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Organizing Information to Support the Ecosystem Services Approach: An Ecosystem Services Indicators Framework

(background paper)

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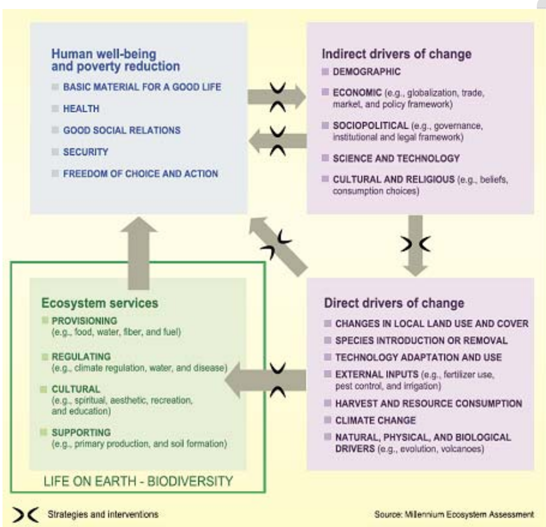
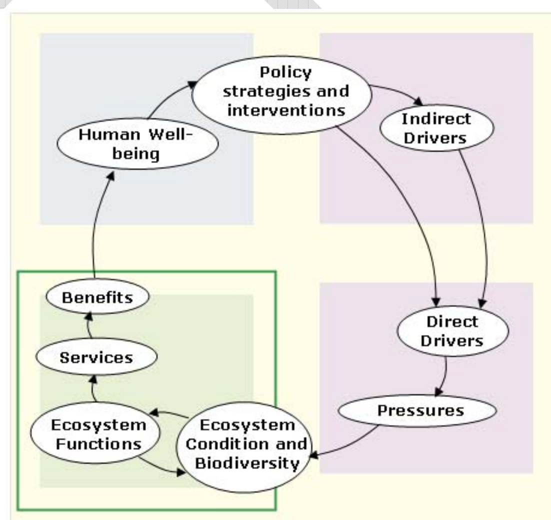
Executive Summary

Precise contents to be determined, but will include a depiction of the framework side-by-side with the MA framework so readers have a visual depiction of the framework in the very front of the report.

Elements to include:

- Need: indicators poor. Framework part of solution.
- Audience
- Framework looks like: Accompanied by online database in development
- Meets characteristics of indicators framework: conceptually effective but practically applicable.
- Characteristics:
    - Scalable: full framework not necessary to use in all cases.





1. Introduction

People are dependent on nature for our physical, economic and social well-being. We rely on ecosystems for food, water, energy and other goods. Nature also provides services such as erosion control, water purification, and pollination that maintain a resilient and productive environment (see Table 1 for a full list and definitions of ecosystem services). In addition, humans derive ethical services such as recreationand spiritual well-being from nature.

The millennium ecosystem assessment (MA) was a global study that assessed the condition and trends of the world's ecosystem services. Building on earlier studies exploring people's dependence on nature (e.g Daily, 1997; Costanza et al., 1997; De Groot, 2002) , the MA developed a conceptual framework illustrating the linkages between ecosystems and humans (see Box 1). In contrast with many environmental approaches, the ecosystem services conceptual framework puts people at the center by focusing on the services that humans derive from nature.

The MA found that in the last half of the 20th century,humans have increasingly rapidly changed ecosystemsto meetgrowing needs for food, freshwater, timber, fiber, and fuel. While resulting in improvinghuman health and reducing in theproportion of malnourished people, these wide-scale changes to ecosystems come at an increasing cost: The MA found that 60 percent of ecosystem services assessed are degraded.

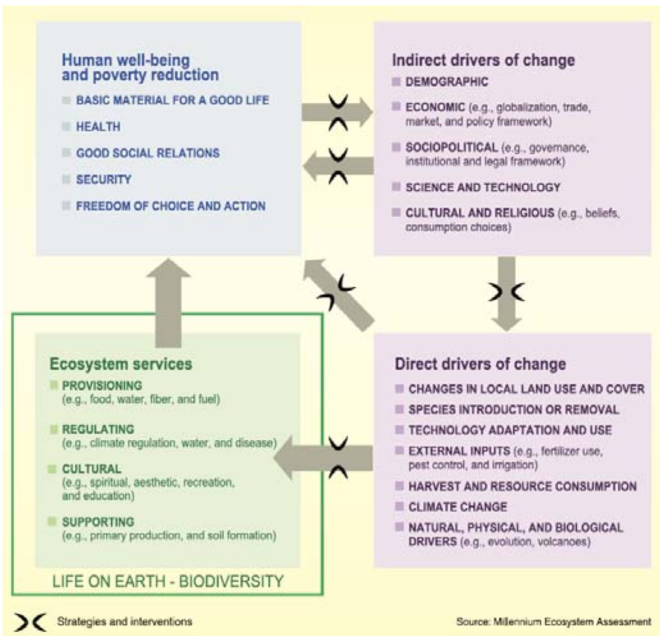
If trends toward poverty reduction and improved human well-being are to be sustained, the ecosystem services people rely on cannot continue to be degraded indefinitely. Reversing degradation will, however, require changing attitudes regarding the relationship between nature and economic development. Mainstream economic and development planning need to adopt approaches that integrate ecosystems' vital role as a foundation for continued improvements in humans' quality of life.

The development of the ecosystem services conceptual framework and the widespread dissemination of the MA findings represent an important opportunity for developing new approaches and getting them accepted into mainstream policy-making. By focusing on the services that people receive from nature, the ecosystem services framework integrates ecological and socio-economic realms in the way that previous environmental frameworks have not. Numerous efforts to develop approaches based on the ecosystem service conceptual framework have been initiated. However, a framework for organizing indicators and data in support of policy analysis and decision-making has not yet been developed. Given the importance of indicators for analyzing current state and trends, informing policy, tracking progress, and initiating corrective action, an ecosystem service indicators framework is needed for mainstreaming ecosystem service approaches in the longer term.

Box 1: The Millennium Ecosystem Assessment Ecosystem Service Conceptual Framework

The Millennium Ecosystem Assessment (MA), a four-year global effort involving more than 1,300 experts, released a conceptual framework that describes the links between ecosystems and human well-being. The clarity with which this ecosystem service framework communicates people's dependence on ecosystems provides policy-makers with a basis for reconciling economic development and ecosystems. The framework is described in greater detail in the XXX section below.

The ecosystem service conceptual framework was applied by the scientists convened by the MA to assess the capacity of ecosystems to provide the goods and services on which people rely in the MA global study (2005) and by local teams to conduct over 20 sub-global assessments. The framework has also underpinned numerous other studies and assessments, including The Economics of Ecosystems and Biodiversity (TEEB) (EC, 2008), The Corporate Ecosystem Service Review (Hanson et. al, 2008) and **others here.**



The framework is conceptual clear and straightforward for communicating the principles of ecosystem services to varied audiences. Experience applying the framework to organize indicators and data and underpin analyses has identified limitations in practically applying the framework. This paper builds on the experiences of these experiences to propose an ecosystem service indicators framework.

This paper presents an ecosystem service indicators framework for organizing indicators and metrics. The primary intended purpose of the ES indicators framework is to support policy analysis, including both public and private sector decision-making. As presented, the framework is not intended to hold data, but can serve as a high-level organizational guide for constructing a database to hold data for specific indicators. The framework is not intended to break new conceptual ground. Rather, it integrates existing framework elements to construct a framework that is intended to meet the needs of diverse audiences that need to identify, gather, and apply indicators to help make decisions that integrate ecological with socio-economic knowledge.

This paper builds on WRI's publication *Measuring Nature's Benefits: A Preliminary Roadmap for Improving Ecosystem Service Indicators*(Layke 2009). *Measuring Nature's Benefits* presented an analysis of how effectively indicators used in the global MA (see box 1) are able to communicate information, and how well they are supported by data sets. It then presented some preliminary steps toward improving ecosystem service indicators. This paper and the accompanying online database represent an initial move toward collaborative initiatives to improve ecosystem service indicators.

note

> **Box 2: Terms and Definitions**
>
> **Indicator:**information that efficiently communicates characteristics about a topic. Due to the emerging state of ecosystem service indicators and the need for indicators that can be applied at very local as well a wider scales, this paper uses the tern indicatorto include specific metrics as well as more aggregated indicators.
>
> **Metric:** a measure of a specific component or phenomenon. Metrics can serve as indicators, but multiple metrics are often aggregated to efficiently communicate information.
>
> **Ecosystem Service:** Goods and services ecosystems produce that either provide for humans' physical or spiritual needs, or that maintain ecosystems' productive capacity. A list of ecosystem services and their definitions can be found in Table X.
>
> **Benefit:** Those ecosystem services that are directly consumed by humans. Freshwater is an ecosystem service, but only a portion is directly consumed by humans, as some is used indirectly, as an input into aquaculture for example, or left in the ecosystem.
>
> **Etc.**

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mainstreaming ecosystem services concepts into policy-making (Layke, 1999; MA Follow-up Advisory Group, 2008; review of BIP cite).

The limited number of high-quality metrics and indicators remains a barrier to applying ecosystem service concepts and approaches (Layke, 2009; UNEP-WCMC, 2010). However, the lack of a common framework for organizing those indicators that do exist and making them available to potential users is also a significant constraint that can be addressed. An ecosystem service indicators framework is needed to support policy analysis and to ease the adoption of the ecosystem service methods mentioned above by broader audiences. The organization of indicators and metrics within a policy-relevant framework helps identify concerns, understand potential causality and formulate policy responses (Borja et al., 2006; Svarstad et al., 2008). Broad application of emerging ecosystem service approaches such as valuation also will require the ability to organize and classify metrics and indicators in ways that are relevant to their intended application (Fisher et al, 2008; Wallace, 2007).

There are currently multiple ecosystem service frameworks being used to organize metrics and indicators, depending on the approach being used. For example, many ecosystem assessments building on the MA continue to apply the MA conceptual framework, while economic valuation approaches have refined elements of that framework. In addition to making it seem as though the approaches conflict, the lack of a common framework that meets the needs of the various emerging approaches will make it difficult to gather and share the experiences and knowledge gained by applying the approach. Currently, there is no repository of the indicators and metrics identified and applied other than the database developed as part of this project. A database built around a common framework will help facilitate gathering and iteratively improving indicators needed to mainstream ecosystem service concepts.

1.2 Goals and Audiences

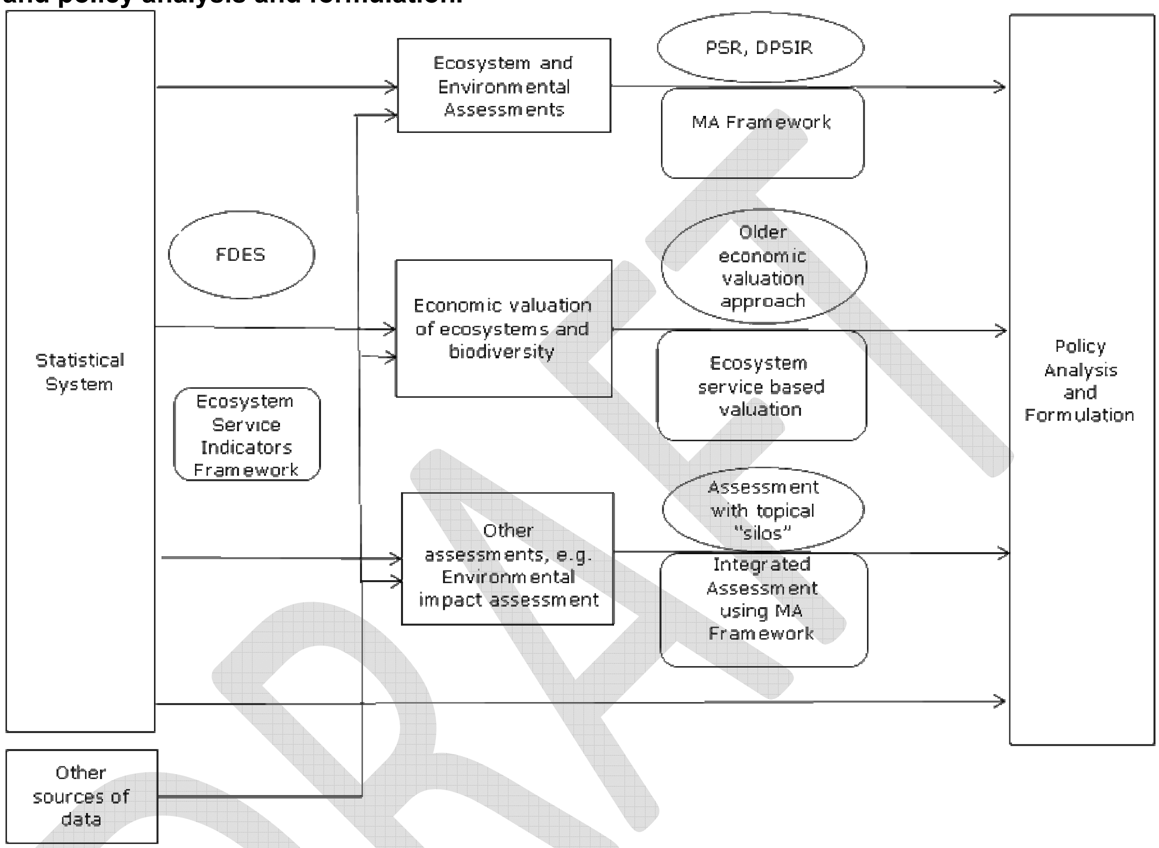
The goal of ecosystem service indicators framework is to foster the integration of ecosystem service concepts into policy-making, especiallypolicy analysis and formulation of environmental, economic, and social development policies. The target audience for the indicators framework is statistical systems at multiple scales, includingnational, sub-national, regional and global scales.

Statistical systems provide a foundation for holistic policy analysis and formulation. Figure X depicts a simplified relationship between statistical systems, assessments and policy analysis and formulation. Statistical systems, depicted in the left-hand column, directly support policy analyses, represented on the right. The information compiled by statistical systems includingare necessary to formulate policies that will address problems and improve citizens' overall social and economic well-being. Information from statistical systems also supports assessments, such as ecosystem assessments and economic valuation of ecosystems and biodiversity, depicted in the center of figure X. In addition to relying on information from statistical systems directly, policy analyses rely on these assessments.

If statistical systems adopt elements ofa framework based on ecosystem service concepts to organize indicators and data, they will enhance the ability of policy analysts to use the approaches being developed around ecosystem service concepts and help identify key environment-human linkages.While the approaches used by statistical systems vary, many statistical systems are organized around frameworks, such as the Framework for the Development of Environment Statistics (FDES) and Driving Force-Pressure-Impact-State-Response (DPSIR), both of which lack key elements needed to apply ecosystem service concepts.

The ES indicators framework was developed to be consistent with existing frameworks used by statistical systems, including FDES and DPSIR as well as the MA framework and recently-developed approaches applying ecosystem service concepts in economic valuation of ecosystems and biodiversity. The goal is that the framework elements necessary for applying ecosystem service concepts can be integrated into existing frameworks being used by statistical agencies. The data then compiled by these agencies in the future will be able to support developing approaches such as economic valuation of ecosystems and biodiversity, ecosystem assessments, modeling of ecosystem services such as that being done by InVEST, and policy analyses.

Figure X: Representation of the relationship between statistical systems, assessments, and policy analysis and formulation.



Support Formulation of Policy Strategies and Interventions

Themanner in which statistical agencies' adopting the ecosystem service indicators framework will help facilitate the use of ecosystem service approaches is depicted in figure X. Statistical systems currently use a number of different frameworks such as FDES, which does not include elements necessary for applying ecosystem service concepts. The statistical systems, along with external sources of information, support various assessments including ecosystem assessments, economic valuation, and environmental impact assessments. Current statistical systems are able to support status quo approaches used by assessments, but less able to support the application of ecosystem service approaches. Statistical systems that use FDES to organize their data can, for example, support State of Environment assessments that use a pressure-state-response framework, but would be missing key information needed to use an MA framework. Similarly, to support environmental economic valuation using the framework developed by The Economics of Ecosystems and Biodiversity (EC, 2008), statistical systems would need to add framework elements that support this approach. By supporting the ability of assessments to use ecosystem service approaches and by making relevant data directly available, statistical systems that adopt an ecosystem service indicators framework will be able to directly support policy analyses that are able to more fully consider the linkages between ecosystems and biodiversity and human well-being. In conducting cost-benefit analyses, for example, the full range of potential impacts on the goods and services provided by ecosystems can be considered. These more holistic analyses can then be used to inform legislation, regulations, and other kinds of policies.

To realize this goal, the framework is designed to support the ability of policy analysis to understand and consider:

- The full suite of contributions ecosystem services make to human well-being, including regulating and cultural services in addition to provisioning services.
- The impact of human actions on the quality and quantity of ecosystem services and, indirectly, onpeoples' well-being.
- Assess policy options for probable impacts on peoples' economic and social well-being due to impacts on ecosystem services.
- Understand the impact of policy strategies and interventions on indirect and direct drivers that drive the condition and trends of ecosystems and ecosystem services.
- Weigh trade-offs associated with different options in policy decisions.
- Formulate the impact of new policy strategies and interventions to improve the ecosystem services that underpin human well-being. Track and iteratively improve these policy strategies and interventions.

A Supporting Framework for Ecosystem Service Approaches

The ecosystem service indicators framework is not intended to replace the MA framework used for ecosystem assessments, or the economic valuation approach developed by TEEB and others. Rather, it is intended to help statistical systems gather data in ways that support both, as well as other assessments that incorporate methodologies based on ecosystem service concepts.

Although they contain consistent elements, the framework developed by the MA and that continues to be used by ecosystem assessments, and the frameworks being developed for economic valuation are not consistent. However, both are important and can contribute valuable information to policy-makers. Because the ES indicators framework was designed to include the elements required by both approaches and to be compatible with existing frameworks such as DPSIR, it should help statistical agencies to support multiple approaches.

The common framework will provide practical support to these approaches by organizing the compilation of indicators, metrics and data needed to implement these approaches at increasing levels of sophistication at varied scales, geographies and contexts. In some cases such as environmental impact statements, the framework may help refine the approaches by providing information on how to integrate elements that will strengthen the ability to consider important but missing information. Environmental impact assessments, for example, will benefit from an improved ability to incorporate indirect drivers of ecosystem change that would be exacerbated by proposed projects, and by improving the linkages between the ecosystem changes and human well-being.

Audiences
The ES indicators framework is intended to help incorporate ecosystem service concepts into statistical systems. The primary audience for this report is therefore statistical agencies and the organizations, such as the United Nations Statistical Agency and the Food and Agriculture Organization of the United Nations, that support them.

In addition, organizations applying ecosystem services concepts, or working to expand the use of ecosystem service concepts in policy-making will find aspects of the framework and paper useful in their work. In particular, those responsible for generating and organizing information in support of an assessment or study may find aspects of the framework and the compiled indicators informative. Secondary audiences for this publication therefore include individuals and institutions who:

- Are developing approaches to apply ecosystem service concepts.
- Organizing information in preparation for an assessment that includes ecosystem service concepts.
- Are responsible for generating the information needed to apply those approaches.

More specifically, secondary audiences include organizations or initiatives that are currently or prospectively engaged in developing or improving approaches to apply ecosystem services concepts. These include:

- Sub-global assessment teams
- Economic valuation
- Private sector identification of risks and strategies to reduce externalities.

2. The Ecosystem Services Indicators Framework

Intro here… this section introduces the framework etc. etc.

2.1 What the ES Indicators Framework is and is Not

The ecosystem service indicators framework is intended to help organize the indicators, metrics and data needed to successfully integrate ecosystem service concepts in policy. The framework is intended to be a common framework, supporting the needs of different audiences and relevant to varied tools and methodologies emerging in support of the ecosystem service conceptual framework. It is comprehensive yet scalable, allowing audiences to use all elements of the framework or only portions relevant to their specific needs.

Sometimes specifying what one is not trying to be can help clarify and land focus to one's goals. The ES indicators framework is not a new conceptual framework. Nor is it a statistical system or a framework intended to support green accounting.

The ES indicators framework is not intended to be a new conceptual framework, but rather to integrate the elements of multiple existing frameworks to establish a common framework. The MA and other conceptual work on ecosystem services have established sufficient conceptual underpinning for exploring the linkages between people and ecosystems. Existing and widely used environmental indicator frameworks such as Driving force-Pressure-State-Impact-Response (DPSIR) have illustrated the categories of information that effectively support the ability of policy processes to integrate information. The ES indicators framework presented here is mostly a consolidation of approaches from existing conceptual frameworks into a new one intended to help lower barriers to users seeking to implement ecosystem services concepts.

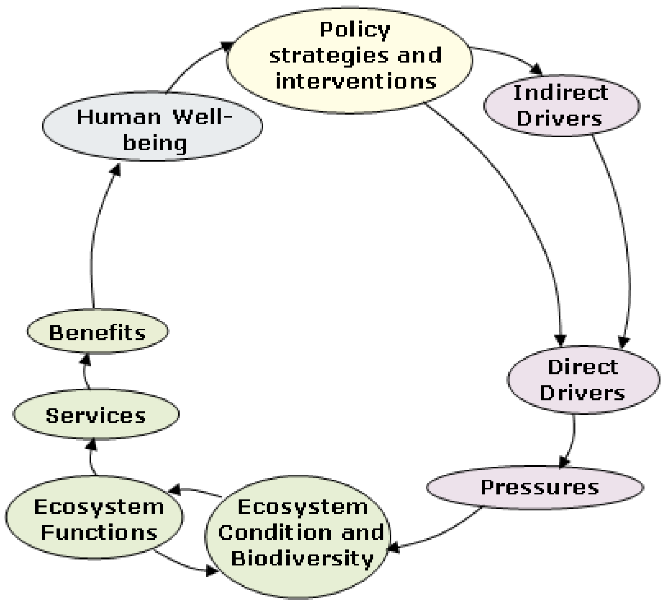
Similarly, the ES indicators framework is not intended to be a statistical system or approach to facilitate green accounting. Statistical systems typically try to be comprehensive and to support aggregation and disaggregation by using consistent units, usually monetary units (UN, 1984). The ecosystem service indicators framework does notseek to connect all the parts and variables of a system. ESID is a framework intended to organize information into categories and topics that support the ability to see linkages between environmental, social and economic sectors, and to analyze policy options.

2.2 Introducing the Framework

The ES indicators framework consists of 9 elements grouped in four categories (Figure X):

- Ecosystems, Services, and Benefits (shown in green in figure x)
    - Ecosystem Condition and Biodiversity
    - Ecosystem Functions
    - Services
    - Benefits
- Human Well-being (shown in blue in figure x)
    - Human well-being
- Policy Strategies and Interventions (shown in yellow in figure x)
    - Policy strategies and interventions
- Drivers and Pressures (shown in purple in figure x)
    - Indirect drivers
    - Direct drivers
    - Pressures

Figure X: Ecosystem services indicators framework. The colors used are consistent with the elements of the MA framework. Elements shown in green depict the delivery of ecosystem services and represent the ecological realm. Blue is to hold indicators of human well-being. Yellow is for policy strategies and interventions. Purple presents the forces impacting ecosystems, biodiversity, and the ecosystem services they deliver.



A brief definition for each framework element is provided below. Examples of relevant indicators for each category are presented in Table X. Definitions and classifications for ES have been proposed and debated (Boyd and Banzhaf, 2006; Wallace, 2007; Fisher at al, 2008, etc) and will undoubtedly continue to be examined. The definitions used here have been used before both in ways that are consistent and inconsistent with how we define them. Box 3presents some of the other terms that are used for the concepts we describe below.

- ***Ecosystem Condition and Biodiversity***: together, ecosystem condition and biodiversity represent the ability of ecosystems to support ecosystem processes and deliver ecosystem services. The indicators in this category can therefore be understood as measuring the "stock" of ecosystem services. Biodiversity and ecosystems directly constitute some ecosystem services, such as genetic resources. However, most services and benefits are the product of ecosystem functions as opposed to flowing directly from biodiversity. Ecosystem condition and biodiversity are not synonymous, but both are vital to sustaining ecosystem services in the long-term (insert box on this topic?). An ecosystem's condition is the ability of the ecosystem to support the functions that give rise to services. Biodiversity, defined as"the variability among living organisms […] and the ecological complexes of which they are part" (UNCED, 1992).
- ***Ecosystem Functions:*** the processes by which ecosystems deliver services and benefits. Most regulating and supporting serviceswithin the MA framework are ecosystem functions. Many ecosystem functions are also responsible for maintaining ecosystem condition in a healthy state. For example, soils buffering capacity avoids acidification by SOx, oysters cleansing water and depositing shells maintains clean water and physical structures required for their reproduction and fish and crab nurseries.

Box: Overlapping and Conflicting Terms (needs to be finished)

Organizing ecosystem services into separate categories of ecosystem functions, ecosystem services, and benefit is increasing being accepted as a useful structure (see section on Ecosystem Function-Service-Benefit Models). However, the terminology used by different authors is inconsistent, and sometimes conflicting. For clarity, some of these inconsistencies are included here

Ecosystem Function: Sometimes referred to as ecosystem processes, Should they be grouped? For example, the various terms associated with intermediate services vs. benefits?

Ecosystem services: Sometimes referred to as intermediate services.

Benefit: Also referred to as final service

- ***Services:***ecosystem products that are important for supporting human well-being, but not directly consumed by people. For example, freshwater that is used for irrigation or aquaculture is classified as a service since the freshwater supports peoples' livelihoods but is not directly consumed. Most provisioning and cultural services within the MA framework can be classified as services.
- ***Benefits:*** tangible productsfrom ecosystems that humans directly consume; the "thing that has direct impact on human welfare" (Fisher, Turner et al. 2008). The fish produced by aquaculture in the example above, for example, would be classified as a benefit. Most provisioning and cultural services within the MA framework can be classified as services.For many purposes other than economic valuation, the distinction between services and benefits may not be important.
- ***Human well-being:*** the state of people's physical, economic, social, and spiritual well-being.
- ***Policy strategies and interventions:*** decisions and actions that influence direct and indirect drivers. Policy strategies and interventions can be taken by government, the private sector, individuals or other actors.
- ***Indirect drivers:*** conditions such as poverty, equity, population size and growth, governance, economic conditions that increase or decrease the magnitude of direct drivers.
- ***Direct drivers:*** human activities and actions that directly lead to pressures. Application of agricultural inputs, emissions from fossil fuel combustion, and conversion of forests to farmland are examples of direct drivers.
- ***Pressures:*** biophysical influences that act directly on ecosystemsand the biodiversity they harbor. Pressures also act on socio-economic systems, but that line of impact is not a focus of the ES indicators framework (see figure X). Pressures are differentiated from direct drivers in that they are the biophysical representation of human actions that directly impact ecosystems. The direct driver fossil fuel combustion would have various pressure indicators such as carbon dioxide and sulfur and nitrogen oxides associated with it. Pressures can have neutral, positive or negative impacts on ecosystemsand biodiversity — keeping them in steady state or engendering either positive or negative trends.

2.2.1 A Simplified Depiction

Prior to detailed discussion of the ES indicators framework, it is relevant to recognize that the ES indicators framework depicts a simplified version of "reality". As with most conceptual frameworks, the ecosystem services indicators framework simplifies reality to make it easier to comprehend and apply. The ES indicators framework simplifies reality in two major ways: it lumps all policy strategies and interventions into one framework component, and it reduces the number and nature of interactions between framework elements.

Simplified Depiction of Policy Strategies and Interventions

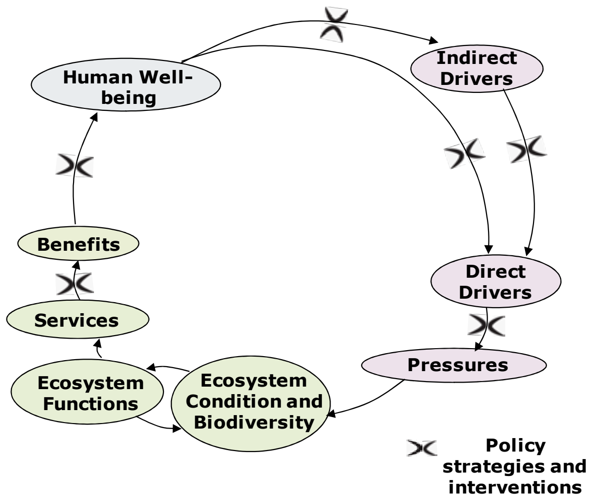
The ES indicators framework depicts one element for storing indicators on policy strategies and interventions. This simplifies the reality of where policy interventions are actually implemented. Policy interventions impact nearly all interactions within the socio-economic portion of the framework and the points at which ecosystem services are utilized by people and impact human well-being (see figure X).

The possible intervention points need to understood in order to apply indicators to design and target effective policies. The version of the ES indicators framework depicting the policy intervention points (figure X) is therefore important when using the framework in support of policy analysis and design. This version of the framework is not used as the standard depiction, however, because it is more complex and it is less effective at depicting policy strategies and interventions as one of the nine information components of the ES indicators framework.

Including each of the policy intervention points increases the visual and conceptual complexity of the framework. Given the large number of framework elements required to integrate socio-economic and ecological elements, the increased complexity could lead to barriers when introducing the framework to non-technical audiences.

One of the goals of the ES indicators framework is to serve as a top-level architecture for organizing indicators in support of applying ecosystem service concepts in policy-making. This purpose is better served by having one framework element to collect policy interventions and strategies rather multiple. When designing tools to store indicators for the framework, a system can be employed allowing users to tag the specific point where each policy strategy is focused.

Figure X: Points in the ecosystem service indicators framework at which policy strategies and interventions are implemented.



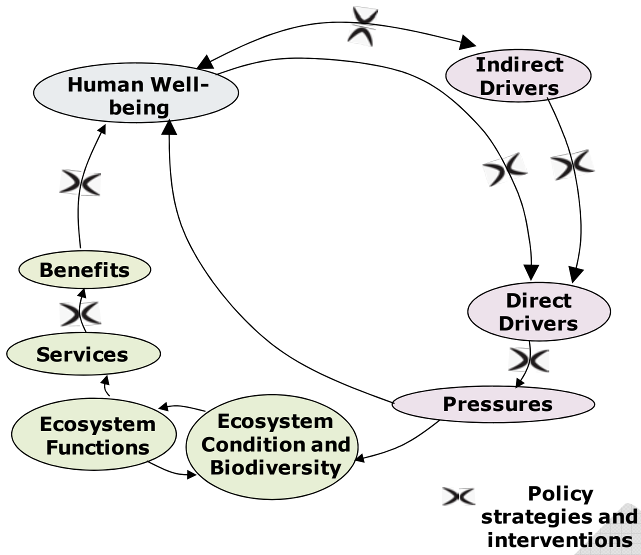
Reducing Number and Nature of Interactions

The ES indicators framework does not attempt to illustrate the manner in which all framework components impact each other. The intention is to keep the framework sufficiently simple that it can be practically applied in policy debates and decision. Second, keeping the focus on the causal interactions between components in a clockwise direction maintains attention on the primary intent of the framework: to illuminate interactions between the socio-economic and ecological realms.

The interactions between indirect and direct drivers and human well-being do not only flow one direction as depicted in the ES indicators framework. Instead, there are feedback interactions that flow both directions, as depicted in the upper right portion of figure X and in the MA ecosystem service conceptual framework (figure X). Indirect drivers can directly impact human well-being as well as direct drivers. Likewise, pressures caused by direct drivers can directly impact social well-being in addition to influencing ecosystem services.

In fact, excluding the ecosystem services portion (shown in green) of the framework results in a functional and relevant focused on the socio-economic portion of the ES indicators framework. The majority of policy debate and supporting indicators and information are already focused in this area, however, and isn't the purpose of the ES indicators framework. The ES indicators framework seeks to illuminate the interactions that are central to understanding how humans are impacting ecosystems and how those impacts in turn affect human well-being. The clockwise flow of impacts from the socio-economic segments of the framework on the ecological components maintains a focus on how human systems influence ecological systems and how those changing ecological systems in turn affect people.

Figure X: Ecosystem service indicators framework with arrows illustrating multi-directional influences of framework components and influences that take place purely within the socio-economic space.



2. 2.2 A Causal Cycle

The ES indicators framework depicts a causal cycle. The conditions in each framework element influence current conditions and trends in the following framework element, with additional influences arising frompolicy strategies and interventions. The explicit recognition of causality is important for applying the framework for its intended purpose of identifying policies that can improve the ability of ecosystems to deliver ecosystem services that support peoples' livelihoods and well-being. Once anticipated impacts of a proposed policy change to a specific part of the framework are assessed, the cascading impacts on the other portions of the framework can be followed through the rest of the framework. In this way, multiple policy proposals can be compared based on their eventual impact on human well-being.

The clockwise flow of causality presented in ES indicators framework is important for supporting these kinds of policy analysis. It helps facilitate the analysis by limiting the number of influences that need to be considered, and it focuses the exercise on the issue of how to improve the delivery of ecosystem services.

Using indicators chosen for each framework element, it is possible to track whether enacted policies are having the anticipated impacts and, if they are not, where in the causal cycle the additional policy changes are needed to achieve desired impacts. Depending on the quality of data and level of analytical rigor invested, the causal cycle can support cost-benefit and trade-off analysis.

2.2.3 Scalable

The ES indicators framework is not going to be useful to everybody in its entirety. Nine individual elements will be too exhaustive to meet the needs of many audiences. The framework is intended to be scalable according to meet the varied needs of different audiences.

The framework is exhaustive because it is intended to be a common framework able to meet the needs of varied audiences and approaches applying ecosystem service approaches. Using a common framework will allow indicators and metrics from diverse initiatives to be compiled and used to populate databases with the indicators and associated data. Database-driven software tools can then allow the framework to be depicted by different audiences while accessing the indicators stored in the entire framework.

For the framework to be embraced by the intended audiences of this paper—policy makers and those who advise them—it is important to illustrate how the framework can be simplified to meet varied users' needs. Some examples are provided below. The examples provided are intended to be possibilities. Determination of the best options will best be done in consultation with intended audiences.

Drivers and Pressures Combined

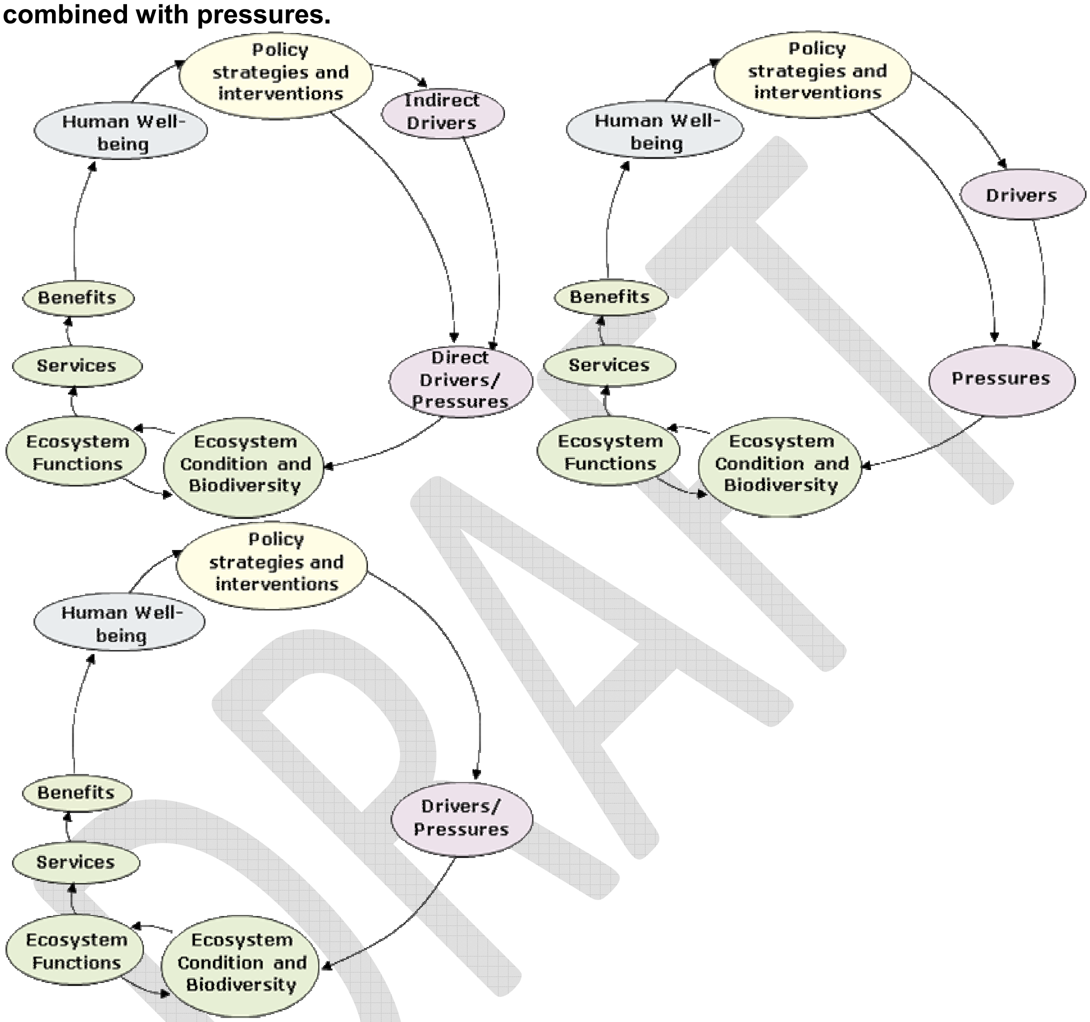
Among the easiest conceptual simplifications to make to the ES indicators framework is to combine drivers and pressures (figure Xa, b and c). Since direct drivers and pressures are closely related, with pressures being a biophysical representation of drivers, combining the two is conceptually straightforward (figure Xa). Some information relevant to informing policy decisions is lost, however. The level of understanding of the relationship between drivers and pressures, including for example, the magnitude of the contribution of different drivers to a pressure may be lost. If all indicators used in the combined direct drivers/pressures element are presented as human activity rather than biophysical terms, the comparative contributions of different drivers on trends of ecosystem heath could become difficult to separate when these two elements are combined.

In figure Xb, indirect and direct drivers are combined, but pressures are kept separate. This approach is most consistent with the DPSIR framework in that it keeps the cause of and the nature of drivers separate. Combining indirect and direct drivers, however, reduces the ability to understand the underlying causes of direct drivers. As this understanding of underlying causes is considered of vital importance in the MA conceptual framework, combining indicators for indirect drivers with indicators of human well-being may serve as a better approach to reducing the number of elements while retaining as much of the analytical value of the ES indicators framework as possible.

In figure Xc, both indirect and direct drivers are combined with pressures. This represents a more dramatic departure from the MA framework and is more consistent with Pressure-State-Response than with DPSIR (see the section on foundations of the ES indicators framework below for more information on this topic).

While all of these simplifications of the ES indicators framework will result in the loss of policy relevant information, the changes may make the framework more relevant to some specific circumstances. Users implementing ecosystem service approaches for the first time may be more comfortable with a less detailed approach. In other cases, teams will not have the detailed data needed to track multiple specific direct drivers causing a specific pressure and will not be able to benefit from separating direct drivers and pressures.

Figure Xa and b: Drivers and Pressures Collapsed. In figure a, only direct drivers and pressures have been combined. In figure b, both indirect and direct drivers have been combined with pressures.

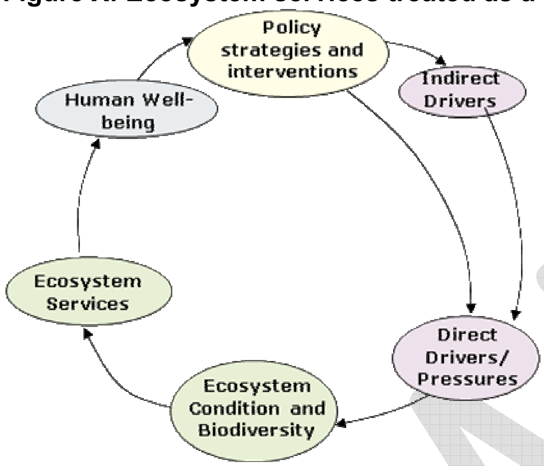


Grouping Ecosystem Services

For some audiences,treating ecosystem services as one unit will be most relevant approach. For presentations to generalists, communicating the importance of ecosystems for development, for example, this simplified approach may often work better than a more disaggregated one. In this approach, the ecosystem functions, services and benefits elements are combined (see figure X). Ecosystem condition and biodiversity, however, remain separate. Within the combined ecosystem services category, users would be able to sort indicators identified as relevant by MA definitions of provisioning, regulating, cultural and supporting, and/or by the ES indicators framework classifications.

The depiction of the ES indicators framework with ecosystem services grouped into one unit is consistent with the ecosystem services conceptual framework as depicted in the MA. It also remains consistent with DPSIR. However, this simplification of the ES indicators framework will clearly result in the loss of information necessary for conducting economic valuation, landscape planning, and other approaches requiring the differentiation of ecosystem functions from services and benefit.

Figure X: Ecosystem services treated as a single component



2.3 Relationships between Framework Elements

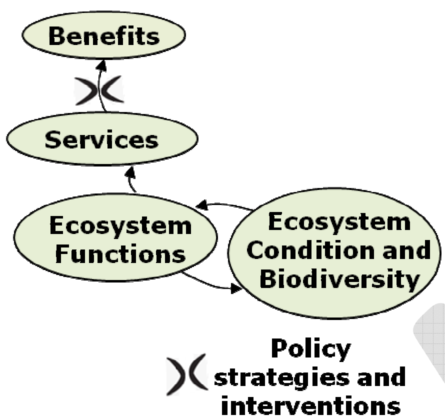
The nature of the relationships between the framework elements that make up the causal cycle is important for being able to apply the framework to inform policy decisions. General descriptions of the relationships between elements excluding policy strategies and interventions are provided below along with brief examples. The implications of the relationships for policy formulation are also briefly discussed.

Because the relationships are complicated and the specific ways in which framework elements relate will vary depending on the circumstances, it should be noted that these examples are intended to be illustrative only. The particular relationships in one country, and in regions within the same country, can vary in significant ways. Identifying relevant indicators and compiling data for them will illuminate the nature of the relationships in a given location. This understanding of the relationships can then be used to inform policies to reduce negative pressures and enhance positive pressures acting on ecosystems.

2.3.1 Ecosystem Condition and Biodiversity, Ecosystem Functions, Services and Benefits

Ecosystem functions, which include a wide variety of processes such as primary productivity, nutrient cycling, evapotranspiration, and many others, Ecosystem condition and biodiversity is fundamental to the overall ES indicator framework.   The health of ecosystems and associated biodiversity, based on the relative presence or absence of the biotic and abiotic ecosystem components and structures in the right quantities and combinations, determines the ability of ecosystem functions to take place. The ecosystem functions thenplay two important roles: they maintain ecosystem condition as part of a positive feedback cycle and deliver services. A subset of services are then used by humans in the form of benefits.

Figure X: Relationships between Ecosystem condition and biodiversity, ecosystem functions, services and benefits

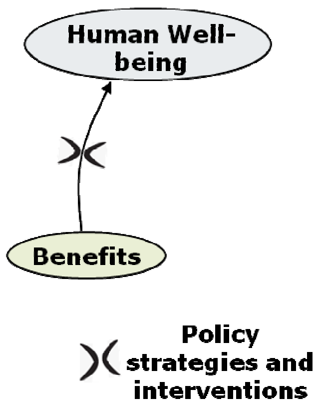


Ecosystems The feedback between ecosystem function and ecosystem condition is a key determinant in resilience to pressures. The positive feedback between ecosystem functions and ecosystem condition and biodiversity is an important aspect of the ES indicators framework for informing policy. Through ecosystem functions of water filtration and assimilation of nutrients and carbon, oysters in a estuary provide a final product of shellfish for consumption. The same oysters, however, perform ecosystem functions of water filtration, calcium deposition, etc. that maintain the ecosystem in a productive state. The filtration reduces water pollution, oyster shells provide a substrate for larvae to adhere to. Where ecosystem state and biodiversity remain intact, the positive feedback from the ecosystem functions are able to maintain a healthy ecosystem state. When pressures build to a point where ecosystem state no longer provides one or more key elements necessary for the performance of ecosystem functions, the resilience maintained by the positive feedback cycle is undermined. Continuing the oyster example from above, when oyster beds in the Eastern United States were significantly overharvested in the late 19th and early 20th centuries, and then further decimated by disease in the mid 20th centuries, the resilience of the system was overwhelmed; ecosystem functions that previously supported a healthy ecosystem state for oysters ceased. Biodiversity is part of resilience. Functions provided by oysters are fundamental for other species. Difficult to know where loss of one function will impact others.

2.3.2 Benefits and Human Well-being

Benefits directly support human well-being by providing for tangible needs, including shelter, fuel, and food and water, and psychological and spiritual well-being.   People harvest crops, cut trees or use crop residues for cooking and heating, harvest poles, timber, rock and other building materials, and extract drinking water from surface and underground water sources. Benefits also contribute indirectly to material human well-being by supporting enterprises that provide employment and income to support individuals, families, communities and societies. Spiritual well-being is also supported by ecosystems in a variety of ways. The Southern Africa sub-global Assessment (Biggs et al., 2004), for example, noted that many people assign a high degree of importance to living close to where they were born, and noted the importance of natural sites for religious and cultural rituals.

Figure X: Relationships between benefits and human well-being



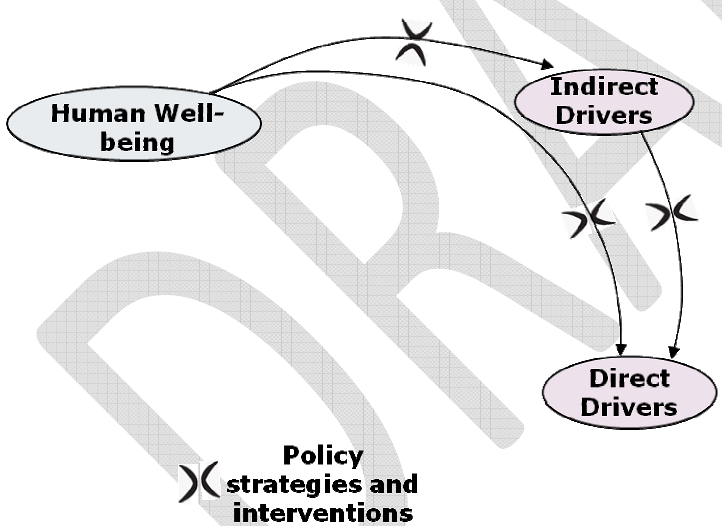
Policy strategies and interventions are vital to ensuring that benefits are used sustainably so they continue to be available. While these policies will primarily be considered under the drivers and pressures element, they should be informed by an understanding of the ways in which benefits contribute to human well-being, and where well-being is being maintained or compromised by sufficiency or deficit of needed benefits. Policies are also important for providing access and equitable distributionof benefits. Where land ownership is disproportionately controlled by a small percentage of the population or rule of law and land ownership rights are weak , it can happen that people do not have sufficient access to benefits to provide themselves, their families and communities with sufficient benefits to maintain a sufficient quality of life. The unbalanced use of benefits does not have to be intentional. In South Africa, for example, exotic trees that had reproduced from plantations were transpiring enough water that local communities and ecosystems were water stressed. Company policies to remove exotics were developed and implemented to help ensure a sufficient water supply for other actors (Hanson et al., 2008). Another way policies can support the ability of people to use benefits to maximize well-being is by supporting nature-based enterprise. Providing transportation systems that allow communities to transport products to markets and ensuring access to credit to launch enterprises that add value to local products are examples of ways that can help communities build a higher quality of life using locally available ecosystem services.

2.3.3. Human Well-being and Drivers

Human well-being is one determinant of indirect and direct drivers, but well-being affects drivers in varied, complex, and not always predictable ways. Level of poverty or wealth, cultural expectations of degree of material wealth, governance and peoples' perception of their ownership and control of local resources, traditions of interactions with the natural world, and many other factors play roles in determining how human well-being affects drivers and pressures.

For example, poverty is directly related to the need to provide for oneself and one's family, which can force people to harvest resources at rates or using techniques that can damage ecosystems, or to convert one ecosystem to another that is more aligned with providing for peoples' material needs. On the other hand, poverty reduces overall consumption, which is one of the primary drivers identified by the MA (MA, 2005). Affluent populations have financial resources that allow them to consume large quantities of resources, putting pressure on ecosystems that can be on the opposite side of the globe. Affluent countries in North America and Europe, for example, consume large amounts of energy, which is a direct driver leading to changing climates both regionally and globally, which itself is a major pressure on ecosystems.

Figure X: Relationships between human well-being and Drivers



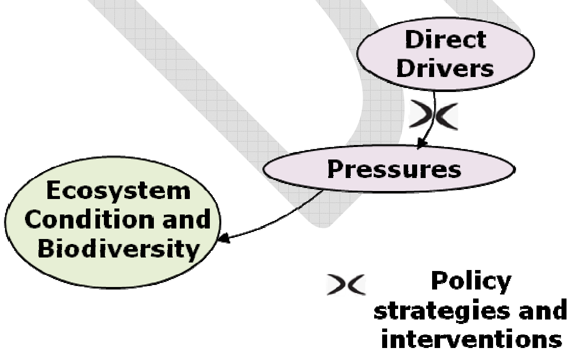
Less material aspects of human well-being like perception of freedom and self-determination, including over one's private or communal land, are also related to indirect and direct drivers. Land management philosophies and approaches are indirect drivers that can be impacted by local residents understanding of whether they have rights to access and use the land over the longer term and ultimately to pass on to their children. In this way, strong land tenure and ownership rights can shape crop choice, forest harvest rates, investments into erosion control, and myriad other direct drivers.

In some cases in which human well-being contributes to drivers that degrade ecosystems, policy strategies and interventions have the potential to impact the relationship in a positive way. Where poverty and/or inequitable access to benefits are root causes of a need to use ecosystems in an unsustainable way, policies that put high priority on addressing the high poverty and poor governance should be priorities. As illustrated in the example above, these policies can be focused on making better use of ecosystem services. However, the policies necessary to address many aspects of low human well-being require a more holistic look at policies, including delivery of basic services such as health care, education, and access to transportation. Where affluence is leading to unsustainable consumption, these consumption patterns are clearly not best addressed by trying to reduce the level of affluence. Rather, these consumption patterns are best addressed by examining the relationship between pressures and ecosystem condition and designing policies that reducing the pressures from consumption without overly impacting well-being.

2.3.4. Direct Drivers, Pressures and Ecosystem Condition and Biodiversity

The links between direct drivers, pressures and ecosystem condition and biodiversity are intimate and direct. Direct drivers are human activities that result in pressures, which directly impact ecosystem health. Although it is common for people to think first of direct drivers and pressures with negative impacts, they can be either positive or negative. Management activities to improve ecosystem health—planting trees on a slope or installing a buffer strip to capture nutrients before they enter a stream, for example, are direct drivers. The pressure is the biophysical representation of the direct driver. In many cases, multiple drivers will play a role in determining the magnitude of single driver. Continuing the example of the buffer strip, the pressure from the strip will be a reduction in nutrient run-off from the land adjacent to the stream. However, for a bay or delta ecosystem, the aggregate nutrient loading from wastewater treatment plants, urban run-off, agricultural fields, and other sources throughout the entire watershed is an important pressure indicator.

Figure X: Relationships between direct drivers, pressures and ecosystem condition and biodiversity



There are also natural stresses on ecosystem condition and biodiversity, which the framework for development of environmental statistics (FDES) includes (UNSD, 1984). Although it doesn't include natural pressures, the ES indicators framework captures the majority of pressures since most directly result from human activities. Among those that are natural, many are exacerbated by human actions and should therefore be included as pressures. For example, the pine beetle causing massive tree mortality in North American forests is a native insect. The beetles' impact, however, has gone from localized to epidemic as a result of warmer winters caused by climate change.

Direct drivers and the relationship between direct drivers and pressures are important policy areas. First, policies can reduce the magnitude of activities that constitute a negative direct driver or enhance those that result in a positive one. Second, policies can influence the way activities are done in order to reduce the magnitude of the pressure resulting from a direct driver. In the context of the framework, pressures represent the nature of impact direct drivers are having on ecosystems. Policies therefore are not intended to change the way a pressure acts on an ecosystem—those policy actions would be instead be intended to be influence direct drivers by reducing the magnitude of the pressure or to support the health and resilience of ecosystems to resist pressures.

There are many examples of policies that limit negative drivers and enhance positive ones. The degree and manner of extracting benefits for human consumption is one of the main sources of pressures on ecosystems (MA, 2005). Extracting too much water from rivers, for example, will not reduce the amount of habitat for aquatic organisms, and overharvesting trees from forests or drylands can affect biodiversity by changing the makeup of forest species andcan leave the soils subject to erosion. Policies dictating the nature and extent of these sort of extractive activitiesalready exist in most places. Based on the degree of pressures and trends in ecosystem condition, those policies may need to be changed to improve their focus on a direct driver with the greatest impact, or improve enforcement. Payment for ecosystem services is an example of a policy that provides incentives enhancing positive direct drivers. Installing buffer strips, improving habitat value by planting native species and similar management activities are examples of long-standing approaches. More recent ideas like providing payments for maintaining forests through Reduction in Deforestation and Degradation (REDD) may hold promise for applying payments for ecosystem service across wider landscapes.

There are also many examples of applying policies to influence the way activities are implemented in order to limit the extent of the pressure. Requiring scrubbers on coal-burning power plants to reduce emissions of SOxand NOx, for example, does not reduce the direct driver of coal burning, but adds a positive direct driver that reduces the overall degree of the pressure.

2.4 Foundations of the Ecosystem Service Indicators Framework

The ecosystem service indicators framework presented here builds on a long history of developing frameworks to organize indicators to support informed policy-making. The importance of a framework to organize environmental indicators to provide guidance on organizing indicators in support of policy-making has long been recognized. The United Nations Statistical Office began to convene sessions on the topic in the 1970s and released its first review draft a framework for the development of environment statistics (FDES) in 1981 (UNSO, 1984). More recently, other frameworks such as Pressure-State-Response (PSR) and Driving Force-Pressure-State-Impact-Response (DPSIR) have been developed to “reflect the cross-cutting nature of environment problems” (Stanners et al, 2007). With the increasing acceptance of ecosystem services approaches, additional changes to the indicator frameworks are needed to more fully reflect the integration of socio-economic and ecological realms inherent in the ecosystem service conceptual framework. The preliminary framework presented in this paper is intended to present the next iteration in the development of ecosystem service frameworks needed to achieve this goal.

A framework to facilitate applying indicators requires categories to organize information and structure thinking. The categories the ES indicators framework uses to accomplish these tasks have been aggregated from a number of other sources. Together, these “borrowed” categories add up to a complete and conceptually framework or organize information and thinking for incorporating ecosystem service concepts into policy-making. In addition to the categories that make up the ES indicators framework, existing indicators framework informed the content and presentation of material on ways to apply the framework.

The primary sources that influenced the ES indicator framework include:

- Millennium Ecosystem Assessment conceptual framework
- Ecological function-service-benefit models
- Driving force-Pressure-State-Impact-Response (DPSIR) indicator framework.
- Framework for the Development of Environmental Statistics
- Maybe end up adding others?

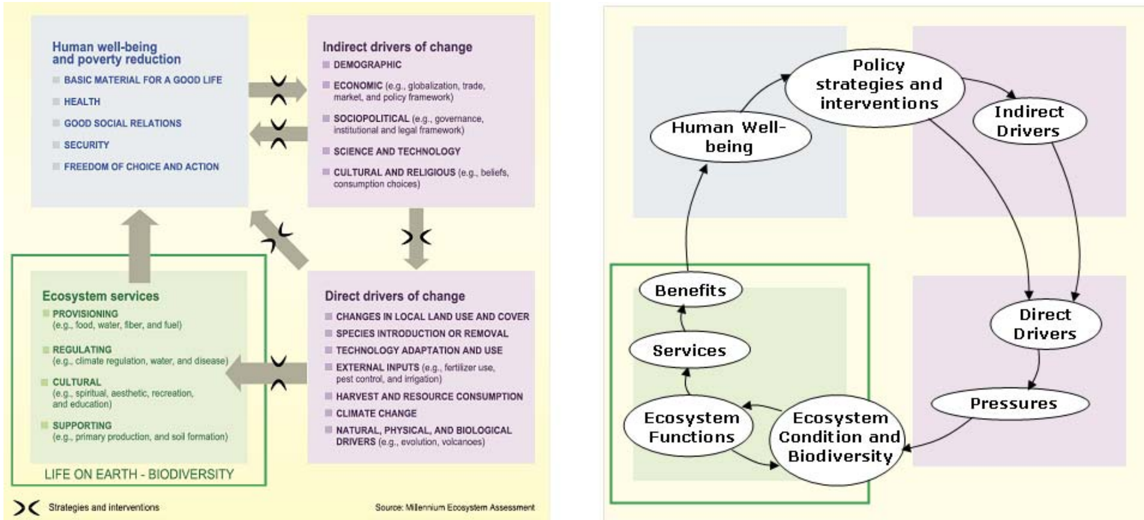
These sources were used as the foundation for the ES indicators framework because each was able to contribute elements that integrated into a complete ecosystem service indicators framework that included elements that had been missing in previous versions.

Another advantage to drawing on proven frameworks, especially DPSIR, is that the policy relevance of this framework has already been demonstrated (Stanners et al., 2008). In addition, the familiarity of DPSIR and the other contributing frameworks should also make it easier for prospective users familiar with those contributing frameworks to adapt the ES indicators framework. This should make it easier for those responsible for indicator systems to incorporate ecosystem services concepts into their existing systems.

2.4.1 Millennium Ecosystem Service Assessment Framework

The Millennium Ecoystem Assessment (MA) released their ecosystem service conceptual framework in 2005 (MA, 2005). The concept of nature’s benefits and ecological services had been developed and applied years earlier (e.g. Daily, 1997; De Groot et al., 2002) The 1500 scientists convened by the MA built on this existing work by applying the concepts to multiple ecosystems, varied locations and scales and reaching conclusions about the state of the world’s ecosystem services. The result was a simplified presentation of ecosystem services concepts that is relatively easy to communicate and integrate into a broader socio-economic-political context (see figure X).

Figure X: Alignment between the MA conceptual framework and the Ecosystem Service indicators framework



As a result of the thorough assessment and outreach around the MA, the United Nations and policy-makers in many countries recognized the importance of ecosystems and ecosystem services for human development (Wells et al., 2006). The concepts introduced by the MA are beginning to be used to inform policy (Daily et al., 2009; more), and the framework being adapted and refined to improve its relevance to specific policy questions (cites). Provide examples here. However, the information needed to apply ecosystem services concepts broadly are poorly developed (Layke, 2009, others). There are significant gaps in the number of indicators, their quality in terms of their ability to communicate information, and the data sets behind them. In order to accelerate and broaden the ability to apply ecosystem service concepts in public and private sector policy-making, it will be necessary to develop relevant indicators, populate them with data, and make them available in user-friendly and interactive tools to support the indicators' use by relevant end users.

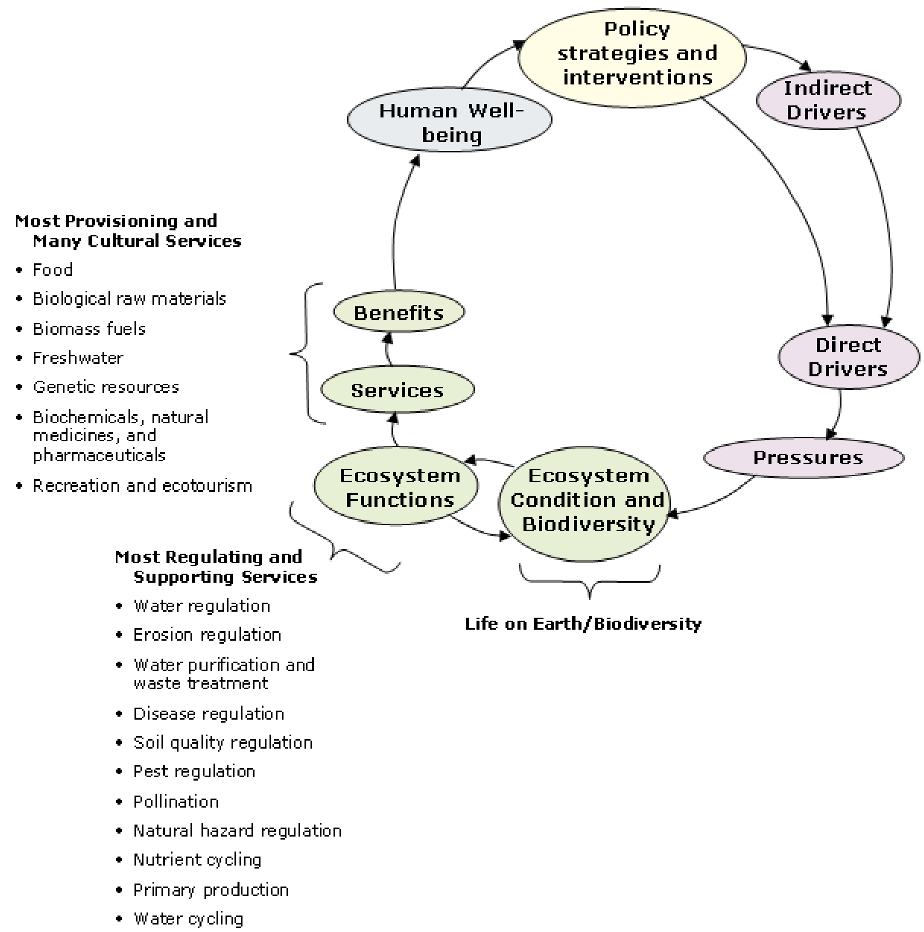
Alignment between MA and ES indicator Frameworks

Each of the 8 categories used for the ES indicators framework corresponds to either one of the four quadrants of the MA framework or the arrows depicting the influence of policy strategies and interventions on each quadrant (see figure X). The alignment between the MA framework and ES indicator framework elements is explained below:

- Loose causal cycle: The ES indicators framework adopts the causal cyclical nature of the MA framework. Both recognize the importance of ecosystems and their services for human well-being, and the influence of people, through policies and indirect and direct drivers, on ecosystems and their ability to deliver services.
- Ecosystem services:The ES indicators framework builds on the elements included in the MA framework by splitting ecosystem services into two elements, beneficial ecosystem processes and benefits
- Human well-being: The ES indicator s framework are the MA framework are consistent in their treatment of human well-being. Both see ecosystem services as

an important influence on human well-being, and share the goal of illuminating this link.

Figure X: Alignment between MA Ecosystem Services Framework Terminology and ES indicators Framework Terminology. The MA broke ecosystem services into supporting, regulating, cultural and provisioning services, all of which derive from what is termed "life on Earth/Biodiversity. These terms are not used in the ES indicators framework, but do align with the categories used. Ecosystem condition and biodiversity is consistent with Life on Earth/Biodiversity. Most regulating and supporting services are provided by ecosystem functions, and so align with that ES indicators framework category. Most provisioning and cultural services are under the ES indicator framework's services and benefits categories. A database will allow indicators and data stored within the ES indicator framework to be associated with both the ES indicators framework category and the MA framework. This will allow information to be depicted in the MA framework for those audiences more familiar with that depiction or within the ES indicators framework for analysts using the overall framework for policy analysis.



- Indirect drivers of change: The ES indicators framework follows the MA framework in its treatment of indirect drivers as a major influence in the overall causal cycle.
- Direct drivers of change: As with indirect drivers, both the ES framework and the MA framework treat direct drivers as a distinct element that must be taken into consideration when conducting ecosystem assessments or designing policy interventions.

- Pressures: The ES indicators framework departs slightly from the MA framework by distinguishing drivers from direct pressures. This difference is based on the thinking of the DPSIR framework described below.
- Policy strategies and interventions: In the MA framework, strategies and interventions are denoted by the carrots around the lines leading from ecosystem services to human well-being, from there to indirect drivers, on to direct drivers and ultimately back to ecosystems and ecosystem services. In the ES indicators framework, policy strategies and interventions are shown as one entity, reflecting the fact that this framework is designed to help store and retrieve information in a logically straightforward manner.

2.4.2 Ecosystem Function-Service-Benefit Models

Since the MA was released, efforts to apply ecosystem service concepts to inform policy have accelerated (Turner et al., 2008; Fisher et al., 2008; Daily et al., 2009). The use of economic valuation to support the overall case being made policymakers that biodiversity and ecosystems are vital parts of our economies have been a major part of these efforts.One result has been the realization that the MA framework, while effective at communicating ecosystem service concepts, does not as effectively support some important applications like economic valuation and landscape planning. Economists have made refinements to the MA framework in order to support these approaches.

The ecosystem service indicators framework is designed with the intent to support diverse policy analysis, including ecosystem service valuation. Refinements to the MA framework that support economic valuation are therefore included in the ES indicators framework. While these frameworks have been developed primarily with economic valuation in mind, they also have utility for other applications such as preparing environmental impact assessments, risk and opportunity analyses for businesses, and adapting to and reducing vulnerability to climate change. Classifying ecosystem services in a way that differentiates causality—the ends and means—helps understand the potential impacts of policies on the benefits people directly depend on, illuminating possible trade-offs and clarifying policy options. The alignment between the classification approaches proposed in economic valuation studies and indicators framework is outlined in this section.

Scholarly Research on Ecosystem Service Classification for Economic Valuation

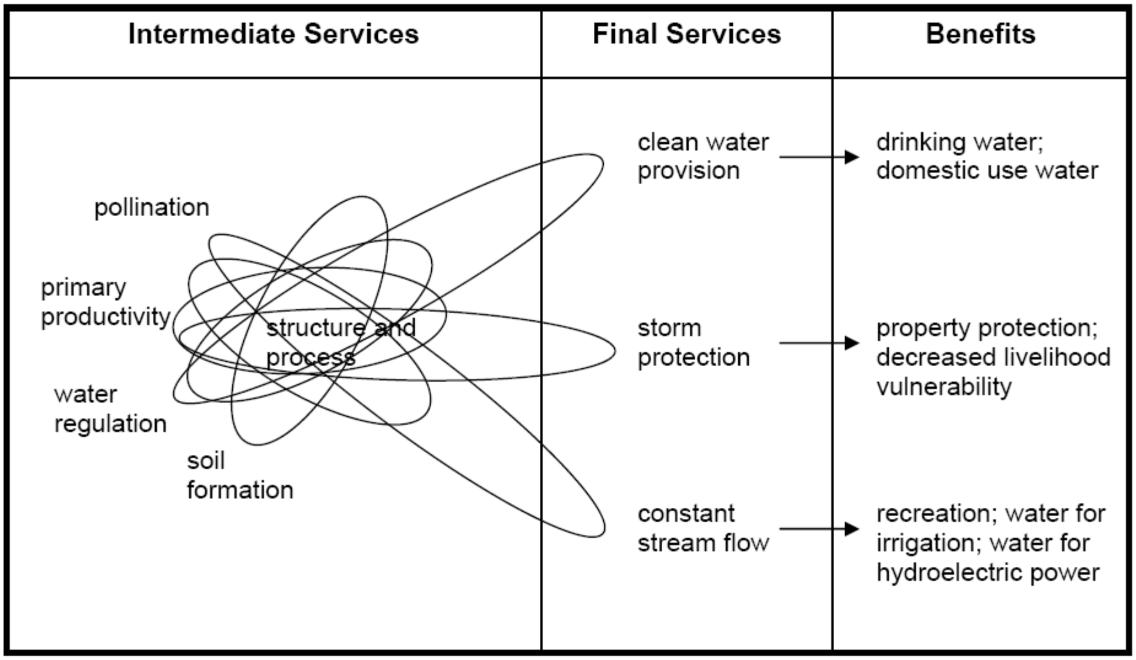
Economists seeking to incorporate ecosystem service approaches after the release of the MA found the MA conceptual framework needed to be refined. The division of services into four the four categories of supporting, regulating, provisioning and cultural is useful as a heuristic tool, but led to confusion when assigning economic values to ecosystem services (Fisher et al, 2009). Multiple economic valuation efforts have proposed refinements to the MA ecosystem services classification system (Fisher et al., 2009; Turner et al., 2008; Wallace et al., 2008;Costanza, 2008). Among the arguments these valuation made is that no single classification system is appropriate for all cases. Rather, a flexible approach is needed that allows different approaches informed by the characteristics of the ecosystem under examination and the decision-making context for which services are being considered (Turner et al., 2008; Costanza, 2008).

The core challenge economists faces using the MA ecosystem services conceptual framework is that services are lumped. This leads to a situation where the*ends*and the *means* are mixed (Fisher et al., 2009; Costanza, 2008). Assigning economic value requires organizing services in ways that avoid accounting and valuation problems of double-counting. In these approaches, services are often classified as the *end products* human consume to benefit human welfare (Boyd and Banzhaf, 2006; Wallace et al., 2008). Those ecosystem services that are not directly consumed but contribute to the availability of those that are require other means of classification.

Brendan Fisher et al. (2008) recommend using the terms benefits, final services and intermediate services to organize ecosystem services information (figure X). This approach supports for economic valuation and highlights that benefits are what has direct impact on human welfare, and that ecosystem services are ecological phemonena. Under this approach, only the benefits can be aggregated, avoiding the issue of double counting. Through the separation of other services into intermediate and final benefits, it is possible to gain an explicit understanding of the valuation in each phase.

While the terminology differs, very similar approaches have been applied by other efforts to apply economic valuation (e.g. Costanza, 2008; Balmford et al., 2008; EC, 2008). In the book *Valuing Ecosystem Services: the case of multi-functional wetlands*, for example, Turner et al. (2008) apply called the Ecosystem Services Approach (ESApp). ESApp, services are designated to be final or intermediate, similar to figure X. Kerry R. Turner et al. (2008) utilize the ESApp in detail through a step by step model in valuating wetlands. A more simple example examines water regulation services provided by a vegetated landscape, this can be valued as a final service if the interest lies in a steady water supply, but also valued as an intermediate service to someone interested in a final service of *clean* water for the potable water supplies (Turner et al., 2008).

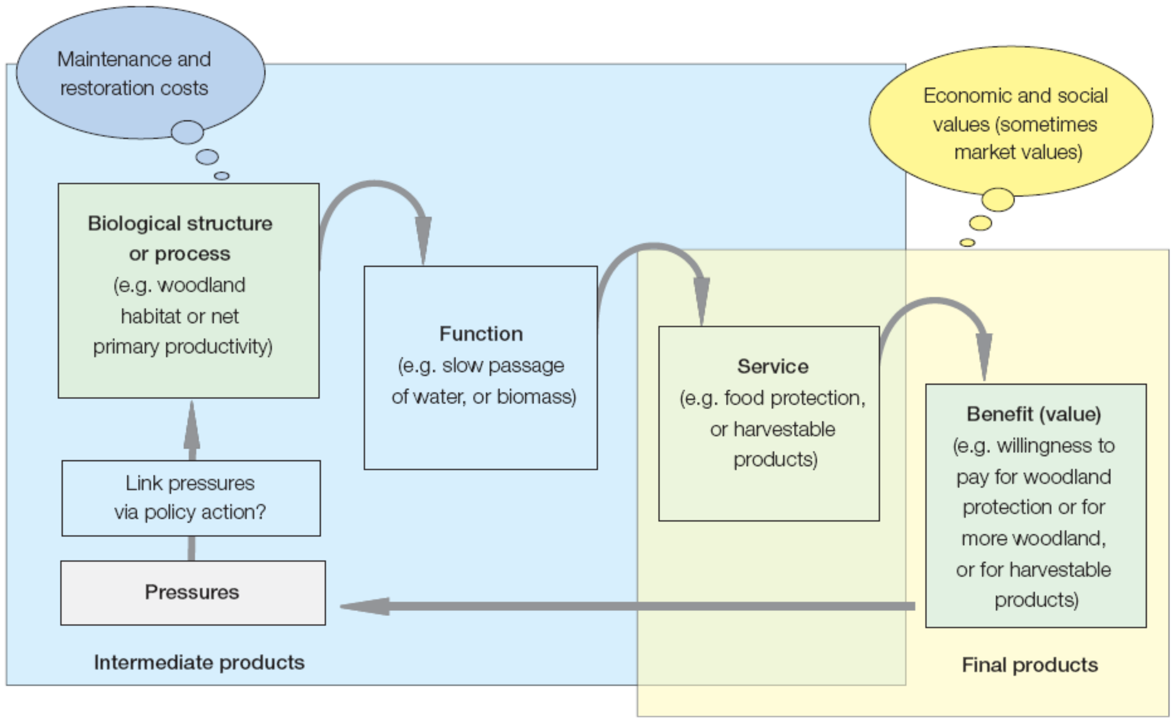
Figure X: The Ecosystem Services Approach Sources: Fisher et al., 2009.



Applying Ecosystem Service Economic Valuation Approaches—
The Economics of Ecosystems and Biodiversity

In addition to the scholarly articles noted above, a series of research efforts in support of *The Economics of Ecosystems and Biodiversity*(TEEB) (EC, 2008) have come to similar conclusions about how to structure information. TEEB, *The Cost of Policy Inaction on Biodiversity Loss* (Braat and ten Brink, 2008), and Review on the *Economics of Biodiversity Loss: Scoping the Science* (Balmford et al., 2008)have adopted consistent frameworks that support ecosystem service valuation. Figure X below presents the framework used in the interim TEEB report (EC, 2008) and the forthcoming revised version. Both illustrate the need for being able to categorize information about ecosystem condition and biodiversity, ecological functions, services and benfits. Figure X, taken from the *Economics of Biodiversity Loss: Scoping the Science*, particularly effectively presents the differences between ecosystem services (labeled beneficial ecosystem processes in the figure) and benefits.

Figure X a and b: Frameworks used to organize information and analysis for The Economics of Ecosystems and Biodiversity (TEEB). Sources: EC, 2008, EC, forthcoming.



Source: EC. 2008

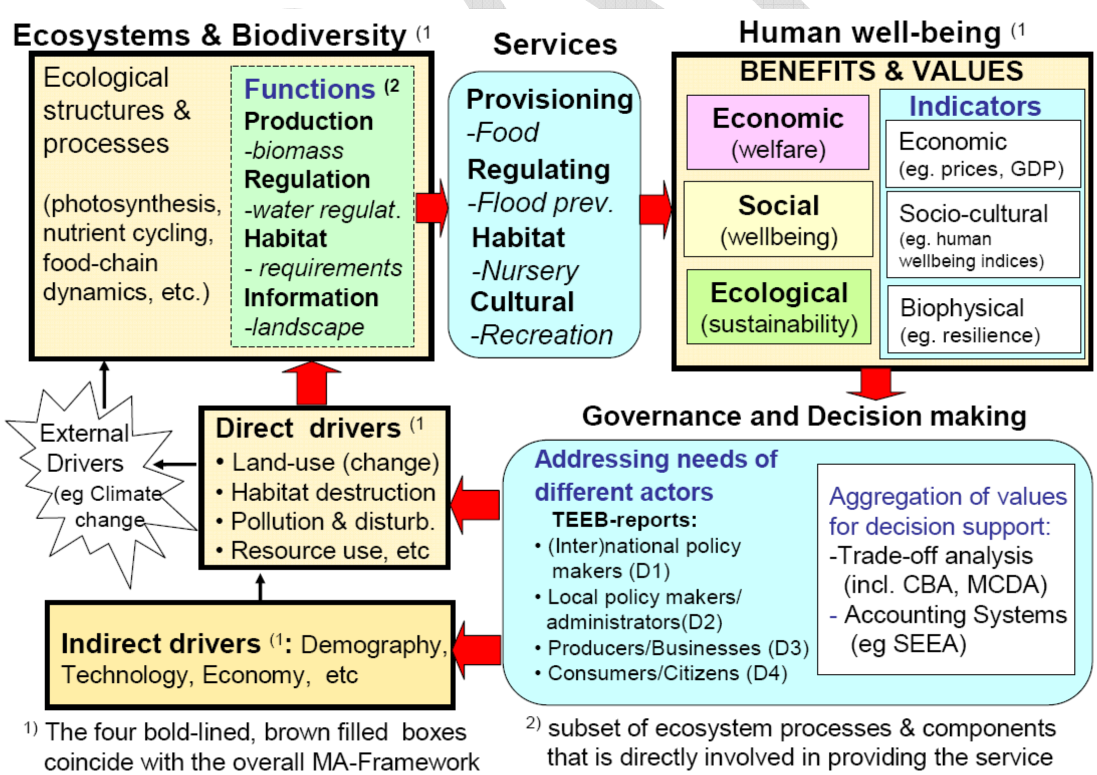


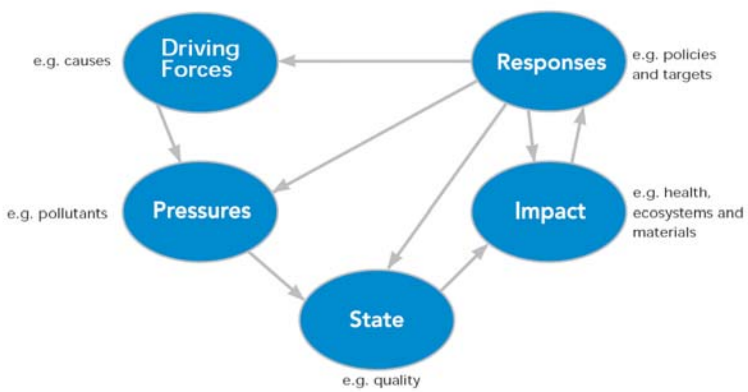
Figure X: Benefits model building on the ecosystem services framework, as depicted in *Economics of Biodiversity Loss: Scoping the Science.* Source: Balmford et al. (2008)

2.4.3 Driving Force-Pressure-State-Impact-Response

In addition to including elements of the MA conceptual framework and recent frameworks developed for economic valuation, the ecosystem service indicators framework incorporates the DPSIR indicators framework. DPSIR is used by the European Environmental Agency (EEA), is integrated with the flow of information, and has been demonstrated to be effective in informing the policy cycle (Stanners, Bosch et al. 2007).

DPSIR has evolved from earlier versions of frameworks seeking to integrate indicators of environmental stress and state in order to help inform policy responses. In the 1970s and 1980s, the United Nations Statistics Department (UNSD) began development of such a framework and released the Stress Response Environment Statistics System (STRESS) (Statistics Canada, 2009).

Figure X: Driving Force-Pressure-State-Impact-Response Framework. Source: EEA, 1993.

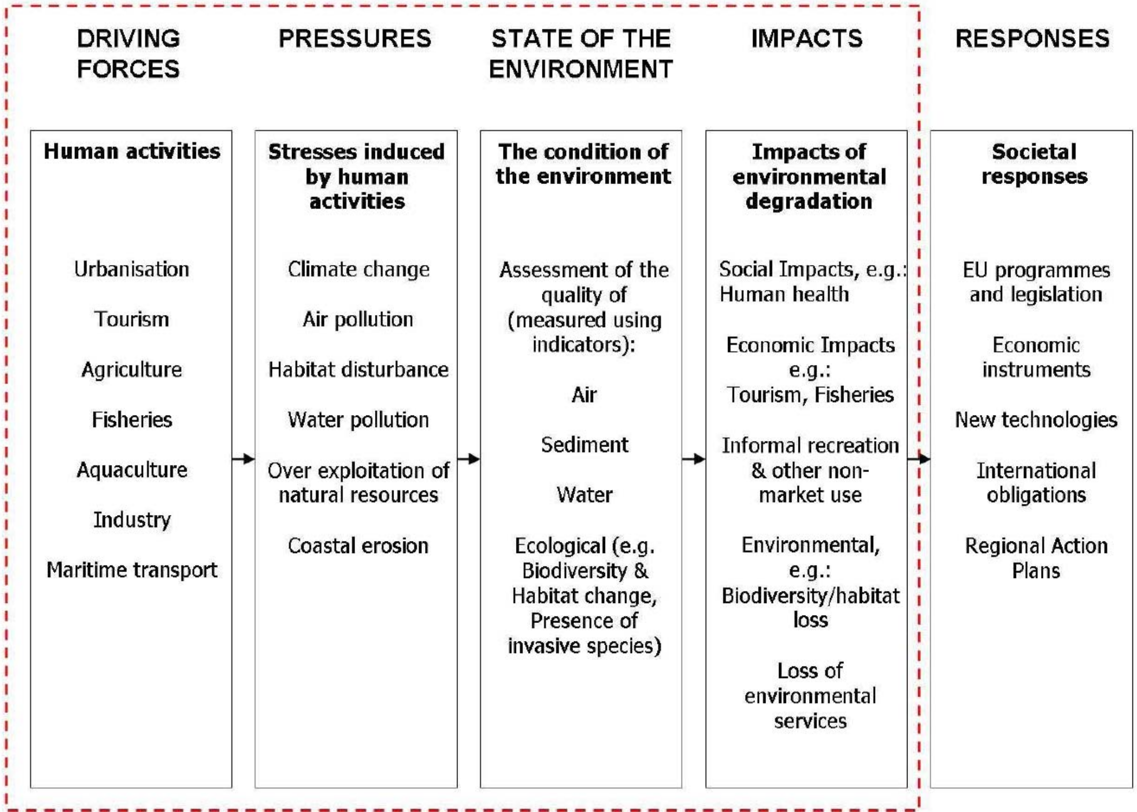


Further refinements to the concepts underlying STRESS were soon made, including the Pressure-State-Response (PSR) framework (OECD, 1993). The PSR framework built on STRESS, and continues to be used today by major organizations, including the Organization of Economic Co-operation and Development (OECD) and United Nations Environment Programme (UNEP). The PSR framework allows to evaluate the *pressures* of human activities on environmental *states* and to provide political *responses* in order to reach a "desirable state". Variations on PSR have also been developed (Levrel, 2009).

In support of the European Environment Agency (EEAthe Netherlands National Institute of Public Health and Environment (RIVM)proposed adapting PSR to distinguish driving forces, pressures, states, impacts and responses (Kristensen, 2004). The DPSIR framework is a chain of causal links starting with '*drivingforces*' (economic sectors, human activities) through '*pressures*' (emissions, waste) to '*states*' (physical, chemical and biological) and '*impacts*' on ecosystems, human health and functions, eventually leading to political '*responses*' (prioritisation, target setting, indicators).

The framework is seen as giving a structure within which to present the indicators needed to enable feedback to policy makers on environmental quality and the resulting impact of the political choices made, or to be made in the future. Examples of the kinds of indicators included in each DPSIR category are presented in Figure X.

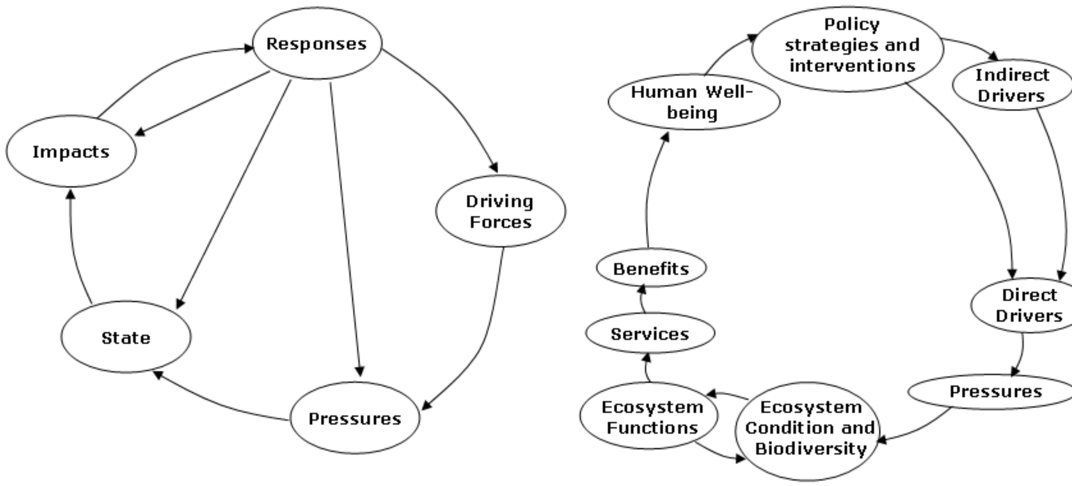
Figure X: Examples of Issues Included in DPSIR Framework Elements. Source: Braat et al, 2008



There have been criticisms of DPSIR, especially that it tends to oversimplify complex social and ecological interactions, making it hard to establish valid cause-effect relationships (OECD 1994; Hukkinen 2003b; Wolfslehner and Vacik 2008; Levrel et al., 2009). However, the framework has proven useful and has been widely adopted, including by the EEA as an integrated approach for reporting, e.g. in the EEA's State of the Environment Reports (EEA, 2003),by UNEP (e.g. for GEO (UNEP-DEPI, 2006)), EUROSTAT, and others. There are two main features that have contributed to the wide use of the DPSIR framework: the first is that it structures indicators with reference to objectives related to environmental management; the second is that it focuses on causal relationships that appeals to policy makers (Maxim et al., 2009).

However, the PSR-DPSIR family of environmental indicator frameworks does not include the core concept of the ecosystem service approach: the goods and services humans receive from ecosystems. The ES indicators framework is consistent with the factors that have made DPSIR useful, including the structure and causal relationships, and adds elements that can help address some of the criticisms of DPSIR (see figure X). By more completely incorporating socio-economic elements, the ES indicators framework will help identify the complex social and ecological interactions that the framework is criticised for not being able to help identify, including interactions between biodiversity trends and changes in human well-being.

Figure X: Alignment between the ES Indicators Framework and the Driving force-Pressure-State-Impact-Response framework (note, the positioning of DPSIR framework elements has been shifted for easier comparison.



2.3.4 Framework for the Development of Environment Statistics

The United Nations Statistical Division released the Framework for Development of Environment in 1984 (UNSD, 1984). A technical report providing more detailed information on applying the framework within statistical systems was released in 1991 (UNSD, 1991). The framework and supporting technical document have been instrumental in supporting and aligning national efforts to gather and organize environmental statistics (Kabaija, 2009; Kaba, 2009, Wah, 2009).

FDES is organized around information categories and components of the environment (see Figure X). Users of FDES need to identify relevant statistical topics within each information category and environmental component in order to identify relevant statistical variables.

Figure X: The Framework for the Development of Environmental Statistics. Source: UNSD, 1984.

	Information categories			
Components of the environment	Social and economic activities, natural events	Environmental impacts of activities/ events	Responses to environmental impacts	Inventories, stocks and background conditions
1. Flora				
2. Fauna				
3. Atmosphere				
4. Water (a) Freshwater (b) Marine water				
5. Land/soil (a) Surface (b) Sub-surface				
6. Human settlements				

As with DPSIR, there are key consistencies between FDES and the ES indicators framework, which makes sense given that FDES was an early contributor to the development of PSR and DPSIR frameworks. The framework is intended to be a causal one, with information categories presented as the "sequence of action, impact and reaction." (UNSD, 1984). The information categories in FDES consistent with a number of the categories in the ES indicators framework—they broadly align as follows:

- Social and economic activities aligns with direct drivers
- Environmental impacts of activities aligns with pressures
- Responses to environmental impacts aligns with policy strategies, and
- Inventories, stocks and background conditions aligns with interventions, and ecosystem condition and biodiversity.

The components of the environment presented in Figure X appear simplified compared to the extent of information needed to implement ecosystem service approaches. However, the framework is intended to be flexible, and "the intention is not to pre-empt choices of disaggregation." (UNDS, 1984). In fact, many of the statistical topics presented in the technical report building on FDES (UNSD, 1991) are consistent with and helped to inform the classification and metadata elements proposed below as ways to organize indicators within the ES indicators framework.

The United Nations Statistical Division is preparing to update FDES. A first experts meeting was held in 2009, with a second planned for 2010. The inclusion of ecosystem services concepts is one of the possible changes being explored (Statistics Canada, 2009). The adoption of ecosystem service principles into FDES would dramatically help increase ability of national governments and the sub-national agencies they support and to apply ecosystem service concepts.

2.4 Indicator Framework Requirements

At its core, an indicators framework is a structure for organizing indicators, metrics and associated data. However, indicators, metrics and data are collected for a purpose, in the case of the ES indicators framework, informing policy decisions and implementation. Over time, characteristics and criteria for indicator frameworks that conceptually relevant but also practically useful have been identified. The ES indicators framework has been constructed to fit within these guidelines. Some of the specifics of good indicator framework design and the ways in which the ES indicators framework has been designed to meet them are provided below.

2.4.1 Guiding principles for an Indicators Framework

To be helpful, an indicators frameworkneeds to guide the development, organization and presentation of indicators and data. To do so, the framework needs to consist of clear categories that differentiate information into an appropriate number of categories—enough to support policy-relevant analyses, but not so many as to be overwhelming. Since different users' needs will be different, frameworks should ideally be flexible. Indicator s framework will often be related to other frameworks, but are adapted to meet the needs of storing, retrieving and applying information.

An indicators framework provides a clear structure for organizing metrics, allowing practitioners to focus on the practical process of pulling metrics and data together. The Framework for the Development of Environment Statistics (FDES) (United Nations Statistical Office, 1984), for example, has helped guide statistical agencies in many countries to compile environmental indicators by providing clarity on what kinds of indicators and statistics are needed, and how they relate to each other. In Botswana, the Environmental Statistics Unit found the clear instructions of the FDES to be essential to their early efforts to pull environmental statistics together (Kabaija, 2009).

2.4.2 Framework Criteria:

Based on the above, a number of criteria for the ES indicators framework were identified. To add value to existing frameworks, the ES indicators framework must be:

- Flexible: Users can effectively use the full framework or contracted version of it as relevant to their specific needs.
- Consistent: The framework elements are sufficiently differentiated and clear enough that indicators will consistently be assigned to the appropriate framework element.
- Comprehensive: support integration of information about the whole spectrum of environmental and social issues.
- Integrate environment with social and economic realms.
- Useful to multiple types of end users: draw on and be consistent with multiple existing frameworks.

It is important to emphasize that the framework is intended to be flexible. As described above, ecosystem services have been classified in differing ways. Despite calls for developing a standardized framework (deGroot et al., 2002), differing approaches continue to exist (Fisher et al., 2008). While classification approaches represent differing opinions on how to apply ecosystem services for a specific applications (e.g. economic valuation), the existence of multiple classification approaches also represents the need for different approaches to support different applications (cite).

Rather than attempting to choose any one framework as the "correct" one to organize an indicators database around, the framework builds on multiple influences, with the intention to support multiple applications taking the lessons and approaches being created based on the MAforward. A collaborative process was employed to help ensure that the indicators framework presented here supports multiple applications of the MA conceptual framework,

By drawing on multiple frameworks in developing a framework to organize These other influences help to ensure policy relevance, as is the case with the Driving force-Pressure-State-Impact-Response indicators framework, and improve our confidence that the information framework will be relevant for most approaches being developed for applying ecosystem service concepts. Some of the applications are explored more later in this section.

Developing a framework to organize information about the ecosystem services conceptual approach requires breaking the elements down to the point that information about each element that influences the other elements can be stored separately.

2.5 Indicator Examples

Applying indicator frameworks can be difficult. While some constraints are practical—data constraints for example—others barriers are conceptual. One of the easiest ways to help overcome these conceptual barriers is to provide examples of the indicators relevant to each framework element. In fact, these example can also prove relevant for helping to overcome practical constraints. In the case of a lack of relevant data, for example, one of the only solutions Some of the challenges, such as data constraints, can only be solved by substituting indicators for which one does improving have data.

This section presents a compilation of indicators organized by ES indicator framework element. Table and Figure X present a description and conceptual examples of the kinds of indicators that are relevant for each ES indicator framework element. Tables X-Y present tables with examples of indicators compiled from ecosystem assessments and other analyses using an ecosystem service approach.

More complete tables of the compiled indicators are presented in Appendix A, and a larger number of compiled indicators can be online at the Ecosystem Service Indicators Database (http://esindicators.org). Please note that, as of the publication of this report, the Ecosystem Service Indicators Database is still in development.

Figure X: Examples of indicators relevant to each category in the ecosystem services indicators framework

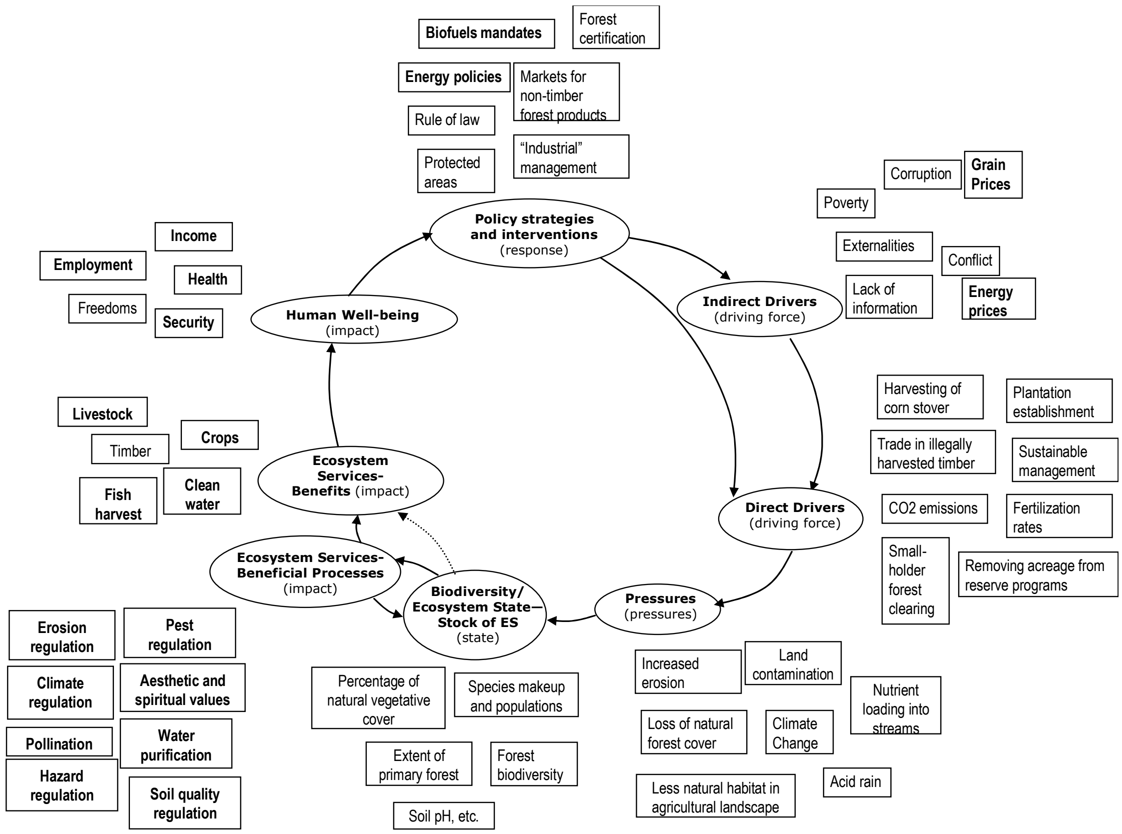

Biofuels mandates
Forest certification
Energy policies
Markets for non-timber forest products
Rule of law
Protected areas
"Industrial" management
Policy strategies and interventions (response)
Corruption
Grain Prices
Poverty
Externalities
Conflict
Lack of information
Energy prices
Indirect Drivers (driving force)
Income
Employment
Health
Freedoms
Security
Human Well-being (impact)
Harvesting of corn stover
Plantation establishment
Trade in illegally harvested timber
Sustainable management
CO2 emissions
Fertilization rates
Small-holder forest clearing
Removing acreage from reserve programs
Direct Drivers (driving force)
Livestock
Crops
Timber
Fish harvest
Clean water
Ecosystem Services-Benefits (impact)
Ecosystem Services-Beneficial Processes (impact)
Biodiversity/ Ecosystem State—Stock of ES (state)
Pressures (pressures)
Erosion regulation
Pest regulation
Climate regulation
Aesthetic and spiritual values
Pollination
Water purification
Hazard regulation
Soil quality regulation
Percentage of natural vegetative cover
Species makeup and populations
Extent of primary forest
Forest biodiversity
Soil pH, etc.
Increased erosion
Land contamination
Nutrient loading into streams
Loss of natural forest cover
Climate Change
Acid rain
Less natural habitat in agricultural landscape

Table X: Examples of Indicators for each Ecosystem Service Indicators Framework Element

Framework	Descriptions of relevant types of measures	Indicator examples
Ecosystem condition and biodiversity	Ecosystem condition indicators are focused on physical, chemical and biological measures of land. Some simply report status (e.g. ecosystem extent) while others focus on condition (e.g. hypoxic area). Indicators that help assess the capacity to support ecosystem functions and how close current condition is to thresholds will include… Biodiversity indicators include measures of the number of species and health of various species. Measures of habitat requirements for biodiversity are also included.	• Extent of ecosystems • Vegetation/land use classification • Trends in land use • Ecosystem condition, including o hypoxic area in estuaries o salinized land in agro-ecosystems o water quality in stream • Number of species on IUCN Red List
Ecosystem function	Since many ecosystem functions are difficult to measure directly, most indicators will initially be proxy indicators. These indicators will be based on known links between ecosystem condition and the ability of ecosystem functions to deliver services.	• Extent of wetlands situated between agricultural crops and a stream (waste processing) • Percentage of "natural" land cover within an agricultural landscape (pollination)
Services	Indicators of services will include the quantity and quality of services. Due In some cases, Depending on the service, indicators will vary in terms of the level of difficulty to identify and implement.	• Flows of water in watersheds • Biomass growth in forests • Carbon uptake by ecosystems • Crop harvests • Water consumption for agriculture, aquaculture, etc.
Benefits	As the goods and services consumed by people, most benefits can be measured directly. Many of these data are tracked as part of national accounts.	• Consumption of agricultural and wild-caught products.. • Number of visitors and tourism receipts in natural areas • Water consumption for drinking and sanitation
Human well-being	Human well-being indicators communicate how ecosystem services provide for people's economic, social, and spiritual well-being. This includesmetrics that provide insights into how ecosystem services manage risk and vulnerability. This category also includes broader measures of well-being such as poverty rates, employment and and health care.	• People employed in agricultures, fisheries, tourism, etc. • Percentage of children wasted/stunted • Access to clean water/sanitation • Proximity to markets for selling goods
Policy strategies and interventions	Policy strategies and interventions are not indicators or measures, per se. However, a compilation of different policy strategies and interventions put in place by different actors can help inform action by others.	• Hagazetted as protected area • Adoption of "user management" approaches in fisheries • Establishment of markets for ecosystem services
Indirect drivers	Indicators of indirect drivers provide information about the conditions that increase or decrease the magnitude of direct drivers. Indirect drivers include demographic trends like migration and population, poverty, and governance. Relevant indicators will differ depending on the set of issues, actors, and desired outcomes being considered	• Corruption index • Percent of land owners with secure land tenure • Food security • Unemployment/diversity of opportunities for earning a living
Direct drivers	Direct driver indicators are primarily measures of the nature and extent of human activities. The activities are often disaggregated in order to provide a clear link with pressures. For example, in addition to fossil fuel combustion for commercial energy, the CO_2, SOxNOx, emissions from would be tracked.	• Fertilization rates • Hectares converted from forest to cropland • Tons of coal burned in power plants •
Pressures	Pressures indicators provide information about the biological, physical, or chemical influences that act, positively or negatively, directly on ecosystems and biodiversity. Pressures do not describe human actions, but the result of human actions that engender either positive or negative trends.	• Change in total forest ecosystem • Increase in fragmentation index • Emissions of CO_2, NOx, SOx, etc. • Decrease in acidity of rain • Nutrient run-off from fields • Area coverage of invasive species

Table X: Indicator examples for Ecosystem Condition and Biodiversity Framework Element

[redacted]

Table X: Indicator examples for Ecosystem Function

[redacted]

Table X: Indicator examples for Ecosystem Function

[redacted]

Table X: Indicator examples for Benefits

[redacted]

Table X: Indicator examples for Human Well-being

[redacted]

Table X: Indicator examples for Policy Strategies and Interventions

[redacted]

Table X: Indicator examples for Indirect Drivers

[redacted]

Table X: Indicator examples for Direct Drivers

[redacted]

Table X: Indicator examples for Pressures

[redacted]

2.6Cataloging and Organizing Indicators within the Framework

As noted above, an indicators framework is intended to structure indicators so they can be applied to orient lines of inquiry and help answer questions. The ES indicators framework presented thus far is the top-level organizational structure. Additional structure is needed to organize information within each of the indicators framework elements. In addition, detailed metadata that support application of the indicator are also necessary. The detailed organization of indicators with framework elements, and metadata categories are presented in this section.

2.6.1 Indicator Classification Elements and Metadata

To be useful, indicators need to be organized in ways they can be searched and sorted so potential users can find those most suited to their needs. In addition, metadata are needed to provide essential information about the indicator and how it can be applied.

Fields to classify the indicators and record metadata have therefore been identified and are presented below. The ES indicators framework uses classification fields to help organize the indicators and metadata fields to hold vital information about how the indicators can be applied. There is some potential overlap between classification fields and metadata fields, but a primary distinction is that metadata fields are generally core information that should typically be recorded for each indicator, while classification fields help inform where the indicator fits within the framework. It is important to note that multiple choices within a given classification or metadata field can be relevant to a specific indicator. For example, daily average calorie supply is an indicator of benefits, but is also relevant as an indicator of human well-being. For this reason, multiple choices can be made for each indicator. In addition, there will be instances in which a given field is not relevant for an indicator, or it is relevant for all choices. Each field therefore has options to choose "not relevant," "multiple," and "all."

The classification elements and metadata fields are presented assuming the ability to compile indicators into a database using an interactive computer application, such as that developed in draft form for the ecosystem service indicators database. This will permit users to submit locally relevant indicators and associated metadata, potentially helping others develop capacity to implement ecosystem service concepts. Filling in the classification and metadata fields when compiling the indicators is time consuming, but important as the metadata are vital for guiding users' application of the indicators. Information recorded for each of the fields will allow the indicators to be searched and filtered to help potential users identify indicators that meet their needs and work within data and resource constraints. The Ecosystem Service Indicator Database is an example of an application that allows this kind of filtering and sorting.

The classification and metadata fields care presented in Table X. Definitions and the choices within each field are expanded on below.

Table X: MetadataFields for Classifying Indicators within the ES Indicators Framework to Support the Application of Indicators

Classification Fields
• Ecosystem Service Indicator Framework Element
• MA classification
o Ecosystem Service Type
o Ecosystem Service Category
o Ecosystem Service Sub-Category
• Ecosystem
• Indicator element
• Human well-being sector

• Type of Policy Strategy / Intervention
• Driver sector
• Media affected
• Response to
• Response to detailed
Metadata Fields
• Name
• Data units
• Data gathering methodology
• Possible data sources
• Definition
• Relevant scale
• Keywords
• Example of indicator application
• Citations where indicator used

Classification Fields

The highest-level classification field is the ES indicators frameworkelement —ecosystem condition and biodiversity, ecosystem function, etc—are. As shown in Table X, other fields such as ecosystem, ecosystem service classification under the MA framework, and relevant scale provide additional information. The definition and choices within each field are presented below.

ES Indicator Framework Element

The ES indicator framework elements have already been defined in earlier sections, and will not be repeated here. The choices when entering the indicators will be the same as presented above, namely:

- Ecosystem condition and biodiversity
- Ecosystem function
- Ecosystem service
- Benefit
- Human well-being
- Policy strategy and intervention
- Indirect driver
- Direct driver
- Pressure

MA Classification: Ecosystem Service Type, Category and Sub-Category

Ecosystem service type, category and sub-category are classifications based on the naming conventions used in the MA conceptual framework (see table X). These fields reflect the fact that the naming convention based on the MA conceptual framework hasthreenesting levels. The indicator "Percent increase in grain yields," for example, is an indicator of crops, which is one of the classifications within food services, which itself falls within provisioning services. Due to this nesting approach, the naming conventions are a bit unwieldy and initially appear confusing. For example, some indicators will have three levels of classification while others will have only two. In addition, the classifications continue to evolve. While the evolution is a positive sign that ecosystem services concepts and approaches are being applied and refined, it does pose difficulties in developing common approaches.

The MA classification used within the Ecosystem Services Indicators Database is as follows:

- Ecosystem service type: The four ecosystem service types—provisioning, regulating, cultural and supporting services—are the highest organizational level within the ecosystem service classification.
- Ecosystem service category: The category level is the level of detail below ecosystem service type. Examples of categories include the provisioning services biological raw materials and freshwater and the regulating services erosion regulation and pollination. There are six categories in provisioning services, eight in regulating, 2 in cultural, and 3 in supporting services. The categories are presented in table X.
- Ecosystem service sub-category: Sub-categories are the most detailed level of ecosystem service classification. Examples include timber and other wood fibers, fibers and resins, and animal skins within the biological raw materials category. Many ecosystem service categories are not further differentiated into sub-categories. The categories freshwater, erosion regulation and pollination, for example, do not include any sub-categories. As the concepts continue to be applied and developed, sub-categories will probably be developed for some categories that currently do not include them.

The choices for ecosystem service type, category and sub-category are presented below in Table X.

Table X: Fields for Ecosystem service type, category, and sub-categories

Ecosystem Service Type	Ecosystem Service Category	Ecosystem Service Sub-Category
Provisioning	Food	Crops
		Livestock
		Capture Fisheries
		Aquaculture
		Wild Foods
	Biological raw materials	Timber and other wood fiber
		Fibers and resins
		Animal skins
		Sand
		Ornamental resources
	Biomass fuel	
	Freshwater	
	Genetic resources	
	Biochemicals, natural medicines, and pharmaceuticals	

Regulating	Air quality regulation	
	Climate regulation	Global climate regulation
		Regional and local climate regulation
	Water regulation	
	Erosion regulation	
	Water purification and waste treatment	
	Disease regulation	
	Soil quality regulation	
	Pest regulation	
	Pollination	
	Natural hazard regulation	
Cultural / Aesthetic Services	Recreation and ecotourism	
	Ethical values	
Supporting services	Nutrient Cycling	
	Primary production	
	Water cycling	

Table X: Definitions of Ecosystem Services using the Millennium Ecosystem Assessment Conceptual Framework.

Definitions of Ecosystem Services, Version 1.1			
Service	**Sub-category**	**Definition**	**Examples**
Provisioning services: The goods or products obtained from ecosystems.			
Food	Crops	Cultivated plants or agricultural produce harvested by people for human or animal consumption as food	• Grains • Vegetables • Fruits
	Livestock	Animals raised for domestic or commercial consumption or use	• Chicken • Pigs • Cattle
	Capture fisheries	Wild fish captured through trawling, nets, lines & hooks, and other nonfarming methods	• Cod • Crabs • Tuna
	Aquaculture	Fish, shellfish, and/or plants that are bred and reared in ponds, enclosures, and other forms of freshwater or saltwater confinement for purposes of harvesting	• Shrimp • Oysters • Salmon
	Wild foods	Edible plant and animal species gathered or captured in the wild	• Fruits and nuts • Fungi • Bushmeat
Biological raw materials	Timber and other wood fiber	Products made from trees harvested from natural forest ecosystems, plantations, or nonforested lands	• Industrial roundwood • Wood pulp • Paper
	Fibers and resins	Nonwood and nonfuel fibers and resins extracted from the natural environment	• Cotton, hemp, and silk • Twine and rope • Natural rubber
	Animal skins	Processed skins of cattle, deer, pig, snakes, sting rays, or other animals	• Leather, rawhide, and cordwain
	Sand	Sand formed from coral and shells	• White sand from coral
	Ornamental resources	Ecosystem-derived products that serve aesthetic purposes	• Tagua nut, wild flowers, coral jewelry
Biomass fuel		Biological material derived from living or recently living organisms – both plant and animal – that serves as a source of energy	• Fuelwood and charcoal • Grain for ethanol production • Dung
Freshwater		Inland bodies of water, groundwater, rainwater, and surface waters for household, industrial, and agricultural uses	• Freshwater for drinking, cleaning, cooling, industrial processes, electricity generation, or mode of transportation
Genetic resources		Genes and genetic information used for animal breeding, plant improvement, and biotechnology	• Genes used to increase crop resistance
Biochemicals, natural medicines, and pharmaceuticals		Medicines, biocides, food additives, and other biological materials derived from ecosystems for commercial or domestic use	• Echinacea, ginseng, and garlic • Paclitaxel as basis for cancer drugs • Tree extracts used for pest control
Regulating services: The benefits obtained from an ecosystem's control of natural processes.			
Air quality regulation		Influence ecosystems have on air quality by emitting chemicals to the atmosphere (i.e., serving as a "source") or extracting chemicals from the atmosphere (i.e., serving as a "sink")	• Lakes serve as a sink for industrial emissions of sulfur compounds • Vegetation fires emit particulates, ground-level ozone, and volatile organic compounds
Climate regulation	Global	Influence ecosystems have on global climate by emitting greenhouse gases or aerosols to the atmosphere or by absorbing greenhouse gases or aerosols from the atmosphere	• Forests capture and store carbon dioxide • Cattle and rice paddies emit methane
	Regional and local	Influence ecosystems have on local or regional temperature, precipitation, and other climatic factors	• Forests can impact regional rainfall levels

Definitions of Ecosystem Services, Version 1.1 *(continued)*		
Service	**Definition**	**Examples**
Regulating services *(continued)*		
Water regulation	Influence ecosystems have on the timing and magnitude of water runoff, flooding, and aquifer recharge, particularly in terms of the water storage potential of the ecosystem or landscape	• Permeable soil facilitates aquifer recharge • River floodplains and wetlands retain water – which can decrease flooding during runoff peaks – reducing the need for engineered flood control infrastructure
Erosion regulation	Vegetative cover retains soil; coral reefs protect coastal areas	• Vegetation such as grass and trees prevents soil loss due to wind and rain and prevents siltation of water ways • Forests on slopes hold soil in place, thereby preventing landslides
Water purification and waste treatment	Role ecosystems play in the filtration and decomposition of organic wastes and pollutants in water; assimilation and detoxification of compounds through soil and subsoil processes	• Wetlands remove harmful pollutants from water by trapping metals and organic materials • Soil microbes degrade organic waste, rendering it less harmful
Disease regulation	Influence that ecosystems have on the incidence and abundance of human pathogens	• Intact forests reduce the occurrence of standing water – a breeding area for mosquitoes – and thereby can reduce the prevalence of malaria
Soil quality regulation	Role ecosystems play in sustaining soil's biological activity, diversity and productivity; in regulating and partitioning water and solute flow; and, in storing and recycling nutrients and gases	• Some organisms aid in decomposition of organic matter, increasing soil nutrient levels • Some organisms aerate soil, improve soil chemistry, and increase moisture retention • Animal waste fertilizes soil
Pest regulation	Influence ecosystems have on the prevalence of crop and livestock pests and diseases	• Predators from nearby forests – such as bats, toads, and snakes – consume crop pests
Pollination	Role ecosystems play in transferring pollen from male to female flower parts	• Bees from nearby forests pollinate crops
Natural hazard regulation	Capacity for ecosystems to reduce the damage caused by natural disasters such as hurricanes to maintain natural fire frequency and intensity	• Mangrove forests and coral reefs protect coastlines from storm surges • Biological decomposition processes reduce potential fuel for wildfires
Cultural services: The nonmaterial benefits obtained from ecosystems.		
Recreation and ecotourism	Recreational pleasure people derive from natural or cultivated ecosystems	• Hiking, camping, and bird watching • Going on safari
Ethical values	Spiritual, religious, aesthetic, intrinsic, "existence," or other values people attach to ecosystems, landscapes, or species	• Spiritual fulfillment derived from sacred lands and rivers • Belief that all species are worth protecting regardless of their utility to people – "biodiversity for biodiversity's sake"
Supporting services: The natural processes that maintain the other ecosystem services.		
Nutrient cycling	Flow of nutrients (e.g., nitrogen, sulfur, phosphorus, carbon) through ecosystems	• Transfer of nitrogen from plants to soil, from soil to oceans, from oceans to the atmosphere, and from the atmosphere to plants
Primary production	Formation of biological material by plants through photosynthesis and nutrient assimilation	• Algae transform sunlight and nutrients into biomass, thereby forming the base of the food chain in aquatic ecosystems
Water cycling	Flow of water through ecosystems in its solid, liquid, or gaseous forms	• Transfer of water from soil to plants, plants to air, and air to rain

Ecosystem: Many indicators will be most closely aligned with specific ecosystems. Crop production, for example, is most closely aligned with cultivated systems, and can also be aligned with drylands and wetlands. Untreated waste flowing into water bodies will mostly be relevant to inland water, wetlands, and coastal systems. The ecosystem field is relevant for most indicators, with indirect drivers and human well-being exceptions. The ecosystem fields are:

- Wetland
- Coastal
- Dryland
- Forest
- Inland water
- Island
- Marine
- Mountain
- Polar
- Urban

Indicator Element: This refers to metrics that a subset of the overall metric. For example, data on most grain crops are gathered individually. The core concept of grain production is more relevant as an indicator than each individual crop, but in many cases gathering data on rice, maize, millet, etc. is important. These specific elements within grain production are referred to as indicator elements. There were many instances of metrics used in ecosystem assessments thatincluded many indicator elements as well as the overarching concept. Indicator elements are specific to the indicator being considered, and are recorded by the person compiling the indicator rather than chosen from a list.

Human well-being sector:The human well-being sector field is intended to categorize indicators by the way they contribute to or measure human well-being. The choices, listed below, represent the common human well-being sectors used in compilations of social indicators.

- Health
- Food security
- Employment/Livelihood
- Economy
- Social well-being/belonging
- Education
- Security/crime
- Freedom

Policy response to: To help identify the types of policies that have been attempted elsewhere, compiled policy responses should be categorized. The type of driver the policy seeks to address is an important means of providing relevant information. Policy response to will be differentiated into indirect and direct drivers, and into more detailed categories within those.

- Indirect driver
- Direct driver

- Pressure

Driver sector:The driver sector is the economic sector most closely associated with the driver. Users will be reminded that drivers can be positive or negative. Many of the options presented were taken from Concepts and Methods in Environmental Statistics – Statistics of the Natural Environment (UNSD, 1991).

- Agriculture
- Commercial forestry
- Biomass energy production
- Hunting, trapping, gathering
- Fishing
- Mining and quarrying
- Industrial energy production and conversion
- Energy use
- Water harvesting and use
- Land use and environmental restructuring (e.g habitat conversion, construction)

Driver sector, detailed: Based on the option selected for driver sector, additional detail on the driver can be entered.Many of the options presented were taken from Concepts and Methods in Environmental Statistics –Statistics of the Natural Environment (UNSD, 1991).

- Crop and livestock practices—cultivation practices (direct driver)
- Crop and livestock practices—level of fertilizer and pesticide use (direct driver)
- Crop and livestock practices—shifting cultivation, extensification (direct driver)
- Crop and livestock practices—introduction of new cultivars. (direct driver)
- Crop and livestock practices—irrigation practices. (direct driver)
- Forestry—commercial harvesting
- Forestry—informal harvesting for fuelwood, charcoal, wild foods, village building materials, etc.
- Forestry—natural tree mortality from disease, fire, wind, pollution, etc.
- Forestry—natural regeneration
- Forestry—plantation establishment and managed afforestation
- Hunting, trapping, gathering—subsistence
- Hunting, trapping, gathering—commercial
- Hunting, trapping, gathering—recreational
- Fishing—subsistence
- Fishing —commercial
- Fishing —recreational
- Mining and quarrying—
- Industrial energy production and conversion—discovery, development and extraction
- Industrial energy production and conversion—energy conversion
- Energy use—heavy industry

- Energy use—other manufacturing
- Energy use—transportation
- Energy use—household use
- Energy use—services to households
- Energy use—government energy use
- Water harvesting and use—water abstraction
- Water harvesting and use—water use for irrigation
- Water harvesting and use—water use forestry
- Water harvesting and use—water use households
- Water harvesting and use—water use for energy production
- Land use and environmental restructuring—habitat conversion (e.g. from forest to farmland)
- Land use and environmental restructuring—construction

Type of Policy Strategies and Interventions: This section presents types of policy strategies and interventions. The choices presented were taken from Concepts and Methods in Environmental Statistics –Statistics of the Natural Environment (UNSD, 1991).

- Economics and Incentives
- Standards, enforcement, and regulations
- Education toward Social and Behavioral changes
- Restoration and rehabiliatation
- Technological and Infrastructure
- Institutions and Governance
- Improved knowledge

Media / environmental component: Media are a major way of organizing environmental information and regulation. Media / environmental component was one of the primary organizing approaches within the framework for environmental statistics. Including it here will help the ES indicators framework align with the way environmental information is organized in many existing databases. The media presented below arefrom Concepts and Methods in Environmental Statistics –Statistics of the Natural Environment (UNSD, 1991).

- Flora
- Fauna
- Atmosphere
- Freshwater
- Marine water
- Land and soil (surface)
- Land and soil (sub-surface)
- Human settlements

Metadata Fields
The following metadata fields are important for providing the necessary information and context needed to successfully use the indicators and metrics within the ES indicators framework. A definition for each field in provided in the next section. The metadata for indicators within the ES indicators framework include the following:

Metadata Field Definitions
Indicator name: Entered by compiler

<u>Data units:</u> Entered by compiler. In ES indicators database the units are chosen by a list populated by user entries.

<u>Data gathering methodology:</u> The methodology used to gather data for the indicator. Where multiple data gathering approaches are possible, this should be noted. Entered by compiler

<u>Definition:</u> The definition is the description of what the indicator means and why it is relevant within the ES indicators framework. The definition should be brief.

<u>Relevant scale</u>: Many indicators are relevant at multiple scales depending on data availability. Some, however, are primarily relevant at only one or two scales. That information will be recorded in this field.

- Local
- Watershed
- Sub-national
- National
- Regional
- Global

<u>Keywords</u>: Keywords are terms that communicate the most important concepts inherent in the indicator. These are terms that, if someone searches on it, should return the indicator.

<u>How the indicator was applied in ecosystem service contexts</u>: This field is intended to help other potential users understand how the indicator was used in assessment, policy documents, or other analysis done using ecosystem service approaches.

<u>Relevant sources indicator was used in:</u>Sources in which the indicator has been used can be compiled to help potential users see how they have been applied.

<u>Example of how the indicator was used</u>: This field will contain sentences or paragraphs illustrating how the indicator contributed to the analysis or source from which it was compiled.

2.7 Considerations in identifying relevant indicators and metrics

Depending on the purpose the data and indicators are intended to support, the audience, and some specific factors noted below, the relevant metrics and indicators will vary.

Geographic scale: data collected for narrower scales can be more precise and specific. To keep the number of individual metrics manageable, metrics and indicators chosen for broader scales will often need to cover greater breadth.

Temporal scale: Metrics and indicators should be sensitive enough that they will detect change within a time scale relevant to the purpose they are chosen for.

Level of aggregation: Level of aggregation should be chosen based on the intended audiences for the metrics and indicators. If the goal is to communicate information to senior policy makers and other non-technical audiences, then more aggregated indicators should be chose in addition to disaggregated metrics. If the goal is to support an analysis, such as a sub-global ecosystem assessment, a greater proportion of non-aggregated metrics will suffice.

2.7.1 Building an Interactive Ecosystem Service Indicators Data Base

The intention of developing the ecosystem service indicator framework is to help mainstream ecosystem services concepts and support implementation of ecosystem service approaches. Improving the information base make information about ecosystem services readily available to the various practioners and end users who need the information Building an online database (http://XXX) to accompany the framework. Intention is to establish a readily available and easy-to-use database for the community of ecosystem service researchers and practitioners to use in their work and contribute indicators and data to for others to use. Over time, an indicators database should help in the process of developing should become possible to identify the indicators that work best for different applications and

Building database intended to be an iterative process. The DB will be released in a preliminary form to allow for testing and consultation about what how well the database can meet various users' needs as currently designed, what elements need to be added in the next release, and how those elements should be designed. The preliminary version of the database will not be capable of storing data, but will rather be a compilation of indicators within each category of the ES indicators framework described above.

Database Design

As specifics become better know, describe here.

Populating the Framework with Indicators

For *Measuring Nature's Benefits*, WRI compiled ES indicators from the global MA. The scope of that compilation was limited, however, in that only indicators ecosystem services—specifically the flow of services—were compiled from the global MA and three sub-global assessments. For this paper, WRI and UNEP-WCMC compiled indicators from the entire suite of sub-global assessment done as part of the MA and the pilot ecosystem assessments funded by the Poverty-Environment Initiative. Since ES assessments, and the MA conceptual framework overall, is an integrated approach, the addition of indicators for other framework components such as drivers, pressures and human well-being constitute an important addition.

- State of indicators knowledge (this may work well as a box since the other doc will focus on this)
    - Work done up to and since MA
    - New approaches are being developed, assessments ramping up,

Toward Data Storage

As we move toward being able to store data for ecosystem service indicators, numerous challenges will need to be met.

Some principles for storing data in the indicators database will be:

- Spatial extent of ecosystems, and the spatial location of ecosystem service provision, intermediate services, and benefits. Specifically, the fact that the location where an ecosystem exists and an ecosystem process takes place can be disparate from where the final service is delivered (EC, 2008 and Fisher et al., 2009). The benefit can be consumed in yet a completely different location.
- Multiple scales: This is closely related to above.
- Beneficiaries
- Support multiple levels of information (See TEEB fig 3.2 on pp. 33-34.)

These requirements lead toward the need for a spatial tool to display information. Should explore using online mapping software such as google maps, visual earth, etc. to support widespread dissemination of information and permit distributed data input.

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Appendix 1: Compiled indicators with definitions and [redacted]

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