MEASURING ECOSYSTEM SERVICES

GUIDANCE ON DEVELOPING ECOSYSTEM SERVICE INDICATORS

UNEP

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship

Stockholm University

CSIR

This document has been produced as an output of a UNEP-WCMC project, funded by the Swedish International Development Cooperation Agency (Sida) through the Resilience and Development Programme (SwedBio) at Stockholm Resilience Centre, Stockholm University and produced in collaboration with the Council for Scientific and Industrial Research.

Acknowledgements

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and the Council for Scientific and Industrial Research (CSIR) would like to gratefully acknowledge the economic support provided by the Swedish International Development Cooperation Agency (Sida) through the Resilience and Development Programme (SwedBio) at Stockholm Resilience Centre, Stockholm University.

The authors wish to express deep gratitude to the following individuals for their help and guidance in the production of this document: Neil Burgess, Alex Forbes, Joachim Maes, Dilys Roe and Jamie Tratalos (expert reviewers); Katherine Despot Delmonte (document preparation); Katharine Trumper (copy-editing); and Ralph Design Ltd (graphic design).

The authors would also like to acknowledge: the NBSAPs 2.0: Mainstreaming Biodiversity and Development Project being implemented by the International Institute for Environment and Development (IIED) and UNEP-WCMC, whose work underpins Section 3 of these guidelines; and P. Balvanera and the GEO BON Ecosystem Services Working Group..

Published: November 2014

Citation: Brown, C., Reyers, B., Ingwall-King, L., Mapendembe, A., Nel, J., O'Farrell, P., Dixon, M. & Bowles-Newark, N. J. (2014). Measuring ecosystem services: Guidance on developing ecosystem service indicators. UNEP-WCMC, Cambridge, UK.

Front cover photo: Asian male rice farmer. © Swissmacky 2008. Used under license from Shutterstock.com

ISBN: 978-92-807-4919-5

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) is the specialist biodiversity assessment centre of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organization. The Centre has been in operation for over 30 years, combining scientific research with practical policy advice.

Contents

Foreword

It is recognized that ecosystem services play an important role in supporting economic activity, development and general human well-being. To manage them sustainably as an asset underpinning the economy, it is essential to be able to assess the status and trends of these services and flow of values. Hence the need for ecosystem service indicators is increasingly recognized as a key part of assessing whether ecosystem services are being appropriately managed and sustainably used.

Measurement and communication of progress towards policy targets is primarily achieved through the use of indicators. As such, indicators can play a central role in decision-making and adaptive management, and provide an important interface between science and policy. As the global community has become more aware of their reliance on natural systems-and of the signs that many are degrading at alarming rates-ecosystem service indicators are becoming increasingly important to government and intergovernmental processes. Included amongst these are the Convention on Biological Diversity, and the Aichi Targets contained within its strategic plan for 2011-2020; the Intergovernmental Platform on Biodiversity and Ecosystem Services work programme; and the tools used to monitor progress towards the Sustainable Development Goals. At a national level, ecosystem service indicators can support ecosystem accounting processes, natural capital reporting, and mainstreaming ecosystems into development policies and plans.

This guidance report is underpinned by work carried out as part of the collaboration between the United Nations Environment Programme-World Conservation Monitoring Centre and the Council for Scientific and Industrial Research funded by SwedBio. The aim of the programme was to enhance the development, use and uptake of indicators and approaches for assessing the consequences of changes in ecosystem services and their implications for society, human well-being and poverty alleviation, at national and local scales.

A pilot set of ecosystem service indicators and approaches in South Africa, which move beyond current state-of-the-art indicators to capture bundles, benefits and flow of values to society, were developed and these are set out as a series of fact sheets in the report.

I hope that this guide proves to be a valuable resource for ecosystem assessment practitioners and decision-makers.

Achim Steiner
Executive Director
United Nations Environment Programme (UNEP)

Executive Summary

Ecosystem services are vital to human survival and wellbeing, and the judicious management of the systems that produce these benefits is essential. Ecosystem service indicators are increasingly recognized as a key part of assessing whether ecosystem services are being managed appropriately and used sustainably.

Developing ecosystem services indicators is challenging, for example:

1. The ability of indicators to convey information about ecosystem services is low overall, although it varies widely among services;
2. The indicators available for most ecosystem services are not comprehensive and are often inadequate to characterize the diversity and complexity of the benefits they provide;
3. Data are often insufficient to support the use of these indicators; and
4. Indicators for regulating and cultural services lag behind provisioning services in each of the limitations identified above.

Further, we propose that a key gap hampering the development of useful, relevant indicators is that many of them measure the levels of ecosystem services provided by a particular area (e.g. crop production, water regulation), but do not provide an indication of the actual benefits gained by people (food, domestic water) and how these benefits are distributed across space and time. These include economic, as well as social and cultural benefits. Understanding the benefit flows from ecosystem services is essential if we are to be able to assess the consequences of changes in ecosystem services for human wellbeing – an aim which is at the heart of most policies and programs focused on ecosystem service management. However, benefit flows remain a poorly understood and poorly quantified component of ecosystem service measurement and monitoring programs.

These guidelines have been produced to support the development of ecosystem service indicators at the national and regional level for uses in reporting, assessments, policy making, biodiversity conservation, ecosystem management, environmental management, development planning and education.

The guidance contains four key sections:

1. Introduction to ecosystem service indicators (section 1)
2. Steps in developing ecosystem service indicators (section 2)
3. Mainstreaming ecosystem service indicators (section 3)
4. Ecosystem indicators developed and piloted in South Africa (section 4)

TABLE OF BOXES

TABLE OF FIGURES

TABLE OF TABLES

LIST OF ACRONYMS

ARIES	Artificial Intelligence for Ecosystem Services
BBN	Baysian Belief Networks
BIP	Biodiversity Indicators Partnership
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CICES	Common International Classification of Ecosystem Services
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CSIR	Council for Scientific and Industrial Research
CSO	Civil society organizations
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GEF	Global Environment Facility
GRI	Global Reporting Initiative
IEA	International Energy Agency
IEEP	Institute for European Environmental Policy
IIED	International Institute for Environment and Development
InVEST	Integrated Valuation of Environmental Services and Trade-offs
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MDG	Millennium Development Goal
MEA	Multilateral Environmental Agreement
MENE	Monitor of Engagement with the Natural Environment
MIMES	Multi-scale Integrated Models of Ecosystem Services

LIST OF ACRONYMS (continued)

NASA	National Aeronautics and Space Administration
NBSAP	National Biodiversity Strategies and Action Plan
NDP	National Development Plan
NFI	National Forest Inventory
NGO	Non-Governmental Organisation
PEI	UNDP-UNEP Poverty-Environment Initiative
PES	Payment for Ecosystem Services
SANBI	South African National Biodiversity Institute
SDG	Sustainable Development Goal
SEEA	System of Environmental-Economic Accounts
SGA	Sub-global assessment
STAP	Scientific and Technical Advisory Panel
TESSA	Toolkit for Ecosystem Service Site-based Assessments
UBC	University of British Columbia
UK NEAFO	UK National Ecosystem Assessment Follow On
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
USLE	Universal Soil Loss Equation
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WDCGG	World Data Centre for Green House Gases
WTTC	World Travel and Tourism Council

1 Introduction

1.1 Background to the Guidelines

This section presents the background to the Guidelines including introducing the concept of ecosystem services and their importance to poverty eradication and economic development. It also presents a brief business case for developing ecosystem service indicators.

1.2 What is the purpose of these Guidelines?

This section describes the purpose of the Guidelines, which is to help the development of ecosystem service indicators at national, sub-national and sectoral levels for uses in reporting, policy and decision making, environment and economic development planning, biodiversity conservation, ecosystem management and education.

1.3 Who should use these Guidelines?

This section describes the intended users of the Guidelines, primarily those developing and using indicators.

1.4 How to use these Guidelines?

This section describes the different contexts in which the Guidelines can be used as a decision-support tool.

1.5 The scope and structure of these Guidelines

This section provides an overview of the scope and structure of these Guidelines (i.e. what the Guidelines are and what they are not) and illustrates the conceptual approach adopted.

1.1 BACKGROUND TO THE GUIDELINES

Ecosystem services can be defined as all the benefits people obtain from ecosystems (Millennium Ecosystem Assessment; MA, 2005). These benefits include provisioning, regulating, supporting and cultural services. Examples of ecosystem services include basic services and goods such as clean air, water, food, medicine and fibre; as well as more complex services that regulate our climate, protect us from natural disasters and provide us with a rich heritage of nature-based cultural traditions, among many others (MA, 2005) see Box 1.

Box 1: Categories of ecosystem services

Supporting services: The services that are necessary for the production of all other ecosystem services including soil formation, photosynthesis, primary production, nutrient cycling and water cycling.

Provisioning services: The products obtained from ecosystems, including food, fibre, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources and fresh water.

Regulating services: The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination and natural hazard regulation.

Cultural services: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences – thereby taking account of landscape values.

Individuals, households, businesses and industries all rely on ecosystem services for different aspects of their wellbeing (for example basic material for good life, health and security) and growth. So, ecosystem services are essential for poverty reduction and socio-economic development at local and national level, including through:

- **Service delivery** — delivering key functions such as pollination and water provisioning far more effectively than human-made alternatives.
- **Risk-reduction** — including disaster and climate risk reduction in key sectors (e.g. providing a diverse resource base that offers alternatives if one food crop fails).
- **Direct financial value** — through certain products and species that may be tradable (e.g. medicinal plants and animals; species attractive to tourists).
- **National economic diversification** — through habitat, species and genetic diversity that present options and alternatives (e.g. in tourism and forestry).
- **Intrinsic and cultural value** — related to identity, tradition, social cohesion, recreation and spirituality.

Conversely, both poverty and economic development may negatively affect the provision of important ecosystem services. Given the importance of ecosystem services, their degradation has considerable economic, social and political consequences especially for poor people. In general, poor people are more reliant on ecosystem services because their livelihoods are often based on natural resources and they are particularly vulnerable to natural hazards (Convention on Biological Diversity; CBD, 2010; MA, 2005; PBL, 2010; United Nations Environment Programme; UNEP, 2007). Against this backdrop, incorporating ecosystem services management into national development policy and planning at all levels is essential to equitable and sustainable growth and development (Kok et al., 2010).

Such policy making and planning require metrics to measure progress and effectiveness, which is why "ecosystem service indicators" are necessary. In this guide we define "ecosystem service indicators" as information that efficiently communicates the characteristics and trends of ecosystem services, making it possible for policymakers to understand the condition, trends and rate of change in ecosystem services. Robust ecosystem service indicators, based on reliable metrics and measures, are critical to knowing whether or not these essential services are being maintained and used in a sustainable manner (UNEP-World Conservation Monitoring Centre; UNEP-WCMC, 2011). Ecosystem service indicators are therefore of increasing interest and importance to a variety of users at a range of scales.

Ecosystem service indicators can inform our understanding and appreciation of the complex relationships between ecosystem services and their implications for society, human wellbeing and poverty reduction (Reyers et al., 2014; UNEP-WCMC, 2011). The indicators can serve as important tools for national and sub-national economic development planning that aims to achieve sustainable growth and development, monitoring and reporting (e.g. on National Biodiversity Strategies and Action Plans (NBSAPs) and National Development Plans (NDPs); UNEP-WCMC & IEEP, 2013; Wilkinson et al., 2013) or for national and regional assessments. At the international level, users of ecosystem service indicators include Parties to multilateral environmental agreements (MEAs) such as the CBD, the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification (UNCCD), Ramsar Convention on Wetlands as well as other international processes such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) assessments, Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs). Ecosystem service indicators can also be used to raise awareness about threatened ecosystem services and motivate key actors who are affected by ecosystem services, or who are in a position to act on or affect them.

Key definitions

Measure (or measurement): Actual measurement of a state, quantity or process derived from observations or monitoring. e.g. bird counts, total dissolved solids, biomass, runoff.

An **indicator** uses measures to communicate something of interest. They are purpose and audience specific.

Metric: a set of measurements or data collected and used to underpin each indicator.

An **index** comprises a number of measures combined in a particular way to increase their sensitivity, reliability or ease of communication e.g. Red List Index for birds shows changes in threat status over time obtained through a specific formula. Disaggregation and traceability are important.

Ecosystem service indicators are information that efficiently communicates the characteristics and trends of ecosystem services, making it possible for policymakers to understand the condition, trends and rate of change in ecosystem services.

Port Barton, Palawan, Phillipines © Mary Aileen M Delas Alas, WordFish (2011)

1.2 WHAT IS THE PURPOSE OF THESE GUIDELINES?

The purpose of these Guidelines is to help government agencies, academia, research institutes and/or non-governmental organisations (NGOs), among others, with the process of developing ecosystem service indicators at local/sub-national and national level. Uses for such indicators include:

- policy and decision making;
- planning for environmentally sustainable economic development;
- assessing, tracking and reporting changes in ecosystems and their effects on economy and human well-being; and
- ecosystem management.

These Guidelines are designed to assist in the development of ecosystem service indicators on both a 'one-off' basis to meet the needs for a particular study or report (e.g. ecosystem assessments at national and regional scales); for national economic development planning and decision making; or for long-term monitoring and reporting (e.g. NBSAPs and NDPs).

The information in these Guidelines is not meant to be exhaustive, as each situation will vary according to country or region and over time. However, it should serve as a useful starting point and enable you to follow a simplified process while consulting other sources for detail. The Guidelines were developed on the basis of experiences in developing biodiversity and ecosystem service indicators including by the UNEP-WCMC, the Council for Scientific and Industrial Research (CSIR) of South Africa and their partners and of many other research institutes and organizations across the globe.

1.3 WHO SHOULD USE THESE GUIDELINES?

The target audience for these Guidelines is primarily those concerned with the development of ecosystem service indicators, including representatives of government agencies, academia, research institutes and/or NGOs. These Guidelines will also be useful for experts whose work contributes to improving indicators, data, and policy-support tools, as well as those who will apply ecosystem service indicators to improve decision making in their institutions. Examples of target audiences include:

- National data gathering entities, including national statistical accounts and scientific agencies. International organisations such as the United Nations (UN) Statistical Agency and international aid organisations that support national and sub-national capacity for data gathering;
- Public sector policymakers at sub-national, national, regional, and international levels who will benefit from incorporating ecosystem service considerations into policy dialogue;
- Decision makers in the private sector whose companies can use ecosystem service indicators to inform strategic decisions;
- Policy research institutions supporting the public and private sectors' ability to apply ecosystem services concepts;
- Scientific institutions with expertise to research and propose policy-relevant indicators of ecosystem services to fill outstanding gaps;
- Ecosystem assessments building on and improving the approaches, indicators, data sets, and policy input developed for the MA; and
- International organisations—including environmental and development agencies—responsible for gathering, analysing, and disseminating data about environment and economic development.

1.4 HOW AND WHEN TO USE THESE GUIDELINES

These Guidelines should be used:

- **As a decision-support tool:** With the aid of an indicator development framework, the Guidelines provide generic steps in developing ecosystem service indicators; information on the types of indicators; available datasets; communicating and interpreting indicators; and how ecosystem service indicators can be integrated into existing monitoring and reporting systems of economic development policies and plans at international, national, sub-national and sectoral levels.
- **In conjunction with other guidelines:** These Guidelines should be used in conjunction with other guiding documents on ecosystem, biodiversity and development indicators, data, policy-support tools and on applying the ecosystem service approach and ecosystem service indicators to improve decision making.

The guidelines can be used in training for people in government agencies, academia, research institutes or NGOs whose work involves developing ecosystem service indicators, and to support dialogues information-sharing networks or learning communities on ecosystem services and their indicators.

1.5 THE SCOPE AND STRUCTURE OF THESE GUIDELINES

These Guidelines are organised around the 'Ecosystem Service Indicator Development Framework' (see Section 2), which presents a series of key steps in successful indicator development. The framework is adapted from the 'Biodiversity Indicator Development Framework' developed on the basis of the experience of the Biodiversity Indicators Partnership (BIP), UNEP-WCMC and their partners. The framework describes steps that may be used as a guideline for the production of an individual ecosystem service indicator, or for a suite of ecosystem service indicators brought together to answer a specific policy question. Detailed information is provided for each step, including identifying indicator needs and key questions, gathering and analysing data, testing results, and the communication of indicators. It also provides entry points and approaches and tools for mainstreaming ecosystem service indicators into existing monitoring and reporting systems of policies and plans at all levels. The main focus of the Guidelines is on the process aspects of producing and using ecosystem service indicators.

Bamboo Raft, Li River Gunxi Province, China © Mikhail Nekrasov, Shutterstock.com

2 Development of ecosystem service indicators

This section introduces the ecosystem service indicators development framework, and details the 10 steps in putting together ecosystem service indicators. The need for an open, participatory process in collaboration with stakeholders is explained, along with how to identify, calculate and communicate indicators for ecosystem services.

2.1 ECOSYSTEM SERVICE INDICATORS DEVELOPMENT FRAMEWORK

The framework shown in Figure 1 was originally produced to assist in the development and use of national indicators within the context of biodiversity. However, this Indicator Development Framework is equally suitable for an ecosystem services context. The framework contains key steps for the development of appropriate ecosystem services indicators and, crucially, encourages a participatory approach with relevant stakeholders from the start of the process to foster ownership and effective use of the indicators.

The following section of the Guidelines goes through each of the steps in the framework. However it is important to recognize that the framework is an "ideal" standard and it may not be necessary to cover every step. Similarly, the framework is presented in a logical sequence from top to bottom, but there are other possible directions and starting points depending on the context in which it is used. Indicator development is an iterative process, which means that indicator developers need to consider and allow for back and forth movement between the steps. For example, the steps 'identify possible indicators' and 'gather and review data' are often undertaken simultaneously.

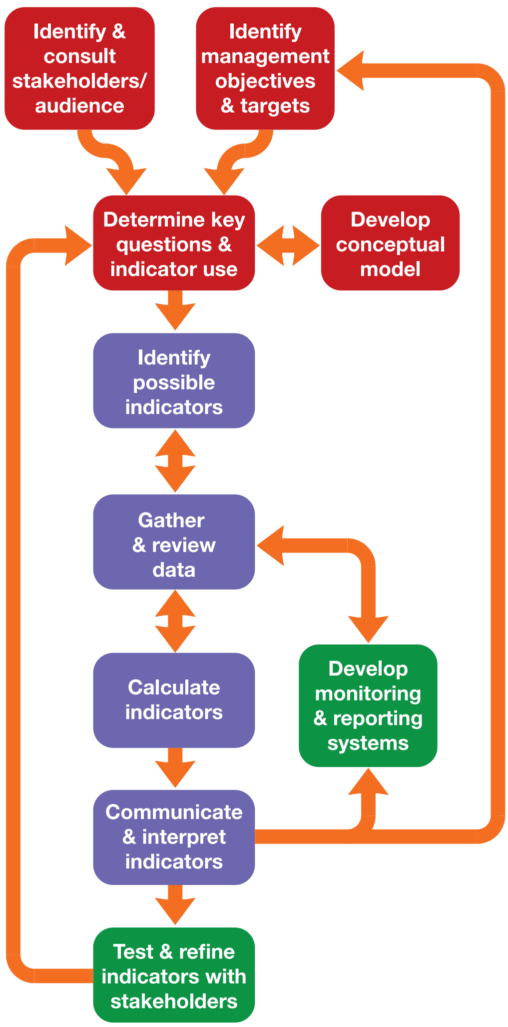

Figure 1. Indicator Development Framework

Source: adapted from BIP, 2011

Step 1: Identify and consult stakeholders and the target audience

Ecosystem service indicators should be developed to meet the needs of the end users. It is therefore strongly recommended that all relevant stakeholders are consulted as early in the indicator development process as possible in order to identify the purpose of the indicator and its audience. Relevant stakeholders are: potential users of the indicator; relevant data providers; and those with a broader interest in the issue. A good place to start is to find out which stakeholders perceive a need for indicators and in what context. It is crucial to establish a dialogue between the indicator users and the data providers, as without this the indicators risk being of no practical use. Wider engagement with stakeholders will help make the indicator clearer and reduce the threat of misinterpretation. It may also be helpful to identify *ecosystem services indicator champions;* these are people that have the technical skills to develop indicators and the influence to advocate their use.

To identify relevant stakeholders to engage in the process, it is helpful to first consider who uses ecosystem services indicators, which is likely to be a wide range of sectors. National, sub-national and local governments are prime users. Other likely users are NGOs, media, research institutes and universities.

Ecosystem services indicators can serve as an important tool for national development planning, reporting and decision making (e.g. NDPs), sector planning, report and decision making (e.g. NBSAPs) and local decision making (e.g. watershed management plans, Payment for Ecosystem Services (PES) schemes, and district development plans). Governmental bodies use indicators particularly, but not exclusively, to track and report progress against specific policy objectives for sustainable development and conservation. NGOs may use ecosystem service indicators to raise awareness about environmental and conservation issues, and to hold government to account on their policies. Media can use these indicators when reporting on environmental issues and government actions. Universities and other educational institutions may use ecosystem service indicators for teaching. The corporate world may produce and use ecosystem service indicators as part of their analyses and reporting of environmental issues, including for Environmental Impact Assessments. Users of ecosystem service indicators can also be found at the international level, and include Parties to MEAs (e.g. CBD, UNFCCC, UNCCD, Ramsar Convention on Wetlands), as well as other international processes such as IPBES, MDGs and SDGs.

One way of identifying who the relevant stakeholders are is stakeholder mapping and analysis. According to Pretty et al. (1995) and Chambers (1997) stakeholder analysis is closely associated with participatory approaches and is often seen as a tool for effective management of natural resources through stakeholder participation. This guidance will not go into any details of stakeholder analysis, as it has been covered extensively elsewhere (e.g. Pretty et al., 1995; Chambers, 1997).

Questions to ask during this step:

- Who are the relevant stakeholders, and do they all need to be consulted?
- What questions do the stakeholders want answers to regarding the ecosystem service of concern?
- How will the stakeholders want to use the indicator(s)? e.g. for decision making, for reporting, for education.
- Have the inputs, expectations and outputs of the indicator development process been clearly defined for the stakeholders?
- How much ownership and decision making power are different stakeholders going to have over the choice of indicators?

Step 2: Identify ecosystem services related policy objectives and targets

When ecosystem services indicators are developed to support decision making and management, the indicator developer(s) and users should identify which objectives and targets have already been agreed. We advise beginning by reviewing national objectives, which all countries have, and policies with direct or indirect impact on ecosystem services. Reporting on progress and change towards these national objectives is a major role for ecosystem service indicators.

Good places to start to identify existing objectives and targets are:

- NBSAPs
- National Ecosystem Assessments
- District development plans
- Protected areas systems plans
- National forest plans
- Fisheries policies
- Water policies
- Land-use plans
- Agricultural plans
- Environmental impact legislation
- Endangered species legislation
- Long-term development strategies
- Five year economic development plans
- District development plans
- Adoption of MDGs at the national level
- Adoption of SDGs at the national level

National and sub-national economic development plans and other sectoral policies rarely have ecosystem services indicators. Not all environmental policies have them either, as they are a relatively new concept that can be difficult to apply in practice. In countries where there is little or no national legislation on ecosystem services, the targets and plans in international agreements such as the CBD (Aichi Biodiversity Target 14) and the MDGs (Goal 7) could be good sources for established ecosystem services related objectives, targets and indicators. The MDG Goal 7 has two tasks:

- 7a Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources.
- 7b Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss.

A number of countries have included one of the seven indicators that correspond to these tasks – (e.g. Indicator 7.1 'Proportion of land area covered by forests') – in their NBSAPs and NDPs.

Some regional strategies, such as the European Biodiversity Strategy also include ecosystem service objectives. Indicators are a key part of reporting on national progress to such international agreements and they serve to raise the awareness and understanding of the policy issue.

If it is difficult to identify relevant management objectives and targets this step might need to be combined with the earlier step of "Identify and consult stakeholders/audience" (Step 1) to obtain more information to guide the development of indicators.

Step 3: Determine key questions and indicator use

Determine key questions

We strongly recommend identifying 'key questions', which describe what the user or audience for the indicator wants to know about the subject. They help define the purpose of the indicator, and since indicators are purpose dependent, this is very important.

One of the benefits of defining a key question is that it naturally encourages people to choose indicators that can be readily interpreted and communicated. Usually some form of narrative text accompanies the presentation of an indicator, for example something explaining the significance of a trend line on a graph, as can be seen in the newly developed indicators in Section 4. The logic of addressing a key question also encourages further analysis and the use of more than one indicator to explain complex issues.

Key questions can be general, such as:

- What ecosystem services does this habitat provide?
- Where are the priority areas for a sustainable supply of ecosystem services?
- Are the ecosystem services declining in our country?

To answer some of these more general key questions several indicators and data sets might be needed. However, if the key questions are precise and specific it makes the selection and development of suitable indicators easier. The more specific key questions tend to be related to management issues, such as:

- What are the main threats to the ecosystem services in the area?
- What is the annual catch level for a fishery?
- What is the status of the tourism numbers visiting the national park?

If struggling to identify indicators, the objectives and targets identified in the previous step can be rephrased as questions, for example; 'Have we achieved the Aichi Biodiversity Target 14?' or 'Are the essential ecosystem services restored and safeguarded?'.

However, if a great variety of questions has been identified, some of them may be so broad or complex in their scope that they may not be best answered using indicators. In these situations, the indicator development team may need to build a shared understanding about the purpose of the indicators being developed and manage the expectations of all involved. A more comprehensive approach might be needed where developing indicators is not sufficient and more detailed analyses are needed or even gathering of field data is necessary.

However, regardless of how easy or difficult it is to identify key questions, this step should ideally be an iterative process where the stakeholders and audience of the indicators are continuously consulted.

Determine indicator use

It is extremely helpful if the intended use of an indicator is detailed as soon as possible. This not only makes communication easier, but also ensures a greater likelihood of the indicator having an impact and continuing to be used.

Relevant stakeholders can be asked about how indicators will be used and this question can be incorporated in the discussion around identifying key questions. The definition of the key question(s) also provides clues to who the user might be. For example, it could be used for: measuring progress; early-warning of problems; understanding an issue; reporting; and/or awareness-raising. If the indicator is to be used for management decision making, will it be used on specific occasions when decisions are made or progress reported, such as an annual review of a programme of work? Who specifically will be using this information? What levels of education and familiarity with the subject does the intended audience already have?

Questions to ask during this step

- What are the key questions that the intended user or audience have about ecosystem services?
- Can the key questions be made more specific or focused?
- How will the indicator be used?
- Who will be using the indicator?
- What level of education and familiarity with the subject does the intended audience already have?

Step 4: Develop a conceptual model

Developing a conceptual model can help to select and communicate indicators in response to key questions. A conceptual model is a diagram that illustrates the main issues of concern and how they are related to each other. Typically the diagram has each issue in a box or circle and the relationships between them are shown by arrows or lines. Accompanying text can give further explanation of the diagram.

A conceptual model helps to clarify this issue for all involved and helps determine the relationship between an indicator and its purpose. The relationship between the measure chosen as an indicator and the purpose of the indicator needs to be scientifically valid and easy to understand. However, it is important to remember that indicators should not be too restricted to make them conform to a conceptual model which might not have complete buy-in from all stakeholders.

Clarifying key questions

The starting point in the production of a conceptual model is the key question(s) of the indicator and any management objectives that have been identified. From these, the scope or boundaries of the subject (e.g. site-specific or national) can be defined. The main subjects or issues in addressing the key question(s) are then identified. These issues and their relationships are then drawn on a preliminary diagram for discussion by the indicator development team, and ideally with the users of the indicator. The conceptual model is then reworked and refined, helping to build a clearer and shared understanding of the subject. This process may lead to changes or further definition of the key questions. At the stage of indicator selection there could potentially be indicators for each of the issues in the conceptual model and for the lines or linkages between them.

What should ecosystem service indicators measure?

One of the major challenges in developing indicators is deciding what to measure. There is not yet a generally accepted approach to measuring the complete bundle of ecosystem services provided by an area (Reyers et al., 2014). As a consequence, proxies are often used and there is a dominance of indicators developed for provisioning services (e.g. fish stock, timber biomass) as these are easier to measure and value.

What makes this even more challenging is that the concept of 'human well-being', which is linked to the ecosystem services concept, is also complex with similar constraints. Figure 2 illustrates how the MA linked ecosystem services to human-wellbeing. In this model, ecosystem services are generated by ecosystem functions, which in turn are underpinned by biophysical structures and processes. The actual ecosystem service provides benefits (e.g. nutrition, health, pleasure) which in turn can be valued in economic terms if deemed useful (UNEP-WCMC, 2011). It is worth noting that any individual service will be supported by a range of ecosystem structures and processes, and that individual structures and processes will support a range of services (Balmford et al., 2008).

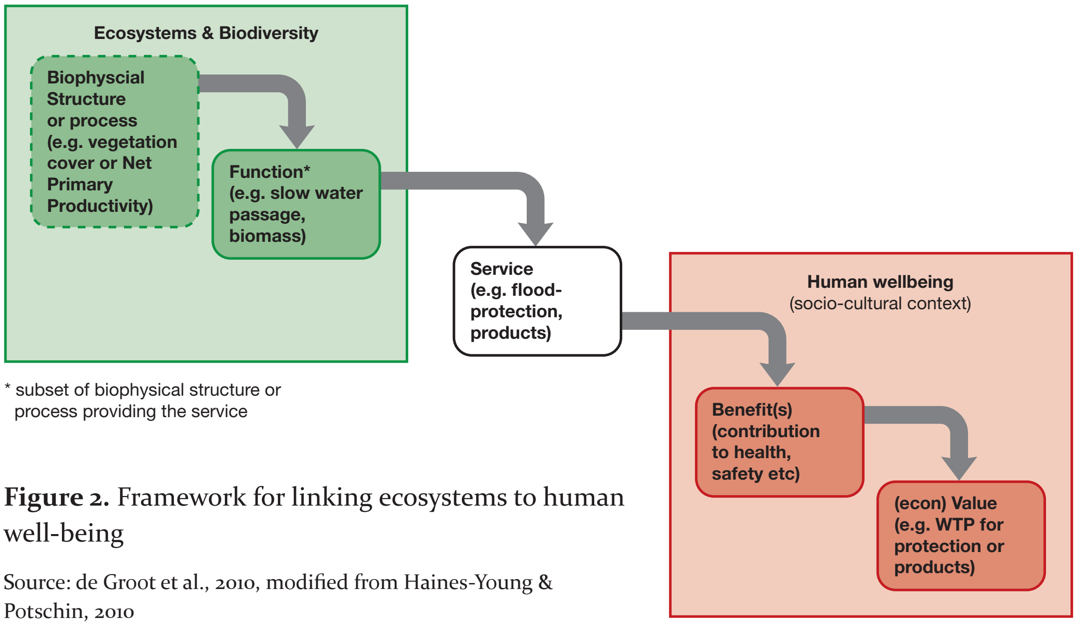

Figure 2. Framework for linking ecosystems to human well-being

Source: de Groot et al., 2010, modified from Haines-Young & Potschin, 2010

Since the MA, several authors (Haines-Young & Potschin, 2009; Rounsevell et al., 2010; Nahlik et al., 2012) have conducted comprehensive reviews of frameworks for defining and assessing ecosystem services and highlighted key strengths and weaknesses with these frameworks (Reyers et al., 2014). Further thinking around the issue has resulted in the development of new frameworks which attempt to make the links between ecosystem structures and processes and human well-being much more explicit (e.g. Tallis et al., 2008, de Groot et al., 2010; Mace et al., 2011; Haines-Young & Potschin, 2009; Turner & Daily, 2008; Fisher et al., 2009; Potschin & Haines-Young, 2011; Boyd & Banzhaf, 2007; Wallace, 2007).

These frameworks and classifications have been instrumental in simplifying the complex process of ecosystem services provision as they provide the logical connections between ecological processes through to human wellbeing and thus offer a useful basis for making ecosystem services measurements and developing ecosystem service indicators (Figure 3) (Reyers et al., 2014). Using these frameworks, ecosystem service indicators can be divided into four types representing different points in the ecosystem-well-being chains. These are: supply, delivery, contribution to well-being and economic value. Table 1 illustrates how the different indicators are divided according to the type of data they use.

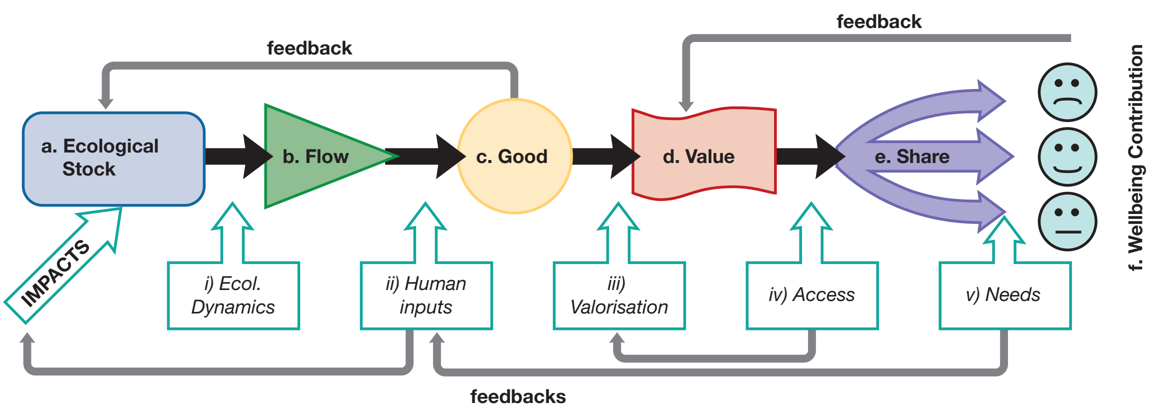

Figure 3. Framework of ecosystem well-being chains.

Source: Ecosystem Service for Poverty Alleviation (ESPA; 2014).

Table 1. Examples of ecosystem services definitions and indicators categorised according to: supply; delivery; contribution to well-being; and economic value.

Source: GEO BON Ecosystem Services Working Group

	Ecosystem Service Component			
Type of services	**Supply**	**Delivery**	**Contributions to well-being**	**Value**
Provisioning	Amount of biomass available for fodder (pasture or forage, Tons) Biomass or abundance of important species	Total production of all commercial crops (Tons), Caloric or micronutrient content of fish landings (grams) Volume of harvested wood (m3)	% caloric or micronutrient intake contributed by crops, % income or number of jobs contributed by aquaculture Basic needs satisfied via ecosystem good or service	Market value of all livestock products (US$) Marginal contribution of irrigation to crop market value Change in malnutrition rate due to wild harvest food
Regulating	Amount of carbon absorbed by vegetation from the atmosphere (Tons of C) Mass of nutrients, organic matter, sediments, or toxic organisms or compounds removed (Kg), changes in temperature, pH Pollinator abundances and pollination rates	Water conditions (e.g. nutrient content, presence of harmfull bacteria) in relation to standards for different water users at or above withdrawal point Marginal contribution of soils to agricultural, forestry and biofuel production Area of avoided flood damaged due to regulation by vegetation and soils (ha)	% of population with reduced negative impacts (e.g. from floods, wind, drought) Number of people protected from infrastructure loss, flooding and erosion from coastal protection Marginal contribution of pest control to food or biofuel production	Market value of carbon uptake (US$) Avoided water treatment costs (US$) Avoided economic loss by flood regulation from vegetation and soils (US$)
Cultural	Area that provides aesthetic views Area that is suitable for nature-based tourism Abundance of plants	Nature based tourism visitation rates, collection rates of plants used for ritual practices	Marginal contributions to income or well-being of visitors and to local inhabitants derived from aesthetic views, attendance at ritual events, frequency of cultural activities	Economic revenues derived from visits to aesthetic areas, marginal contribution to real estate prices by nature-based tourism (US$), strength of cultural identity

Drivers of change on ecosystem service

The IPBES conceptual framework (Figure 4) illustrates how nature and humans are linked. In particular, it includes 'drivers of change' as influencing both natural and human assets. When identifying ecosystem services indicators it is necessary to consider what drivers and pressures affect the particular ecosystem services and create indicators that are linked to these issues. This helps the indicators take into account and reflect the influence of the driver on the state of the ecosystem services in question.

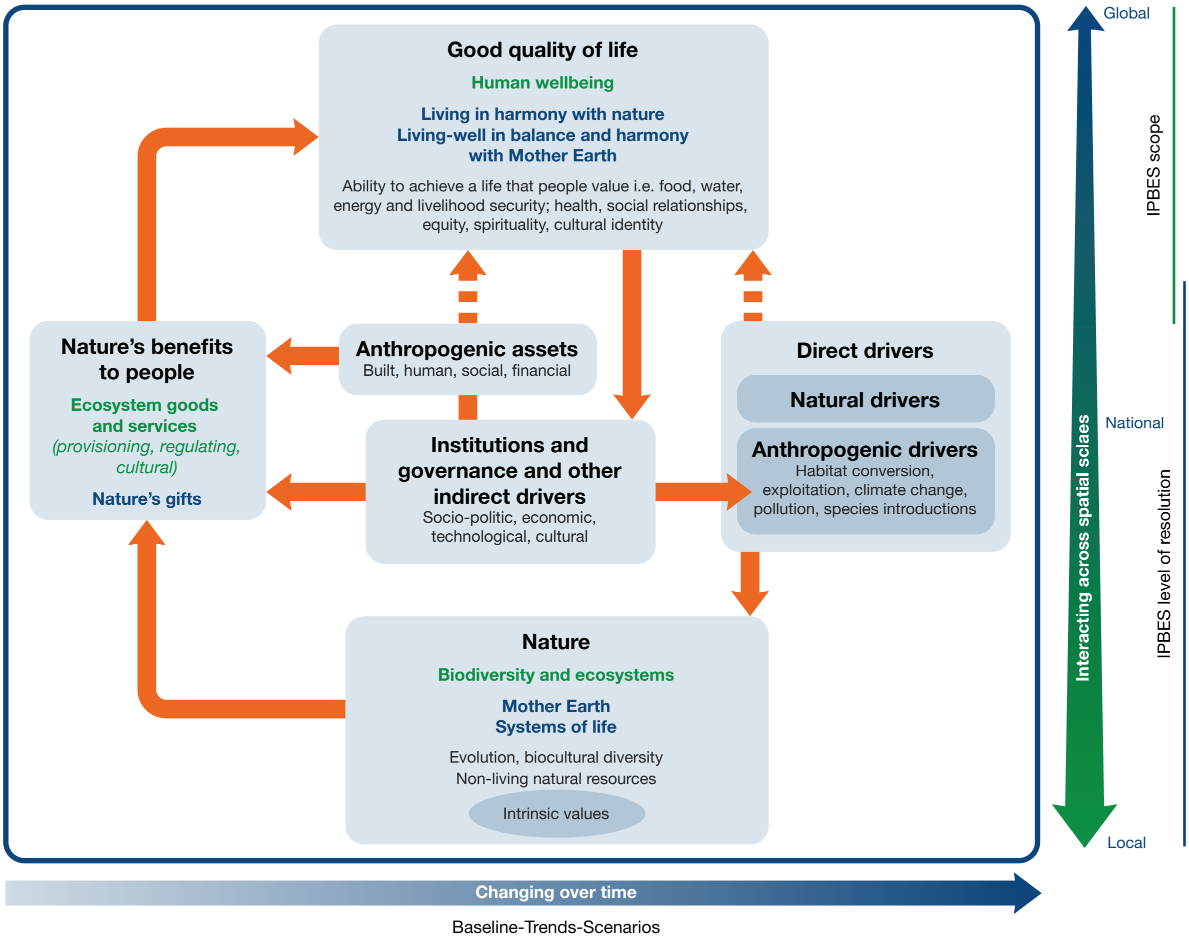

Figure 4. IPBES conceptual framework

Source: IPBES, 2013

The main threats to ecosystem services are (Boulter, 2011):

- Habitat loss and degradation (impacting water cycling and erosion prevention; see Box 2 for example indicators to address these threats).
- Overexploitation and unsustainable use (impacting the provision of food and raw materials).
- Climate change (impacting climate regulation and regulation of water flows).
- Pollution and nutrient load (impacting pollination and recreation).
- Invasive alien species (impacting biological control and genetic resources).

Box 2: Developing ecosystem service indicators for businesses

When developing ecosystem service indicators for businesses one approach is to focus the development on the principle threats to ecosystems. This is called the Global Reporting Initiative (GRI) Framework. The key challenge is to combine ecosystem services-related data, which by nature is site-specific, into aggregated figures that work for businesses. For example, a site-based indicator may show the actual change in soil depth or soil pH, whereas a corporate-level indicator would show the number and location of sites where soil degradation is occurring. The GRI has also developed a range of example ecosystem service indicators against the five main threats to ecosystems (for full list see Boulter, 2011). Example indicators developed to address the key threat of habitat loss and degradation include:

i. Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas.

ii. Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas.

iii. Habitats protected or restored.

iv. Strategies, current actions, and future plans for managing impacts on biodiversity.

Source: Boulter, 2011

Questions to ask during this step:

- Which are the most important or over-arching key questions that can be examined with the aid of a conceptual model?
- What level of detail is required for the conceptual model?
- Who should be involved in the definition of the conceptual model?

Step 5: Identify possible indicators

Identifying indicators takes a combination of scientific rigour and creative thinking. Creative thinking may be a surprising skill in this context, but the indicators with the greatest impact are often produced by using and presenting data in novel ways, including combining different kinds of data in ways that may not seem immediately obvious. Scientific rigour is necessary to identify indicators that are conceptually valid and defensible for their purpose.

This step is best carried out in combination with the next step "gather and review data" as both steps are dependent on each other. Indicators rely on the availability and suitability of data and the searches of data is guided by the identified indicators.

What makes a good ecosystem service indicator?

Successful ecosystem service indicators are:

- **Relevant** to the user's needs.
- **Understandable** – conceptually how the measure relates to the purpose, in its presentation and in the interpretation of the data.
- **Useable** - for measuring progress, early warning of problems, understanding an issue, reporting, awareness raising etc.
- **Scientifically sound** – an accepted theory of the relationship between the indicator and its purpose, with agreement that change in the indicator does indicate change in the issue of concern and that the data used is reliable and verifiable.
- **Sensitive to relevant change / issues**.
- **Practical and affordable** – to ensure its continued use and in this way improve the rigour of the indicator as longer time series are collected.

Indicators for provisioning ecosystem services

Most provisioning services can be documented at national and local scale using national statistics, remote sensing, field estimates and/or models (Reyers et al., 2014). Indicators for food production are commonly used, for example fodder provision for livestock, grain production or productivity in landscapes (Egoh et al., 2012). Secondary indicators are often used to address the lack of data for primary indicators (Egoh et al., 2012). Examples of secondary indicators for food production include: area (hectares) of agricultural land (e.g. from land cover maps); livestock numbers; or vegetation suitability for fodder production and grain yield (e.g. tonnes of rice and maize). National statistics and global datasets (e.g. the Food and Agriculture Organization of the United Nations; FAO) can provide data on livestock and grain production. Information on land cover and vegetation maps can be accessed through continental or global data sets such as GLOBCOVER; GLC2000; and CORINE land cover products (Egoh et al., 2012). These data sources are further described in Step 6.

Considering the four types of indicator – supply, delivery, contribution to well-being and economic value (Table 1) – only delivery and economic value indicators have been widely used so far, because food production and market data are readily available. However, there are little data on biophysical conditions so few 'supply' indicators have been developed so far (Reyers et al., 2014). Provisioning services indicators focusing on contribution to well-being are still in the development stage.

Indicators for regulating ecosystem services

Data needed to develop indicators for regulating services are becoming available, often from national statistics or remote sensing (Reyers et al., 2014). The most commonly available data for these services are those suitable for supply and delivery indicators (Reyers et al., 2014). Indicators of economic value are mostly linked to avoided costs or marginal contributions to economic activities from regulating services. Developing indicators to measure well-being from regulating services is still difficult and in development (Reyers et al., 2014).

By far the most common indicators of regulating services are for climate and water regulation (Egoh et al., 2012). The climate regulation services mainly relate to the regulation of greenhouse gases, where primary indicators can be carbon storage, carbon sequestration, and greenhouse gas regulation (Egoh et al., 2012). Secondary indicators are used to model primary indicators and the most commonly used data is aboveground biomass and belowground biomass but soil carbon, nutrients and vegetation maps can also be important input data (Egoh et al., 2012).

Indicators for cultural services

It is hard to develop indicators for cultural services. The non-material benefits provided by cultural ecosystem services are often deeply interconnected with each other and with material benefits provided by provisioning and regulating services. This means that many of the most important cultural services are co-produced by the same ecosystem components and human activities that produce material objects for consumption (Reyers et al., 2014). For example, the cultural integrity and heritage of coastal communities is often associated with the practice of fishing, which is intimately connected with the provisioning service associated with fish for consumption (Reyers et al., 2014). The development of cultural ecosystem service indicators undertaken during the UK National Ecosystem Assessment Follow-on project (UK NEAFO) is discussed in Box 3.

Walkers in Borrowdale Valley © Undivided 2012. Used under licence from Shutterstock.com

Box 3: Development of cultural ecosystem service indicators in the UK

In the UK National Ecosystem Assessment Follow On (UK NEAFO) project, cultural services indicators were a major component in the cultural ecosystem services chapter. The indicators developed were designed to measure the characteristics of local areas and access to environmental spaces. Indicators were analysed for both the supply side – which environmental spaces are available in a given area – and the demand side – which environmental spaces people seek out and which practices they carry out there.

Through engagement with stakeholders, the UK NEAFO found that, indicators that were focussed on environmental spaces were more useful to environmental decision makers, especially at the local level than those which were more distributed or dislocated. Consequently, indicators were not calculated to measure subjects such as the consumption of cultural ecosystem services through the media or interest in cultural ecosystem services shown through the use of social media groups (although measures of this type are considered important by some stakeholders). The intention of the UK NEAFO was primarily to move discussion forward on cultural services by exploring a range of possible indicators rather than presenting a definitive set of them.

The indicators calculated are of the following types:

1. **Information on the *supply* of environmental spaces**, measured through percentage cover for a range of types of environmental space, e.g. ancient woodland, country parks, grasslands and mountains. Measuring the percentage cover of environmental spaces provides useful indication of differences in the supply of cultural services at a local level.

2. **Measures of *accessibility* to environmental spaces** (these focussed on ancient woodland, country parks, nature reserves and natural land cover as they offer opportunities for a range of cultural practices). This type of indicator takes into consideration that access within an area will vary and that people living within one local area may benefit from access to environmental spaces outside it. The UK NEAFO team therefore calculated measures of accessibility for each 2011 Census Output Area in the UK (N = 181,408), for four different types of environmental space. Two methods were used to calculate accessibility, both borrowed from the ANGSt methodology used to calculate access to public green space (Handley et al., 2003).

3. **Measures of *demand* for certain types of environmental spaces or practices associated with them, such as watching wildlife or walking.** This is important to measure as the degree to which people would like to have access to environmental spaces may differ locally. To address this they produced a Bayesian Belief Network (BBN) showing the probability that a given individual would visit environmental places of various sorts and engage in certain activities within them within a given week. These calculations were done using the HUGIN[1] Expert software and the Monitor of Engagement with the Natural Environment (MENE) dataset; the work drew on a subset of 50,000 records from these which contained spatial information on the location visited, which is based on a questionnaire of over 50,000 individuals within England.

4. **Indicators which may be used to measure the *quality* of environmental spaces such as parks** (e.g. crime rates, noise levels, proxies for biodiversity and the availability of facilities such as play areas). Indicators developed for these types utilise data available nationally, at least for the whole of England. However, there is a wealth of data available at a local level, often under the custodianship of local authorities, which allow a more in depth and richer examination of cultural ecosystem services than is possible using national data sets. Keep Britain Tidy's use of the Green Flag Award for England and Scotland as a quality standard for local parks is a rare example of a peer-assessed standard operating at the national level.

Source: UK NEAFO, 2014

[1] www.hugin.com

The difficulties of separating the different services and identifying which one of the four types of ecosystem service indicators would be best suited to cultural ecosystem service indicators mean that few indicators have been developed for them. Reyers et al. (2014) advise starting with a participatory evaluation of the benefits that are associated with ecosystems and pertinent for a given population.

A very diverse range of indicators have been used to measure cultural ecosystem services. Some completely transformed ecosystems provide cultural services, such suitability for summer cottages, deer hunting and fishing. Services such as recreation are also provided by natural areas, such as forests. Commonly used secondary indicators are distance to resources (such as scenic sites, water bodies, or forests; Naidoo et al., 2011), visitor numbers, land cover, and accessibility to natural areas. Visitor information data are readily available and can be extracted from national statistics or from National Park databases. Accessibility to natural areas could be mapped from easily accessible national or continental data on land cover and roads. However, some services, such as spiritual experience, are difficult to quantify and have thus received the least attention (Egoh et al., 2012).

Who decides which indicators to choose

The selection of the most suitable indicator or indicators may be the responsibility of a single institution, or it might be decided by a committee with representatives from multiple organisations or research groups, such as a steering or advisory committee. Each stakeholder may have a different perspective and there may be many different suggestions of how to approach the problem and how best to answer the key question. Input and critique of this kind is always valuable, but ultimately an indicator or suite of indicators must be decided upon and an approach agreed before the project can move forwards to the next stage. It is worth bearing in mind throughout this development step that no solution or approach is perfect and there will probably always be some criticisms of it. Box 4 contains examples of how the Mapping and Assessment of Ecosystems and their Services (MAES) report presented indicators of provisioning services delivered by forests using a 'traffic light system' to illustrate their readiness for use.

Box 4: Mapping and Assessment of Ecosystems and their Services

The European Commission report 'Mapping and Assessment of Ecosystems and their Services' (MAES) includes a chapter on indicators that were collected in four pilot studies to measure ecosystem services at the national scale. The report takes a traditional approach to dividing ecosystem services according to habitat type and then outlining a number of indicators according to the Common International Classification of Ecosystem Services (CICES) three categories of ecosystem service (provisioning services, regulating/maintenance services, cultural services). The four habitat types that are covered are: forest services; cropland and grassland services; freshwater services; and marine services.

For example, the forest's provisioning services (Table 2) includes those forest services related to forest production of biomass, water and energy. In their analyses the MAES applied a traffic lights system for the identified indicators, which can be seen in Table 2, depending on their readiness of use (green-indicator ready to use, yellow – indicator a relatively good option but requiring further work to be operational, red – much more work is needed to make them operational). Most of the indicators with a green light are related to forest biomass supply and several of the available indicators use data derived from National Forest Inventories (NFI) and from the European Forest Data Centre for European level datasets. The report suggests that Member States use data from their NFI for mapping and assessment of forest-related ecosystem services. They also recognise that remote sensing could be another source of data for forest biomass provision but that these still require ground information from NFI for model fitting and validation of results.

Source: MAES, 2014

Table 2. Indicators for provisioning services delivered by forests. The ecosystem service classification system (division, group and class) used to identify indicators, is based on CICES (http://cices.eu/) and is hierarchical in nature.

Division	Group	Class	Indicators
Nutrition	Biomass	Cultivated crops	
		Reared animals and their outputs	Meat production (Iberian pig species) Meat consumption (Iberian pig species) Number of individuals (Iberian pig) Meat production (reindeer) Meat consumption (reindeer) Number of individuals (reindeer)
		Wild plants, algae and their outputs	Distribution of healthlands and other habitats for bees Distribution of plants important for honey production Distribution of wild berries, fruits, mushrooms (NFI plot data) Distribution of wild berries (modelling) Honey production Honey consumption Wild berries, fruits and mushroom harvest
		Wild animals and their outputs	Amount of meat (hunting) Value of game Hunting records (killed animals)
		Plants and algae from *in-situ* aquaculture	
		Animals from *in-situ* aquaculture	
	Water	Surface water for drinking	Total supply of water per forest area (modelling) Area of forest dedicated to preserve water resources Surface water supply per forest area (at river basin level) River discharge Reservoir water (proxy) Population and per capita water consumption
		Ground water for drinking	None

Division	Group	Class	Indicators
Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	● Forest biomass stock ● Forest biomass increment ● Forest for timber, pulp wood, etc. Production ● Commercial forest tree volume & harvesting rates ● Trees (presence) cork oak for cork & pines for resins ● Tree species (timber trees) ● Wood consumption (industrial roundwood, fuelwood) ● Consumption of cork and resins
		Materials from plants, algae and animals for agricultural use	● Distribution of foraging areas in forest; estimate of grassland shrubland (NPP) ● Marketed forage
		Genetic materials from all biota	● Distribution of plants species with biochemical/ pharmaceutical uses ● Raw materials for medicines
	Water	Surface water for non-drinking purposes	***Same as for drinking purposes***
		Ground water for non-drinking purposes	
Energy	Biomass-based energy sources	Plant-based resources	● Wood fuel stock (fraction of forest biomass stock) ● Wood fuel production (fraction of forest biomass increment) ● Distribution of tress for wood production ● Fuel wood consumption
		Animal-based resources	
	Mechanical energy	Animal-based energy	

Questions to ask during this step:

- Are there existing indicators that can help to answer the key question(s)?
- How well does each of the potential indicators help to answer the key question(s)?
- Is the relationship between the measure used as an indicator and the indicator's purpose scientifically supported and easy for the user to understand?
- Are potential reasons for change in the value of the indicator well understood?
- How easily will it be understood by the intended users?
- Is there suitable data for each of the possible indicators?
- Can existing data be transformed into appropriate indicators?
- What are the resources available now and in the future for producing the possible indicators?
- Who will decide which indicators will be calculated?

Step 6: Gather and review data

The gathering and reviewing of data will most likely be conducted at the same time. The identified key questions will guide the data searches and once data sets have been identified, they will need to be reviewed to determine their suitability. For example, an important aspect of the indicator may be the ability to detect change, for which the data needs to be collected with sufficient frequency and using methods appropriate to give the necessary sensitivity to change. The review of data sets could also include standardising the data to common units and scales, and ensuring the methods used to collect the data are comparable.

Data considerations

Ecosystem services can be considered at multiple scales, from local to national to global, and unlike some biodiversity indicators, there is always an inherent spatial component. Services occur in space, as does the demand for and consumption of those services, which is why the development of many ecosystem service indicators involves a mapping exercise. By definition, an ecosystem service must have a human consumer and the spatial complexities of this make measuring ecosystem services challenging.

Services are underpinned by the associated landscape features and their ecosystem function, such as presence of a forest or river (natural capital). The link between functions and service provision is a growing area of research and it is often the function or the potential for a service that is calculated or mapped, not the service itself. Consumption or benefit (impact on human well-being) is much harder to calculate and attempts to date are most common through calculating economic value.

When indicators are calculated, you will need to consider their scale, resolution, ability to be operationalised and quality assessment (Hernandez-Morcillo et al., 2013; see Box 5).

Estimating carbon stock © Daniel Murdiyarso, Centre for International Forestry Research (2009)

Box 5: Considerations to take when calculating indicators

Spatial scale

Spatial scale can vary from a specific site and a local scale, up to regional, national, continental and even global. The decision made here will depend on the context of the intended outcome of the indicator, the data availability, the needs of the end-user and its relevance to decision making. Conducting a global analysis is possible for a variety of indicators but the data underlying these will undoubtedly be coarser in spatial and temporal resolution.

Temporal scale

Daily, monthly, quarterly, annually and decadal scales can be considered. The choice of temporal scale will depend on the intended outcome of the indicator. For example daily carbon storage calculations at a global scale will be unnecessary and data-heavy, whereas daily values may be crucial for water run-off models in extreme event regulation.

Baseline

Establishing a baseline value will be important for making comparisons over time and this should either reflect a relevant time period i.e. before an event such as the implementation of a new policy to enable review of impact, or one that is accurately measurable.

Operationality

The data and methodology should be selected so that the process can be reproduced in future and by other people.

Validation

This is an important consideration when calculating indicators as it will help to explain outliers and identify inaccuracies.

Multiple data layers

Given the complexity of ecosystem services it is usually a requirement that several indicators be used to more completely represent a service (Müller & Burkhard, 2012). This involves collecting, storing and manipulating a large amount of data.

Measurement units

It is important that the data is collected or can be amended in a way that allows the units to be compared.

Divide/aggregate to spatial unit

Data must also be to the same spatial unit and extent. For example data must be consistent to country level or 1 degree grid cells. Data may need to be interpolated or aggregated which can introduce errors.

Raw/derived data

Data required for indicators often needs to be derived from other datasets to be useful, for example a slope layer calculated using a digital elevation model. This can be done in a number of software packages and will require the correct level of expertise in areas such as GIS or statistics.

Types of data

Data relevant for developing ecosystem service indicators can be found in many different forms and at different scales, including: downloadable databases, statistical compendia, spatially mapped data, academic research and books. The most common sources of data for ecosystem service indicators can be divided into four categories:

1. National statistics
2. *In-situ* observations
3. Remote sensing
4. Numerical simulation models

National statistics

Census data is readily available for several ecosystem services at national scales. Census data may be presented as an individual figure for a country or may be spatially disaggregated.

Examples of indicators calculated using national statistics:

1. Provisioning - annual national fish catch and employment in the forestry sector.
2. Regulating - incidence of waterborne/water-related disease per year and area of sloping farmland of 25 degrees or greater.
3. Cultural - percentage of land designated as a protected area and number of people employed in the tourism industry.

Global databases of ecosystem services held by FAO[2] are a good starting point for information on provisioning services. Data can be found on the amount produced and extracted (delivery), traded and the monetary value for many crops and other foods (for example, FAO, 2012). For some services, the data are updated annually and monitored in most countries (e.g. crops), while others are only updated infrequently and by a smaller number of states (~5 years, e.g. water withdrawal) (FAO, 2014).

Be aware that data accuracy varies in national statistics. The quality of the data depends on a country's monitoring infrastructure which is much dependent on the resources available. Data gaps across years are thus common in poorer countries and FAO use estimates to compensate for this lack of data which contains biases. So care needs to be taken when using this type of data and uncertainty analyses are recommended to improve the reliability of the data.

In-situ observations

In-situ observations can be data gathered from both field-based estimations, community monitoring and local/household surveys of ecosystem services. Data gathered through field-based estimations is important for validating models and remotely sensed data products.

Examples of indicators calculated using *in-situ* observations:

1. Provisioning - total annual rainfall; the number of floral species providing medicinal use.
2. Regulating - soil organic content; percentage contribution of groundwater to base flows per quaternary catchment (Egoh et al., 2009).
3. Cultural - number of recreational facilities (Ingold & Zimmermann, 2011); song lyrics in local music (Rodríguez et al., 2006).

There are several challenges with collecting primary data. First, it can be costly, time consuming and require technical expertise. Second, methods and information from different data sources need to be standardized. However, toolkits are emerging to deal with these challenges. For example, the Toolkit for Ecosystem Service Site-based Assessments (TESSA; Peh et al., 2013) whether development or restoration, would affect the delivery of services and the distribution of any benefits among stakeholders. However, there are relatively few empirical studies that present this information.

[2] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/biodiversity-and-ecosystem-services/en/

One reason is the lack of appropriate methods and tools for ecosystem service assessment that do not require substantial resources or specialist technical knowledge, or rely heavily upon existing data. Here we address this gap by describing the Toolkit for Ecosystem Service Site-based Assessment (TESSA) which provides practical guidance on how to measure and monitor a number of ecosystem services at the site scale with limited time and resources, and how to assess the potential impacts of changes in land use on these services. It also helps the user to decide which services to include in the assessment, what methods to use, and how to communicate the results.

Community monitoring of ecosystem services enables year-round, low cost generation of local data and wide spatial coverage. Further advantages of this data gathering technique are that it: provides information for local-level decision making; generates local jobs; raises interest in conservation; allows for the incorporation of traditional ecological knowledge; and helps maintain cultural heritage and identity (Dickinson et al., 2010). Several data gathering tools now exist to facilitate communities to gather, store and share data. Cybertracker (Liebenberg et al., 1999) and Open Data Kit by Google are two of the major tools that local communities are able to use to collect accurate data. However further work is needed to develop adequate validation mechanisms for these kind of data.

Remote sensing

Remote sensing consists of data collection from a distance and can be classified according to the height in which data is recorded; ground level, airborne level such as aircraft and balloon; space borne such as satellites and space stations (Secades, 2014). Remote sensing can be used to estimate both terrestrial and ocean primary production, enabling the measurement of production of crops, feed, wood, biofuel and the regulation of climate through changes in carbon stock. Remote sensing has also shown potential for monitoring inland and marine water quality, as well as water quantity. With new tools such as Global Forest Watch[3], where changes in forest cover can be detected in real time, opens opportunities for much more frequent data gathering and close monitoring.

Examples of indicators using remote sensing:

1. Provisioning - area of agricultural land per grid cell (Anderson et al., 2009).
2. Regulating - Total mg/ha of above ground carbon and global loss of annual net productivity between 1981 and 2003.
3. Cultural - number/area of heritage sites.

Using remote sensing for indicator development has many advantages, some of the key ones are: it is a relatively cheap and rapid method to acquire up-to-date information over a large geographical area; it provides a continuous, repetitive and large scale synoptic view; it is a practical way to obtain data from inaccessible and dangerous areas; and these data are easy to manipulate with a computer and combine with other geographic coverage in GIS (Secades et al. 2014). However, there are also some disadvantages that it is important to be aware of, these are: high uncertainty in remote sensing data as they are not direct samples of the phenomenon; it is expensive to build and operate remote sensing instruments; and it can be difficult to interpret remote sensing data, unless the person has a good knowledge of how the instruments work, the measurement uncertainties and the phenomena being observed (Secades et al. 2014).

Numerical Simulation Models

Often data is not collected or cannot be obtained through the methods described previously, for example because the service is complex, such as climate regulation or water regulation. In these instances numerical simulation models are able to calculate phenomena, given other variables.

Examples of indicators using numerical simulation models:

1. Provisioning - total annual water yield per unit area and potential annual agricultural yield per unit area (Koschke et al., 2014).

[3] http://www.globalforestwatch.org/

2. Regulating - Annual carbon flux per unit area and soil water storage capacity per unit area.

Modelling software, such as WaterWorld[4] and the Universal Soil Loss Equation (USLE), allow numerical modelling of an area to establish ecosystem service values. WaterWorld can be used to understand the hydrological and water resources baseline and water risk factors associated with specific activities under current conditions and under scenarios for land use, land management and climate change. The USLE has been applied in more than 100 countries to estimate soil erosion by raindrop impact and surface runoff, and has been used to guide conservation planning, assess soil erosion for conservation policy development, and to estimate sediment yield (Stone & Hilborn, 2000).

A wide range of models exist for monitoring ecosystem services, and these are useful to understand how ecosystem services respond to changes in biophysical or societal conditions (Bagstad et al., 2013; Crossman et al., 2013). Some of these models also describe how the supply, delivery, benefits to well-being and value of ecosystem services change across space and time. Data inputs needed for these models can be gathered from remote sensing, field-based estimations or data simulation models. There is a range of software tools available to help calculate ecosystem services, for example tools such as the Integrated Valuation of Environmental Services and Tradeoffs (InVEST) and Co$ting Nature provide platforms for users to analyse data and produce values, maps and other information that are useful. The most common modelling platforms used for monitoring ecosystem services are described in Box 6.

Box 6: Decision-support and modelling tools

InVEST[5] has been widely used to assess multiple ecosystem services in one geographical region and show the workflow of implementing the tool. It uses ecological production functions to model the provision and demand for services, i.e. how changes in inputs (ecosystem service supply or potential) affect outputs (services) (Nemec & Raudsepp-Hearne, 2013). Ecosystem processes and services that can be modeled by InVEST so far include: wave energy, coastal vulnerability, coastal protection, marine fish aquaculture, marine aesthetic quality, fisheries and recreation, marine habitat, terrestrial biodiversity, carbon storage and sequestration, reservoir hydropower production, water purification, nutrient retention, sediment retention, timber production and crop pollination (Nemec & Raudsepp-Hearne, 2013).

Co$ting Nature[6] calculates the spatial distribution of ecosystem services for water, carbon, hazard mitigation and tourism and combines these with maps of conservation priority, threatened biodiversity and endemism to understand the spatial distribution of critical ecosystems. The tool identifies the potential and realised services. These data are combined with analysis of current human pressures and future threats on ecosystems and their services in order to assess conservation priorities.

ARtificial Intelligence for Ecosystem Services (ARIES)[7] maps and values ecosystem services and assesses the impacts of land use on them. ARIES is a software application that supports ecosystem service assessment and valuation. It builds models of supply and demand for ecosystem services from stored component models, and simulates the dynamic flow of benefits spatially.

Multi-scale Integrated Models of Ecosystem Services (MIMES)[8] is a suite of models for land use change and marine spatial planning decision making. The models quantify the effects of land and sea use change on ecosystem services and run at global, regional, and local levels. Access to the SIMILE software is required.

Lund-Potsdam-Jena Managed Land model (LPJmL)[9] is designed to simulate vegetation composition and distribution as well as stocks and land-atmosphere exchange flows of carbon and water, for both natural and agricultural ecosystems.

[4] http://www.policysupport.org/waterworld
[5] http://naturalcapitalproject.org/InVEST.html
[6] http://www.policysupport.org/costingnature
[7] http://www.ariesonline.org/
[8] http://www.ebmtools.org/mimes.html
[9] http://www.pik-potsdam.de/research/projects/activities/biosphere-water-modelling/lpjml

Table 3 compares the different data sources that can be useful in choosing the types of indicator and data sources to use. Despite the numerous potential sources of data described here, availability of data is one of the major challenges when developing ecosystem service indicators.

Table 3. Comparison between different ecosystem service data sources. National statistics: FAOSTAT, The Statistics Division of FAO[¥]. TESSA: Toolkit for Ecosystem Service Assessments (Peh et al. 2013), Natura 2000: Assessing Socioeconomic Benefits (Kettunen et al., 2009), InVEST (Talllis et al., 2013), LPJmL (Bondeau et al., 2007), ARIES (Bagstad et al., 2011), MIMES (Altman et al., 2012)

	National statistics	Remote sensing		Field estimations		Models			
		High resolution	Low resolution	TESSA	Natura 2000	InVEST	LPJmL	ARIES	MIMES
Ecosystem service component									
Supply		✓	✓			✓	✓	✓	✓
Delivery	✓			✓	✓	✓		✓	✓
Contribution to well-being				✓	✓				✓
Value	✓			✓	✓	✓		✓	✓
Spatial scale									
Local/ landscape		✓		✓	✓	✓		✓	✓
National	✓		✓			✓	✓	✓	✓
Global									✓

[¥]http://faostat.fao.org/

Source: GEO BON Ecosystem Services Working Group

Data sources

Ecosystem service indicators often require information from a variety of sources, including environmental, social, economic, political and judicial sources. For example, economic government departments, health charities and NGOs, tourism bodies and the general public are all possible sources of useful information and data that can be used to calculate indicators. Table 4 provides guidance as to what data source and tool might be useful when calculating indicators for a range of ecosystem services and Box 7 presents datasets and sources of data that were used to develop indicators with sub-global assessments.

Table 4. Data sources for ecosystem services. The list of data sources is not exhaustive but only refers to the data sources we were able to review. Additional sources: IEA: International Energy Agency, provides information on land cover by biofuel crops, CDM: Methodologies developed by the Clean Development Mechanism (CDM), ISO14040/44: Standard Methodologies for full life cycle assessments of biofuels (Finkbeiner et al., 2006), WDCGG: World Data Centre for Green House Gases, IPCC: Standards for measuring carbon stocks and uptakes developed by the Intergovernmental Panel on Climate Change, IPM: Integrated Pest Management protocols for field surveys developed by University of California, Davis. i: Contribution of remote sensing as one of the information layers.

Service	National statistics	Remote sensing	Field estimations	Models	Additional data sources and comments
Provisioning					
Crop	FAOSTAT	✓	TESSA	ARIES, LPJml, MIMES	
Fodder		✓		MIMES	
Livestock	FAOSTAT			MIMES	
Aquaculture	FAOSTAT	✓		INVEST	
Fisheries	FAOSTAT	✓		ARIES, MIMES	Only subsistence fisheries from ARIES
Wood	FAOSTAT	✓		INVEST, LPJmL, MIMES	
Biofuels	FAOSTAT	✓		MIMES	IEA, CDM, ISO14040/44
Game meat	FAOSTAT	✓		MIMES	
All harvested wild goods		✓i	Natura	ARIES, MIMES	
Water		✓i	TESSA	INVEST, LJPml, ARIES, MIMES	
Hydropower energy		✓i		INVEST, MIMES	
Regulating					
Climate regulation (Carbon stocks and uptake)	WDCGG	✓	TESSA	INVEST, LJPml, ARIES, MIMES	IPCC, National statistics available for selected countries. Carbon uptake needs monitoring through time
Regulation of marine and freshwater quality		✓	Natura	INVEST, MIMES	Only nutrients-freshwater for Natura. Highly patchy data availability. Quality defined with respect to users.
Regulation of soil fertility				MIMES	Multiple local survey methods
Regulation of soil erosion		✓i	Natura	INVEST, ARIES, MIMES	Marine/coastal and terrestrial erosion models from INVEST
Flood regulation		✓i		ARIES, MIMES	
Coastal protection		✓i		INVEST, MIMES	
Contribution of coastal habitat to fisheries		✓i		INVEST, MIMES	
Pollination			Natura	INVEST	
Pest control			Natura, IPM		
Cultural					
All non-tangible benefits				MIMES	Chan et al., 2012; Klain & Chan, 2012 for field protocols.
MIMES models differential user demand					
Aesthetic views		✓i		INVEST, ARIES	
Nature-based tourism		✓i	Natura, TESSA		

Source: GEO BON Ecosystem Services Working Group

Box 7: Datasets and sources of data used to develop indicators within Sub-global Assessments

For developing ecosystem service indicators, Sub-Global Assessments (SGAs) used data from national statistics, government databases, regional and international agencies (e.g. FAO, Convention on International Trade in Endangered Species; CITES, World Travel and Tourism Council; WTTC and National Aeronautics and Space Administration; NASA), databases from university and research institutes, as well as literature review and expert assessments. Additionally, original research including field observations and measurements, monitoring data and expert assessments also provided valuable information for developing ecosystem services indicators.

The majority of assessments used data from national statistics and government databases, government ministries and departments (e.g. forestry, water, natural resource, land and agriculture ministries), regional and international agencies (e.g. FAO, CITES, WTTC and NASA) and databases from university and research institutes (e.g. University of British Columbia (UBC) Fisheries Centre Sea Around US project).

Data and information used for developing indicators of **provisioning services** such as food provisioning and in particular of capture fisheries (e.g. annual fish harvest, real USD value of fish harvest and catch per unit effort) were obtained mainly from institutions such as FAO, global and regional fish datasets from FISHSTAT and UBC Fisheries Centre, Sea Around Us Project 2006 and government databases. Institutions such as CITES also provided data used to develop provisioning services indicators such as traded species products.

Data used for developing indicators of **regulating services** was principally obtained from literature reviews, national statistics (e.g. statistical datasets on land-use change and satellite image), remote sensing data (MODIS), NASA, and government ministries of forestry, water management, natural resources management, land and agriculture, field measurements and expert assessments and regional institutes (e.g. the Caribbean Institute for Meteorology and Hydrology).

Data for developing indicators of **cultural service***s* was obtained mainly from WTTC, interviews with local experts, protected area managers, data from local authorities and protected areas, literature review, field counts, reports of the hunting control service in Altai-Sayan Ecoregion, expert assessments, household views, literature review and national statistics from forestry and environment and tourism ministries.

Supporting services data sources included national statistical datasets on land-use change and satellite images. As for indicators fulfilling more than one ecosystem service, data sources included literature reviews, national statistical datasets on land-use change and satellite images, various research reports, UN World Statistics Pocket Book, government departments and ministries, FAO's, Forest Resources Assessment Division and Landsat ETM+, Earth Trends and Global Land Cover Facility.

The analysis found out the datasets used had a variety of shortcomings, which therefore present key challenges in developing sound ecosystem service indicators. Most of these data are often patchy and in some cases based on one-off or ad hoc studies, rather than ongoing monitoring. Some of the data are not comparable over a number of years. As a result, integrating existing data sets and making them comparable to produce time-series statistics is a key challenge. Improving the data collected at different scales by these agencies could be essential to the development of robust ecosystem service indicators.

Source: UNEP-WCMC, 2011

> **Questions to ask during this step:**
>
> - Are the methods of data collection and analysis scientifically valid and defensible (considering the conceptual model)?
> - Have all the steps for calculating the indicator been documented so that someone without prior experience of the indicator can follow them?

Step 7: Calculating indicators

The actual calculation of indicators through the use and presentation of data is an iterative process to explore different methods and find the most suitable ones. Since this is an iterative and creative process, in many ways this step overlaps with the previous ones to identify possible indicators and review the data, as well as the communication of indicators.

The starting point for calculating an indicator is the identification of the key question to be addressed. The calculation method of an indicator will depend on the rationale, the intended use and the ecosystem service classification system and conceptual framework being used. It is important to clarify exactly what each term means and to whom, so as to establish a common language.

We now consider a hypothetical example to illustrate these issues. Imagine that a key question has been chosen to be "What value does our forest stock in x catchment provide?" In this case, an environmental agency reports water, vegetation and population catchment figures to the government's environment department. Two data sources available are interview responses conducted with a subset of inhabitants who live in forested areas and daily water flow measurements of rivers in the catchment.

To be able to calculate indicators these data must first be understood, in terms of source, accuracy, strengths and limitations. In this example only a subset of inhabitants were interviewed and the water dataset has blank values for one year as the equipment was washed away following a storm. Considering these two data sets it is likely that extra data sets will be required to provide a more suitable range of indicators, such as tourism, timber harvest and forest type data.

Once data sets have been identified, assessed and understood, then methods of calculating the indicator(s) can be tried. For example, a bar graph might be used to show how water flow has changed over time, or a series of pie charts used to demonstrate demographic changes. Extra data could be introduced to show the impacts on water provision following an event such as a storm or deforestation. A map could be used to show the spatial relationship between water provision and water resource users. The indicator calculation could use a method to produce an index value, such as the Living Planet Index[10], for example the calculation of the overall ecosystem service value of an area given a suite of services. Box 8 shows how a proxy indicator to measure progress towards Aichi Biodiversity Target 14 was calculated.

[10] http://www.bipindicators.net/lpi

Box 8: Calculation of an indicator for Aichi Biodiversity Target 14

The Biodiversity Indicators Partnership (BIP) brings together over 40 international data providers in order to produce a suite of global indicators. These indicators are used to track progress towards the Aichi Biodiversity Targets, a framework for monitoring implementation of the Strategic Plan for Biodiversity 2011-2020, adopted by the CBD Conference of the Parties in 2010.

Within the BIP suite of indicators, the indicator '*Biodiversity for Food and Medicine*' has been used as a proxy to measure progress towards Aichi Biodiversity Target 14.[11] This indicator comprises of a Red List Index for amphibians, birds and mammals used for food and medicine, the Accessibility Index to track the changes of affordability of wild sourced products (Figure 5), change over time in the conservation status of animals used for food and medicine and a baseline for the conservation status of medicinal plants.

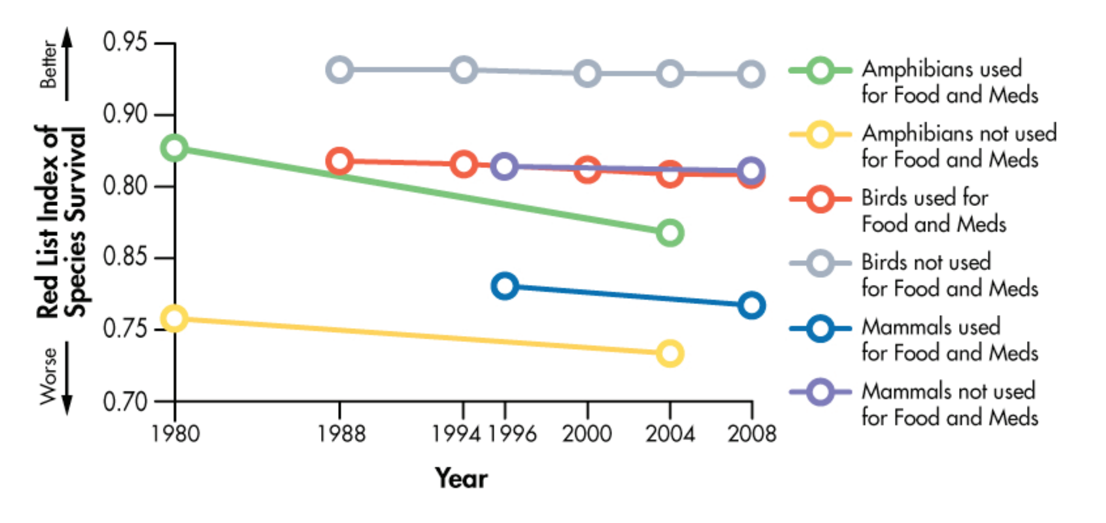

Figure 5. Red List Indices showing the proportion of species expected to remain extant in the near future without additional conservation action for amphibians, birds and mammals.

Source: IUCN & BirdLife International, 2008 & Chenery et al., 2013

[11] Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

Step 8: Communicate and interpret indicators

Indicators as communication tools

Indicators can be seen as a communication tool to help people understand complex issues. They therefore need to be presented and interpreted appropriately for their intended audience. For example, one of the benefits of defining a key question is that it naturally encourages the selection and communication of the indicators in a form that aids their interpretation. Defining this key question with stakeholders also means that the presentation and communication methods are more likely to be appropriate for the intended audience, in terms of language, graphics and media.

Visuals such as graphs or maps can be much more appealing to the end user and often portray the key message more succinctly than text alone. They also allow several pieces of information to be presented at once (Box 9). Maps identify spatial patterns, overlaps and gaps and also provide a focus and context to facilitate discussion and support decision making (MAES, 2013). Using succinct text in response to a key question to accompany these visuals will facilitate the reader's understanding of the indicator message. This explanation may be part of the legend below a figure or within the text surrounding it and should include the purpose of the indicator and how to interpret any trends.

Box 9: Using maps to present ecosystem service indicator information

The MA (2005) gave increasing prominence to the role played by ecosystems in providing for the health and well-being of humans. The 'Health and well-being of communities directly dependent on ecosystem goods and services' indicator is an attempt to develop an associated metric that reflects such important and complex linkages. The indicator demonstrates the link between poverty and vulnerability to the loss of biodiversity. It builds on the statement in the MA that it is the poorest members of society whom suffer most greatly from such loss, and looks to raise awareness of this fact to decision makers. The indicator is an overlay of (i) the health status (using subnational infant mortality statistics) of (ii) the numbers of people that are highly dependent on their environment – defined as living more than six hours from urban areas of at least 50,000 people – against (iii) the threat category assigned to ecoregions. The indicator information is displayed as a 'heat map' (Figure 6), with the most badly affected areas displayed in dark red. This aids the easy interpretation of the indicator, and communicates the important message in a powerful visual manner.

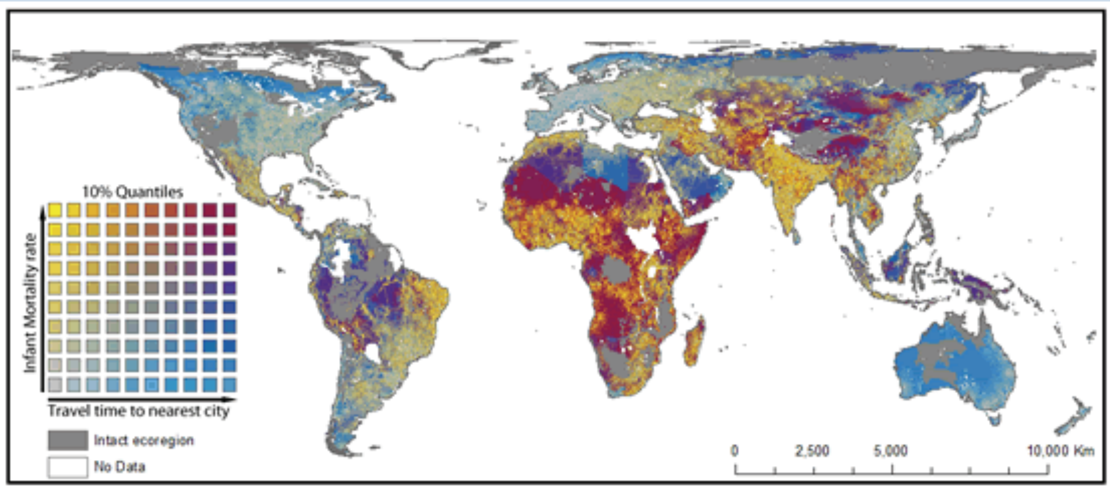

Figure 6. Poverty and Isolation within critically threatened and vulnerable ecoregions

Source: BIP, 2012

Using indicators to communicate stories

Overall we recommend that the communication of indicators be designed in the form of a 'story' or narrative about the subject, in response to the key question(s). The narrative surrounding an indicator is essential, as indicators by themselves provide only a partial understanding (indication) of an issue. They always need some analysis and interpretation of why they are changing and how those changes relate to the system or issue as a whole. Additional information allows the reader to put the indicator in context and see how it relates to other issues and areas. Information to support and explain the indicator should therefore be collected as the indicator is developed.

It is important to know your audience when communicating your message using indicators. This will greatly affect the method and style of how you present the information, for example scientists and technical experts will require a very different product to policy makers and the general public. The former will have knowledge and experience in technical methodologies and data and are likely to want to see a range of information and uncertainty levels. The latter generally respond well to the presentation of single indicators which clearly communicate the message, using as few indicators as possible with an engaging layout.

Questions to ask during this step:

- Is the indicator presented appropriately to facilitate communication?
- Does the indicator communicate a story to the intended audience?
- What kind of media do I want to use to communicate the indicator storyline?
- Have I tailored the indicator outputs to the intended audiences?

Step 9: Test and refine the indicators with stakeholders

A key step in the production of successful indicators is to test and refine the indicators with the stakeholders who will use them. For indicators which involve the development of new methods, or new combinations of datasets, this testing and refining is a central part of indicator development.

The presentation of draft or preliminary indicators is useful for both indicator developers and stakeholders. For stakeholders, it allows them to see how the indicator is progressing, whether it answers their questions and how it might be used in decision making. Those producing and presenting the indicators should be ready to make changes in response to this feedback. This consultation should therefore be regarded as an ongoing, iterative process.

If the development of the indicator involves a number of stakeholders, each may have differing expectations of the degree to which they are expected to be involved in ongoing review of the indicator. For example, in developing ecosystem service indicators at the watershed level, different categories of stakeholder will have distinct expectations of their involvement. Local communities and resource users may be mainly interested in just the resulting indicators and interpretation of the issues, to empower them in decision making and resource use. However their involvement in the development of the indicator will be crucial in understanding resource use, cultural priorities and the impact on well-being. Policy makers and regulators may be primarily interested in the end results of the process as it provides them with background information on the state of the resource. Government resource management and research institutions, who are actively involved in the indicator development process, may use it to build their own capacity and understanding. NGOs may also often be interested in the process as much as in the end-product, seeing it as a possible way of enhancing the participation of the wider community in decision making. All of these groups may also be interested in the process and the final indicator if it will inform potential payment for ecosystem service schemes to be implemented in the area.

Even though the opinions, or needs, of stakeholder organisations may differ and there are practical limits to the extent to which indicator developers can make changes to accommodate them. It is important for the organisation or group leading the development of the indicator to manage these expectations, and to co-ordinate the review of the indicator in such a way so that stakeholders provide appropriate input and review it in a constructive and positive way.

Questions to ask during this step:

- Does the indicator answer the users' key question(s)?
- Is the indicator fit for purpose?
- Is the indicator understood in the intended manner by the users?
- What improvements could be made to the indicator and its presentation?

Step 10: Develop monitoring and reporting systems

A lack of suitable data, especially data with comparable time series, is often given as a barrier to producing ecosystem service indicators. If valuable ecosystem service indicators are identified and chosen for use over time then an investment is required in the monitoring systems to produce trustworthy and accessible data. The ongoing production and reporting of ecosystem service indicators also requires establishing the institutional and technical capacity for this work. This capacity may not exist within a single agency, and may involve both NGOs and government agencies working in partnerships to generate indicators and collect data over time. The need for capacity may not solely be in scientific analysis but also in such areas as communication and writing skills. Therefore, teams with diverse backgrounds and training may be most effective in generating and communicating indicators.

Working in partnerships and different organizational configurations makes careful documentation of the work done and data collected even more important. Careful management of data and associated metadata is a vital part of this process. Producing an indicator fact sheet is a powerful way to guide and support all stages of indicator development and its ongoing production. The consistent production and reporting of an indicator over time requires one institution to have this responsibility, although it is not necessary for this to be the same institution as that which produces and uses the indicator.

One way to promote the sustainable production of an indicator is for it to be recognised and adopted by a national statistical agency. This endorsement and demand for its regular calculation provides a strong case for the necessary long-term investment of resources. This investment must include the maintenance of a monitoring system to produce reliable data over time. Also, the more an indicator meets a real decision making need, and is effectively communicated, the greater the likelihood that resources will be found for its continued production.

Questions to ask during this step:

- Is there sufficient institutional technical capacity and resources to produce the indicator now and in the future?
- Is there a clear institutional responsibility for the continued production and reporting of the indicator?
- Do data collection and monitoring systems or agreements need to be strengthened?

Coffee plantation, Colombia © David Persson, Shutterstock.com

3 Mainstreaming ecosystem service indicators

This section describes the process of mainstreaming ecosystem service indicators into existing monitoring and reporting systems of policies and plans at international, national, sub-national and sectoral levels. It explains the why and how of mainstreaming ecosystem service indicators with a particular focus on the entry points, enabling factors and approaches and tools for mainstreaming. Finally the section describes approaches that are available to support mainstreaming ecosystem service indicators as well as key success factors for mainstreaming.

3.1 WHAT IS MAINSTREAMING OF ECOSYSTEM SERVICE INDICATORS?

Mainstreaming biodiversity is one of the priorities of high level international policy and processes, for example, the CBD, UNCCD, IPBES, the MDGs and SDGs. The term mainstreaming is often used as a verb by itself. The concept was developed out of the need to influence dominant institutions with the values and practices of those of lesser political influence(Huntley & Redford, 2014). There are several definitions of mainstreaming (Box 10).

Box 10: Examples of definitions of mainstreaming

International Institute for Environment and Development (IIED): Mainstreaming can be thought of as "*inclusion or integrating a set of actions that have traditionally been seen as marginal issues into broader development policy*" (Dalal-Clayton & Bass, 2009).

Convention on Biological Diversity (CBD): mainstreaming is the "*integration of the conservation and sustainable use of biodiversity in both cross-sectoral plans such as sustainable development, poverty reduction, climate change adaptation/mitigation, trade and international cooperation, and in sector-specific plans such as agriculture, fisheries, forestry, mining, energy, tourism, transport and others*" (CBD, 2011).

The African Leadership of the NBSAPs 2.0 Project: Mainstreaming is the "*the integration of biodiversity concerns into defined sectors and development goals, through a variety of approaches and mechanisms, so as to achieve sustainable biodiversity and development outcomes*" (African Leadership Group, 2012)

Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF): Biodiversity mainstreaming is "*the process of embedding biodiversity considerations into policies, strategies and practices of key public and private actors that impact or rely on biodiversity, so that it is conserved and sustainably used both locally and globally*" (Huntley & Redford, 2014).

Most of the definitions highlight three key characteristics of mainstreaming:

1. Mainstreaming is a deliberate process.
2. There are multiple routes and/or outputs that can be targeted (e.g. policies, plans and legislation).
3. Mainstreaming should should take place across multiple levels of government as well as across central government and sectors.

The overall desired outcomes of mainstreaming ecosystem service indicators are that:

- chosen indicators are formally incorporated into monitoring and reporting systems of development and environment policies and plans at all levels – i.e. sectoral, local, national and global levels;
- indicators are updated on a regular basis, so that they can be used to track change over time;
- indicators are actually used to support policy and decision making, whether this be in reports on progress towards targets, analysis of important issues, or in education and the news/media.

In these guidelines, we define "mainstreaming ecosystem service indicators" as the integration of ecosystem service indicators, that are identified and chosen for use over time, into existing monitoring and reporting systems of economic development and biodiversity policies and plans at global, national, sub-national and sectoral levels, through a variety of approaches and mechanisms to achieve specific outcomes.

Ecosystem service indicators can be both a tool for mainstreaming ecosystem services into policy processes (for example, ecosystem service indicators can play an important function in supporting the incorporation of biodiversity and ecosystem service values into policies such as NBSAPs), and can also be mainstreamed themselves into existing monitoring and reporting systems of policies and plans at global, national, sub-national and sectoral levels. However, these Guidelines focuses on the latter i.e. mainstreaming ecosystem service indicators into existing monitoring and reporting systems of policies and plans. Mainstreaming of ecosystem service indicators into existing monitoring and reporting systems of policies and plans at global, national, sub-national and sectoral levels denotes that the chosen indicators for ecosystem services are, for example, incorporated into mandates of data-gathering and monitoring and reporting institutions such as national statistical agencies. Furthermore, it will also ensure that monitoring and reporting systems gather ecosystem service data at sufficient temporal and special scales with sufficient regularity and at a relevant scale to track changes at a rate appropriate to the "characteristic scale" of ecosystem processes and flow of services.

3.2 WHY IS MAINSTREAMING ECOSYSTEM SERVICE INDICATORS IMPORTANT?

Ecosystem service indicators are generally missing from standard monitoring and reporting frameworks of national and sub-national economic development policies and plans. As a result, ecosystem service impacts have the potential to be overlooked in planning and decision making. Mainstreaming ecosystem service indicators will help to enhance the recognition of the importance of ecosystem services to humans and the importance of measuring and assessing these services over time. In doing so, it is anticipated that the business case for ecosystem service indicators will become more self-evident and, consequently, will draw greater financial, human and technical resources for their development and regular update.

3.3 WHAT MIGHT ECOSYSTEM SERVICE INDICATORS MAINSTREAMING LOOK LIKE?

The mainstreaming process entails strengthening and adapting the existing national monitoring and reporting systems to integrate ecosystem service indicators. The process will build on existing institutions and sources of information as well as adapting existing statistical systems and data sources. The ultimate objective of mainstreaming of ecosystem service indicators is that national and sectoral monitoring and reporting systems include consistent data over time on the status and trends of ecosystem services and enable regular update of the indicators. Mainstreaming can be helped by having databases that can store information for ecosystem service metrics and indicators and integrate those data with information on human well-being, direct and indirect drivers of ecosystem change, and policy responses. For example, the European Union makes indicators on natural resource management publicly available online (Eurostat) and the Global Reporting Initiative standards for corporate sustainability reports require companies to report on water. If ecosystem service indicators are to be mainstreamed, they need to be produced regularly and with consistent and accessible data, so adequate investment in monitoring and reporting systems is critical. However, it is worth noting that mainstreaming ecosystem service indicators, like many other mainstreaming processes, requires a sustained effort, over several years and on several fronts (CBD, 2011; Dalal-Clayton & Bass, 2009; IIED & UNEP-WCMC, 2013).

3.4 BASIC TASKS AND TIPS IN MAINSTREAMING ECOSYSTEMS SERVICE INDICATORS

This section outlines a set of key tasks which will help to mainstream ecosystem service indicators into monitoring and reporting systems of policies and plans. Mainstreaming ecosystem service indicators is not a mechanical exercise which would follow a clear 'recipe'. It is more likely that it will occur irregularly within and across sectors and levels of government with some sectors being more amenable than others. As an institutional change process, ecosystems service indicators mainstreaming will take time and will be iterative. However, there are basic tasks that need to be undertaken as far as possible in the process of mainstreaming ecosystem service indicators. These tasks are based on mainstreaming experiences from the NBSAPs 2.0: Mainstreaming Biodiversity and Development Project[12] being implemented by IIED and UNEP-WCMC (2013) and from mainstreaming experiences elsewhere. It should be noted that these basic tasks are not sequential, and are to be used as part of an iterative process.

3.4.1 Identify and engage a broad range of key stakeholders

This involves initial discussions about associated institutional, governance and capacity changes required to achieve the overall desired goal of mainstreaming, in order to identify who should be engaged. The main stakeholders who can help achieve mainstreaming of ecosystem service indicators are likely to be the same people or organisations identified and consulted during the first step of the Ecosystem Service Indicators Development Framework, i.e. stakeholders that have monitoring and reporting systems that you want to insert ecosystem service indicators into (see Figure 1, Section 2.1). In identifying key stakeholders, you need to ask yourself who knows what; who controls what; who can support the process and who can block the process.

[12] For more information on the NBSAPs 2.0: Mainstreaming Biodiversity and Development project: http://www.unep-wcmc.org/featured-projects/integrating-biodiversity-and-development

3.4.2 Identify entry points

Identifying, understanding and prioritising national, sectoral, sub-national or local level entry points for mainstreaming ecosystem service indicators sets the stage for mainstreaming. There is no single way to choose entry points for mainstreaming ecosystem service indicators, and no one factor that promises success in a particular entry point. However it is important to choose and prioritise entry points because mainstreaming efforts that attempt to mainstream everywhere, at once, may be overambitious (Box 11).

Box 11: Tips for choosing and prioritising entry points for a mainstreaming effort

Some criteria for choosing and prioritising entry points can include the monitoring and reporting systems of policies and plans for which:

- The links between ecosystem services and human well-being are most easily demonstrated and communicated.
- The links between ecosystem services and human well-being are the most direct.
- There is a potential "champion" to take on the cause and/or where there is substantial interest in sustainability.
- Their timing creates an opportunity.

Source: adapted from CBD, 2011

Mainstreaming may start at different scales and levels of government, and/or in specific sectors and geographic areas (Table 5).

Table 5. Entry points for mainstreaming ecosystem service indicators at different levels (CBD, 2011; IIED & UNEP-WCMC, 2013).

Level	Entry point
Global	The United Nations Statistics Division, the World Banks' World Development Indicators, United Nations Development Programme (UNDP) Human Development Statistics and FAOSTAT
National	
National government	National Statistical Offices, National Accounting System
Development assistance agencies	Monitoring and reporting systems of UN Development Assistance Frameworks, Bilateral Country Assistance Strategies and County Programmes, etc.
Non-governmental and civil society organizations (NGO/CSOs)	Programmes and projects monitoring and reporting system
Sectoral	
Sectoral ministries	Monitoring and reporting systems of sector policies and plans (e.g. agriculture, forestry, wildlife, tourism)
Private sector companies	Environmental monitoring and reporting systems of private companies and businesses
Sub-national	
Local government	Monitoring and reporting systems of district development plans and decentralised sector policies
Area-based management initiatives (e.g. watersheds, marine areas and coastal zones)	Monitoring and reporting systems of initiatives such as integrated marine and coastal area management, integrated watershed management, and integrated oceans management

Particularly important entry points for ecosystem service indicators are those at the national and sub-national level (i.e. national and sub-national level plans and sector plans). However mainstreaming at this level may be the most difficult to achieve. Sub-national and area based plans are relevant and useful to the extent that they can motivate and serve as model for mainstreaming at higher levels of government.

3.4.3 Develop a business case for mainstreaming ecosystem service indicators

Once the entry points have been identified and prioritised, the next step entails developing and making a strong case for the benefits of mainstreaming ecosystem service indicators in the identified monitoring and reporting systems. To help your case, identify the most important stakeholders you seek to influence. These will be people, organisations or sectors that can benefit from using ecosystem service indicators (see Step 1, Section 2).

A strong case needs to be as specific as possible and to give evidence of direct benefits of monitoring and reporting on ecosystem service indicators. Align your arguments in your case with the key policy priorities of the government and the country's development needs. This might include the role of ecosystem service indicators in national planning, reporting and decision making on job creation, health, food and water security, growth and equity, and rural development.

The arguments for investing in ecosystem service indicators should focus on their importance for tracking and communicating trends in the quantity and quality of provisioning, regulating and cultural services, and their supply and contribution of ecosystem services to human well-being. This is essential to knowing whether or not these services are being appropriately managed and sustainably used or lost, and how sustainability-related policies and management decisions should be designed to ensure the sustainable flow of services to support human wellbeing and poverty reduction, and maintain biodiversity. It will also help countries to meet their reporting obligations under different multilateral processes such as the CBD, UNCCD, MDGs and SDGs. You will need to tailor the case for each audience because the same messages may not be suitable for everyone.

3.4.4 Identify enabling factors for mainstreaming ecosystem service indictors

There may be particular catalysts or enabling factors that can make best use of entry points from national to local and sectoral levels, which may be formal or informal. They may be enduring or rather ephemeral, depending upon changing issues and timing. Existing enabling factors that need to be worked with might include:

- Political will and leadership.
- Media and public perception and awareness of values.
- Inter-sectoral coordination.
- Lobbying by interest groups.
- Transparent, accountable and inclusive governance.
- Stakeholder participation.
- Availability of funding.

Identifying which enabling factors are absent should also inform the approaches and tools you choose for mainstreaming ecosystem services and their indicators.

3.4.5 Shape a communication strategy

Effective communication is essential for bringing about the changes in policy, norms and behavior of institutions needed for mainstreaming ecosystem service indicators. There must be strong communication throughout the ecosystem service indicator mainstreaming process. It is vital during stakeholder engagement and making the case for ecosystem service indicators. You must identify who needs to change, what needs to change, and what decisions, methods and instruments best bring about these changes.

3.4.6 Tools and approaches for mainstreaming ecosystem service indicators

Several practical tools can be used to support mainstreaming of ecosystem service indicators. These help to ensure ecosystem service indicators are built into the monitoring systems, and there is close collaboration with the national statistics office and other relevant bodies.

- **Ecosystem and ecosystem services assessment:** Assessments can inform decision making processes, such as national and local plans like NBSAPs, NDPs and sector plans, of the value of ecosystem services and biodiversity by highlighting the links between healthy ecosystems and the attainment of economic and social goals. A key component of the ecosystem assessment approach is stakeholder engagement designed to achieve core values of relevance, credibility and legitimacy. This means that assessments can form not only a credible and robust scientific evidence base for action, but also develop information which is directly relevant to policy, as well as practical and useable tools to inform better decision making and mainstream biodiversity and ecosystem services across sectors.
- **Ecosystem service mapping:** Mapping provides an important opportunity for mainstreaming ecosystem service indicators as it is generally used to assess status and trends in ecosystem service provision and human well-being, providing spatial quantification of ecosystem services and their values. Ecosystem service mapping is also used in the context of developing spatial ecosystem service indicators.
- **Economic and non-economic valuation of ecosystem services:** Valuation of ecosystem services provides useful and reliable information for decision making, when applied carefully according to best practice. The increasing reliability of economic valuation tools has led governments and other stakeholders to apply them more frequently and to give increasing weight in decision making to the estimates derived from using these tools. Exploring the economic value of ecosystem services is just an additional way of assessing the role and importance of nature (UNEP-WCMC & Insititute for European Environmental Policy; IEEP, 2013).
- **Natural capital accounting frameworks:** Accounting can provide detailed statistics for better management of the economy. For example land and water accounts can help countries interested in increasing hydro power capacity to assess the value of competing land uses and the optimal way to meet this goal. Ecosystem accounts can help biodiversity rich countries design a management strategy that balances trade-offs among ecotourism, agriculture, subsistence livelihoods, and ecosystem services like flood protection and groundwater recharge.
- **Legal instruments:** Ecosystem services and ecosystem service indicators may be integrated into a country's legal framework. This can be done at national or sub-national levels. Laws can also be designed specifically for a sector or an economic activity with stipulations on reporting on ecosystem services and ecosystem service indicators. For example, legal instruments can have provision for data gathering organisations and National Statistics offices to include ecosystem services and their indicators in their mandates.

- **Spatial Planning:** Spatial plans determine where economic activities and infrastructure developments are established. They also deal with specific spatial areas and the activities undertaken within them and provide for the coordination of different sectors and tiers of government. Many countries have begun to integrate environmental and sustainability objectives into spatial plans opening a door for ecosystem services. While spatial plans were once the exclusive domain of national governments, they are now also used in sub-national planning.

- **Guidelines on how to mainstream ecosystem service indicators:** Making guidelines on how to mainstream ecosystem services and their indicators and ecosystem services available online and offline via CDs and hard copies can help the process of mainstreaming biodiversity. Training workshops on developing and mainstreaming ecosystem service indicators also help with uptake. Successful mainstreaming requires in situ support to users of the tools, usually over an extended period.

- **Establishing a network for monitoring ecosystem services at local to global scales:** Setting up multi-stakeholder network for monitoring ecosystem services at local, nation and global scales can also help to augment efforts to mainstream ecosystem service indicators. National monitoring systems could create mechanisms by which local stakeholders can provide input and feed into the national system. City and regional governments may help facilitate the engagement with local stakeholders, and help assess the status of ecosystem services at local scales. Local scale monitoring could dovetail into existing ecosystem services research and monitoring initiatives (Box 12).

Stakeholder workshop © Uzbekistan Society for the Protection of Birds (2014)

Box 12: Existing networks and mainstreaming initiatives

Existing networks:

- The Ecosystem Service Partnership (http://www.es-partnership.org/esp)
- The International Long-Term Research (http://www.ilternet.edu)
- MIMES (http://www.ebmtools.org/mimes.html)
- The Natural Capital Project (www.naturalcapitalproject.org)
- The Program for Ecosystem Change and Society (http://www.pecs-science.org)
- The Sub-Global Assessment Network (http://www.ecosystemassessments.net/)
- The Tropical Ecology Assessment and Monitoring Network (http://www.teamnetwork.org)

Existing mainstreaming initiatives:

- The WAVES initiative: Wealth Accounting and the Valuation of Ecosystem Services (www.wavespartnership.org)
- The System of Environmental-Economic Accounts (SEEA) (SEEA; http://unstats.un.org/unsd/envaccounting/seea.asp)
- Project on Ecosystem Services (ProEcoServ; www.proecoserv.org)
- Eco taxation in forestry sector and accounting of ecosystem services in Senegal.
- Economic valuation of ecosystem services for estimating 'Gross Domestic Product' (GDP) of the Poor', Southern Sudan (www.ese-valuation.org)
- Implementation of ecosystem accounting: Inclusive Wealth Report (with IHDP)
- Establishing the linkages of macroeconomic policies and ecosystem services with the help of scientific evidence in selected countries (Valuation of ecosystem assets in Morocco and Kazakhstan)
- The UNDP-UNEP Poverty-Environment Initiative (PEI; www.unpei.org)

3.4.7 Key success factors for mainstreaming ecosystem service indicators

The tools and approaches discussed here provide an essential foundation for mainstreaming ecosystem service indicators in other sectors. However, they are not the whole story. Experience from mainstreaming poverty–environment and biodiversity and ecosystem services show that a range of "soft" factors are equally important for mainstreaming success (IIED & UNEP-WCMC, 2013; Republic of South Africa, 2014). Some of these less tangible aspects include:

- **Paying close attention to policy, institutional and practice context:** Mainstreaming ecosystem service indicators into monitoring and reporting systems of policy and plans requires an intimate understanding of the policy, institutional and practice context in that sector, which can be developed only through substantial contact and careful listening.
- **Building ongoing relationships:** Mainstreaming is not a one-off event but a process, which can be achieved only through building ongoing long-term working relationships with key individuals in the receiving sector.
- **Providing *in situ* support:** No matter how user-friendly mainstreaming guidelines are, mainstreaming can never be achieved simply by handing guidelines over and expecting them to be used. Training workshops help with uptake, but are also not sufficient. Successful mainstreaming requires *in situ* support to users of the tools, usually over an extended period (for example several years).
- **Convening regular forums for co-ordination and lesson sharing** among those involved in mainstreaming in a particular sector, and strengthening networks of relationships between key individuals. These forums can take the form of, for example, task teams or learning networks. Investing time and resources in such processes can be invaluable for developing shared objectives and understanding across sectors and disciplines, thereby helping to embed mainstreaming outcomes.
- **Online access to information:** Making the mainstreaming guidelines freely available online is essential for facilitating their use and uptake.
- **Create champions:** One way to promote the sustainable production of ecosystem service indicators is for it to be recognised and adopted by a national statistical agency. This endorsement and demand for its regular calculation provides a strong case for the necessary long-term investment of resources.
- **Synergies with other conventions:** A synergistic approach to implementation, monitoring and reporting to the CBD, UNFCCC, UNCCD, CITES and Ramsar Convention can also help the process of mainstreaming ecosystem service indicators.

Drakensburg Gardens, South Africa © Jonathan Gill (2014)

4 Ecosystem services indicators developed in South Africa

In South Africa the concept of ecosystem services is becoming well embedded in environmental policy, mainly due to the country's engagement in the South African Millennium Ecosystem Assessment (Reyers et al., 2014). The South African Government has proposed a set of 12 outcomes which reflect the desired development impact the country seeks to achieve. These outcomes have been used to set performance agreements with all national departments and an opportunity to develop ecosystem service indicators to Outcome 10, "*Environmental assets and natural resources that are well protected and continually enhanced*". So far approximately 40 indicators have been proposed for the measurement of these targets and Table 6 depicts part of these indicators related to the water resources, where they have made it clear which type of ecosystem services category the ecosystem service indicator addresses and if the benefit flow to human well-being is explicit.

Table 6. Part of South Africa's national indicators proposed and in use

Source: Reyers et al., 2014

Outcome/ Policy objective	Indicator	Unit	Ecosystem service category	Benefit flow to human well-being explicit?	Currently measured	Source
Water resources are protected, with quality and quantity enhanced	Number of wetlands rehabilitated per year (100 per year)	Number of wetlands rehabilitated	All	No	No	Outcome 10
	Number of wetlands under formal protection (Ramsar sites)	Number of wetlands formally protected	All	No	No	Outcome 10
	Number of major rivers with healthy ecosystems meeting resource quality objectives	Number of rivers with healthy ecosystems	All	No	No	Outcome 10
	Enhanced fresh water quality (eutrophication levels)	Phosphorus and Chlorophyll A concentration	Provisioning	No	Yes	DEAT
	Ground water quality	Total dissolved solids in mg/l	Provisioning/ Regulating	No	Yes	DEAT
	Fresh water availability	% demand of available water	Provisioning	No	Yes	DEAT
		Access required per person/household	Provisioning	Yes	Yes	DEAT

In addition to the national level performance targets, the country's NBSAP also includes policy targets for ecosystem services and describes indicators needed for assessing progress towards these (Reyers et al., 2014). However, Reyers et al. (2014) reviewed the proposed ecosystem service indicators and found that most indicators are not in use or being measured (only 12 out of 31 presented are evidenced). They also showed that the majority of indicators still focus on the provisioning services and supply side of measures, indicating that the difficulties of developing ecosystem service indicators have not been overcome completely. Seven new ecosystem service indicators, developed by CSIR to address these weaknesses, are now presented in this section.

4.1 TRENDS IN RIVER ECOSYSTEM REGULATION OF WATER QUALITY FOR DOMESTIC AND AGRICULTURAL USE

4.1.1 Rationale

Globally the supply of good quality water depends on a variety of social and ecological factors. In developing countries where water treatment infrastructure may be poorly maintained, the condition of the underpinning ecosystems is critical for providing water "fit for use". In many cases, data sets used to assess the supply of good quality water usually only provide an indirect measure of water quantity and quality and do not assess the consequences for human wellbeing.

The indicator developed here integrates data set states of river ecological condition relevant to ecological functions necessary for water quality regulation. It uses conventional aquatic ecology data and enables trends in ecological condition of rivers to be made explicit at a national scale. This information can then be used for national decision making and policy processes.

4.1.2 Development

Data were supplied by the Directorate of Water Ecosystems in the national Department of Water Affairs (DWA).

- *Present ecological state 1999* (Kleynhans, 2000) *and 2011* (DWA, 2013).
  These data provide an assessment of river ecological condition by estimating the extent of human modification relative to a pre-modification reference ecological condition. Modification to six criteria considered key drivers of ecological functioning were included: flow, inundation, water quality, stream bed condition, introduced instream biota and riparian or stream bank condition. Each criterion was assessed per river reach by local experts, assigning a category from Table 1 (see Section 1).
- *River condition from the National Freshwater Ecosystem Priority Areas project* (Nel et al., 2011)
  The 2011 present ecological state data included all river reaches in the 1:500,000 rivers network of South Africa, while the 1999 data only assessed large rivers, which tend to be more modified. To obtain a timeline for all 1:500,000 rivers, data for smaller tributaries in 1999 were obtained from the river condition of the National Freshwater Ecosystem Priority Areas project, which tend to be in good ecological condition.

Data for 1999 and 2011 present ecological state were summarised and joined to a 1:500,000 rivers GIS layer used by the national DWA for strategic planning. The percentage of total river length in the Good, Fair and Poor conditions (Table 7) were then calculated at a national level and summarised at a Water Management Area scale. Water Management Areas are administrative units based on catchment boundaries used to implement integrated water resource management.

Table 7. Description of Present ecological state categories used to describe river ecological condition. For this study, A and B rivers can be considered to be in a "Good" condition, C rivers a "Fair" condition, and D, E or F rivers a "Poor" condition (Kleynhans, 2000).

Ecological category	Description
A (Good)	Unmodified, natural.
B (Good)	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C (Fair)	Moderately-modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
D (Poor)	Largely-modified. A large loss of natural habitat, biota and basic ecosystem functions have occurred.
E (Poor)	Seriously-modified. The loss of natural habitat, biota and basic ecosystem functions are extensive.
F (Poor)	Critically/Extremely-modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

4.1.3 How to interpret the indicator

A decline of rivers in good ecological condition indicates loss of biodiversity, while an increase in poor ecological condition indicates a loss of ecosystem function and hence a decline in the capacity of the ecosystem to regulate water quantity and quality. An increase of rivers in poor condition is a particular concern in areas lacking artificial water treatment services.

4.1.4 Assessment

The proportion of rivers in good ecological condition has declined by 21% between 1999 and 2011 while the proportion in poor ecological condition has increased by 7% (Figure 7). The largest decrease of rivers in good condition is in the arid interior and north-eastern portions of South Africa while the largest increases in poor condition are in Greater Cape Town and Johannesburg. The proportion of rivers in good ecological condition has decreased in all of the nine Water Management Areas except Berg-Olifants, where there has been active rehabilitation of headwater catchments in the Berg.

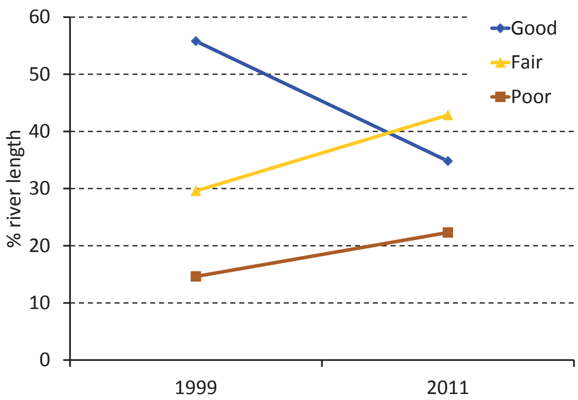

Figure 7. National trends in river ecological condition between 1999 and 2011

Source: Reyers et al., 2014

4.2 CONDITION AND TRENDS OF STRATEGIC WATER SOURCE AREAS FOR WATER SECURITY

4.2.1 Rationale

South Africa's Strategic Water Source Areas supply disproportionately high amounts of the country's water relative to their surface area. They make up about only 8% of the land areas but provide 50% of the water (Figure 8; Nel et al., 2013) and have been mainstreamed into national water policy due to their importance. Deterioration of water quality and quantity in these areas would have large negative effects on the functioning of downstream ecosystems and the sustainability of communities, appropriate land and water management is therefore critical in these areas.

This indicator focuses on land cover-land use data as a measure of the drivers of change that are relevant to water quality and quantity: pollution; erosion; invasive alien plants; land use; and water extraction. The indicator presents a starting point for assessing the condition and trends in key areas of water supply and for the communication of land management impacts on water security.

Figure 8. Map of South Africa's Strategic Water Source Areas.

Source: Nel et al., 2013

4.2.2 Development

GIS and metadata at a 1 x 1 minute grid cell resolution for the Strategic Water Source Areas of South Africa originally mapped by the National Freshwater Ecosystem Project were superimposed on GIS layers of national land cover for 1996 and 2000 obtained from the Agricultural Research Council (Fairbanks et al., 2000; Van Den Bergh et al., 2008) and 2009 land cover data from the South African National Biodiversity Institute (SANBI). The five land cover classes of natural, cultivated, plantation, urban and mining land cover were extracted due to their known impacts on water quality and quantity. There areas were then expressed as a percentage of the total surface areas of the Strategic Water Source Areas.

The indicator excludes data on some important drivers of change in condition, including water quality, invasive alien tree infestation, soil health and mining/prospecting activities. However, as data become available it can be incorporated into the indicator.

4.2.3 How to interpret the indicator

A decline in natural land cover implies a decline in the healthy functioning of the Strategic Water Source Areas, while a rise in either the cultivation, plantation, urban or mining land cover classes would imply expansion of that class is threatening the natural land class extent.

4.2.4 Assessment

No clear trends in the proportion of the Strategic Water Sources with natural land cover can be observed between 1996 and 2009, with the proportion being maintained between 65-70% (Figure 9). Cultivation is the most extensive modifier of natural land cover, occupying over 15% of the Strategic Waster Source Areas in 2009, although a 7% decline in cultivation has occurred since 1996 (Figure 9). Urban areas occupy less than 5% of the Strategic Water Source Areas but show a steady increase by 2% since 1996 (Figure 9).

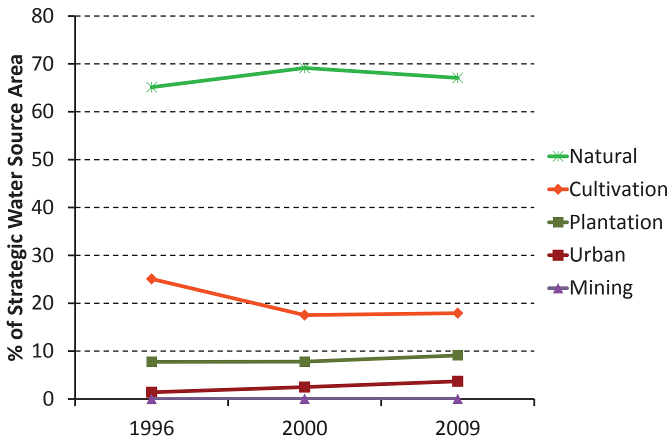

Figure 9. Land cover trends in Strategic Water Source Areas

Source: Reyers et al., 2014

While the extent of mining is less that 1%, a recent assessment of prospecting and mining licenses showed that there is large potential for mined areas to grow, with over 70% of the National Strategic Water Source Areas in Mpumalanga under some sort of mining licence (La Grange, 2011).

4.2.5 National Use

Although South Africa's Strategic Water Source Areas have only recently been mapped (Nel et al., 2013), they have already been included in two influential national policies: the Department of Water Affair's 5-year National Water Resource Strategy 2012 (DWA, 2012) and the Presidential Strategic Integrated Project on investing in ecological infrastructure for water security.

4.3 WATER QUALITY TRENDS IN COMMUNITIES DIRECTLY DEPENDENT ON WATER-RELATED ECOSYSTEM SERVICES

4.3.1 Rationale

Water quality is declining in many regions of the world as the result of a combination of factors. These include industrial and agricultural pollution, as well as declines in the extent and condition of natural ecosystems, such as wetlands, which would normally purify the water. The communities who will be worse affected by these water quality problems will be those without access to piped and treated water, who instead depend directly on the water provided by natural ecosystems such as rivers, springs, boreholes or ponds.

There is a need to develop an indicator of water quality that focuses on these communities in order to better maintain and enhance the ecosystems and services that are key to their wellbeing and health. This preliminary indicator captures trends in the quality of water available to dependent communities using data from South Africa.

4.3.2 Development

Measuring progress towards water quality and security targets is complex, requiring data on: the health and wellbeing of dependent communities, the quality of their water, the condition of the ecosystems purifying and regulating the water supply, and trends in drivers of change of these key ecosystems. The methodology for this preliminary indicator is still under development and review.

Data related to household water accessibility (i.e. piped and treated or from natural sources) was extracted from South Africa's general household survey, which began in 2002 and has since been conducted annually. The data is made publicly available by Statistics South Africa (Figure 10). Survey results related to water quality were then extracted so that the proportion of households dependent on natural water sources reporting water quality problems could be calculated (Figure 11). The indicator was then produced by plotting this information over the period over which the household surveys have been conducted.

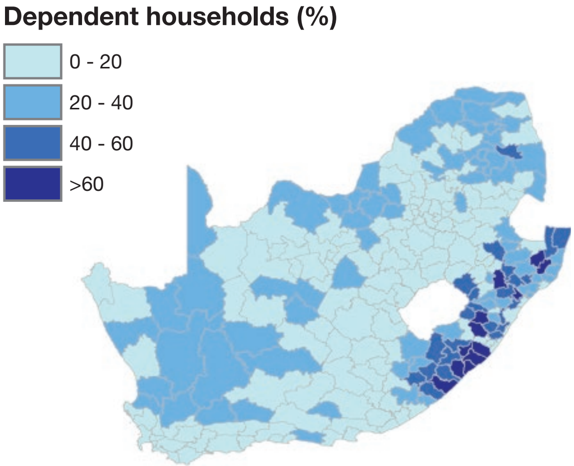

Figure 10. Map of communities without access to treated and piped water, instead dependent on rivers, streams, pools, springs and boreholes for their domestic water.

Source: Stats South Africa (2012a).

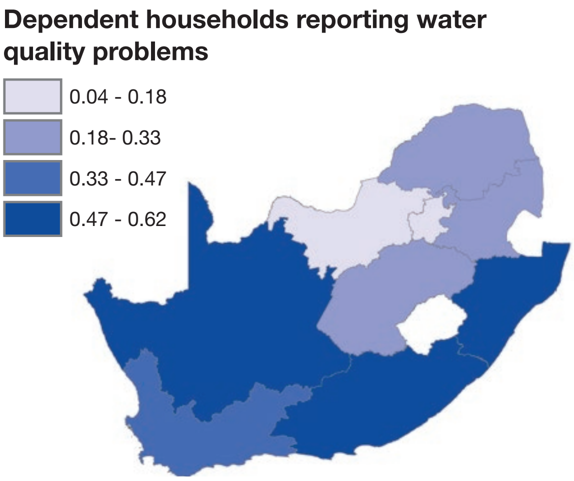

Figure 11. Map of the proportion of households dependent on natural sources of water reporting water quality problems in the general household survey 2011.

Source: Stats South Africa (2012b).

4.3.3 How to interpret the indicator

A decline in the graphs represents a decline in the proportion of households reporting good water quality available for use, both at a national and provincial scale. As the indicator focuses on more vulnerable communities, the decline in water quality will have implications for health and mortality.

4.3.4 Assessment

Within South Africa, communities dependent on ecosystems for their domestic water are mostly found in the Eastern Cape and Kwazulu-Natal, with some in the Northern Cape and Limpopo Province (Figure 10). These provinces also show high proportions of the households surveyed reporting water quality problems (Figure 11), for example in the Eastern Cape over the past 9 years on average more than 80% of households using rivers and other natural sources of water, reported problems with water quality. The national average is that 65% of surveyed households reported water quality problems (Figure 12).

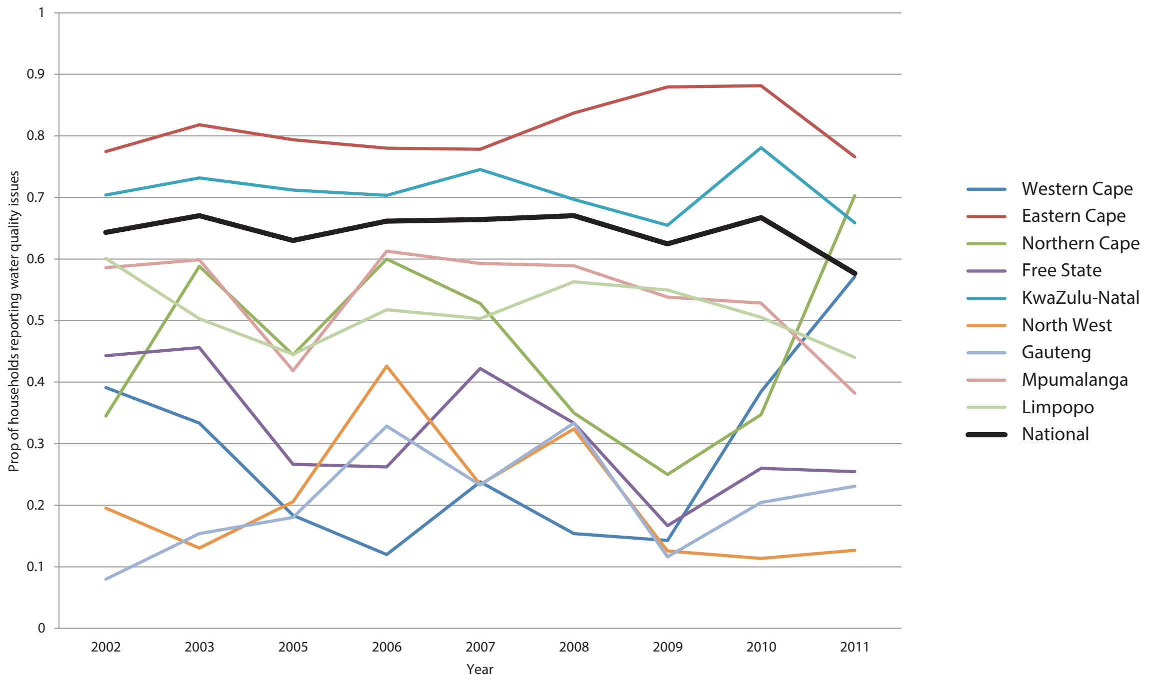

Figure 12. Final indicator showing trends between 2002 and 2011 in the proportion of dependent households surveyed reporting good quality water.

Source: Stats South Africa (2012b)

While the national trend appears relatively stable with a slight improvement of water quality reported, the provincial trends are highly variable. Given the randomised design of the survey, it is unlikely the same household would be surveyed twice and thus the variability of the provincial trends may be more the result of sample variation than variation in water quality.

It is important to note that water quality changes shown in the indicator can be the result of changes in the ecosystem services related to water purification and/or the result of changes in the sources of pollutants overwhelming the ecosystem. With sufficient data on ecosystem condition it would be possible to disentangle these causes.

4.4 TRENDS IN URBANISATION IMPACTS ON FOOD PRODUCTION

4.4.1 Rationale

Rapid urbanisation is one of the key characteristics of development in developing countries. The land use transformations that take place during urbanisation often result in unanticipated ecosystem service declines. Indicators that highlight these declines could therefore be used to help direct land use decisions taken in urban planning.

This indicator links the impacts of urban expansion to the potential to produce food within and around urban areas. It provides an initial broad understanding of the rate of loss of potential cultivation areas and therefore the losses of food production potential. The indicator was developed using the city of Cape Town in South Africa as an example.

4.4.2 Development

The indicator shows how land use has changed over a 200 year period in the city of Cape Town. Urban growth over time was captured by city officials from historic maps, references and aerial photographs. Delineated urban regions were intersected with cadastral data for the city so as to standardise the transformation for each time period captured, as earlier time periods tended only to capture generalised transformation patterns. Agricultural capability data was extracted from an agricultural capability data layer supplied by the Agricultural Research Council. Agricultural capability was defined by three categories: no, poor and moderate agricultural potential. Cadastral data were then intersected with moderate and poor potential cultivated data to determine the potential loss or development of these areas over a two hundred year time period. No high potential areas were found within Cape Town and areas with no cultivation potential were excluded from the analysis.

4.4.3 How to interpret the indicator

The indicator highlights change in agricultural potential. An increase in urban areas reflects a loss in areas of moderate and poor cultivation potential as a result of urban expansion (see Figure 13). This loss of potential cultivation could translate into losses of food production.

4.4.4 Assessment

The indicator suggests that urban food production is not considered to be a priority within city planning and that the best agricultural areas (although in the example of Cape Town these only have moderate potential) have been the first areas converted. If transformation continues on the trajectory shown over the last 200 years, all moderate potential land will be lost in the coming decade. Therefore, these areas should be flagged as important agricultural sites requiring special consideration when considered up against development pressures. Further work is required for the accurate assessment of how this loss of land potentially translates into tonnes of food production forgone.

While this indicator focuses on the importance of open areas for potential food production, there are multiple non-agricultural benefits associated with open spaces in cities which should also be considered. Thus areas with no agricultural capability may have other benefits not captured in this indicator.

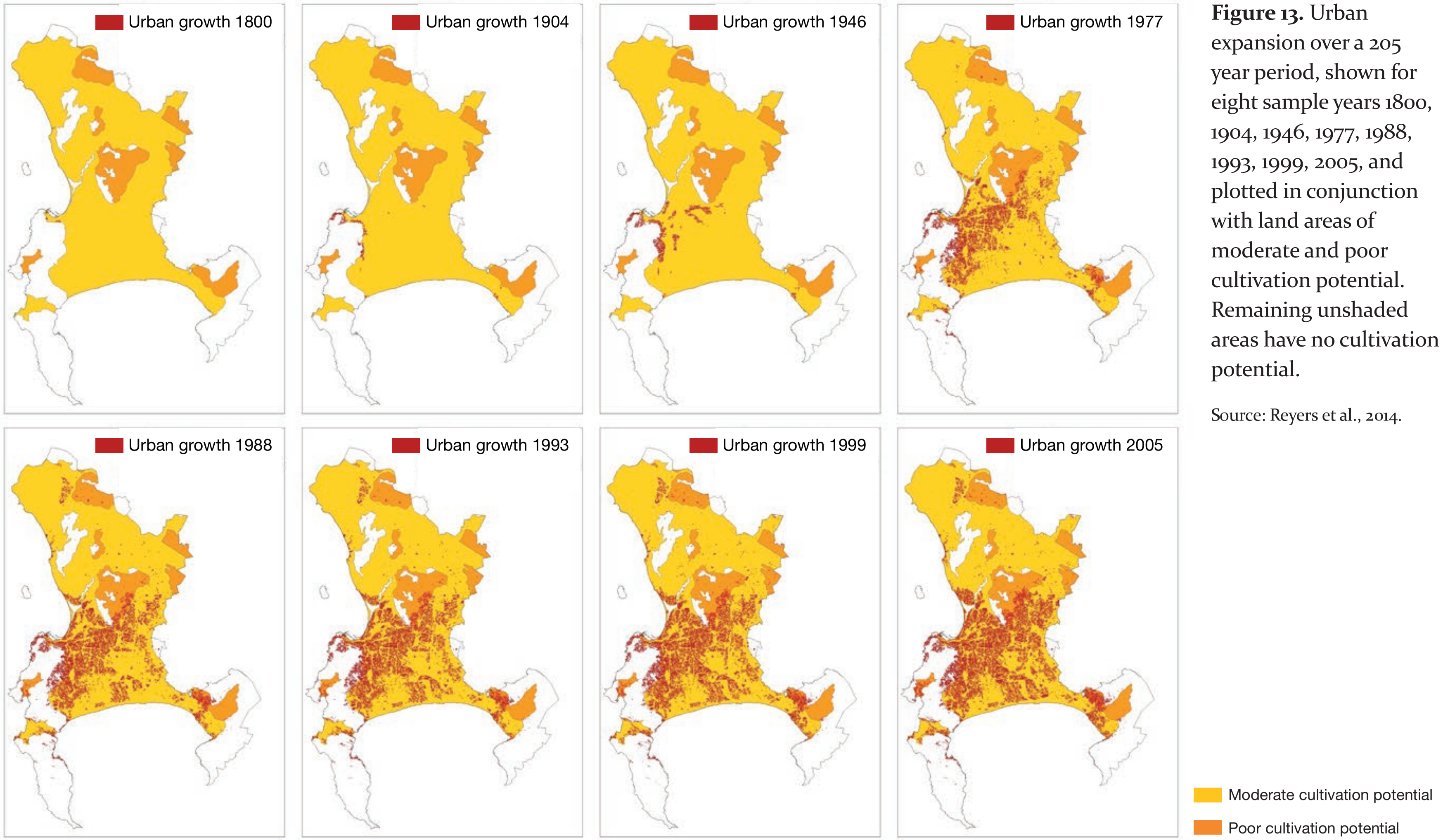

Figure 13. Urban expansion over a 205 year period, shown for eight sample years 1800, 1904, 1946, 1977, 1988, 1993, 1999, 2005, and plotted in conjunction with land areas of moderate and poor cultivation potential. Remaining unshaded areas have no cultivation potential.

Source: Reyers et al., 2014.

4.5 TRENDS IN FOOD SECURITY IN COMMUNAL AREAS

4.5.1 Rationale

Food security is an issue of national strategic importance. A key component of food security is livestock production. Livestock are also an important livelihood component of many households, providing an array of goods and services as well as being used for ceremonial services and customary practices. Natural ecosystems are a vital source of forage for livestock and the degradation of these ecosystems is a critical challenge that threatens the sustainability of the livestock industry.

Invasion by alien plant species is an important factor contributing to the degradation of ecosystems. These invasions have negative impacts on natural processes, in turn affecting species richness, biomass and native flora and fauna composition. As a result, ecosystem productivity is impacted, affecting all organisms sustained by the system including grazing livestock.

This indicator explores the impacts of invasive alien plants on livestock production using an example in South Africa. It was developed for two governmental departments, the Natural Resource Management Programme–Department of Environmental Affairs and the Departments of Agriculture and highlights an additional criterion for prioritising the clearing of alien plant species.

4.5.2 Development

The Stutterheim magisterial district was selected to demonstrate the indicator as it is both an important livestock production area and is currently being invaded by alien species. The analysis focused on a single invasive species *Acacia mearnsii* commonly known as black wattle, which is regarded as one of the most problematic invasive species in South Africa. Areas of natural rangeland vegetation were extracted from the National Land Cover data layer (van den Berg et al., 2008). The carrying capacity for areas in Stutterheim was determined from the homogenous grazing potential data layer (Scholes, 1998). Invasion levels within the district were extracted from the national invasive alien plant survey (Kotze et al., 2010). Fieldwork studies within Stutterheim have demonstrated that as grassland becomes invaded by *Acacia mearnsii*, the livestock carrying capacity is reduced by 54% under light invasions and by 73% under dense invasion (Yapi, 2013; see Figure 14).

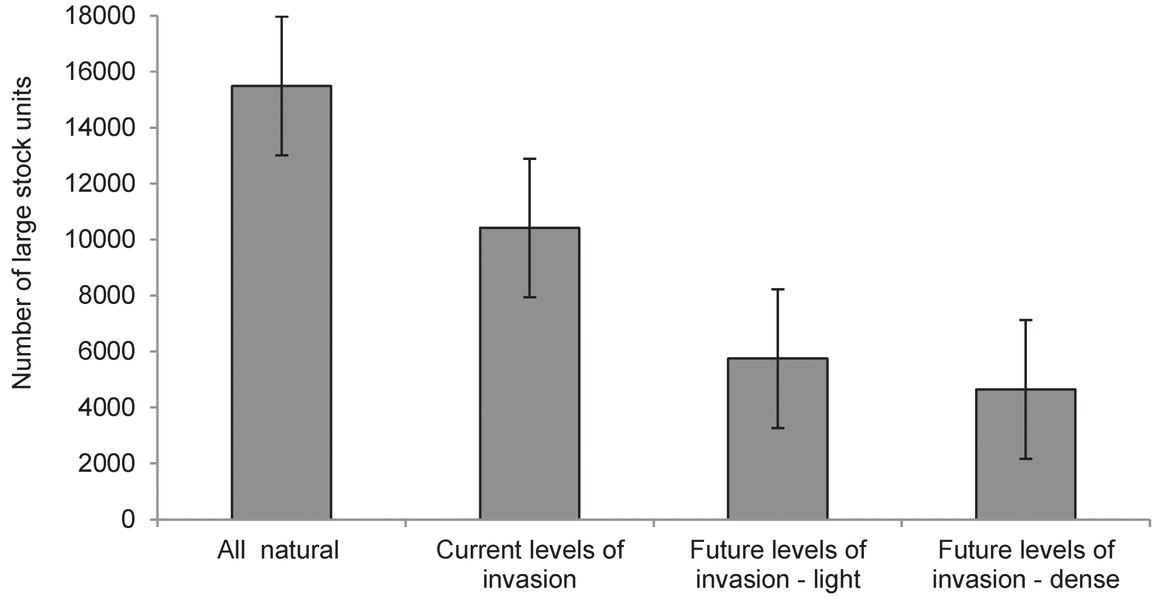

Figure 14. Expected change in potential number of livestock in the Stutterheim area as invasion by *Acacia mearnsii* expands and becomes more dense

Source: Yapi, 2013

Using the above combination of data on land cover, livestock carrying capacity, invasion level and the invasion levels impact on livestock carrying capacity, impacts of invasion by *Acacia mearnsii* on livestock production were estimated in two possible future scenarios. In the first scenario considered, all areas that are natural and lightly invaded are converted to lightly and densely invaded respectively. In the second scenario, all areas are transformed to densely invaded.

4.5.3 How to interpret the indicator

The indicator shows the potential number of livestock that could be grazed on land under four scenarios of invasion by *Acacia mearnsii* in the natural rangeland vegetation in the Stutterheim district: no invasion, current levels of invasion, future light and future dense levels of invasion. As carrying capacity falls, a greater area will be required to support the same number of livestock.

4.5.4 Assessment

Although the indicator is focussed on a single species of invasive tree, it already highlights dramatic changes in grazing provision potential within Stutterheim grasslands of South Africa. The indicator shows a trend of decreased carrying capacity within grassland vegetation types as levels of invasion increase, with about double the amount of land required to support the same number of animals under conditions of light invasion. The severity of the impact of invasion is demonstrated by contrasting the natural uninvaded carrying capacity with carrying capacities under dense invasion, which is about four times lower.

Currently the indicator is focussed at a magisterial level, which is the scale at which livestock census data is available and the scale of agricultural planning and management. Where data permits, the indicator could be expanded to incorporate other invasive species and vegetation types. Moreover, it could be developed to capture the effects of invasive species on other ecosystem services.

References

African Leadership Group. (2012). *Maun Statement on Biodiversity and Development Mainstreaming.* IIED.

Altman, I., Boumans, R., Roman, J. & Kaufman, L. (2012). *Multi-scale Integrated Model of Ecosystem Services (MIMES) for the Massachusetts Ocean (v 1.0): Technical Document.* Boston University.

Anderson, B. J., Armsworth, P. R., Eigenbrod, F., Thomas, C. D., Gillings, S., Heinemeyer, A., & Gaston, K. J. (2009). Spatial covariance between biodiversity and other ecosystem service priorities. *Journal of Applied Ecology,* 46(4), 888–896.

Bagstad, K.J., Villa, F., Johnson, G.W., & Voigt, B. (2011). ARIES – *Artificial Intelligence for Ecosystem Services: A guide to models and data, version 1.0*. ARIES report series n.1.

Bagstad, K. J., Semmens, D. J., Waage, S., & Winthrop, R. (2013). A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services*, 5, 27-39.

Balmford, A., Rodrigues, A., Walpole, M., ten Brink, P., Kettunen, M., Braat, L., & de Groot, R. (2008). *Review on the Economics of Biodiversity Loss: Scoping the Science.* Report to the European Commission, Brussels, Belgium.

Biodiversity Indicator Partnership. (2011). *Guidance for national biodiversity indicator development and use.* UNEP World Conservation Monitoring Centre, Cambridge, UK. 40pp

Biodiversity Indicators Partnership. (2012). *Health & well-being of communities directly dependent on ecosystem goods and services.* Retrieved 1 September 2014 from http://www.bipindicators.net/healthofcommunities

Bondeau, A., Smith, P. C., Zaehle, S., Schaphoff, S., Lucht, W., Cramer, W., Gerten, D., Lotze-Campen, H., Muller, C., Reichstein, M. & Smith, B. (2007). Modelling the role of agriculture for the 20th century global terrestrial carbon balance. *Global Change Biology*, 13, 679–706.

Boulter, J. (2011). *Approaches for reporting on ecosystem services: Incorporating ecosystem services into an organization's performance disclosure.* Global Reporting Initiative, pp.44.

Boyd, J. & Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics*, 63(2-3), 616-626.

CBD. (2010). *Global Biodiversity Outlook 3*. Montréal: Canada.

CBD. (2011). *NBSAP training modules version 2.1 – Module 3. Mainstreaming biodiversity into national sectoral and cross-sectoral strategies, policies, plans and programs.* Montreal: Canada.

Chambers, R. (1997). *Whose reality counts? Putting the first last.* ITP: London.

Chan, K. M. A., Guerry, A. D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Bostrom, A., Chuenpagdee, R., Gould, R., Halpern, B.S., Hannahs, N., Levine, J., Norton, B., Ruckelshaus, M., Russell, R., Tam, J. & Woodside, U. (2012). Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement. *BioScience*, 62, 744–756.

Chenery, A., Plumpton, H., Brown, C. & Walpole, M. (2013). *Aichi Targets Passport.* UNEP-WCMC: Cambridge.

Church, A., Fish, R., Haines-Young, R., Mourato, S., Tratalos, J., Stapleton, L.,Willis, C., Coates, P., Gibbons, S., Leyshon, C., Potschin, M., Ravenscroft, N., Sanchis-Guarner, R.,Winter, M., & Kenter, J. (2014). *UK National Ecosystem Assessment Follow-on. Work Package Report 5: Cultural ecosystem services and indicators.* LWEC: UK.

Crossman, N. D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., Drakou, E, G., Martin-Lopez, B., McPhearson, Boyanova, K., Alkemade, R., Egoh, B., Dunbar, M, B. & Maes, J. (2013). A blueprint for mapping and modelling ecosystem services. *Ecosystem Services*, 4, 4–14.

Dalal-Clayton, D. B., & Bass, S. (2009). *The challenges of environmental mainstreaming: Experience of integrating environment into development institutions and decisions. Environmental Governance No. 3.* International Institute for Environment and Development: London.

de Groot., R.S., Alkemade, R., Braat, L., Hein, L. & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Journal of Ecological Complexity*. 7, 260-272.

Dickinson, J. L., Zuckerberg, B., & Bonter, D. N. (2010). Citizen Science as an Ecological Research Tool: Challenges and Benefits. *Annual Review of Ecology, Evolution, and Systematics*, 41, 149-172

Department of Water Affairs. (2012). *National Water Resource Strategy 2012.* Retrieved March 4, 2014 from http://www.dwaf.gov.za/nwrs/NWRS2012.aspx

Department of Water Affairs. (2013). *Desktop Present Ecological State, Ecological Importance and Ecological Sensitivity (PESEIS) Information.* Available on request from Directorate Water Ecosystems, Department of Water Affairs, Pretoria, South Africa.

'Ecosystem Services for Poverty Alleviation. (2014). Framework of ecosystem well-being chains: SPACES Project. Retrieved 1 October 2014 from www.espa-spaces.org

Egoh, B., Reyers, B., Rouget, M., Bode, M., & Richardson, D. (2009). Spatial congruence between biodiversity and ecosystem services in South Africa. *Biological Conservation*, 142(3), 553–562.

Egoh, B., Drakou, E.G., Dunbar, M.B., Maes, J. & Willemen, L. (2012). *Indicators for mapping ecosystem services: a review.* JRC Scientific and policy reports. European Commission.

Fairbanks, D.H.K.., Thompson, M.W., Vink, D.E., Newby, T.S., Van den Berg, H.M. & Everard, D.A. (2000). The South African Land-Cover Characteristics Database: A synopsis of the landscape. *SA Journal of Science*, 96(2), 69-82.

Food and Agriculture Organization of the United Nations. (2012). The state of food and agriculture. FAO: Rome.

Food and Agriculture Organization of the United Nations. (2014). FAO AQUASTAT database. Retrieved 27 September 2014 from http://www.fao.org/nr/water/aquastat/main/index.stm.

Finkbeiner, M., Inaba, A., Tan, R., Christiansen, K., & Klüppel, H.-J. (2006). The New International Standards for Life Cycle Assessment: ISO 14040 and ISO 14044. *The International Journal of Life Cycle Assessment*, 11, 80–85.

Fisher, B., Turner, R. & Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, 68(3), 643-653.

Haines-Young, R. & Potschin, M. (2009). *Methodologies for defining and assessing ecosystem services.* Final Report, JNCC, Project Code C08-0170-0062.

Haines-Young, R. & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. In: *Ecosystem Ecology: a new synthesis.* Raffaelli, D. and Frid, C. (eds). Cambridge University Press: Cambridge.

Handley, J., Pauleit, S., Slinn, P., Lindley, S., Baker, M., Barber, A., & Jones, C. (2003). *English Nature Research Report 526: Accessible Natural Green Space Standards in Towns and Cities: A Review and Toolkit for their Implementation.* Peterborough.

Hernandez-Morcillo, M., Plieninger, T. & Bieling, C. (2013). An empirical review of cultural ecosystem service indicators. *Ecological Indicators,* 29, 434-444.

Huntley, B. J., & Redford, K. H. (2014). *Mainstreaming biodiversity in Practice: a STAP advisory document*. Washington, DC.

IIED, & UNEP-WCMC. (2013). *Ten steps to biodiversity mainstreaming: Tips for NBSAPs 2.0 and beyond.* IIED: London.

Ingold, K., & Zimmermann, W. (2011). How and why forest managers adapt to socio-economic changes: A case study analysis in Swiss forest enterprises. *Forest Policy and Economics*, 13(2), 97–103.

IPBES (2013). *Conceptual framework for the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services.* Decision IPBES-2/4.

Kettunen, M., Bassi, S., Gantioler, S. and ten Brink, P. (2009). *Assessing Socio-Economic Benefits of Natura 2000: A Toolkit for Practitioners (November 2009 edition)*. Output of the European Commission project Financing Natura 2000: Cost estimate and benefits of Natura 2000. IEEP: Brussels.

Klain, S. C., & Chan, K. M. A. (2012). Navigating coastal values: Participatory mapping of ecosystem services for spatial planning. *Ecological Economics*, 82, 104–113.

Kleynhans, C.J. (2000). *Desktop Estimates of the Ecological Importance and Sensitivity Categories (EISC), Default Ecological Management Classes (DEMC), Present Ecological Status Categories (PESC), Present Attainable Ecological Management Classes (Present AEMC), and Best Attainable Ecological Management Class (Best AEMC) for Quaternary Catchments in South Africa.* DWAF report, Institute for Water Quality Studies, Department of Water Affairs and Forestry. Pretoria: South Africa.

Kok, M. T., Tyler, S. R., Prins, A., Pintér, L., Baumüller, H., Bernstein, J. & Grosshans, R. (2010). *Prospects for Mainstreaming Ecosystem Goods and Services in International Policies*. Bilthoven: The Hague.

Koschke, L., Lorz, C., Fürst, C., Lehmann, T., & Makeschin, F. (2014). Assessing hydrological and provisioning ecosystem services in a case study in Western Central Brazil. *Ecological Processes*, 3(2), 1–15.

Kotzé, I., Beukes, H., van den Berg, E. & Newby, T. (2010). *National Invasive Alien Plant Survey*. Report No. GW/A/2010/21, Agricultural Research Council – Institute for Soil, Climate and Water: Pretoria.

La Grange, M.R. (2011). *The rate and projected impact of development, with emphasis on mining, on biodiversity in the Mpumalanga Province, South Africa*. Honours Thesis, Dept Plant Science, University of Pretoria, South Africa.

Liebenberg, L., Steventon, L., Benadie, K. & Minye, J. (1999). Rhino tracking with the CyberTracker field computer. *Pachyderm*, 27, 59-61

Mace, G.M., Norris K., & Fitter A.H. (2011). Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology and Evolution* 27(1), 19-26.

MAES. (2013). *An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020.* Discussion paper –version 9.6.

MAES (2014). *Mapping and assessment of ecosystems and their services – Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020.* Technical report – 2014-080. European Commission.

Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Synthesis.* Washington, DC: Island Press.

Müller, F., & Burkhard, B. (2012). The indicator side of ecosystem services. *Ecosystem Services,* 1(1), 26–30.

Nahlik, A. M., Kentula, M. E., Fennessy, M. S., & Landers, D. H. (2012). Where is the consensus? A proposed foundation for moving ecosystem service concepts into practice. *Ecological Economics*, 77, 27-35

Naidoo, R., Weaver, L. C., Stuart-Hill, G., & Tagg, J. (2011). Effect of biodiversity on economic benefits from communal lands in Namibia. *Journal of Applied Ecology,* 48(2), 310-316.

Nel, J.L., Driver, A., Strydom, W., Maherry, A., Petersen, C., Hill, L., Roux, D.J., Nienaber, S., van Deventer H, Swartz, E., and Smith-Adao. (2011). *Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources.* WRC Report No.TT 500/11, Water Research Commission, Pretoria.

Nel, .JL., Colvin, C., Le Maitre, D.C., Smith, J. and Haines, I. (2013). *Defining South Africa's Water Source Areas.* WWF-World Wide Fund for Nature: Cape Town.

Nemec, K. T., & Raudsepp-Hearne, C. (2013). The use of geographic information systems to map and assess ecosystem services. *Biodiversity and Conservation*, 22, 1-15.

PBL. (2010). *Rethinking Global Biodiversity Strategies.* Den Haag/Bilthoven: The Netherlands.

Peh, K. S. H., Balmford, A., Bradbury, R. B., Brown, C., Butchart, S. H. M., Hughes, F. M. R., Stattersfiled, A., Thomas, D.H.L., Walpole, M., Bayliss, J., Gowing, D., Jones, J.P.G., Lewis, S. L., Mulligan, M., Pandeya, B., Stratford, C., Thompson, J.R., Turner, K., Vira, B., Wilcock, S. & Birch, J. C. (2013). TESSA: A toolkit for rapid assessment of ecosystem services at sites of biodiversity conservation importance. *Ecosystem Services*, 5, 51–57.

Potschin, M. B., & Haines-Young, R. H. (2011). Ecosystem services: Exploring a geographical perspective. *Progress in Physical Geography*, 35 (5), 575-594.

Pretty, J., Guijt, I., Scoones, I., Thompson, J. (1995). A *trainer's guide for participatory learning and action.* IIED: London.

Republic of South Africa. (2014). *South Africa's Fifth National Report to the Convention on Biological Diversity.* Pretoria: South Africa.

Reyers, B., Nel, J., O'Farrell, P., Selomane, O., Smith, J. & Yapi, T. (2014). *Assessing ecosystem service change & its impacts on human wellbeing: A national pilot of indicator approaches and data.* Council for Scientific and Industrial Research: Report No: CSIR/NRE/ECOS/IR/2014/0016/B

Rodríguez, L. C., Pascual, U., & Niemeyer, H. M. (2006). Local identification and valuation of ecosystem goods and services from Opuntia scrublands of Ayacucho, Peru. *Ecological Economics,* 57(1), 30–44.

Rounsevell, M. D. A., Dawson, T. P., & Harrison, P. A. (2010). A conceptual framework to assess the effects of environmental change on ecosystem services. *Biodiversity and Conservation*, 19(10), 2823-2842.

Secades, C., O'Connor, B., Brown, C., and Walpole, M. (2014). *Earth observations for biodiversity monitoring: A review of current approaches and future opportunities for tracking progress towards the Aichi Biodiversity Targets*. Technical Series No. 72. Secreteriat of the CBD: Montreal.

Scholes, R.J. (1998). *The South African 1: 250 000 maps of areas of homogenous grazing potential.* Report ENV-P-C 98190, CSIR, Pretoria.

Stats SA. (2012a). *Census 2011 Statistical Release*. Statistics South Africa: Pretoria.

Stats SA. (2012b). *General Household Survey 2011.* Statistics South Africa: Pretoria.

Stone, R.P. & Hilborn, D. (2000). *Universal soil loss equation (USLE).* Factsheet ISSN 1198-712X, Ministry of Agriculture and Food, Ontario, Canada.

Tallis, H., Kareiva, P., Marvier, M. & Chang, A. (2008). An ecosystem services framework to support both practical conservation and economic development. *PNAS*, 105 (28), 9457-9464.

Tallis, H.T., Ricketts, T., Guerry, A.D., Wood, S.A., Sharp, R., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Pennington, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Arkema, K., Lonsdorf, E., Kennedy, C., Verutes, G., Kim, C.K., Guannel, G., Papenfus, M., Toft, J., Marsik, M., Bernhardt, J., and Griffin, R., Glowinski, K., Chaumont, N., Perelman, A., Lacayo, M. (2013). *InVEST 2.5.6 User's Guide.* The Natural Capital Project, Stanford.

Turner, R.K. & Daily, G.C. (2008). The Ecosystem Services Framework and Natural Capital Conservation. *Environmental and Resource Economics*, 39(1), 25-35.

UK National Ecosystem Assessment. (2014). *The UK National Ecosystem Assessment: Synthesis of the Key Findings*. UNEP-WCMC, LWEC: UK.

UNEP. (2007). *Global Environment Outlook IV: Environment for Development.* London.

UNEP-WCMC. (2011). *Developing ecosystem service indicators: Experiences and lessons learned from sub-global assessments and other initiatives.* CBD: Canada.

UNEP-WCMC, & IEEP. (2013). *Incorporating biodiversity and ecosystem service values into NBSAPs: Guidance to support NBSAP practitioners.* Cambridge, Brussels.

Van den Berg, E.C., Plarre, C., Van den Berg, H.M. & Thompson, M.W. (2008). *The South African National Land Cover 2000***.** Agricultural Research Council (ARC) and Council for Scientific and Industrial Research (CSIR), Pretoria. Report No. GW/A/2008/86.

Wallace, K. (2007). Classification of ecosystem services: Problems and solutions. *Biological Conservation*, 139(3-4), 235-246.

Wilkinson, C., Saarne, T., Peterson, G.D., & Colding, J.C. (2013). Strategic spatial planning and the ecosystem services concept – an historical exploration. *Ecology and Society*, 18(1).

Yapi, T. (2013). *An assessment of the impacts of invasive Australian wattle species on grazing provision and livestock production in South Africa.* MSc Thesis, Stellenbosch University, South Africa.

www.unep.org

United Nations Environment Programme
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
e-mail: uneppub@unep.org
www.unep.org

UNEP WCMC