape use into the ecological fabric of a landscape maintaining critical ecosystem function, service flows and biodiversity retention." (O'Farrell and Anderson, 2010, p. 59).

The idea of multifunctional landscapes encompasses a variety of planning and management perspectives. It has been part of much professional practice in Europe for over half a century and has become more common in North America over the last two or three decades. The historical background and contemporary situation are summarized in Jesper et al. (2003) and Mander, Wiggering and Helmring (2010) and key points are made by Naveh (2001) and Lange (2008). The specific links of multifunctional landscapes and planning with ecosystem services are explored by Gren et al. (2010), O'Farrell and Anderson (2010) Hermann, Schleifer and Wrbka (2011) and Bolliger et al. (2011). When integrated into regional and landscape planning, the idea of ecosystem services is sometimes rephrased as landscape services (Willemen, Hein and Verburg, 2010).

The idea of the multifunctional landscape, therefore, overlaps very much with the central ideas of ecosystem services. However, the history of multifunctional landscapes has a broader perspective. Planning for multifunctional landscapes comes from concerns about sustainability, ecological integrity, conservation, designing with nature, a human presence within psychologically supportive surroundings, smart growth, livable communities, healthy watersheds and regional and municipal planning. The ecosystem services concept is now entwined with the idea of multifunctional landscapes, but it is one of a number of desirable and environmentally-relevant goals.

2.2 Approaches, Guidelines and Tools

The idea of the multifunctional landscape is a goal for professionals and society to aspire to. As mentioned just above, there are many perspectives from different professional fields that organize human activities in environmentally sensitive ways. Many textbooks, journals and organizations provide guidance to do this. We introduce a few major resources here.

John Randolph's (2004) textbook Environmental Land Use Planning and Management is a very wide-ranging review of many different practices appropriate at a regional landscape scale. A comprehensive approach called 'landscape planning', addressing steps from baseline studies of soils and slopes to site suitability analysis, is described by Steiner (2008) and Marsh (2010). Perlman and Milder's (2005) book, Practical Ecology for Planners, Developers and Citizens provides introduces tools for development planning based on ecological principles and ecosystem services. The authors discuss management and policy suggestions at three nested scales: landscape scale (counties and regions), sub-landscape scale (cities, towns and counties), and habitat scale (sites and lots). Lovell and Johnson (2009) link ecological principles and the design of multifunctional landscapes.

Urban planners assembled many ideas and guidelines related to environmental protection and developing urban areas into a perspective called 'smart growth'. It is an umbrella idea that assembles many useful tools and themes. Duane, Speck and Lyon (2010) provide principles and suggestions at different scales from region to neighbourhood, street and building. The Smart Growth Network also assembles a variety of guidelines and procedures, as does the Urban Land Institute and Smart Growth BC (there are many links and resources on those three websites.) Downs (2005) describes some early history and challenges to implementing smart growth practices.

The Landscape Architecture Foundation provides a range of guidelines (Landscape Performance Series), performance metrics and case studies that provide useful resources for work at regional, local and site scales. Beck (2013) provides background principles and many site specific suggestions for landscape design involving plants and ecosystems.

The suggestions from the sources above summarize ideas from fields as diverse as forestry, engineering, hydrology, biology or soil science. Recommended management themes (with activities to support each) include:

- Protect watersheds and their soils, forests, wetlands, streams and rivers
- Preserve or reestablish forests, grasslands or native vegetation,
- Keep forested and vegetated patches where possible,
- Retain vegetation and ground cover beside streams,
- Provide for vegetated corridors and buffer zones around development
- Provide local habitats for birds and other animals,

- Reduce impermeable surfaces and provide mechanisms for stormwater infiltration,
- Use bioswales, retention ponds, green roofs and other specific techniques to manage urban runoff
- • reduce energy use in buildings and from transportation
- Provide more opportunities for bicycles, walking and interaction among people

One very flexible and detailed resource for implementing ideas of multifunctional landscapes is the SITES program led by the American Society of Landscape Architects. It encourages implementation of practices such as those just listed. The handbook of practices is The Sustainable Sites Initiative: Guidelines and Performance Benchmarks (2009) provided as downloadable 233 page workbook. The purpose is to provide standards for landscape design, based upon the model of the LEEDS program for building design (Leadership in Energy and Environmental Design Green Building Rating System). The title emphasizes the goal of sustainability, their central purpose. However they explicitly include considerations of ecosystem services in their perspective on sustainability, described in The Case for Sustainable Landscapes (2009).

The SITES guidelines provide a list of performance benchmarks for each of nine steps, from initial Site Selection to final post-construction Monitoring. They provide dozens of suggestions for good management practices, including references for further information. The SITES program is linked with a certification system, based on points that can be awarded for different levels of compliance with the guidelines. A recently published 500-page textbook (Calkins 2012), organized around the same nine steps, provides extensive background and support. The SITES principles and guidelines are likely to be very practical and helpful for practitioners at the urban landscape scale.

Two other practical perspectives on multifunctional landscapes are worth mentioning. First is the idea that multiple ecosystem services are interlinked. These can be referred to as 'bundles' of geographically correlated or causally related ecosystem services. Identifying such bundles within a landscape could help organize and analyze data (Elmqvist et al. 2010, Raudsepp-Hearne, Peterson and Bennett 2010). However, doing so is complex and methods are still being developed. The simper approach, of mapping land cover, habitat types or land use as a proxy for ecosystem services that are presumed to take place there, is much more common.

Agricultural production is often designed to produce multiple outputs from landscapes. Although the agricultural literature is often distinct from other landscape planning perspectives, it contains useful ideas and approaches to multifunctional landscapes (see Clemens and Shrestha 2004, Pretty 2008, Scherr and McNeely 2008).

We describe a number of projects relevant to multifunctional landscapes in the Section 4 Case Studies. The Case Study projects show parks, mixed use urban and suburban developments, constructed wetlands, recreational sites, stormwater control facilities and industrial sites designed and implemented as sustainable or multifunctional landscape projects. They show how specific ecosystem services are generated by good planning and management practices.

3.0 Sustainable Ecosystems

3.1 Background Perspectives

The twentieth century saw advances in the fields of wildlife conservation, natural resource management, ecology and environmental management (see Weddell 2002, Meffe et al. 2002). Early efforts managed natural resources like forests and wildlife. By the 1960s work began to reduce pollution and preserve wilderness and endangered species in carefully designed parks and protected areas. Those targets, and the tools that were developed to assist them, are still useful. By the 1990s an additional goal was added to the earlier ones. Conservationists tried to support the continuing needs of people, and especially local people, while trying to manage species, ecosystems and biodiversity. That goal is the pursuit of 'sustainable ecosystems.'

The idea of sustainable ecosystems is a specific subset of sustainable development. Maintaining sustainable ecosystems is concerned with the basic underpinnings of ecosystem services and benefits: the soil, water, photosynthesis, habitat, decomposition processes—the structure and functions of ecosystems. A definition follows:

(the sustainable ecosystem approach) strives to maintain ecosystem structure and function as a means of maintaining both biodiversity and productive capacity. Thus, its twin goals, management to produce goods and services and to maintain species and communities, encompass the goals of both utilitarian and preservationist management. Weddell 2002, p. 279

Thus, the biologist's sustainable ecosystems approach keeps explicitly in mind how people are using the system, which is exactly what the ecosystem services focus does.

We will look at some specific tools and approaches that biological fields use to manage species and ecosystems. The emphasis is on protecting species, habitats, natural communities and, more recently, biodiversity. Managing ecosystems for human benefits is a more recent concern, but is compatible with the other priorities.

3.2 Approaches, Guidelines and Tools

We will look, in order, at the overall field of ecology and then at three sub-fields that are most associated with sustainable ecosystems:

- Landscape ecology,
- Conservation biology and
- Ecosystem management

A fourth ecological sub-field (ecological restoration) is so strongly related to natural capital and ecosystem services that we consider it separately, in another section below.

Ecology as a science is about understanding nature, and 'applied ecology' focuses on practical uses of scientific principles. These are the ideas we report here, found in the fields of landscape ecology and conservation biology. Those ideas underpin ecosystem management. We describe some of the basic principles, refer to useful resources, and provide some practical guidelines for effective practice.

The histories of landscape ecology and conservation biology are directed towards protecting wildlife and biodiversity. Biodiversity is a central part of natural capital, and protecting biodiversity is essential to providing ecosystem services. However, only in recent years has concern for ecosystem services entered the field of ecology itself.

3.2.1 Ecology

Two resources can guide practitioners and citizens to ecological science and its applications. The popular textbook Ecology by Cain et al. (2012) describes the field. It has two chapters on applied ecology, including conservation biology, ecological restoration and ecosystem management. In a more advanced text (Levin 2008) 14% of the 760 pages is devoted to 13 chapters on ecosystem services. There are also several chapters on general principles of ecosystem services and others about the services provided from multiple different habitats. The website of the Ecological Society of America offers many resources for the field of ecology.

3.2.2 Landscape ecology

The field of landscape ecology describes the features of natural habitats as they change across the geographical landscape. It explores how habitats are connected and disconnected from each other, how they change in time due to natural events like disease and fire, how such patterns affect success in reproduction and growth, and how they affect predators and the dispersal of young to new habitats. There is much discussion of corridors, patches, edges, connectivity, disturbance, fragmentation, and of patterns and processes across the landscape. Human activities can alter such patterns, and in doing so disrupt the structure and function of ecosystems. Ideas about these patterns and processes make up the concepts and principles of the science. The field is described by Turner, Gardner and O'Neill (2001), Burel (2003) and Ross et al. (2006) as well as by journals and websites in the field. A major website with multiple resources is maintained by the International Society for Landscape Ecology, which publishes several journals, including the well-known Landscape Ecology.

An important observation is that by planning and managing landscape patterns and processes, one can have sound management without knowing the identity of individual species within the landscape. Landscape ecologists suggest ways to modify human actions on the landscape to retain ecological functions while maximizing human benefits. Such ideas overlap with, and provide a scientific basis for, the goals of the multifunctional landscape discussed earlier. Specific connections between the landscape ecology perspective, ecology and multifunctional landscape are described by Otte, Simmering and Wolters (2007) and Musacchio (2009). Below we identify some guidelines for practice.

Forman (1995) provides a variety of development guidelines in his book describing the science of landscapes. Prominent are four 'indispensable patterns' that try to protect biodiversity within a landscape converting to human use (His term 'plan' refers to a development plan for an urbanizing area). In the section sub-titled Whole Landscapes, he says:

"Four indispensable patterns, the top priority components in a plan, are recognized. No substitute for their benefits is known.

Maintaining a few large patches of natural vegetation is a familiar theme in this book. Another key component is wide vegetation corridors along major water courses. Almost all natural resources and human activities in a landscape depend in some measure on stream and river systems, if present in a landscape.

A third indispensable component is maintaining connectivity for movement of key species among large patches. Wide continuous corridors forming a major green network are considered to be the best mechanism. A second best alternative apparently is a cluster of stepping stones, as long as the intervening matrix is not completely unsuitable for movement of key species.

A fourth such component is to maintain heterogenous bits of nature throughout human-developed areas. This provides some connectivity for movement of most other species over all portions of the landscape. It also interrupts extensive areas of matrix subject to wind erosion, heat buildup, and the like." (Forman 1995, p. 542-543, italics in original, internal citations omitted)

Other science-based principles guiding land use are provided by the Ecological Society of America (2000), Liu and Taylor (2002), Lindenmayer and Hobbs (2007), and Lovell (2009). Forman's (2008) book Urban Regions: Ecology and Planning Beyond the City contains a penultimate chapter called Basic principles for molding land mosaics. He provides more detailed principles which build upon his earlier approach. He also provides an important statement about using guiding principles. His idea is a reminder to practitioners who work to apply scientific principles to sustainable ecosystems, and multifunctional landscapes:

"Rather than simply ideas or hypotheses or even concepts, principles can be thought of as solid rigorous guidelines, a basis or foundation for planning and action. They do not apply everywhere anytime as we expect universal law to do, but the often-considerable direct or indirect evidence supporting them is a basis for their widespread application (Dramstad et al. 1996, Forman 2004a).

Principles alone, however, lead to generic solutions. Monotonous, out-of-date, or lack-of-creativity might describe designs and plans using only principles on our palette. Instead, as for the artist whom we so admire, principles are mixed with imagination and inspiration to produce solutions for the land. Results are both dependable and creative." (Forman 2008)

Our Case Studies include examples that follow landscape principles but which apply creativity and design to do so.

3.2.3 Conservation biology

Conservation biology uses ecological principles to conserve biodiversity. Biodiversity is an encompassing term which emphasizes the full range of variation that species and ecosystems can contain: diversity of genes, species, ecosystems and landscapes. Conservation biology is described by the final three of 24 chapters in Cain et al.'s (2012) textbook and the final three of seven sections in Levin's text. Conservation biology offers landscape design principles such as those discussed earlier concerning landscape ecology and multifunctional landscapes. Ideas about sustainable ecosystems are central to the field.

Conservation biology is a field with introductory texts (Hunter and Gibbs 2006, Primack 2010), senior texts (Groome, Meffe, Carroll 2006) and a major society with a website and journals (Society for Conservation Biology). Many large organizations also offer suggestions, guidelines and conservation resources (World Wildlife Fund, Conservation International, The Nature Conservancy, Fauna and Flora International, International Union for the Conservation of Nature) as do major branches of the United Nations, Environment Canada and the US EPA.

These resources offer help to identify and respond to the major threats to biodiversity. The major threats are:

- Habitat degradation and loss
- Habitat fragmentation
- Species extinction
- Reduced population sizes and decline in genetic diversity
- Invasive species
- Overexploitation
- Global change including climate change

Key tools and approaches to preserving biodiversity in general, or threatened species and ecosystems in specific, include:

- Design protected areas and systems of protected areas
- Manage protected areas
- Outside of protected areas: link habitat protection with landscape management
- Manage modified, cultivated, or built environments for biodiversity
- Maintain vegetation, soils and habitats even if fragmented
- Use habitat buffers, corridors, connectivity and networks
- Use population and metapopulation modeling and species management plans
- Design and implement species management; provide resources, control threats
- Establish and manage new populations

- Use ex situ conservation-zoos and gardens to maintain threatened species
- Restore damaged ecosystems
- Cooperate and share benefits with local communities and volunteers

Books and journals in the field provide details of specific tools and applications of these topics. There has been an expanding emphasis to including local people who live near protected areas and other conservation projects (Meffe et al. 2002). Perrings et al. (2011) show how the revised 2020 goals from the Convention on Biological Diversity are related to ecosystem services and benefits to people. Those linked concerns represent the pursuit of sustainable ecosystems.

3.2.4 Biodiversity and Ecosystem Services

Biodiversity and ecosystem services are clearly related. Cascade diagrams demonstrate how ecosystems and biodiversity are 'upstream' of ecosystem services and that benefits to people flow from them. Elmqvist et al. (2010) and Haines-Young and Potschin (2010) summarize current understanding of relationships between biodiversity and ecosystem services: more biodiversity generally leads to more ecosystem services. However, the relationships between the two are not well understood or constant from one place to another or from one service to another. One could lose some species or genetic diversity and not always lose ecosystem services. For example, water infiltration and purification by a forested watershed might not be much influenced if the number of species in the forest declined somewhat.

We also don't know exactly how ecosystem services change when biodiversity changes. Threshold effects and non-linear relationships exist between biodiversity and ecosystem services. Kremen (2005) discusses which species or groups of species provide particular benefits, how efficient they are, what we know of some interactions and what is still unknown. Kock et al. (2009) discuss non-linearities between coastal processes and ecosystem services. Bennett, Peterson and Gordon (2009) show how relationships among multiple services are still little known. They document trade-offs and synergies which occur as different services change with respect to each other.

Despite these uncertainties, the main patterns are clear.

"There is clear evidence for a central role of high biodiversity in the delivery of many—but not all—services… We can say with high certainty that maintaining functioning ecosystems capable of delivering multiple services requires a general approach to sustaining biodiversity." (Elmqvist et al., 2010 p. 44)

In the light of our available knowledge, there is no level of biodiversity loss that can be considered to be safe (Diaz et al. 2006).

4.0 Ecological Restoration

4.1 Background Perspectives

In rural, agricultural landscapes and in urban areas, enhancing ecosystem services requires repairing damage. Enhancing the multifunctionality of landscapes can often be addressed by improving degraded sites. The field of ecological restoration provides resources for those challenges.

While 'restoration ecology' is the scientific background for working with degraded sites (see Falk, Palmer and Zedler 2006, Hobbs and Suding 2008, Greipsson 2011), 'ecological restoration' is the applied field addressing specific challenges in specific places (see Clewell and Aronson 2013). The Society for Ecological Restoration (SER) has two journals, one for each focus. We address the practical steps of ecological restoration below.

SER gives a broad definition of Ecological restoration. "Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." (SER 2004. p 3.)

Encompassed in this general definition there are different degrees of restoration. Different levels of restoration are suitable for different sites depending on the goals of the project, the budget, context and the degree of site degradation that has occurred.

- 'Revegetation' establishes some vegetative cover on a site, to establish part of the structure and function of an ecosystem, stabilize soil and protect the land surface. Revegetation might start with agricultural seeding of grasses or planting non-native species. After initial revegetation, other processes, natural or assisted, can further change the vegetative cover.

- 'Reclamation' refers to efforts directed at severely degraded sites, such as landfills and mine sites, often to recreate a new soil and provide vegetative cover and habitat for wildlife. The intention might be eventual rehabilitation or restoration, as described below.

- 'Rehabilitation' aims at creating some of the structure and function of ecosystems, but without the intention of returning to the site to a predisturbance state. A self-perpetuating vegetative cover might be the target but perhaps with plant species that were not originally present (Greipsson 2011).

- 'Restoration' is an effort to recreate, as closely as possible, the kind of ecosystem that was or could have been on the site before disturbance. Complete restoration might not be possible, but a close approximation is the intent. "Restoration attempts to return an ecosystem to its historic trajectory" (SER Primer p. 1).

Collectively these definitions indicate the 'what' of restoration practice: improving conditions of a degraded site by arresting negative processes and establishing conditions closer to the original ecosystem. Doing so will reestablish natural capital and improve ecosystem services.

Most projects are designed to be self-sustaining. In some special cases ongoing management might be required, such as the creation of an artificial pond or wetland where the natural water supply is not sufficient and must be augmented.

4.2 Approaches, Guidelines and Tools

There are many opportunities for restoration at the urban landscape scale. Large areas of 'greyfields' (bare, underused or derelict lands which are not contaminated) and 'brownfields' (bare or underused lands with some degree of contamination) are often present. In agricultural areas, many streams have been degraded due to absence of riparian vegetation, pollution from agricultural activities and soil erosion. Terrestrial and aquatic habitat has been lost in many places. There are spaces between developments, around buildings and throughout urban regions that are degraded from their original condition.

Practical ecological restoration to improve these sites is very site specific. Actions must be appropriate to the context, the nature of the original substrate and of the target goal for the soil and habitat. Different sites have different conditions and require different steps for repair.

A short practical introduction to the field comes from two downloadable documents from SER (2004, 2005). The first, a 'primer on ecological restoration' describes the field in 13 pages. The second 'guidelines for practical management steps' gives a framework for organizing restoration projects through 51 guidelines organized into six phases. The SER website has more details. We provide a short introduction to considerations for practical restoration, using the headings of their six phases.

1. Conceptual Planning

This phase identifies the location, stakeholder responsibilities, legal requirements, funding sources, project duration and likely major challenges. This takes place before the decision is made to conduct the project and helps with that decision. It includes selecting project goals. Clarifying the goals can be quite challenging. Due to the extent of damage, or available funds, or desire for future land use, there is more than one possible target for a given site. In addition to a final land use goal can be other purposes for restoration, such as reducing erosion from land, reducing sedimentation in streams, increasing infiltration and restoring more natural stream flow regimes, restoring wildlife habitat or making the landscape more attractive. Restoring natural capital and ecosystem services can also be explicit project targets.

2. Preliminary Tasks

The preliminary tasks involve project planning. It includes picking the team, doing initial site studies, and selecting specific objectives needed to meet the project goals.

Restoration planning usually includes explicit comparison to a reference ecosystem which indicates the target endpoint the project seeks to achieve or approximate. Creating a conceptual model of the restoration ecosystem that is based on the reference ecosystem, and which defines the environmental conditions or gradients to be established in the restoration is critical to the success of the restoration project.
Enhancing for wildlife involves a two-step modeling process. First, the restorationist needs to research available species/habitat models for the specie(s) in question. Once the site conditions necessary for a species to inhabit a site are known, the restorationist will need to understand the necessary environmental gradients that will allow those site conditions to be developed.

A model can often be summarized in diagrams and maps and connected to step by step planning. It can organize expectations and demonstrate critical biophysical challenges or unknowns.

When the basic models have been established, the critical factors within those models can be analyzed. This often requires field work and the laboratory testing of soils and water. For a wetland restoration, the critical factor is the hydrologic regime on the site. Other factors may be mitigated, but lack of water is much more difficult to remedy. These critical factors are best understood as environmental gradients. Soil is a site attribute or factor, but the soil moisture regime, pH, fertility, carbon/nitrogen ratio, pollution and salinity exist along environmental gradients. Water is a site factor, but available moisture exists along a gradient of elevation above the water table, depth to the impermeable layer and other conditions. Plants have a range of tolerances but within that range are found at the convergence of their required environmental gradients. The restorationist must be assured that the hydrologic, soil and other conditions necessary to support the intended species are found or can be developed on the restoration site. If the critical environmental gradients cannot be established, the project will need to be modified or even abandoned.

3. Implementation Planning

This step schedules the necessary tasks, obtains supplies and secures the budget.

4. Implementation Tasks

This phase carries out the plans.

5. Post-Implementation Tasks

A number of post-implementation tasks are necessary for success. They include maintenance, protection for vandalism, and monitoring key indicators.

6. Evaluation and Publicity

This phase involves examining monitoring data and responding as needed to new information. Responding to change is an essential element of adaptive management, mentioned in the Discussion section below. Successful projects also involve communication with important stakeholders and the general public.

These notes suggest the breadth of effort needed for restoration projects. More details and a broader background to the technical side of ecological restoration can be found from Howell, Harrison and Glass (2011), Galatowitsch (2012) and Clewell and Aronson (2013). Each of these textbooks covers multiple aspects of restoration. Tongway and Ludwig (2012) provide a practical step by step management approach for restoration projects of all kinds. Nellemann and Corcoran (2010) emphasize restoration in the context of biodiversity protection and economic development. Aronson, Milton and Blignaut (2007) specifically connect restoration practices to their book's title: Restoring Natural Capital. You can find more information, technical support and case study examples from the Society for Ecological Restoration.

Several examples relevant to urban landscapes follow below.

HABITAT	**RESTORATION GUIDELINES**
Urban Sites & Brownfields	U. S. Environmental Protection Agency. Land Revitalization Program
Streams & Corridors	Riley. Restoring Streams in Cites: A Guide for Planners, Policymakers and Citizens. Federal Interagency Stream Restoration Working Group. Stream Corridor Restoration: Principles, Processes and Practices
Wetlands	Maltby & Barker. The Wetlands Handbook
Watersheds	Williams, Wood & Dombeck. Watershed Management: Principles and Practices

5.0 Discussion

Earlier Special Topics described methods that focus directly on natural capital and ecosystems. The fields of multifunctional landscapes, sustainable ecosystems and restoration ecology predate concern with ecosystem services. They offer many good ideas and professional practices. They have started to incorporate natural capital and ecosystem services into their own discussions. However, their literature does not necessarily integrate ecosystem service ideas thoroughly yet. You can actively plan your work to integrate useful practices from these fields while explicitly addressing ecosystem services. Three specific steps to help you do so follow.

Integrate ecosystem services with environmental planning and management

These steps can help initiate projects:

1. Identify the ecosystem services in your project site or area. The TEEB cities manual provides steps for doing this (TEEB 2011, pp 11-19). Other TEEB manuals (TEEB 2010a, 2010b) also make suggestions. Identifying what you have also helps consider what you could have in future.

2. It is common to rank the more important services, as it is not usually practical to protect all services equally. Identifying benefits and beneficiaries of the services also helps identify your goals. Select some target priorities for your work. The TEEB guidelines help to do this. The template matrix used in our Case Studies can organize this information in a site-specific way.

3. Mapping the services and values associated with them might also help identify local resources and priorities.

4. Identify specific options and practices that will protect or enhance your target services. Linking your local environment and its services to the different steps of the ecosystem cascade can guide you towards which ecosystems and services to work with. You can select practices from the fields discussed in this Special Topic to implement your chosen tasks. This step represents the explicit integration of ecosystem services with environmental design, planning and management practices.

5. The world does not yet know exactly how to maximizing all ecosystem services. Despite your best efforts to link ecosystem services with good management practices, you might not always be able to produce a plan for all specific services. That is when using best practices from these three fields is most appropriate.

6. Use what you consider to be the most relevant guidelines and best practices from multifunctional landscapes, sustainable ecosystems and ecological restoration perspectives. These practices tend to support natural capital and ecosystem services. For example, maintaining vegetative cover, reducing stormwater runoff, and providing green corridors are practices that have environmental benefits. Try to maximize the natural capital and ecosystem service results from the practices you use, even if no one knows all the scientific interrelationships. For specific practices, follow guidelines from SITES and the Landscape Performance Series which suggest ecosystem service benefits from different practices.

7. Add communications and policy activities, to complement the integration of ecosystem services into professional practices.

5.1 Target ecosystem services in addition to biodiversity or sustainability

Ecosystem services are not completely correlated with biodiversity, or water retention or many other targets of environmental practices. For example, Rey Benayas et al. (2009) studied improvements in both biodiversity and ecosystem services resulting from 89 restoration projects. They found that restoration increased biodiversity and ecosystem services by 44 and 25%, respectively and that both were positively correlated. But clearly the two were not identically affected by the restoration projects.

The good practices described in this Special Topic are sound and helpful. But if ecosystem services are going to be part of project goals, they should be targeted and measured specifically to the extent possible. Urban practices which enhance storm water retention, for example, might be more helpful for ecosystem services than for biodiversity itself. Try to specify your natural capital and ecosystem service goals specifically in addition to other environmental goals. Your projects can target, monitor, and get credit for, several worthwhile goals.

5.2 Include Adaptive Management to make technical projects more effective

Making projects effective is challenging. One set of tools that can help your technical projects is called adaptive management. Although that phrase is used loosely, we refer to the method initially developed by Carl Walters and Buzz Holling and now popularized in the Open Standards for the Practice of Conservation (Conservation Measures Partnership 2013). It is based on a repeating cycle of:

- Planning and goal setting
- Establishing starting points, a conceptual model, and indicators of success
- Implementing steps, sometimes specifically testing key assumptions
- Describing progress and monitoring indicators
- Using the data gathered to help adjust (adapt) future actions

Meffe et al.'s (2002) textbook describes adaptive management in ecosystem management. Salafsky, Margolius and Redford (2001) also provide an introduction. Cowling et al. 2008 encourage using a process including adaptive management explicitly to help implement ecosystem services projects. The six phase process described previously for ecological restoration can itself be an adaptive management cycle. Adaptive management helps organize and improve professional practice and can make your ecosystem services projects more effective.

Special Topic #5

Policy & Governance

1.0 Introduction

Most of this document is about the technical details of ecosystem services and how they can be assessed and protected on the landscape. In this Special Topic we provide some details about the policy and governance context in which technical activities might take place. We assemble this information around four topics:

- Decision making processes
- Legislation and regulation
- Encouraging social action without legislation
- Market-based instruments

The first topic is about essential processes undertaken to support policy and governance. The other three provide background to specific kinds of policy and governance.

2.0 Decision Making Processes

We repeatedly mention that understanding ecosystem services can help influence social decisions and influence government decision makers. These statements are true, but they can be misunderstood.

The idea that information about natural capital and ecosystem services could contribute to decision making is correct. Whether such information actually does influence a government decision or not is another matter. Professionals and citizens can gather useful information to assist society's decision makers. But there are many decisions about land use and environmental management that professionals and citizens make on their own behalf.

Understanding some basic features of decision making can put the role of information about ecosystem services into perspective. Basic decision theory points out some first principles (Goodwin and Wright 2009). Decisions always represent the selection of at least one choice from among alternatives. Sometimes there might appear to be only one suggested action, but even then, there is really always the choice of yes or no.

There is at very minimum a three part process in decision making:

1. Acquiring facts

All decisions require some facts about the situation at hand: what are the options, what are their features, what is important in this situation, how likely are the supposed consequences, etc.

2. Selecting the weights of relevant values

All decisions also require the application of values and the relative weighting of different criteria. It might be an empirical fact that certain features are important to the audience, but it is a separate issue to determine just what weight, or value, or utility, to apply to what are called the decision criteria.

3. Applying the weights to the alternatives to reach a final choice

When the criteria are applied to the choices at hand, the final deliberate act of decision making takes place.

Information about ecosystems services does not guarantee any particular decision, nor does information about the potential monetary worth of a given benefit. Those features simply provide input to the decision making process. Such information helps make the process more comprehensive, but does not ultimately make the decision. Most professionals and members of the public do not make large social decisions, like where to put highways and whether to build a new solar array. Those are the assigned tasks of elected politicians and senior governmental staff. But information can be organized and presented in ways that make decision making easier, for society's decision makers and for professionals and citizens.

Organizations can use approaches like scenario planning and other decision support tools, which explicitly organize information in ways that help decision makers understand it. They can use approaches such as cost-benefit analysis, multi-criteria analysis and public participatory processes to gather, integrate and weigh information to help make decisions. Sections 1 and 2 in the Foundations, and the corresponding Special Topics, addressed the kind of data that can be gathered and used as input for these processes. The decision processes themselves are addressed next.

The steps and processes of decision making itself are important and can be complex and controversial, but they are not specific to the field of ecosystem services. Interested readers can explore several references to get better information about decision making tools. An extremely relevant synthesis of decision making theory in an environmental context is provided by Gregory et al. (2012). Also helpful is the integrated textbook by Burgman (2005) that is oriented to gathering, analyzing and using appropriate environmental data. Two sets of papers related to decision making about environmental matters are assembled by Dale and English (1999) and Sexton et al. (1999). Fisher et al. (2008) organize information about ecosystem services and economic valuation specifically to support decision making and policy. Background concerning decision making in general is provided in several similar books—written by experts but with the general reader in mind. Kahneman (2011) explains the psychology of decision making and what contributes to people making so many errors. Russo and Schoemaker (2002) and Hammond, Keeney and Raiffa (1999) describe step-by-step processes to address business and personal decision making, respectively. Standard textbooks in the field of decision analysis by Goodwin and Wright (2009) and Clemen and Reilly (2001) might also be useful.

The common challenge of involving multiple stakeholders in public decision making is addressed explicitly by Kaner et al. (2007), Chambers (2002), the World Bank (1996) and the Multi-Stakeholders Process Portal. Public participation methods applicable to environmental decision processes are described by Brown (2004), Rauschmayer and Wittmer (2006), Renn (2006), and Burgess et al. (2007). Some of the documents describing comprehensive ecosystem assessment processes include information on public participation (for example Ash et al. 2010, TEEB (The Economics of Ecosystems and Biodiversity) 2010a, 2010b, and Kareiva et al. 2011).

3.0 Legislation and Regulation

Governments can make laws and enforce them with specific regulations. Those aspects of governance apply to environmental matters as much as to any other aspect of life. We address four kinds of legislated public rules here:

- Taxes and subsidies
- Permits and licenses
- Regulations and guidelines for land use and zoning
- Policy statements and green plans

3.1 Taxes and Subsidies

The ability to tax and control funds is an important one. There are complex rules guiding which levels of government can impose taxes on what kinds of item or activity. Taxes (and similar mechanisms such as user fees, surcharges and permit fees) are a revenue source for governments, and also guide actions considered undesirable or desirable. Subsidies, which can be direct payments or reductions in taxes or fees, are also used to influence actions.

Taxes and subsidies can be effective and transparent ways to influence citizen or corporate actions. However, there are challenges dealing with ecosystem services since many aspects of the environment are not part of markets and do not have prices. Using financial tools of policy brings natural capital and resource related matters more into the price and market system, which many people think is desirable.

Taxes and charges can be used to discourage or support desirable activities. Existing tax rates or subsidies can be raised, lower or dispensed with, and new ones added, to better target ecosystem services. Fees to use resources or to purchase permits permitting pollution are one approach. The trend towards gasoline 'carbon' taxes are an example. At the municipal level, where there are or can be charges for water, utilities, garbage, land use, or recreation, changes in such taxes or fees can be targeted in desired directions. Lower fees to developers based on building practices, energy performance in buildings or the percentage of impermeable surfaces are such options.

Taxes and other fees can also generate revenues which can be directed towards specific purposes. One can designate particular taxes towards purchasing land or supporting activities that protect natural capital. This is quite common at the municipal level, where specific charges to land developers are used to support community services, which can include land and water protection. BC hunters, anglers, trappers and guide-outfitters voluntarily directed a portion of their license fees to support conservation through the BC Habitat Conservation Trust Foundation. The same organization also supports conservation with court awarded penalty fees assessed for pollution or resource related offenses (HCTF undated).

Many ways that taxes can be used in an environmental policy context are discussed by Common and Stagl (2005), Steiner (2008) and Field and Olewiler (2011). Specific applications to a regional and municipal context are discussed by Wong and Gordon (2011), Molnar (2011), Molnar, Stewart and Iseman (2012) and TEEB (2010b).

3.2 Permits and Licenses

Governments can provide specific rights to undertake activities that affect land, biodiversity and natural resources. Such permits and licenses can affect both activities by individuals (e.g. hunting) or by corporations (e.g. initiating a new mine or building a housing development). Limiting, or designating particular conditions to those licenses exerts control over the activity. Examples include many kinds of resource harvesting (fishing and hunting), access to recreation (park and wilderness visits) and the conditions for environmental compliance that go with permits to initiate large resource extraction, skiing, waste disposal, transportation and other activities under environmental impact assessment legislation, water resource or fisheries protection legislation. If the permits can be traded or sold after they have been issued, then there is an additional influence upon societal action, described further below under the 'market based instruments' topic. The use of permits and licenses as environmental policy tools is discussed by Common and Stagl (2005), Steiner (2008) and Field and Olewiler (2011).

3.3 Regulations and guidelines for land use and planning

Governments create laws which establish a variety of general guidelines, specific regulations and standards which influence environmental design, planning and management. An important set of such rules are those that affect environmentally relevant industrial and residential development. Such guidelines are often designated to effect different geographical scales. Perlman and Midler (2005) produced a book (Practical ecology for planners, developers and citizens) discussing planning and development to protect and restore nature at different scales. They identify three scales—Landscape scale (counties and regions), Sub-landscape scale (cities, towns and counties), and Habitat scale (sites and lots). They suggest several kinds of management approaches for new development at each scale. Their approach recognizes that regulations overlap with and can encourage professional design and planning practices. We follow their outline on the following page (Based on Perlman and Milder (2008)) , with the different approaches they suggest for each scale in the left column, and a short description beside it.

Their suggestions can guide regulations. These guidelines also overlap with the type of design practices we discussed earlier under the topic 'multifunctional landscapes.' The kind of professional guidelines mentioned earlier, including those provided by the SITES program and the Smart Growth principles, can apply especially at Perlman and Midler's Habitat Scale. Other resources which consider planning and management at regional scales, such as Randolph (2004), Steiner (2008), and March (2010), also recognize the overlap of regulations and professional design. Many of the Case Studies implement this kind of design process.

KIND OF MANAGEMENT PLANNING RULE	EXPLANATION
LANDSCAPE SCALE	COUNTRIES & REGIONS
Landscape conservation and development plan	A plan that identifies the best places to develop and to avoid. Identify four elements: core habitat, secondary habitat, intensive production areas and urban areas. Do your best to protect the first, develop modestly in the second and appropriately in the third and fourth.
Urban growth boundaries and infrastructure target areas	Boundaries try to contain growth in particular areas. The infrastructure target areas are places to direct attention as most appropriate for new growth.
Transfer of development rights	Jurisdictions can identify two areas, a 'sending area' where development is discouraged and from which land owners can sell and transfer rights to develop in their area to people who want to develop in a targeted 'receiving area'.
SUB-LANDSCAPE SCALE	CITIES, TOWNS, & COUNTIES
Conventional zoning	Divide a jurisdiction into multiple zones, based upon the suitability of the land, with different development rules for each. More emphasis upon environmental, compared to other criteria, is suggested.
"Greenprinting"	Create a map of important habitats and work to protect them. Similar to landscape conservation and development plan but at much finer scale such as individual forested slopes or wetlands.
Environmental protection zoning	Apply additional rules to local environmentally sensitive areas such as wetlands, important habitats and unstable slopes. This can include requirements for corridors and buffer zones.
Development phasing	Use rules that limit the amount of development over time, such as limiting development permits to a particular number or to a given percentage of land, within a given time period.

KIND OF MANAGEMENT PLANNING RULE	EXPLANATION
HABITAT SCALE	SITES & LOTS
Reducing development's footprint	By careful planning, concentrate development in particular locations to reduce the amount of land developed within a given site and leave the rest in natural vegetation.
Ecologically based site development practices	Careful use of development practices, such as: reduce clearing and grading, reduce creation of impervious surfaces, manage stormwater to maximize infiltration, keep roads as narrow as practical, and use native species where possible.
Environmental review	Include environmental requirements in the review often required before development.

3.4 Policy Statements and Green Plans

Governments often establish broad policies that guide either the creation of multiple kinds of legislation, or more general actions by the government. Many governments, and particularly municipalities, have established 'sustainability charters' or 'green plans' that have guided the action of the city as a whole. Examples are available from a large city (Toronto-Environmental Task Force 2000), smaller city (Surrey BC-City of Surrey undated) and village (Memramcook NB-Village de Memramcook 2008). These examples reflect established and thoughtful sustainability and environmental concerns but do not use the perspective of ecosystem services. One of the major tasks of the professional staff of municipalities is designing and implementing ways to implement the general policies set up in such charters. Staff can also, perhaps, expand municipal perspectives to include specific reference to natural capital and ecosystem services in future plans, as North Vancouver BC is discussing (Wong and Gordon 2011).

4.0 Encouraging Societal Action without Legislation

Government policies can be very influential in ways other than the direct taxes and rules described above. A major way that governments encourage policies, including those about environmental matters, is through their direct and indirect influence upon civil society. Although some of these steps might involve legislation, to initiate programs or provide funds, the point of these programs is the indirect influence of government on people's actions. We point out two key functions,

- Encouraging direct actions through citizen organizations, and
- Education and communication.

4.1 Supporting Civil Society Organizations that Carry Out Environmental Work

Governments can encourage the activities of many non-profit organizations and citizens. The encouragement can be indirect—for example through legislation that permits the existence of non-profit organizations and structures the rules of their performance. The laws give credibility to the organizations, legal guidance for the directors and employees, and legal legitimacy so they can set up bank accounts and do business as corporate entities. Governments, including municipal governments can provide financial support to citizen organizations via a wide range of funding programs. Governments can also provide important indirect support to small community organizations by letting them meet in government offices, carry out their programs on government property, or access to advice and help from government staff. For example many municipal stewardship projects take place at least partly on government land or in streams that fall under municipal jurisdiction. Community gardens are often on municipal land and NGO meetings often take place in government owned buildings. Environmental organizations have many different mandates, often supporting traditional biodiversity and water quality projects. Governments could encourage greater attention to protecting or restoring natural capital and ecosystem services. They could, for example, include more reference to natural capital and ecosystem services in criteria for funding.

4.2 Education and Communication

Governments provide information to their citizens to support policies, including those relating to natural capital and ecosystem services. There are several ways governments can support ecosystem services through education and communication. Government staff can share information directly with the public by providing publications or staff as speakers. Government programs can act indirectly by encouraging citizen groups or schools to share information or learn more about ecosystem services.

5.0 Market Based Instruments

Market based instruments (MBIs) are policies that adjust markets, prices or economic circumstances to provide incentives to achieve desirable environmental results. That is, they apply to situations where markets appear to be potentially relevant but are not sufficiently effective without the assistance of the market based instrument. They were first introduced to provide alternative mechanisms, other than direct regulation, to control air and water pollution.

Market based instruments are designed to influence behaviour through some market mechanism rather than direct legislation. MBIs have two major advantages. They encourage innovation, and allow individual companies or citizens to customize their actions in ways that suit their circumstances. Both results come from people being guided more by a target rather than specific rules of how to achieve that target.

Although they are becoming more popular and there are many kinds of MBIs, one authority notes: "This (discussion) should not leave the impression that market-based instruments have replaced, or have come anywhere close to replacing, the conventional, command-and-control approach to environmental protection. Further, even where these approaches have been used in their purest form and with some success, such as in the case of tradeable-permit systems in the United States, they have not always performed as anticipated." Stavins 2001, p i)

In this discussion we will provide a general introduction and then provide some background for three kinds of MBI that are common in discussions of natural capital and ecosystem services:

- Tradeable permits
- Payments for Ecosystem Services
- Offset programs

Whitten, van Buren and Collins (undated), identify three different types of MBI, shown in Figure 28 below, with examples of each. The price-based instruments influence behaviour by increasing costs of environmentally undesirable behaviour or reducing costs of desirable actions. The rights-based instruments work by creating 'rights' which are desirable to some audiences, such as the right to release an amount of pollution or the ability to develop a tract of land, which can be bought, sold or traded. The third type of MBI involves mechanisms that reduce circumstances that are currently restricting desirable behaviour. Permitting, or requiring, environmentally-relevant product information on labels of consumer packaging allows customers to adjust their choices.

Figure 28: Examples of market-based instruments by type
From Whitten, van Buren and Collins (undated) p. 4

PRICE-BASED	RIGHTS-BASED	MARKET FRICTION
Emission charges User charges Product charges	Tradeable permits, rights or quotas Offset schemes	Reducing market barriers Extension / education programs Research programs designed to facilitate market exchanges

PRICE-BASED	RIGHTS-BASED	MARKET FRICTION
Performance bonds		Labelling
Non-compliance fees		Information disclosure
Subsidies (materials and financial)		
Removal of perverse subsidies/taxes		
Deposit-refund systems		

5.1 Tradable Permits

A tradable permit is a policy instrument that creates a transferable right to emit a certain amount of pollution or to exploit a certain amount of a resource. They are most famously used to control air pollution. However, they are probably more relevant to natural capital when used to control access to resources, such as wildlife harvests or land.

Tradable permits work when a central authority sets a permissible amount of pollution or a quantity of land to be developed, and then issues corresponding permits, denominated in appropriate units, such as tons of sulphur dioxide emited or hectares of land developed. Once issued, permits can be traded in a market. The authority specifies the final result but not the resource allocation between consumers or the price. Tradeable permits are described in more detail by Stavins, 2001; Common and Stagl, (2005) and Field and Olewiler (2011).

5.2 Payments for Services

The main goals and mechanisms of Payments for Ecosystem Services (PES) are introduced in Section 2 and described in more detail in Special Topic 3.4. PES systems are those in which the people who benefit from an ecosystem service pay those who control the resource that provides the service, to maintain or restore its quality. There are four major services targeted by PES programs:

- Keeping watersheds intact to provide drinking or irrigation water
- Protecting wildlife habitat
- Capturing carbon in forests and soils and
- Protecting attractive landscapes.

Because many landscapes provide multiple services, many PES schemes protect multiple services regardless of their original target. Landscapes in developing countries often provide many potential services for distant beneficiaries, such as carbon storage or protection for charismatic wildlife. A major concern for PES projects in developing countries is ensuring equitable treatment for local people, who provide the service but might not be in a position to negotiate the best prices for themselves.

PES projects have many administrative and legal difficulties. These include determining:

- Who has the services,
- Who will pay for the services
- How the results will be maintained
- How the results will be monitored
- How the payments will be and
- How relevant data will be accessed and maintained

5.3 Offsets

Offset mechanisms have some similarities to tradable credits. However, instead of a central organization setting an overall regional target for pollution or resource use which can be used by anyone, a particular organization usually has a site-specific requirement to maintain environmental or habitat quality. Their own negative actions on their site must be 'offset' by some compensatory action elsewhere. The organization might create offsetting habitat, which might be difficult or beyond their ability, or another organization can provide the offsetting habitat, for a price which can vary.

The most commonly discussed offset programs are for carbon and biodiversity. Carbon markets can include tradable permits for various purposes, but one element within such markets can be to offset particular carbon emissions of a company or individual. Because carbon emissions to the atmosphere can be offset by carbon removal anywhere on the planet, global carbon markets exist. Municipalities are sometimes interested in carbon offsets not just as tools to compensate for local damage, but because they might be able to sell local carbon storage in forests, soils or wetlands to global markets. Good perspectives on carbon markets can be found in Chafe and French (2007) and Kossoy and Guigon (2012),

Biodiversity offsets are usually required to take place near the site where damage has occurred, so that compensation is similar to the damaged habitat. Wetlands are the most common biodiversity offset. Robertson (2006) describes American experience with wetland banks and offsets due to the Clean Water Act's requirement for 'no net loss of wetlands' from development. Although there is a mature system and established mechanisms for payment, there are many incomplete projects. Changes in regulations cause difficulties for the entrepreneurs who create wetlands in advance of someone's need for them. Basic features and principles of biodiversity offsets are described by Quintero and Mathur (2011). Bayon, Fox and Carroll (2007) and the Business and Biodiversity Offsets Program (2012) provide guidelines for implementation, and Madsen, Carroll and Moore Brands (2010) describe 39 biodiversity offset programs worldwide. Bennett (2013) provides examples of water quality offsets, a less known offset process.

In conclusion, there are many prospects for market based instruments. However they often require a great deal of social, economic or biophysical data to be implemented and that data can be unavailable or expensive to obtain (Whitten, van Buren and Collins, undated). They also often require cooperation among partners, and specific legal arrangements, which add to their complexity. Used within their limitations, market-based instruments certainly have a place in the field of ecosystem services.

6.0 Discussion

Thinking about policy and governance can complement technical knowledge and skills. Many policy and governance approaches were developed for environmental or sustainability concerns, but they are now being applied to ecosystem services more specifically. That situation will continue. You can share policy suggestions with the decision makers in your area. In the light of your local priorities, citizens, professionals and decision makers can work to have policies mesh as supportively as possible with your natural capital concerns.

In addition to specific references cited above, there are resources concerning policy and governance more generally. Ruhl, Kraft and Lant (2007) provide a background to policy and legal aspects of ecosystem services, with emphasis on the American situation. Randolph (2005) integrates technical and policy perspective for environmental planning and management. Policy related to environmental and economic contexts is reviewed by Common and Stagl (2005), Hepburn (2010), TEEB (2010a) and Field and Olewiler (2011). Discussions of policy options specifically directed toward ecosystem services at the regional and municipal level are provided by Molnar (2010), TEEB (2010b, 2011), Wong and Gordon (2011), and Molnar, Steward and Iseman (2012). You can find information about several policy and governance topics in the <u>Examples</u> section.

References & Resources Concerning Ecosystem Services

REFERENCES & RESOURCES

Introduction

This section of the document assembles the details about information resources and links to Internet resources. Not every useful published document or resource is listed here. Too much information is available about ecosystem services for this to be a complete review. However we have listed documents or locations which we believe to be worthwhile in some way.

Where can you get the resources listed in this document?

We have provided hot links to the Internet websites where reports and other documents are available for downloading.

Many books, chapters, reports and journal articles are directly downloadable at no cost from the Internet. You can Google the full title, within quotation marks, and see what is currently available: circumstances change daily. Although most Internet sources are legal and provide material with the knowledge and approval of the authors and publishers, some do not. It is the responsibility of the reader to use the former and not the latter.

Some of the textbooks or textbook chapters can be purchased by the chapter or by the book via Internet links. Some books are also downloadable though university or public libraries. Google Books provides overviews of many books and often makes a substantial part of the text available for browsing although not for downloading. Different publishers have different arrangements, and those arrangements change over time. The journal articles are downloadable through most college libraries and many city libraries, although you might have to get help to access a library's paid database services.

REFERENCES & RESOURCES

Starting Points for Further Study

There are specific suggestions about relevant readings for particular topics spread throughout the document. However, we can offer four different ways to get started in following up the information provided by this document.

1. Websites are easy to browse. There are a number of them listed immediately below which might interest you. They all have links to other websites and resources which you can explore. The Ecosystem Services Partnership might be a good one to start with, as it is affiliated with no one project and provides a general perspective.

2. You might want an overall summary, at a somewhat more detailed level than we provide, but still designed as an introduction. Two recent reports from The Economics of Ecosystems and Biodiversity (TEEB) project are intended as introductions, one (TEEB 2012) to the benefits of more closely integrating ecosystem services into the economy, and the other (TEEB 2013) shows the application of ecosystem assessment to water and wetlands. The book chapter by Haines-Young and Potschin (2010) is intended for an under-graduate university audience and the chapter by Fitter et al (2010) is also intended as an introduction. Gomez-Baggethun et al. (2010) review of the economic history linked to the idea of ecosystem services. Molnar (2011) shows how perspectives on natural capital can influence policy at an urban scale. Hein et al. (2006) identified several services from a Dutch wetland and the different beneficiaries of different services at local and regional scales.

3. You can also look at the substantial summary materials that collect the ideas of the many people who worked on two major ecosystem assessment projects. The summary reports of the Millennium Ecosystem Assessment and the TEEB projects are both available online.

4. You might also browse the references in the Master List of References and Resources. The information in the titles or the annotations might suggest something that interests you.

Websites Related to Ecosystem Services and Natural Capital

This list provides some of the most central websites, from a variety of government and agency sources in different parts of the world. These sites include links to other websites.

1. The Ecosystem Services Partnership

http://www.fsd.nl/esp

They describe themselves as "Worldwide network to enhance the science and practical applications of ecosystem services assessment". "The ES-Partnership aims to enhance communication, coordination and cooperation, and to build a strong network of individuals and organizations." This is the main organization currently devoted to Ecosystem Services. While they are not quite a typical academic organization, their website and resources provides a similar function of information transmission. There are many publications, links and information about ecosystem services on their webiste. It is a good place to explore early in learning more about ecosystem services. They sponsor a major annual conference and a journal (Ecosystem Services).

2. The Economics of Ecosystems and Biodiversity (TEEB)

http://www.teebweb.org/

TEEB was founded to expand upon the legacy of the Millennium Assessment and has a substantial staff and financial support from the United Nations and a number of European governments. Their website provides access to many of their publications (see the TEEB entry in the Resources section for a review of many of them) as well as information and links to other resources. TEEB's useful links page is at http://www.teebweb.org/resources/useful-links/

3. Millennium Ecosystem Assessment

www.millenniumassessment.org/en/About.html.

A general description of the MA and its achievements is found here. There also are many links to different reports and follow up projects.

4. Natural Capital Project

www.naturalcapitalproject.org/

The NCP is a partnership among The Nature Conservancy, Stanford University, The World Wildlife Fund and the University of Minnesota to promote the preservation and management of natural capital and ecosystem services. One of their major efforts is the creation and distribution of the InVEST computer models for mapping a variety of ecosystem services and using the maps for planning.

5. Valuing Nature

www.valuing-nature.net

An organization supported by a variety of British universities, government and business organizations, it is "An Interdisciplinary Network for Valuing Biodiversity, Ecosystem Services and Natural Resource Use".

6. Project for Ecosystem Services

www.proecoserv.org

"The Project for Ecosystem Services (ProEcoServ) is a GEF-funded umbrella project aiming at piloting the bundling of ecosystem services and the integration of ecosystem services approaches into resource management and decision making. The overall goal of the project is to better integrate ecosystem assessment, scenario development and economic valuation of ecosystem services into sustainable national development planning." This new project, which follows up from the MA, supports five countries (Chile, Trinidad and Tobago, South Africa, Lesotho and Vietnam) as they work to integrate ecosystem services into economic development and environmental management.

7. The Ecosystem Services Project

www.ecosystemservicesproject.org/index.htm

This is an Australia-based program of ecosystem services projects and research. Their project includes a parallel effort called Markets for Ecosystem Services about creating markets for ecosystem services. www.ecosystemservicesproject.org/html/markets/aboutus/index.htm.

8. The Ecosystem Marketplace

www.ecosystemmarketplace.com

They say "The Ecosystem Marketplace, a project of Forest Trends, is a leading source of news, data, and analytics on markets and payments for ecosystem services" They offer data specifically on markets for water, carbon and biodiversity. Forest Trends is a world wide, non-project organization concerned with sustainable management of forests.

9. Ecosystem Based Management Tools Network

www.ebmtools.org

Although not specifically focused on ecosystem services, this site addresses many organizational and computer based tools for environmental planning and management, including ecosystem services. The particular focus is on marine and coastal ecosystems, but many of the principles and tools apply much more widely. The intention of the network aspect of the website is to connect individuals with these resources. They also have regular free 'webinar' lectures/courses concerning management topics.

10. The Sub-Global Assessment (SGA) Network

www.ecosystemassessments.net

It is coordinated/funded by the United Nations Environment Program and several European government agencies. "The Sub-Global Assessment (SGA) Network seeks to create a common platform for practitioners (individuals and organizations) involved in ecosystem assessment at regional, sub-regional, national and sub-national levels. The intention is to promote and facilitate improved capacity in undertaking and using assessments." Their website has news, events, publications and other relevant information.

11. Inter-governmental Platform on Biodiversity and Ecosystem Services

www.ipbes.net

This is an organization of (currently) 110 governments that serves as a communications and coordination role concerning biodiversity and ecosystem services. It has started its work in 2012 and is moving slowly, but looking at the website can provide substantial perspective on the movement of government interests in the topic areas.

12.Carbon, Biodiversity & Ecosystem Services: Exploring Co-benefits

www.carbon-biodiversity.net

This website, run by UN agencies, is related to the REDD (Reducing Emissions from Deforestation and forest Degradation) program for reducing carbon. "Maintaining natural carbon stocks can generate co-benefits, benefits that are additional to climate change mitigation effects. Ecosystem co-benefits, which include biodiversity conservation and ecosystem services, derive directly from maintaining natural ecosystems."

13. Earth Economics

www.eartheconomics.org

This website provides information and publications are downloadable. Note especially a downloadable list of their ecosystem service economic valuation reports from different parts of the world (but mostly from the US Pacific Northwest, their home area) at http://www.eartheconomics.org/Page105.aspx. Note the ecosystem services valuation toolkit www.esvaluation.org, which is getting started as a data exchange mechanism for benefits-transfer studies.

14. Britain's Natural Capital Committee

www.defra.gov.uk/naturalcapitalcommittee

This is the advisory group that provides technical advice to the UK program on natural capital and ecosystem services.

15. Ecosystem Valuation

http://www.ecosystemvaluation.org/uses.htm

This website is devoted to explaining and providing examples for economic methods for ecosystem valuation. They include both monetary and non-monetary approaches, examples and discussions. The text appears to be written for professionals needing to get started with ecosystem valuations.

16. The Inter-American Development Bank

www.iadb.org/en/topics/environment/biodiversity-platform/the-idbs-biodiversity-platform,6825.html

For more on its Biodiversity and Ecosystem Services Program, go to this website.

Technical Journals that publish extensively related to Ecosystem Services

Haines-Young and Potschin (2009) did a Web of Science key word search and found about 4000 journal articles related to 'ecosystem, ecological or environmental services'. The top ten journals in which those articles appeared, in order of number of articles published, are:

- Ecological Economics
- Ecology and Society
- Environmental Management
- Ecological Applications
- Conservation Biology
- Proceedings of the National Academy of Sciences
- Biological Conservation
- Forest Ecology and Management
- Journal of Environmental Management
- Landscape and Urban Planning

Of these, Ecological Economics had more than twice as many articles as the next journal, Ecology and Society. These, therefore, are journals that would be worth investigating if you are interested in exploring the topic.

Since their study, two journals have arisen with 'ecosystem services' in their title. Their names and websites are listed immediately below. The first has expanded the range of formal interests of an existing journal by adding the topic 'ecosystem services' to the biodiversity science and management that were previously in its title. The second is an entirely new journal, associated with the Ecosystem Services Partnership. Two other journals, which commonly feature articles about ecosystem services, are also mentioned on the ESP website. They are also listed below.

- International Journal of Biodiversity Science, Ecosystem Services & Management
- Ecosystem Services: Science, Policy and Practice
- Ecological Indicators
- Solutions

Annotated Examples

The sequence of topics below follows the sequence of topics within the four sections of the *Foundations of Ecosystem Services*. The boxes contain a variety of specific examples of research, reports or projects directly related to the different topics.

SECTION 1: What are Ecosystem Services, Natural Capital & Nature's Benefits to People	
Toronto, Vancouver and Seattle	The David Suzuki Foundation has completed valuation studies of ecosystem services provided in the Toronto area Greenbelt and the Lower Mainland around Vancouver. The Earth Economics Institute has done a similar analysis for the Puget Sound region around Seattle. These reports introduce the ideas of natural capital, ecosystem services and valuation studies in an urban context.
Ecosystem Services in the United Kingdom	The Ecosystem Services assessment of the United Kingdom in 2012 went through all the steps of an ecosystem assessment, including setting up a general classification system. The steps were much like those of MA although modified with newer ideas from TEEB and the literature discussing definitions and cascades. Although at a geographical scale larger than that of urban landscapes, the UK National Ecosystem Assessment shows how all the general concepts can be applied to a specific case.
"Nature and its role in the economy"	A report with this title reviews the major issues. It is a good review of the ideas behind ecosystem services and how they can be used. It contains a variety of examples. If you are interested in an introduction to the ideas or history of work with ecosystem services, you might explore the suggestions in Recommended Starting Points for Further Study.

Major Examples	All aspects of the concept of ecosystem services, as well as the details of classification are embedded in the major background reports done by the Millennium Assessment in 2005 and The Economics of Ecosystems and Biodiversity in 2010. Some case studies related to those projects are described immediately below. Other studies that demonstrate the ecosystem services of different ecosystems or locations, and sometimes the economic valuations associated with them, are found under the other topic headings in this table.
SECTION 2: Approaches and Tasks that Focus on Using Ecosystem Services	
Ecosystem Assessments: Millennium Ecosystem Assessment	
Millennium Ecosystem Assessment (MA) Sub-global Assessments	In addition to its global assessments, the MA project documented 33 'sub-global assessments' at different national, regional and local scales in the report titled Multiscale Assessments. There are multiple case examples from national and river basin scales to individual villages. They follow the MA approach as a general model, but many devised local variations to match their own circumstances. These describe ecosystem features and managerial considerations, rather than the ecosystem services directly. The summary case study descriptions are short, although many have links for more detailed reports. The main document, the Multiscale Assessments volume, extracts and summarizes the main ideas, approaches and results from all of the sub-global assessments. Its chapters can provide guidance, with many examples from individual studies, which can be helpful at the urban landscape scale. Three of the Multiscale Assessments, which have background documentation available, are described immediately below. The MA offered guidelines for other people to do comprehensive ecosystem assessments in Ash et al. 2010.

Stockholm Urban Assessment	The Assessment of Stockholm and its surrounding landscape is perhaps the most relevant for readers of this document. The objectives were to "investigate how adaptive capacity can be built to better manage change and, more specifically, to find effective ways to manage urban ecosystem services." They focus on the provision of ecosystem services and functions by urban green areas. The main driver of change was loss of those green areas due to population growth. Major responses were "ratification of conventions and development of new governmental policies . . ." The recommended options included the acquisition of more relevant information and a range of management and co-management approaches.
Portugal Multi-scale Assessment	The MA Assessment Study of Portugal was an example of a nested, multi-scale design within which national, river basin and local studies complemented each other. The project cost about $140K. Fire, land use change, agricultural policy, global markets and economic growth were the major drivers of change at the national level. The services from inland waters were the most under threat. Estimated economic value of the services from the forest was 900 million Euros per year, "with at least 20% of this value coming from nonmarketed services such as soil and flood protection." One interesting result was that a regional project which successfully protected biodiversity also 'led to a low performance with respect to soil conservation.' A local scale (village) study showed that some aspects of material well-being were increasing, but some local ecological services were declining. In the short term villagers were able to find local substitutes for the declining services. In addition to the information within the MA Multiscale Assessment report, the details of the village study are also described in a journal article Pereira et al. 2005.

Indian Urban Resource Assessment	Studies in the southern Indian cities of Pune, Bangalore and Badurai gathered information from over 3000 stakeholders. Conditions and trends of significance included increased pollution, rising energy prices, declining biodiversity and increased immigration due to rural poverty. Major drivers of change were changes in consumer behaviour, as well as poor town planning, technological and cultural change, taxes and government policies. Major options identified included changes in education, taxes and individual behaviour. They considered two scenarios, one (techno-commercial scenario) based on high tech inputs driven by commercial incentives and the other (low external input sustainable activities) driven by growing global resource scarcities, rising prices and security risks.
Kenyan Atlas of Ecosystems and Human Well-being	Nature's Benefits in Kenya is an example of a national ecosystem assessment, with emphasis on mapping the ecosystem services among the other elements of the assessment.
Ecosystem Assessments: The Economics of Ecosystems and Biodiversity	
The Economics of Ecosystems and Biodiversity (TEEB)	The TEEB project invented its own approach to assessing ecosystem services, similar in principle but somewhat more specific than the MA approach published five years earlier. As the title of their project suggests, they were more focused on assessing monetary valuations, and especially using non-market mechanisms to identify surrogate measures of monetary worth. They developed their own economically-based assessment process, similar to but simpler than the MA ecosystem assessment process.
Forest, Urban and Mining Applications of the TEEB approach to Ecosystem Services	The document Mainstreaming the Economics of Nature summarizes the main features of the "TEEB approach" to ecosystem services: a tiered approach to "recognizing", "demonstrating" and "capturing" value. It gives examples of analysis of ecosystem services from forest, urban and mining cases.

Water & Wetlands Analysis	The 2013 summary report Water and Wetlands is a comprehensive and integrated report of describing multiple studies linking economic analyses with environmental planning. This report synthesizes many economic analyses of water and wetlands and shows a strong role for biophysical analyses. It is an example of how to integrate studies of all of the elements of the ecosystem service cascade, to guide policy making and societal decision making.
Regional Case Studies of Economic Aspects of Nature	TEEB's website lists over 100 'Regional case studies', organized by the geographical region in which they took place. Each case study provides a very short summary of the study and provides links to the original documents. Although a few of their case studies are part of the TEEB process, most are independent environmental management studies of quite different kinds, which have the common feature of having using economic analysis of some kind in an environmental context.
Nordic Countries TEEB Analysis	The 2013 composite study of the ecosystem services and their connections to environmental planning in the Nordic Countries seems to be a detailed and careful application of environmental analysis of a wide range of natural resources with a strong economic component. Despite its packaging as a formal TEEB report, it does not appear to explicitly apply the 3 tier TEEB approach.
Business applications of TEEB approach	The World Business Council for Sustainable Development prepared a Guide to Corporate Ecosystem Valuation to implement TEEB for businesses. The guide includes several examples from mining, manufacturing, timber harvesting and water use to 'road test' the approach.

Mapping and Modeling: Ecological Production Functions	
Production Function Modeling for Ecosystem Services	The book Natural Capital: Theory and Practice of Mapping Ecosystem Services provides both the background principles and details for modeling and mapping twelve ecosystem services and biodiversity. It explains the ideas behind the InVEST series of computer models for mapping the ecological production functions and economic values of a landscape and addressing social trade-offs in planning and management. The models permit either detailed or general analysis depending upon the amount of data available. There are 10 chapters on models describing different models/topics from water supply and mitigating storm runoff to carbon storage and crop pollination, and other information.
Regional modeling in the Willamette River Valley, Oregon	Nelson and colleagues describe the mapping processes and valuation results of an early application of the InVEST modeling approach in central Oregon. Although this journal article provides descriptions and an appendix with mathematical details, it does not really explain the InVEST process. For background information, one must examine the book Natural Capital (above), of which Nelson is a major contributing author.
Simulation Models	While the InVEST models are currently the best known, there are websites devoted to other well-developed, open source production function simulation models related to ecosystem services. See the ARIES and MIMES projects for more information. Nelson and Daily discuss a number of different models.

Mapping and Modeling: Integrating Ecosystem Services into a Planning System	
Wetlands	Turner and his colleagues have worked with ecosystem services for many years. Their book, Valuing Ecosystem Services: The Case of Multi-functional Wetlands, is intended as an example of how to bring ecosystem services into environmental management. They offer a multistep process, including a layer approach to mapping, but their particular emphasis, as the title of the book suggests, is the use of monetary valuation. This book shows how the many technical and scientific details related to wetlands can be integrated with valuation processes. See the next entry for more details concerning mapping.
Tanzania Mountains	Fisher and his colleagues, including Turner mentioned just above concerning wetlands, apply an organized ecosystem approach in a specific case described in their title: Measuring, modeling and mapping ecosystem services in the Eastern Arc Mountains of Tanzania. Published in 2011, this is paper deals much more with the mapping and modeling processes introduced in Turner et al.'s book.
Wetlands Benefits at Different Scales in The Netherlands	Hein et al. completed an important example of integrating ecosystem services in their study of wetlands and different beneficiaries of ecosystem services at different geographical scales. While not a specific mapping study, this is a sound model that offers useful perspectives to using spatial information for practical planning and management.
Spatial Assessment of Ecosystem Services	The Partnership for European Enviromental Research (PEER) project provided a synthesis report discussing the state of the art their work with spatial assessment (mapping) ecosystem services, along with example studies mapping services of water purification, outdoor recreation and pollination at different scales.

Payment for Services	
Getting started with Payments for Ecosystem Services (PES)	Several international organizations have funded guidance documents to help people start using Payments for Ecosystem Services. Those by the United Nations Environment Program, The World Bank, and the International Union for the Conservation of Nature might be helpful.
Mexico: Payment for Hydrological and Forest Services	In 2003 Mexican federal law was changed to permit a portion of charges made for water supplies to support conservation. The revenues were put into a public fund that has paid over $300 million to over 3000 landowners who control over 2300 square kilometers of land, halving the previous rate of deforestation.
Forest Protection and Carbon Sequestration Reduce Emissions from Deforestation and Forest Degradation. (REDD-Plus)	A program under the United Nations Framework on Climate change, REDD-Plus is designed to provide payments to rural communities for protecting, or ceasing to harvest, local forests, as carbon sequestering projects. REDD-Plus is currently at the pilot project stage, but a number of substantial projects have been undertaken all over the world. A summary is available and documentation from many of the pilot projects is available. The potential exists for many more projects and very large sums are available for payments.
Worldwide Payments for Watershed Services	This summary describes 205 projects in which payments of 8.17 billion dollars were provided by investors and governments, from 2008 to 2011. It is described by its provider as "the most comprehensive inventory to date of initiatives around the world that are paying individuals and communities to revive or preserve water-friendly features of the landscape." The projects described protect or repair watersheds, streams or rivers to maintain watersheds and water supplies.

SECTION 3: Ecosystem Services & Environmental Management at the Urban Landscape Scale	
Multifunctional Landscapes	
Principles for Multifunctional Landscapes	One large project that links principles for sustainable multifunctional landscapes with specific design practices is the Sustainable Sites Initiative (SITES). See the Landscape Architecture Foundation website for many ideas, case studies, and guidelines. The ideas of the Smart Growth projects also provide many principles, guidelines and practices.
Case Studies	Many of the development and restoration projects described in the Case Studies section contribute to multifunctional landscapes.
Sustainable Ecosystems	
Ecological Concepts for Multifunctional Landscapes	With multifunctional landscapes as the goal, Lovell and colleagues discuss ecological principles that specifically contribute to landscape design practice and to agroecology.
Practices for Sustainable Ecosystems	Practices that help make the idea of sustainable ecosystems workable are available. Meffe and colleagues link ecological science with ecosystem management, Lindenmayer addresses forest biodiversity, Franklin emphasizes a landscape perspective for managing biodiversity but links it with species management, and Liu's focus is on landscape ecology and natural resource management.
Ecological Health & Sustainable Ecosystems	The idea of ecological health is used by many people but it is not usually explicitly linked to ecological sustainability. Karr does that and shows a means to measure both.

Adaptive Management	The now-widespread practices of adaptive management are made specifically available to environmental practitioners within in the Open Standards for Conservation and through the work of the Foundations for Success group.
Case Studies	Most of the development projects described in the Case Studies section explicitly applied ecological principles to their project designs.
Ecological Restoration of Natural Capital	
Resources & Books	The Society for Ecological Restoration has a strong influence over the field. In addition to information, their Primer and Guidelines, all available from the SER website, they have made an effort to sponsor a long list of textbooks on many aspects of restoration. They are listed on the website and published commercially by Island Press.
Restoration Text Book	Galatowitsch has written a detailed professional textbook covering all aspects of restoration, including multiple case studies.
Restoration & Economic Development	A United Nations report by Nellemann and Corcoran describes restoration, and provides many international examples, specifically as an approach to support biodiversity and promote economic development.
Stream Corridor Restoration	Despite the seemingly narrow topic of its title, a report by a US government agency on stream corridor restoration actually discusses hydrology, landscape ecology, watershed science, stream chemistry and biology as well as terrestrial and aquatic restoration practice in a free 586 page report. A helpful resource.
Restoring Natural Capital	Ecological restoration is discussed here because it is such an important link to natural capital. Aronson and his colleagues specifically describe how to maximize natural capital during restoration processes..
Case Studies	There are several restoration projects described in the Case Studies section.

SECTION 4: Policy & Governance	
Decision Making Processes	
Professional Decision Making	Gregory and colleagues apply techniques from the field of decision analysis specifically to environmental issues and calling the process structured decision making. Their work is designed for the complex multi-step situations that apply to major resource management problems.
Participatory Processes	Although Gregory's approach, above, is a participatory process, there are other group methods designed for public processes. Burgess's deliberative mapping methods, Brown's trade off analysis and Chambers' participatory processes might be helpful.
Legislation & Regulation	
Public Policy	Field and Olewiler and Common and Stagl both provide organized reviews of public policy in an environmental and economically oriented context. The TEEB project assembles detailed consideration of national policy options.
Municipal Policy & Legislation	Legislation and policy options specifically targeted towards natural capital and the regional and municipal level are described by Molnar and colleagues, TEEB regional and cities, and Wong and Gordon.
Regional & Local Planning Policy	Guidelines and discussions that link to local policies and regulations more targeted towards land planning and development are provided by Perlman and Milder, Randolph and Steiner.
Encouraging Societal Action without Legislation	
Green Charters	Green plans can drive municipal policies but they can also organize and direct actions of the civil society section. Examples from large (Toronto) and smaller cities (Surrey) might be helpful.

Social Marketing	One of the organized approaches to influence social behaviour is called social marketing. The techniques involved are often appropriate for environmental NGOs.
Market Based Instruments	
Market Based Instruments	Stavins provides a thorough introduction to the topic of MBIs. Websites that provide insights into practical projects are run by the Carbon, Biodiversity and Ecosystem Services group and the Ecosystem Services Project.
Payments for Ecosystem Services	A number of suggestions related to PES programs are made earlier in the Examples list, in Section 2 under the title Payments for Ecosystem Services.

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Millennium Ecosystem Assessment. 2005. The Millennium Ecosystem Assessment Series is a series of five large reports that describe the central efforts of the MA. (Their work is logically preceded and outlined by the 2003 volume, A Framework for Assessment, described above.) There are four topic reports (400-800 pages) and a summary report (120 pages).
Ecosystems and Human Well-Being. Volume 1 Current State and Trends
Ecosystems and Human Well-Being. Volume 2 Scenarios
Ecosystems and Human Well-Being. Volume 3 Policy Responses
Ecosystems and Human Well-Being. Volume 4 Multiscale Assessments
Our Human Planet: Summary for Decision Makers

The Assessment series is described here: http://www.millenniumassessment.org/en/Reports.html, They are published as bound volumes by Island Press, but the option to 'view chapters' permits any or all chapters of Volumes 1-4 to be downloaded individually. The most useful single volume, the Summary for Decision Makers, is only available in hard copy.

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Smart Growth Network. A project funded by the US Environmental Protection Agency, the website http://www.smartgrowth.org/network.php provides links to many downloadable reports and manuals. It also provides links to other organizations and literature interested in sustainable communities and the management practices that can support them.

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Society for Ecological Restoration. 2004. Primer on Ecological Restoration. https://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration. Free 13 page document from website in six languages

Society for Ecological Restoration. 2005. Guidelines for Developing and Managing Ecological Restoration. https://www.ser.org/resources/resources-detail-view/guidelines-for-developing-and-managing-ecological-restoration-projects. A 16 page document that contains 51 numbered steps for planning and implementing ecological restoration projects.

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Syngenta case study summary concerning wild pollinators is available, under `Syngenta' at http://usbcsd.org/case-studies/biodiversity-and-ecosystem-services-case-studies. There are other cases studies on this page also.

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Tallis, H, & Polasky, S. 2009. Mapping and valuing ecosystem services as an approach for conservation and natural-resource management. Annals of the New York Academy of Science 1162: 265-283. A description of the InVEST method, with more details than Nelson et al. Uses Nelson and Amazon as examples, but in no more detail than the original. More helpful about InVEST than other sources but not the most detailed tool for ES in general (see Kareiva et al. for most details). Complements Nelson et al. on uses of InVEST.

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Taylor, A. & Kennedy, M. 2008. Scoping Report on Canadian and International Water Valuation. Pembina Institute for Sustainable Development: Edmonton.

TEEB. The Economics of Ecosystems and Biodiversity project is a major international assessment project. It followed the MA project and was built upon interest from that study, and was sponsored by the United Nations and several European governments. It was more focused on economic aspects of, and specifically upon ways to measure monetary benefits from, its title topics. The project produced multiple downloadable resources found in various places (some not easily found) on the TEEB website, which are summarized here. . In mid 2013, the major reports, often in multiple languages, were downloadable at http://www.teebweb.org/publications/all-publications/

Five major reports from the initial years of TEEB and published around 2010-2011 are available under the `study reports' tab on the `publications' menu of the TEEB webpages and also from http://www.teebweb.org/publications/teeb-study-reports:

1 A `synthesis' report (Mainstreaming the Economics of Nature) (39 pages) available in nine languages. http://www.teebweb.org/publications/teeb-study-reports/synthesis/

2 A description of the conceptual underpinnings of the project by Kumar et al. (Ecological and Economic Foundations) (410 pages) http://www.teebweb.org/publications/teeb-study-reports/foundations/

Three major studies to show the application of TEEB ideas to specific audiences have been produced, along with summary volumes of each:

3 TEEB for National and International Policy Makers (429 pages) and TEEB for National and International Policy Makers: Summary: Responding to the Value of Nature (48 pages) in six languages: http://www.teebweb.org/publications/teeb-study-reports/national-and-international/

4 TEEB 2010a The Economics of Ecosystems and Biodiversity for Local and Regional Policy Makers (210 pages) in five languages and A Quick Guide to TEEB for Local and Regional Policy Makers (8 pages), in eight languages http://www.teebweb.org/publications/teeb-study-reports/local-and-regional/. The extensive list of internet-downloadable resources, organized by each chapter of the TEEB for Local and Regional Policy Makers manual, are downloadable at http://www.teebweb.org/local-and-regional-policy-makers-further-information/#tabbed%20box%201.

5 TEEB for Business (213 pages) and TEEB for Business: Executive Summary (27 pages) in seven languages: http://www.teebweb.org/publications/teeb-study-reports/business-and-enterprise

The Figures used in each of these five reports are also downloadable, at the bottom of the same webpages from which the reports are downloaded. The four latter documents have been slightly edited and are available commercially in print : http://www.routledge.com/books/series/ETEEB/.

Several more recent documents, called `additional reports' are found under the `publications' menu on the TEEB home page http://www.teebweb.org:

Why Value the Oceans. TEEB calls this 33 page report a `think piece' published in 2012 in advance of the larger program TEEB for Coasts and Oceans which is still underway. Status reports on some ocean studies can be found here: http://teeboceans.org/teeb-oceans-around-the-world/ and other ocean-related reports and presentations are available here http://teeboceans.org/document-library.

Nature and its Role in the Transition to a Green Economy is a 74 page 2012 report for government leaders that shows how nature (biodiversity and ecosystems) provide the foundation for well-being and indicates a sequence of policies and approaches that support protecting nature and supporting human well-being. Although not specifically identified as such, it seems to be an updated, shortened and practical synthesis of key ideas in the two larger volumes for policy makers, published in 2010.

Water and Wetlands is an 84 page report released in early 2013 which summarizes the TEEB approach of identifying, valuing and considering biodiversity and ecosystems, written as a stand-alone source with specific applications for water and wetland ecosystems. On the download page there are also executive summaries available in six languages.

Nordic Synthesis Report is the short title for Socio-economic Importance of Ecosystem Services in Nordic Countries. Released in 2013, this is a 293 page recent country application of an approach with a strong economic component, is downloadable from http://www.teebweb.org. Called a `sectoral study' other nation-based studies can be found here http://www.teebweb.org/teeb-implementation/national-studies/. Although they all have substantial economic components, they do not seem to follow the 3 tier `TEEB approach' in a formal way.

TEEB produces a regular electronic newsletter that you can subscribe to at now cost. `TEEBriefs' provides a summary of events and major new reports and publications which collectively show the current trends in the field. Register to receive it at http://visitor.r20.constantcontact.com/manage/optin/ea?v=001Jlsow3JA4iDZfvIAgBk_0Q%3D%3D

TEEB also provides:

TEEB 2011. Manual for Cites: Ecosystem Services in Urban Management is a guide application of the TEEB approach to cities: http://www.teebweb.org/teeb-study-and-reports/additional-reports/manual-for-cities/. Despite the implication of the title, the guidelines are very similar to other TEEB documents. That is, they are rather general and it is not easy to move directly to urban scale activities just based upon these guidelines.

Climate Issues Update 2009. This report links TEEB ideas specifically with climate change concerns. http://www.teebweb.org/teeb-study-and-reports/additional-reports/climate-issues-update/

Guidance Manual for Countries. A link on this page http://www.teebweb.org/teeb-implementation/national-studies accesses a short 6 page summary of a larger document still in preparation and planned for release in 2013.

What TEEB calls regional case studies, and elsewhere calls in-country studies, can be accessed here: http://www.teebweb.org/resources/teeb-case-studies-list/. There are over 100 short summaries, groups geographically, with links to the original studies. They describe a wide range of environmental management projects which seem to have the common feature of possessing an element of economic analysis within the study.

The project's website has many other resources, here: www.teebweb.org. The TEEB website's links to related websites are quite helpful http://www.teebweb.org/resources/useful-links.

Specific details of several key reports, which were cited individually in different places in the text, follow.

TEEB 2010a. Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB. http://www.teebweb.org/teeb-study-and-reports/main-reports/synthesis-report. This highlights the main features of TEEB, which are described in a different format and in much more detail in the book by Kumar described above.

TEEB 2010b. The Economics of Ecosystems and Biodiversity for Local and Regional Policy Makers.

TEEB 2011. TEEB manual for cities. This manual is a 48 page shortened version of the regional policy manual, mentioned above. It is intended as a how-to guideline for the TEEB process, which, as described in Section 2, is quite detailed. http://www.teebweb.org/teeb-study-and-reports/additional-reports/manual-for-cities/

TEEB 2012 Nature and its role in the transition to a green economy. Summary report with basic background of natural capital and ecosystem services, particularly useful as an introduction for business or government policy people. http://www.teebweb.org/teeb-study-and-reports/additional-reports/nature-and-its-role-in-a-green-economy

TEEB 2013. The Economics of Ecosystems and Biodiversity for Water and Wetlands. This 84 page summary report is a carefully balanced integration of information identifying and using all steps of the ecosystem service cascade, while emphasizing the role of economic analyses. It provides information about economic valuations of many different kinds of wetlands, and shows the TEEB approach in a policy context. It appears to be the most comprehensive example of a TEEB-related case study, or application.

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Tongway, D. & Ludwig, J. 2012. Restoring disturbed landscapes: putting principles into practice. Washington DC: Island Press. This is a management approach applicable to restoration projects regardless of habitat or technical challenges involved. They describe an overall management system that can work for restoration. They also provide a 'landscape multifunctional analysis' to guide design and implementation.

Tonietto, R., Fant, J., Ascher, J., Ellis, K., & Larkin, D. 2011. A comparison of bee communities of Chicago green roofs, parks and prairies. Landscape and Urban Planning, 103(1), 102-108

Town of Whitchurch-Stouffville 2011 Ballantrae-Musselman Lake and Environs Secondary Plan. Available at http://www.townofws.com/pdfs/OPC/WS%20Official%20Plan%20Section%2011.pdf

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Turner, N. Gardner, R. & O'Neill, R. 2001. Landscape Ecology in Theory and Practice: Pattern and Process. Springer. A popular textbook in landscape ecology.

Turner, R. T., Georgiou, S. & Fisher, B. (2008). Valuing ecosystem services: The case of multi-functional wetlands. Washington DC: Earthscan. They describe a comprehensive approach to ecosystem services, the core of which is a detailed assessment process. Although the example is about wetlands, the process is intended as a model for use with any kind of ecosystem.

United Kingdom National Ecosystem Assessment. (2011). This was a major national assessment of ecosystem services. A website describing the national survey and many related aspects, including many technical documents is http://uknea.unep-wcmc.org. The major final Technical Report (2011) itself is available, but not as a complete document-it comes only chapter by chapter at http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx. The shorter 'Synthesis of Key Findings' is found on the same page.

United Kingdom Natural Capital Committee. 2013. The State of Natural Capital: Towards a Framework for Measurement and Valuation. The report can be found at . Details on the NC Committee and its work are at http://www.defra.gov.uk/naturalcapitalcommittee/files/State-of-Natural-Capital-Report-2013.pdf

United States Department of Energy Information Administration. 1998. Method for calculating carbon sequestration by trees in urban and suburban settings. Accessed at ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/sequester.pdf.

United States Environmental Protection Agency. The Land Revitalization program http://www.epa.gov/landrevitalization/index.htm offers a wide range of resources and information about brownfield restoration and many related topics.

United States Environmental Protection Agency. 2012. US Environmental Protection Agency 2012 Campus RainWorks Challenge Winner: Illinois Institute of Technology, 1st Prize, Small institution. Available at: http://water.epa.gov/infrastructure/greeninfrastructure/upload/Summary-for-Illinois-Inst-of-Technology.pdf

Urban Land Institute. http://www.uli.org/ The website permits purchase of O'Neill's book, (see separate listing), and other related books, and downloadable reports about smart growth and other urban land use topics.

US National Academy of Sciences. 2004. Valuing Ecosystem Services: Toward Better Environmental Decision Making. Report in Brief November 2004.

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