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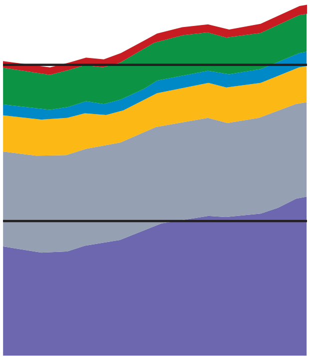
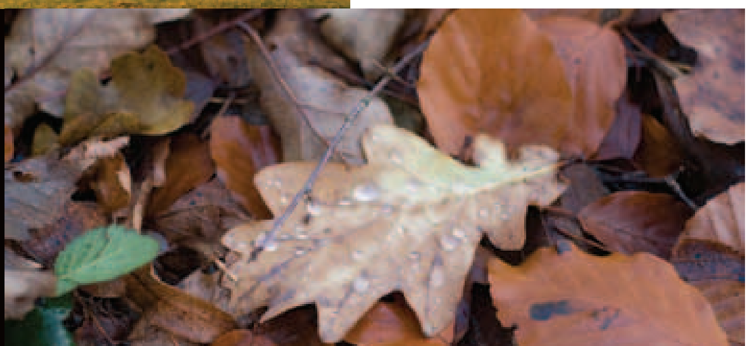


58

# DEVELOPING ECOSYSTEM SERVICE INDICATORS:

## Experiences and lessons learned from sub-global assessments and other initiatives



UNEP WCMC

Convention on Biological Diversity

bip Biodiversity Indicators Partnership

Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems

Stockholm University

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## Experiences and lessons learned from sub-global assessments and other initiatives

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Note that since the 1st January 2011, SwedBio became The Resilience and Development Programme – SwedBio – at the Stockholm Resilience Centre/Stockholm University.

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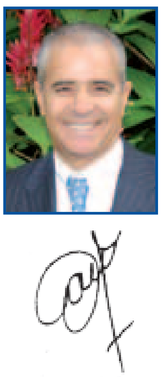
# FOREWORD

The importance of ecosystem services in supporting economic activity and human well-being cannot be underestimated. Actions are required to measure and monitor ecosystems, the services they deliver and their impact on well-being, so as to ensure that their importance and worth is taken into account in decision making processes. In this regard, robust ecosystem service indicators are essential to assess the status and trends of ecosystem services at local, regional, national and global levels. Without this information it will be impossible to judge the success of policies implemented to maintain or restore them.

This report represents the efforts of a wide group of experts who were challenged with identifying how we might improve our understanding of ecosystem services using indicators. It focuses on the practical details of monitoring and measuring ecosystem services at scales that are relevant for policy and management. Drawing from a range of case studies and a thorough analysis of the literature, it lays out both the challenges to developing reliable indicators and the opportunities for improving and enhancing what we currently know.

With the recent adoption of an ambitious set of international commitments for biodiversity and ecosystem services in the form of the Aichi Targets, the need for the best possible information to monitor progress is greater than ever. Likewise, the emergence of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), and the momentum generated by The Economics of Ecosystems and Biodiversity (TEEB) provide added impetus for decision-makers at all scales and in all sectors to address the gaps in information on the values of our ecosystems and natural capital. If we continue to be unable to adequately measure the benefits from our ecosystems then these benefits will continue to be undervalued and eroded. This report is therefore a very timely initiative.

The pages that follow contain a wealth of information and advice on developing practical and pragmatic ways to measure and assess the multitude of ecosystem services. It is our hope and expectation that it will be a valuable resource for scientists, practitioners and policy-makers alike.



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# EXECUTIVE SUMMARY

## BACKGROUND

People depend upon ecosystems to supply a range of services necessary for their survival and well-being. Ecosystem service indicators are critical for knowing whether or not these essential services are being maintained and used in a sustainable manner, thus enabling policy makers to identify the policies and other interventions needed to better manage them. As a result, ecosystem service indicators are of increasing interest and importance to governmental and inter-governmental processes, including amongst others the Convention on Biological Diversity (CBD) and the Aichi Targets contained within its strategic plan for 2011-2020, as well as the emerging Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Despite this growing demand, assessing ecosystem service status and trends and developing robust indicators is often hindered by a lack of information and data, resulting in few available indicators.

In response, the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), together with a wide range of international partners and supported by the Swedish International Biodiversity Programme (SwedBio)*, undertook a project to take stock of the key lessons that have been learnt in developing and using ecosystem service indicators in a range of assessment contexts. The project examined the methodologies, metrics and data sources employed in delivering ecosystem service indicators, so as to inform future indicator development. This report presents the principal results of this project.

## WHAT IS CURRENTLY BEING MEASURED?

There are many different kinds of ecosystem service, and many different kinds of indicators and metrics used to monitor them. The most common and well developed indicators are for provisioning services, for which the most data exist. Some regulating service indicators are well developed, and amongst cultural services information on tourism and recreation is most frequently collected.

Most indicators are derived from data on the structure (extent/condition/stock) of underlying elements of an ecosystem, or on the supply or use of services. In many assessments information on habitats and biodiversity are used as proxies for ecosystem services. There are few measures of ecosystem functioning or sustainability of use of different services.

A variety of data sources are used to compile ecosystem service indicators, including published and unpublished studies as well as data from ongoing monitoring and reporting initiatives. Assessments, which tend to synthesise existing information, often rely on one-off studies which provide baseline data on the magnitude and distribution of ecosystem services without including information on change over time.

Ecosystem service mapping is a useful and increasingly common way to present information, although this is generally data intensive and relies on models which require verification. The scale at which indicators are developed and used varies, and different methods and metrics may be applicable at different scales; indicators developed at global scales may have limited use at local scales and vice versa.

**Now The Resilience and Development Programme at the Stockholm Resilience Centre/Stockholm University*

## ISSUES AND CHALLENGES

Given the range of services delivered by ecosystems and the fact that different ecosystem services do not necessarily co-vary, it will generally be the case that a single indicator will not be sufficient for most assessment purposes. The choice of services to assess, together with the indicators to use, is determined by policy objectives and data availability. The latter is affected by the lack of ongoing monitoring of most ecosystem services in most places. It is important to ensure that any proxy measures used are meaningful, that is that any change in the proxy measure accurately indicates change in the service of interest. Data gaps also mean that ecosystem service indicators and assessments will have relatively high uncertainty levels associated with them which must be made explicit.

It is important to understand what each kind of indicator or metric says about ecosystem services. For example, information on the condition of the ecosystem, including measures of biodiversity, habitat extent, or the stock of particular components says something about the ability of the ecosystem to provide services but not necessarily very much about the benefits derived from those services. Likewise information on off-take or consumption provide information about the flow of benefits but says little about the sustainability of these benefit flows without comparable information on ecosystem condition or extent.

There is an increasing focus on the use of economic metrics to describe ecosystem services. This form of quantification is attractive to decision-makers and can facilitate comparative analyses for many services. There is a growing body of work on improving ecosystem service valuation techniques, and in particular mapping the spatial distribution of ecosystem service values. However, not all ecosystem services can be easily quantified in economic or monetary terms, with cultural services being particularly challenging.

Better understanding of the factors influencing ecosystem service maintenance and delivery requires a systems approach, using linked or bundled indicators that simultaneously track the drivers and pressures on ecosystems, alongside the state of the system and the services and well-being impacts delivered, together with the policy and management responses to change. This can add significant complexity, and so ways to simplify communication of indicator information are important.

## RECOMMENDATIONS

There is increasing activity to develop and test ecosystem service indicators at a range of scales, from wide-scale mapping initiatives to the development of local site-scale assessment tools. Some examples of ecosystem services and their methodologies taken from a range of sub-global assessments and other initiatives are presented as indicator fact sheets at the end of this report.

Although gaps are being filled and progress continues to be made, uncertainty remains regarding how to measure many ecosystem services and how to interpret and use the information provided. Some consolidated key messages for the development and use of ecosystem service indicators were distilled during this project:

1. **Ensure objectives are clear**
   The process of defining and developing indicators requires a guiding plan or framework. Indicators are there to answer specific questions or to assess policy objectives and can only be developed in the context of those questions/objectives. Clear objectives and targets help to identify and define indicators as specifically as possible to avoid misinterpretation.

2. **Adopt a small set of specific, policy-relevant indicators**
   Don't try to do everything. Resources should be used to address key elements (i.e. those most policy relevant) and information gaps. Where possible include linked indicators covering as many aspects of the ecosystem assessment framework (socio-ecological system) as possible (e.g. state and trends, driving forces, policy effectiveness).

3. **Go beyond provisioning services**
   Where possible, create indicators for different types of ecosystem service. Currently there is an over-reliance on indicators that capture the value of a few species and ecosystems relevant to food and fibre production, which are rarely good proxies for other kinds of service or for resilience.

4. **Utilise existing data and proxies (but recognise limits)**
   Developing ecosystem service indicators is best viewed as an iterative process. Start with the low hanging fruit (i.e. do what it is possible) and improve over time. Use available knowledge and indicators as a starting point. Where direct measures are not yet developed or where there are no data, good proxy indicators can be used. Note that not all ecosystem services are easily quantifiable. Qualitative metrics can be as useful as quantitative ones.

5. **Think about sustainability – include indicators for both ecosystems and benefits**
   Measure both the supply of the service (including state/condition of the ecosystem or its relevant components) as well as the benefits from services and impacts on well-being.

6. **Include biodiversity**
   Since biodiversity indicators are better developed, and biodiversity underpins the delivery of ecosystem services, they are sometimes used as proxies for ecosystem services. However, although in some categorisations biodiversity is classified as an ecosystem service they are not inter-changeable. It is important not to lose sight of the importance of biodiversity by focusing only on ecosystem service benefits.

7. **Be sensitive to scale**
   The scale at which ecosystem services are measured and reported should be appropriate to the decision-making context. Some things are more appropriate at certain scales and not others. Not everything can be scaled up.

8. **Assess trends and consider synergies and trade-offs**
   Some indicators are snapshots or baselines, but replicable measures are important for monitoring change and tracking progress. Monitoring multiple services over time allows a better understanding of synergies and trade-offs.

### 9. Engage stakeholders early

Defining and developing indicators should involve all relevant stakeholders from the outset. Ecosystem service indicators should be chosen to meet the needs of specific users. Establishing a dialogue with data providers and end users of indicators is crucial. Wide stakeholder engagement will also aid in defining indicators as specifically as possible to avoid misinterpretation. In addition the process of developing indicators requires collaboration with other sectors. Mainstreaming is a key component of indicator development. Key to this is to identify entry points for mainstreaming ecosystem service indicators in assessments. Linking the indicators to national development plans helps.

### 10. Focus on communication

Communicating indicators is important but sometimes neglected. It may incorporate raising public awareness as well as engaging policy-makers. It is important to use indicators that policymakers are likely to be most interested in, whilst presenting storylines in the most policy-relevant way. Ecosystem services cut across different sectors, all of which may require tailored communication. Some key communication messages include:

a. *Be clear about what indicators are telling you*: Use a common language. Some work may be required on definitions of key terms for communicating that story.

b. *Be transparent about uncertainty*: Keep in mind the limits of indicators, and uncertainty – use clear terminology. Provide accurate interpretation of the storyline.

c. *Use maps (spatially explicit data) where possible*: Where possible and relevant, these can be useful aids to communication and analysis. Be sure to present the findings at the scale most relevant to decision-makers.

d. *Avoid over-simplification*: Ecosystem services do not necessarily co-vary, and so aggregation is challenging and needs further work. Bundling indicators into related packages/storylines may aid communication.

e. *Economic metrics are useful but don't ignore non-monetary values*: Where possible, using economic metrics helps mainstreaming in other sectors. Not all indicators are practical to determine in monetary values but that does not lessen their utility.

# 执行摘要

## 背景

人类依靠生态系统来提供他们生存和福祉所需的一系列服务。生态系统服务指标对了解这些重要的服务是否在可持续的方式下被维护和使用是非常重要的，因此也使政策制定者们可以识别那些能更好地对这些服务进行管理的政策和其它的干预些服务进行管理的政策和其它干预。其结果就是生态系统服务指标对于政府和政府间的进程变得越来越有趣及重要，包括生物多样性公约（CBD）和包含在其2011-2020年战略计划内的爱知县目标，以及正在出现的有关生物多样性和生态系统服务（IPBES）的政府间平台。尽管有这个持续增长的需求，评估生态系统服务状态和趋势以及发展稳定的指标还是常常因为信息和数据的不足而受到限制，这就导致了仅有有限的指标可被获取。

作为反馈，联合国环境署-世界保护监测中心（UNEP-WCMC）在瑞典国际生物多样性计划（SwedBio）*的支持下，同大范围的国际伙伴一起承担了一个积累那些在一系列评估范围内发展和使用生态系统指标中所学到的主要经验教训的项目中所学到的主要经验教训。这个项目评估了在交付生态系统服务指标中所用到的方法、度量和数据资源，以便告知未来的指标发展。本报告涵盖了此项目的主要结果。

## 目前什么正在被量测

有很多不同的生态系统服务，以及很多种指标和度量被用来监测它们。最常用的被很好地发展的指标是被用来提供服务的，在这方面有很多数据是存在的。一些调节文化指标是被发展得比较好，并且在有关旅游业和娱乐的文化服务信息是最经常被收集的。

大多数指标是从有关一个生态系统的基本要素的结构（范围/条件/货存）数据或从服务的提供和使用数据提取出来的。在很多评估中，有关栖息地和生物多样性的信息被用来作为生态系统服务的替代。有非常少的生态系统的运作或不同服务的使用可持续性的量测。

很多数据源被用来编译生态系统服务指标，包括发表的和没有发表的研究以及来自正在进行的监测和报告倡议的数据。评估，往往综合现有的信息，经常依赖那些提供有关生态系统服务的大小和分布提供基线数据而不包括随着时间而变化的信息的一次性研究。

生态系统服务制图是一个有用的和越来越普遍的呈现信息的方式，尽管这往往是数据密集型且依赖于需要通过检验的模型。指标被发展和使用的尺度是变化的，不同的方法和度量或许是可以在不同尺度应用的；在全球尺度发展的指标可能在当地尺度的应用会受到限制，反之亦然。

*现为在斯德哥尔摩的弹性与发展计划

## 问题与挑战

鉴于生态系统所提供的服务范围以及不同生态系统服务并不一定共变的事实，单一的指标对大多数的评估目的来说将是不够的将成为普遍现象。服务的选择来评估以及将使用的指标是由政策目标和数据可获取性决定的。后者被大多数地方的大多数生态系统服务的正在进行的监测的不足所影响。保证任何使用的替代测量方式有意义是非常重要的，即任何替代测量方式的变化都精确反映了感兴趣的服务中的变化。数据差距也意味着生态系统服务指标和评估将会有相对比较高的不确定性，而这些必须被明确指出。

理解每种指标或度量所指的是什么对于生态系统服务是非常重要的。例如，有关生态系统状况的信息，包括生物多样性、栖息地范围、或特定组建货存的量测所指的一些关于生态系统提供服务的能力，而不一定是关于从这些服务中可以提取的惠益。同样的信息有关承购或消费提供了有关惠益流的信息，但是在没有关于生态系统状况或范围的比较信息的情况下，对于这些惠益流的可持续性并没有做过多的解释。

使用经济指标来描述生态系统服务被越来越多地关注。这种形式的量化对于决策者们来说是比较有吸引力的，并且可以辅助很多服务的比较分析。有关改进生态系统服务估价技术的工作正在成长，尤其是在生态系统服务价值的空间分布制图方面。然而，并非所有的生态系统服务都可能在经济或货币术语进行量化，文化服务尤其成为一大挑战。

对于影响生态系统服务维护和交付的因素的更好的理解需要一个系统方式，使用连接的或捆绑的指标来同步跟踪生态系统的动因和压力，以及系统的状态和交付的服务福祉影响，以及对于变化产生反馈的政策和管理。这可以增加非常大的复杂性，并且简化指标信息的交流方式是非常重要的。

## 推荐

在一定范围的尺度上，从大尺度制图倡议到本地尺度评估工具的发展，发展和测试生态系统服务指标的活动越来越多。一些生态系统服务的例子和从子全球评估中得到的它们的方法和其它的倡议被作为指标实况报道在本报告最后呈现出来。

尽管差距正在被填补并且进展也在持续进行，有关如何量测很多生态系统服务和如何解绎和使用所提供的信息的不确定性仍然存在。一些对于生态系统服务指标开发和利用的综合关键信息在本项目中被抽取。

1. 确保目标明确
   定义和发展指标的过程需要一个指导计划或框架。指标是用来回答特定问题或者评估政策目标，且只能在这些问题/目标的范围内被发展。明确的目标有助于识别和定义指标，以避免错误的解绎。

2. 采取一个特定的、政策相关的指标集
   不要尝试去做每一件事情。资源应该被用来解决关键要素和信息的差距。可能的地方包括连接的指标涵盖尽可能多的生态系统评估框架（社会生态系统）的很多方面（例如，状态和趋势，驱动力量，政策的有效性）。

3. 超越供应服务
   哪里有可能，就在哪里生成不同种类生态系统服务的指标。目前，对于获取与食物和纤维产品相关的少数物种和生态系统的值的指标存在一种过分依赖。而这些指标很少可以成为其它种类的服务或弹性的好的替代。

4. 使用已存在的数据和替代（但是意识到不足）
   发展生态系统服务指标被认为是一个反复迭代的过程。从最低垂挂的果实开始（换句话讲就是做当时可能做到的事情）并且随着时间而改进。使用可获取的知识和指标作为一个起始点。在那些没有直接量测的地方或那些没有数据的地方，可以使用好的替代指标。需要注意的是并非所有的生态系统服务都是很容易被量化的。定性的度量可以同定量的度量同样有用。

5. 考虑可持续性-包括生态系统和惠益的指标
   量测服务的供应（包括生态系统的状态或其相关组件）以及来自服务的惠益和对于福祉的影响。

6. 包括生物多样性
   因为生物多样性指标是被更好地发展，并且生物多样性支撑生态系统服务的交付，它们有时候被用来作为生态系统服务的替代。然而，尽管在一些分类方法中生物多样性被分类为一个生态系统服务，它们并非通用的。重要的是不能因为仅仅关注生态系统服务惠益而将生物多样性本身的重要性抛诸脑后。

7. 对尺度敏感
   生态系统服务被量测和报告的尺度应该适应决策制定的境况。一些事情在特定的尺度下更为合适，而在另外一些尺度则不然。并非所有的事情都可以被按比例放大的。

8. 评估趋势并考虑协同效用和权衡
   一些指标是快照或基线，但是可复制的量测对变化监测和进程跟踪都是非常重要的。随着时间变化监测多种服务使得对于协同效用和权衡的更好的理解成为可能。

## 9. 使利益相关者尽早参与进来

定义和发展指标应该从一开始就将所有的利益相关者都包含进来。生态系统服务指标应该被选择来满足特定使用者的需求。建立一个数据提供者和指标终端使用者的对话是非常重要的。利益相关者的大范围参与将同时有助于尽量具体地定义指标，以避免对指标的错误解绎。另外，发展指标的过程需要同其它部门的合作。主流化是一个指标发展的关键组建。这个的关键就是识别评估中的主流生态系统服务指标的切入点。将指标同国家发展计划链接起来是比较有帮助的。

## 10. 关注交流

交流指标是重要的，但是有的时候会被忽视。它或许综合了提升民众的意识以及使政策制定者参与进来。重要的是使用那些政策制定者们更加感兴趣的指标，同时使用同政策最为相关的方式提供故事链。生态系统服务跨越不同部门，所有这些部门都需要量身定制的交流。一些主要的交流信息包括：

a. 明确知道指标的含义：使用通俗的语言。为了交流一个特定的故事，可能需要一些定义关键术语的工作。

b. 不确定性透明化：认识到指标的限制和不确定性——使用清晰的术语。提供对于故事链的准确解绎。

c. 可能的地方使用地图（空间明确的数据）：在可能的和相关的地方，这些有助于交流和分析。确切地在同政策制定者最为相关的尺度呈现调查结果。

d. 避免过分简单化：生态系统服务不一定是共变的，因此聚合是有挑战性的且需要进一步工作。将指标捆绑为相关的包/故事链可能有助于交流。

经济指标是有用的，但是不要忽视非货币的价值：在可能的地方，使用经济指标有助于其它部门的主流。并非所有的指标都可以通过货币而确定价值，但是并不会因此而减少其效用。

# RÉSUMÉ


## CONTEXTE

Les peuples dépendent des écosystèmes pour la provision de services nécessaires à leur survie et leur bien-être. Les indicateurs de services écosystémiques sont cruciaux pour connaitre si ces services essentiels sont maintenus et utilisés de manière durable, permettant ainsi aux décideurs politiques d'identifier les politiques et autres interventions nécessaires à leur meilleure gestion. En conséquence, les indicateurs de services écosystémiques sont d'un intérêt croissant pour les processus gouvernementaux et intergouvernementaux, y compris la Convention sur la Diversité Biologique (CDB) et les objectifs d'Aichi décrits dans le plan stratégique pour 2011-2020, ainsi que la Plate-forme intergouvernementale sur la biodiversité et les services écosystémiques (IPBES) émergente. En dépit d'une demande croissante, l'évaluation du statut des services écosystémiques et de leurs tendances, et le développement d'indicateurs robustes sont souvent entravés par un manque d'information et de données, résultant en peu d'indicateurs disponibles.

En réponse, le Centre Mondial de Surveillance pour la Conservation de la Nature du Programme des Nations Unies pour l'environnement (PNUE-WCMC), en association avec une grande diversité de partenaires internationnaux et l'appui du programme suédois pour la biodiversité internationale (SwedBio)*, a entreprit un projet pour faire le point sur les leçons clefs apprises en développant et en utilisant les indicateurs de services écosystémiques dans une variété de contextes d'évaluation. Le projet a examiné les méthodologies, les jeux de mesures et les sources de données employées dans la délivrance d'indicateurs de services écosystémiques, afin d'informer le développement de futurs indicateurs. Ce rapport présente les principaux résultats de ce projet.

## QU'EST-CE QUI EST MESURÉ À PRÉSENT ?

Il y a différents types de services écosystémiques, et de nombreux types d'indicateurs et de jeux de mesures et données pour leur suivi. Les indicateurs les plus répandus et développés concernent les services de prélèvement, pour lesquels le plus de données existent. Certain indicateurs sur les services de régulation sont bien développés, et parmi eux les informations sur les services culturels relatifs au tourisme et aux loisirs sont les plus souvent collectées.

La plupart des indicateurs sont dérivés de données sur la structure (étendue/condition/stock) des éléments sous-jacents d'un écosystème, ou sur la fourniture de services. Dans de nombreuses évaluations, l'information sur les habitats et la biodiversité sont utilisés comme une approximation des services écosystémiques. Il y a peu de mesures du fonctionnement ou de la durabilité d'utilisation des différents services.

Toutes sortes de sources de données sont utilisées pour assembler les indicateurs de services écosystémiques, y compris des études publiées et non publiées, ainsi que des données provenant de suivis toujours en cours et de rapports. Les évaluations, qui ont tendance à synthétiser les informations existantes, dépendent souvent d'études uniques qui fournissent des données préliminaires sur la magnitude et la distribution des services écosystémiques, sans inclure d'information sur leur changement au cours du temps.

La cartographie des services écosystémiques est une façon utile et de plus en plus fréquente de présenter l'information, bien que cela nécessite généralement beaucoup de données et dépende de modèles qui demandent vérification. L'échelle à laquelle ces indicateurs sont développés et sont utilisés varie, et les différentes méthodes et jeux de mesures et données peuvent être appliqués à différentes échelles ; les indicateurs développés à l'échelle mondiale peuvent avoir une utilisation limitée à l'échelle locale, et vice versa.


*Dorénavant le Programme de Résilience et de Développement du Centre de Résilience de Stockholm / Université de Stockholm.*

## PROBLÈMES ET DÉFIS

Etant donné l'étendue des services délivrés par les écosystèmes et le fait que différents services écosystémiques ne sont pas nécessairement covariants, un indicateur unique ne sera généralement pas suffisant pour la plupart des objectifs d'évaluation. Le choix des services à évaluer, ainsi que des indicateurs à utiliser, est déterminé par les objectifs politiques et la disponibilité des données. Cette dernière est affectée par le manque de suivi régulier de la plupart des services écosystémiques dans la plupart des endroits. Il est important de s'assurer que toute mesure approximative utilisée est appropriée, c'est-à-dire que tout changement de sa valeur indique bien un changement du service étudié. Des carences de données indiquent aussi que les indicateurs de services écosystémiques et les évaluations auront un niveau d'incertitude associé relativement élevé qui doit être rendu explicite.

Il est important de comprendre ce que chaque type d'indicateur ou jeu de mesures et données indique à propos des services écosystémiques. Par exemple, les informations sur la condition de l'écosystème, y compris les mesures de la biodiversité, de l'étendue des habitats, ou du stock de composantes particulières, donnent des renseignements sur la capacité de l'écosystème à fournir des services, mais pas nécessairement beaucoup sur les bénéfices dérivés de ces services. De même, sans fournir d'information sur la condition ou l'étendue de l'écosystème, les informations sur les activités de prélèvement ou la consommation fournissent des informations sur le flux de bénéfices, mais peu de renseignements sur la durabilité de ces flux de bénéfices.

L'utilisation de jeux de mesures et données économiques pour décrire les services écosystémiques fait l'objet d'un d'intérêt croissant. Cette forme de quantification est attirante pour les décideurs et peut faciliter les analyses comparatives de nombreux services.

De plus en plus de travaux sont réalisés sur l'amélioration des techniques d'évaluation des services écosystémiques, et en particulier concernant la cartographie de la distribution spatiale des valeurs du service écosystémique. Toutefois, tous les services écosystémiques ne peuvent être quantifiés en termes économiques et monétaires, les services culturels présentant un défi particulier.

Une meilleure compréhension des facteurs qui influencent le maintien et la provision d'un service écosystémique nécessite une approche systémique qui utilise des indicateurs liés ou groupés qui suivent simultanément les facteurs et les pressions sur les écosystèmes, l'état du système et des services, leurs impacts sur le bien-être, et les réponses politiques et de gestion au changement. Ceci peut ajouter un certain niveau de complexité ; il est donc important de développer des moyens de simplifier la communication de l'information sur les indicateurs.

## RECOMMANDATIONS

Il y a de plus en plus d'activités qui ont pour but de développer et tester les indicateurs de services écosystémiques à une variété d'échelles, allant des initiatives de cartographie à grande échelle au développement d'outils d'évaluation à l'échelle de sites locaux. Des exemples de services écosystémiques et de leurs méthodologies issues d'une variété d'évaluations à l'échelle mondiale intermédiaire ainsi que d'autres initiatives sont présentés comme fiches de renseignements sur les indicateurs à la fin de ce rapport.

Bien que les carences soient en train d'être comblées et que les progrès continuent, l'incertitude demeure sur comment mesurer plusieurs services écosystémiques et comment interpréter et utiliser les informations fournies. Des messages clefs consolidés pour le développement et l'utilisation des indicateurs de services écosystémiques ont été identifiés durant ce projet :

1. **Assurez vous que les objectifs sont clairs**
   Le processus de définition et de développement d'indicateurs nécessite un plan directeur ou cadre. Les indicateurs sont là pour répondre à des questions spécifiques ou pour évaluer des objectifs politiques, et ne peuvent être développés que dans le contexte de ces questions/objectifs. Des objectifs clairs et des cibles précises aident à identifier et à définir des indicateurs aussi spécifiquement que possible afin d'éviter des erreurs d'interprétation.

2. **Adoptez un petit jeu d'indicateurs spécifiques et adaptés aux politiques**
   N'essayez pas de tout faire. Les ressources disponibles doivent être utilisées afin d'adresser les éléments clefs (c'est-à-dire ceux qui sont les plus adaptés aux politiques) et les carences en information. Lorsque cela est possible, incluez des indicateurs apparentés couvrant autant d'aspects du cadre d'évaluation de l'écosystème (système socio-écologique) que possible (par exemple état et tendances, forces agissantes, efficacité de la politique).

3. **Allez au-delà des services de prélèvement**
   Lorsque cela est possible, créez des indicateurs pour différents types de services écosystémiques. A présent, il y a une dépendance trop forte vis-à-vis des indicateurs qui saisissent la valeur de quelques espèces et écosystèmes pertinents pour l'alimentation et la production de fibres, qui constituent rarement de bonnes approximations pour d'autres types de services ou pour la résilience.

4. **Utilisez les données existantes et les approximations (mais reconnaissez leurs limites)**
   Le développement d'indicateurs de services écosystémiques est mieux représenté en tant que processus itératif. Commencez par l'aspect le plus facile (c'est-à-dire faites ce qui est possible) et améliorez vous au cours du temps. Utilisez les connaissances disponibles et les indicateurs comme point de départ. Là où les mesures directes n'ont pas encore été développées, ou là où il n'y a pas de données, de bons indicateurs approximatifs peuvent être utilisés. Notez que tous les services écosystémiques ne sont pas facilement quantifiables. Des jeux de mesures et données qualitatives peuvent être aussi utiles que les mesures quantitatives.

5. **Pensez à la durabilité – Incluez les indicateurs qui concernent à la fois les écosystèmes et leurs bénéfices**
   Mesurez à la fois la fourniture du service (y compris l'état et/ou la condition de l'écosystème ou de ses composantes appropriées), ainsi que les bénéfices des services et leurs impacts sur le bien-être.

6. **Incluez la biodiversité**
   Etant donné que les indicateurs sur la biodiversité sont mieux développés, et que la biodiversité est à la base de la fourniture des services écosystémiques, ils sont quelquefois utilisés comme approximation pour les services écosystémiques. Toutefois, bien que dans certaines catégorisations la biodiversité soit classée comme un service écosystémique, ils ne sont pas interchangeables. Il est important de ne pas perdre de vue l'importance de la biodiversité en se focalisant seulement sur les bénéfices des services écosystémiques.

7. **Soyez sensibles à l'échelle**
   L'échelle à laquelle les services écosystémiques sont mesurés et rapportés doit être appropriée au contexte de prise de décision. Certaines choses sont plus appropriées à certaines échelles que d'autres. Tout ne peut pas faire le sujet d'une augmentation d'échelle.

8. **Evaluez les tendances et considérez les synergies et compromis**
   Certains indicateurs constituent des aperçus ponctuels ou préliminaires, mais des mesures pouvant être répliquées sont importantes pour suivre le changement et le progrès. Le suivi de multiples services au cours du temps permet une meilleure compréhension des synergies et compromis.

### 9. Engagez les parties prenantes tôt

Définir et développer des indicateurs doivent impliquer toutes les parties prenantes dès le début. Les indicateurs de services écosystémiques doivent être choisis afin de répondre aux besoins d'utilisateurs spécifiques. Etablir un dialogue avec les fournisseurs de données et les utilisateurs d'indicateurs est crucial. Un engagement important des parties prenantes aidera également à définir des indicateurs aussi spécifiquement que possible afin d'éviter des erreurs d'interprétation. De plus, le processus de développement des indicateurs nécessite la collaboration avec d'autres secteurs. Transmettre les idées et les concepts associés aux indicateurs plus largement est une composante clef de leur développement. La solution clef à cela est d'identifier les points d'entrée pour mettre les indicateurs de services écosystémiques au cœur des évaluations. Lier les indicateurs aux plans de développement nationaux aide à cela.

### 10. Concentrez-vous sur la communication

Communiquer les indicateurs est important mais quelquefois négligé. Ceci peut incorporer la sensibilisation du public, ainsi que l'engagement des décideurs politiques. Il est important d'utiliser les indicateurs qui sont les plus susceptibles d'intéresser les décideurs politiques, tout en présentant des scenarios de la manière la plus pertinente possible pour les politiques. Les services écosystémiques sont présents dans différents secteurs, qui peuvent tous avoir besoin d'une communication bien adaptée. Des messages clefs de communication incluent :

a. Soyez clair sur ce que les indicateurs vous disent : Utilisez un langage simple. Du travail peut être nécessaire sur les définitions de termes clefs pour communiquer une histoire.

b. Soyez transparent sur l'incertitude : Souvenez-vous des limites des indicateurs, et de l'incertitude – Utilisez une terminologie claire. Fournissez une interprétation exacte du scenario.

c. Utilisez des cartes (données explicites dans l'espace) si possible : Lorsque cela est possible et pertinent, celles-ci peuvent constituer des aides utiles à la communication et à l'analyse. Assurez-vous de présenter les résultats à l'échelle la plus pertinente pour les décideurs politiques.

d. Evitez de trop simplifier : Les services écosystémiques ne sont pas nécessairement covariants, leur agrégation constitue donc un défi et nécessite plus de travail. Le groupement d'indicateurs dans des ensembles et/ou scenarios peut aider à la communication.

e. Les jeux de mesures et données économiques sont utiles, mais n'ignorez pas les valeurs non-monétaires : Si possible, l'utilisation de mesures économiques aide à renforcer l'importance des indicateurs dans d'autres secteurs. Tous les indicateurs ne sont pas aptes à être définis en valeurs monétaires, mais cela ne diminue pas pour autant leur utilité.

# ИСПОЛНИТЕЛЬНОЕ РЕЗЮМЕ

## ОБЩИЕ ДАННЫЕ О ПРОЕКТЕ

Человечество зависит от экосистем по ряду услуг, необходимых для его выживания и поддержания благополучия. Индикаторы услуг экосистем являются критическими в сообщении состояния надлежащего поддержания и рационального использования основных услуг, что позволяет лицам принимающим решения определять стратегии и прочие необходимые вмешательства для более успешного управления ими. В результате индикаторы обслуживания экосистем имеют увеличивающийся интерес и важность правительственных и межправительственных процессов, включая среди прочих Соглашения по Биологическому Разнообразию (КБР) и Задачи Aichi, состоящие в рамках стратегического плана на 2011-2020 гг, а также по ряду с появляющейся межправительственной платформой в области биоразнообразия и экосистемных услуг (IPBES). Несмотря на такую растущую потребность, оценка статуса обслуживания экосистемы и тенденций, и развития надежных индикаторов зачастую затруднительна из-за нехватки информации и данных, что в результате приводит к малому количеству индикаторов.

В ответ, Программа ООН по охране окружающей среды Всемирного Центра мониторинга природоохраны (UNEP-WCMC), вместе с широким рядом международных партнеров и при поддержке Шведской Международной Программы Биоразнообразия (SwedBio)*, предприняли проект, чтобы освоить основные уроки, которые были изучены при развитии и использовании индикаторов обслуживания экосистем в рамках оценочных контекстов. Проект проверил методологии, метрики и источники данных, употребляемые в индикаторах обслуживания экосистем, для того, чтобы информировать будущее развитие индикаторов. Данный отчет представляет принципиальные результаты данного проекта.

## ЧТО В ДАННОЕ ВРЕМЯ ИЗМЕРЯЕТСЯ?

Существуют различные виды обслуживания экосистем, и множество различных видов индикторов и метрик, используемых для их мониторинга. Наиболее общие и хорошо развитые индикаторы предназначены для провизорских услуг, по которым большинство данных существует. Некоторые регулирующие индикаторы обслуживания и среди информации по услугам культуры относительно туризма и отдыха, наиболее часто собираются.

Большинство индикаторов получено из данных по структуре (протяженность/условие/запас) основных элементов экосистемы, или при поставке или пользованию услуг. В основаном анализы информации по средам обитания и биоразнообразию используется в виде показателей по услугам экосистем. Существует несколько измерений по функциональности экосистем или рациональному использованию различных услуг.

Различные источники данных используются для составления индикаторов по услугам экосистем, включая опубликованные и неопубликованные исследования, а также данные из текущих инициатив по мониторингу и отчетности. Анализы, которые способствуют синтезированию существующей информации, зачастую опираются на одноразовые исследования, которые предоставляют данные по основной сюжетной линии по величине и распространению услуг экосистем без включения информации по изменению с истечением времени.

Нанесение на карту услуг экосистем является полезным и возрастающим способом представления информации, а также в целом данные интенсивные и опираются на модели, которые требуют выверки. Масштабы, в которых индикаторы разрабатываются и используются, изменяются, а различные методы и метрики также могут применяться в различных масштабах; индикаторы разработанные в глобальных масштабах могут иметь ограниченное использование в местных масштабах и наоборот.

**Теперь это Программа восстановления и развития при Стокгольмском центре восстановления/Университет Стокгольма.*

## ВОПРОСЫ И ТРУДНОСТИ

С учетом ряда услуг, обеспечиваемых экосистемами, и фактом того, что различные услуги экосистем не обязательно совместно изменяются, что обычно будет являться случаем, когда одиночный индикатор не будет достаточным для большинства оценночных целей. Выбор услуг для оценки совместно с индикаторами для использования определяется посредством стратегических целей и наличия данных. Последнее из двух подвергается воздействию текущего мониторинга большинства услуг экосистем в большинстве мест. Важно обеспечивать, чтобы любые используемые измерения показателей были выражающими, таким образом любые изменения в измерении показателей будут четко определять изменения в интерисующей услуге. Пробелы в данных также означают, что индикаторы по услугам экосистем и анализы будут иметь относительно высокие уровни неточности связанной с ними, которые не должны быть двусмысленными.

Важно понимать, что каждый вид индикаторов или метрики говорит нам об услугах экосистемы. Например, информация по условиям экосистемы, включая измерения биоразнообразия, протяженность среды обитания или запас отдельных компонентов, говорит кое-что о возможности экосистемы предоставлять услуги, но не обязательно о том, какие льготы извлекаются из таких услуг. Аналогично информации по отбору или потреблению, предоставляется информация о потоке льгот, однако это мало сообщает о рациональности таких потоков без сравнительной информации по состоянию или протяженности экосистемы.

Есть увеличивающийся фокус на использование экономических метрик для описания услуг экосистем. Такая форма количественного подсчета является привлекательной для лиц, принимающих решения, и может облегчать проведение сравнительных анализов по множеству услуг. Существует растущая основная часть работы по улучшению оценочных техник услуг экосистем, в частности в нанесении на карту, пространственное распространение значений услуг экосистем. Однако не все услуги экосистем можно легко посчитать в экономических и монетарных условиях, услуги культурологического значения в особенности представляют сложность.

Более лучшее понимание факторов, влияющих на поддержание услуг экосистем и их предоставление, требует системого подхода, используя взаимосвязанные или группированные индикаторы, которые одновременно будут ослеживать движущие силы и давления, оказываемые на экосистемы, наряду с состоянием системы и услуг, а также воздействия, оказываемые на благосостояние вместе с ответными реакциями на изменение стратегии и управления. Это может внести значительную сложность, поэтому способы, чтобы упростить сообщение информации по индикаторам, важны.

## РЕКОМЕНДАЦИИ

Существует увеличивающаяся активность в развитии и апробировании индикаторов услуг экосистем в рамках масштабов от инициатив по широкомасштабному перенесению на карту до развития инструментов проведения оценок на участке в локальном масштабе. Некоторые примеры услуг экосистем и их технологии взяты из ряда суб-глобальных оценок, а прочие инициативы представлены в виде таблиц данных по индикаторам в конце своего отчета.

Также заполняются пробелы, а прогресс продолжается, но конечно остаются неточности относительно измерения большинства услуг экосистем, а также по интерпретации и использованию полученной информации. Некоторые консолидированные ключевые сообщения по развитию и использованию индикаторов услуг экосистем были очищенны во время данного проекта:

1. **Убедитесь в ясности поставленных задач.**
   Процесс определения и развития индикаторов требует ведущего плана или рабочей структуры. Индикаторы предоставляются для ответа на специальные вопросы или для оценки поставленных задач стратегией, и могут разрабатываться только в контексте таких задач/вопросов. Ясные цели и задачи помогут определить и установить индикаторы как можно более точно, чтобы избежать неправильной интерпретации.

2. **Освойте малый набор специальных индикаторов, относящихся к стратегии**
   Не надо пытаться сделать все подряд. Ресурсы можно использоваться для рассмотрения ключевых элементов (т.е. которые имеют наибольшее отношение к стратегии) и пробелов в информации. Там, где это возможно включаются взимосвязанные индикаторы, покрывая как можно больше аспектов структуры оценки экосистем (социо-экологическая система) (например состояние и тенденции, движущие силы, эффективность стратегии).

3. **Выходите за рамки провизорских услуг**
   Там, где это возможно, создавайте индикаторы различных типов услуг экосистемы. В данное время имеется твердая уверенность по индикаторам, которые охватывают значения нескольких видов и экосистем, релевантных к производству продовольствия и фибры, которые являются на редкость хорошими механизмами для других видов услуг или для способности к восстановлению нормального функционирования.

4. **Используйте существующие данные и механизмы (однако надо учитывать их ограничения)**
   Итерационный процесс является лучшим способом для рассмотрения разработки индикаторов услуг экосистем. Начинайте от легко достижимых результов (т.е. делайте что возможно сделать) и улучшайте со временем. Используйте имеющиеся знания и индикаторы как точку отчета. Там, где непосредственные измерения еще не разработаны, или где нет никаких данных, можно использовать хорошие движущие индикаторы. Необходимо отметить, что не все услуги экосистем можно легко подсчитать. Качественные метрики могут использоваться как количественные.

5. **Думайте о рациональности - включая индикаторы по экосистемам и льготам**
   Измеряйте поставку услуги (включая условие/состояние экосистемы или его релевантные компоненты), а также льготы от услуг и воздействие на благосостояние.

6. **Учет биоразнообразия**
   Как только индикаторы биоразнообразия будут более лучше разработаны, а биоразнообразие будет создавать базу для поставки услуг экосистем, их можно будет использовать в виде механизмов услуг экосистем. Однако, хотя в некоторых категориях биоразнообразие классифицируется как услуга экосистем, они не являются взаимозаменяемыми. Важно не потерять из вида важность биоразнообразия при фокусировании только на пользе услуг экосистем.

7. **Необходимо быть внимательными к масштабам**
   Масштаб, в котором услуги экосистем измеряются и рапортуются, должен соответствовать контексту принятия решений. Некоторые вещи имеют больше соответствия в определенных масштабах, чем другие. Не все можно подвести под контекст масштаба.

8. **Оценка тенденций и учет совокупности усилий и компромиссов**
   Некоторые индикаторы представлены в виде снимков или сюжетных линий, однако воспроизводимые измерения важны для мониторинга за изменениями и отслеживанием прогресса. Мониторинг множества услуг по истечению времени позволяет более лучшее понимание совокупностей усилий и компромиссов.

9. **Заранее привлекайте заинтересованные стороны**

Все релевантные заинтересованные стороны должен привлекаться процессом определения и развития индикаторов с самого начала. Индикаторы услуг экосистем должны отбираться, чтобы соответствовать требования специальных пользователей. Установка диалога с поставщиками данных и конечными пользователями индикаторов является важным моментом. Широкое участие заинтересованных сторон будет также способствовать определению индикаторов как можно специализированней, что поможет избегать неправильной интерпретации. В дополнение процесс развития индикаторов требует совместной работы с другими секторами. Главное направление это ключевой компонент развития индикаторов. Ключ к этому заключается в определении подходок к главным направлениям индикаторов услуг экосистем в их оценках. Также будут помогать привязки индикаторов к государственным планам развития.

10. **Фокус на взаимосвязи**

Сообщающие индикаторы важны, но иногда их выпускают из внимания. Это может включать повышение осведомленности общественности, а также задействование лиц, определяющих стратегию. Важно использовать индикаторы в которых лица, определяющие стратегию, наиболее заинтересованны, в то время как сюжетные линии представляются способом, который наиболее релевантен стратегии. Услуги экосистем проходят через различные секторы, все из которых могут потребовать специальной организованной взаимосвязи. Некоторые ключевые сообщения взаимосвязи включают следующее:

a. Будьте четкими о том, что индикаторы говорят вам: используйте общеизвестный язык. Потребуется проведение работы над определением ключевых терминов для сообщения истории.

b. Будьте прозрачны о неопределенностях: Учитывайте ограничения индикаторов, и при неопределенности используйте четкую терминологию. Обеспечьте точную интерпретацию сюжетной линии.

c. Используйте карты (пространственно определенные данные), где возможно: там, где это возможно и уместно, такие данные могут быть полезными в сообщении и проведении анализов. Убедитесь, что представили результаты в масштабе, который наиболее соответствует лицам, принимающим решение.

d. Избегайте чрезмерного упрощения: Услуги экосистем не обязательно совместно изменяются, поэтому группирование вызывает сложности и требует последующей работы. Сбор индикаторов в соответствующие блоки/сюжетные линии может способствовать взаимосвязи.

Экономические метрики полезны, но нельзя игнорироваться немонетарные ценности: Где возможно, использование экономических метрик помогает вести направление в других секторах. Не все индикаторы являются практическими для определения монетарных значений, однако это не умоляет их пользовательских качеств.

# RESUMEN EJECUTIVO

## ANTECEDENTES

La gente depende de que los ecosistemas proporcionen una variedad de servicios necesarios para su supervivencia y bienestar. Los indicadores de los servicios ecosistémicos son críticos para conocer si estos servicios esenciales están siendo mantenidos y usados de manera sostenible, permitiendo así a quienes toman las decisiones identificar políticas y otras intervenciones necesarias para gestionarlos mejor. Como resultado, los indicadores de los sistemas ecosistémicos son cada vez de mayor interés e importancia para los procesos gubernamentales e intergubernamentales, incluyendo entre otros el Convenio sobre la Diversidad Biológica (CDB) y las Metas de Aichi incluidas dentro de su plan estratégico para 2011-2020, además de la emergente Plataforma Intergubernamental sobre Diversidad Biológica y Servicios de los Ecosistemas (IPBES). A pesar de la creciente demanda, la evaluación del estado y de las tendencias de los servicios ecosistémicos y la creación de indicadores robustos se ven a menudo obstaculizadas por la falta de información y de datos, resultando en pocos indicadores disponibles.

Como respuesta, el Centro de Seguimiento de la Conservación Mundial del Programa de las Naciones Unidas para el Medio Ambiente (UNEP-WCMC), junto con un amplio rango de socios internacionales y apoyado por el Programa Sueco de Biodiversidad Internacional (SwedBio)*, llevó a cabo un proyecto para extraer las lecciones clave que se han aprendido al desarrollar y usar indicadores de servicios ecosistémicos en varios contextos de evaluación. El proyecto examinó las metodologías, mediciones y fuentes de datos empleadas para crear indicadores de servicios ecosistémicos, con el fin de informar el desarrollo de futuros indicadores. Este informe presenta los principales resultados del proyecto.

## ¿QUÉ SE ESTÁ MIDIENDO EN LA ACTUALIDAD?

Hay muchos tipos distintos de servicios ecosistémicos y muchos tipos de indicadores y medidas usadas para seguirlos. Los indicadores más comunes y mejor desarrollados se refieren a la provisión de servicios, para lo que existen más datos. Algunos indicadores de servicios reguladores están bien desarrollados, y entre los servicios culturales, la información más frecuentemente recogida se refiere al ocio y al turismo.

La mayoría de los indicadores se derivan de datos sobre la estructura (extensión/condición/reservas) de los elementos base de un ecosistema, o sobre el suministro o el uso de los servicios. En muchas evaluaciones, se usa la información sobre hábitats y biodiversidad como aproximación a los servicios ecosistémicos. Existen pocas medidas del funcionamiento de los ecosistemas o de la sostenibilidad del uso de los distintos servicios.

Para compilar los indicadores de los servicios ecosistémicos, se usan una variedad de fuentes de datos, incluyendo estudios publicados y no publicados, además de datos de iniciativas de seguimiento y de producción de informes. Las evaluaciones, que tienden a sintetizar la información existente, a menudo se fundamentan en estudios puntuales que proporcionan datos de base sobre la magnitud y la distribución de servicios ecosistémicos sin incluir información sobre cambios a lo largo del tiempo.

El mapeo de los servicios ecosistémicos es una forma útil y cada vez más común de presentar información, aunque generalmente requiere muchos datos y se basa en modelos que necesitan ser verificados. La escala a la que se desarrollan y usan los indicadores varía, y distintos métodos y medidas pueden ser aplicables a diferentes escalas; los indicadores desarrollados a escalas globales podrían tener un uso limitado a escalas locales y vice versa.

**Ahora, el Programa de Resiliencia y Desarrollo del Centro de Resiliencia de Estocolmo/Universidad de Estocolmo*

## CUESTIONES Y DESAFÍOS

Dada la variedad de servicios proporcionados por los ecosistemas y el hecho de que los diferentes servicios ecosistémicos no co-varían necesariamente, generalmente se dará el caso de que un único indicador no será suficiente para la mayoría de los propósitos de evaluación. La elección de servicios a evaluar, junto con los indicadores a usar, viene determinada por objetivos políticos y por la disponibilidad de datos. Esta última se ve afectada por la falta de seguimiento actual de la mayoría de los servicios ecosistémicos en la mayoría de lugares. Es importante asegurarse de que las medidas aproximadas que se usan sean coherentes, es decir, que cualquier cambio en la medida aproximada indique de forma precisa cambios en el servicio de interés. Las lagunas informativas también conllevan que los indicadores y las evaluaciones de los servicios ecosistémicos llevarán asociadas unos altos niveles de incertidumbre que deben hacerse explícitos.

Es importante entender qué dice cada tipo de indicador o medida sobre los servicios ecosistémicos. Por ejemplo, la información sobre la condición del ecosistema, incluyendo las medidas de la biodiversidad, la extensión del hábitat o las reservas de componentes particulares, dice algo sobre la habilidad del ecosistema para proporcionar servicios pero no dice necesariamente mucho sobre los beneficios derivados de esos servicios. De manera similar, la información sobre la extracción o el consumo proporciona información sobre el flujo de los beneficios pero dice poco sobre la sostenibilidad de estos flujos de beneficios sin información comparable de la condición o la extensión de los ecosistemas.

El uso de medidas económicas para describir los servicios ecosistémicos es un enfoque que está en aumento. Esta forma de cuantificación les resulta atractiva a los tomadores de decisiones y puede facilitar los análisis comparativos para muchos servicios. Existe una creciente cantidad de trabajos sobre la mejora de las técnicas de valoración de los servicios ecosistémicos, y en particular el mapeo de la distribución espacial de los valores de los servicios ambientales. Sin embargo, no todos los servicios ecosistémicos pueden ser cuantificados fácilmente en términos económicos o monetarios, con los servicios culturales representando un particular reto.

Un mejor entendimiento de los factores que influyen en el mantenimiento y la provisión de los servicios ecosistémicos requiere un enfoque de sistemas, usando indicadores enlazados o agrupados que siguen de forma simultánea las influencias y presiones sobre los ecosistemas, además del estado del sistema y de los servicios e impactos de bienestar proporcionados, junto con las respuestas al cambio de las políticas y la gestión. Esto puede aumentar significativamente la complejidad y por lo tanto las formas para simplificar la comunicación de la información sobre indicadores son importantes.

## RECOMENDACIONES

Existe una creciente actividad para desarrollar y probar indicadores de los servicios ecosistémicos a varias escalas, desde iniciativas de mapeo a gran escala hasta el desarrollo de herramientas para evaluaciones a escala local. Algunos de los ejemplos de servicios ecosistémicos y sus metodologías tomados de varias evaluaciones sub-globales y de otras iniciativas se presentan como fichas de los indicadores al final de este informe.

Aunque se están completando las lagunas y se continúa progresando, queda aun incertidumbre sobre cómo medir muchos de los servicios ambientales y cómo interpretar y usar la información proporcionada. Algunos de los mensajes clave para el desarrollo y el uso de indicadores sobre servicios ecosistémicos se extrajeron durante este proyecto:

1. **Asegúrese de que los objetivos sean claros**
   El proceso de definición y desarrollo de indicadores requiere un plan o marco directriz. Los indicadores están ahí para responder a preguntas específicas o para evaluar los objetivos de las políticas y sólo pueden ser desarrollados en el contexto de esas preguntas/objetivos. Unos objetivos y metas claras ayudan a identificar y definir los indicadores tan específicamente como sea posible para evitar interpretaciones erróneas.

2. **Adopte un pequeño conjunto de indicadores específicos y de relevancia política**
   No intente hacerlo todo. Los recursos deberían usarse para abordar los elementos clave (es decir, los de mayor relevancia política) y las lagunas informativas. En la medida de lo posible, incluya indicadores enlazados que cubran tantos aspectos del marco de evaluación de ecosistemas (sistema socio-ecológico) como sea posible (p.ej. estado y tendencias, fuerzas impulsoras, efectividad política).

3. **Vaya más allá de la provisión de servicios**
   En la medida de lo posible, cree indicadores para distintos tipos de servicios ecosistémicos. Actualmente existe una dependencia excesiva de indicadores que capturan el valor de unas pocas especies y ecosistemas de relevancia para la producción de alimentos y fibras, los cuales raramente son buenas aproximaciones para otros tipos de servicios o para su capacidad de recuperación.

4. **Utilice los datos existentes y aproximaciones (pero reconozca los límites)**
   Conviene ver el desarrollo de indicadores de servicios ecosistémicos como un proceso iterativo. Comience con lo que tenga más al alcance (es decir, haga lo que es posible) y mejore con el tiempo. Use el conocimiento y los indicadores disponibles como punto de partida. Donde no se hayan aun desarrollado medidas directas o donde no haya datos, pueden usarse buenos indicadores aproximativos. Note que no todos los servicios ecosistémicos son fácilmente cuantificables. Las métricas cualitativas pueden ser tan útiles como las cuantitativas.

5. **Piense sobre la sostenibilidad – incluya indicadores tanto para los ecosistemas como para los beneficios**
   Mida tanto el suministro del servicio (incluyendo el estado/condición del ecosistema o de sus componentes relevantes) como los beneficios de los servicios y sus impactos sobre el bienestar.

6. **Incluya la biodiversidad**
   Dado que los indicadores de biodiversidad están mejor desarrollados, y que la biodiversidad es la base del suministro de los servicios ecosistémicos, a veces se usan como aproximación para los servicios ecosistémicos. Sin embargo, aunque en algunas categorizaciones la biodiversidad se clasifica como un servicio ecosistémico, no son intercambiables. Es importante no perder de vista la importancia de la biodiversidad por centrarse únicamente en los beneficios de los servicios ecosistémicos.

7. **Sea consciente de la escala**
   La escala a la cual se miden y reportan los servicios ecosistémicos debería ser apropiada para el contexto de toma de decisiones. Algunas cosas son apropiadas a ciertas escalas pero no a otras. No todo se puede aumentar de escala.

8. **Evalúe las tendencias y considere sinergias y compromisos**
   Algunos indicadores son esquemas o líneas base, pero las mediciones que se pueden repetir son importantes para hacer un seguimiento de los cambios y del progreso. El seguimiento de varios servicios a lo largo del tiempo permite un mejor entendimiento de las sinergias y los compromisos.

### 9. Involucre pronto a las partes interesadas

La definición y el desarrollo de indicadores deberían involucrar a todas las partes relevantes desde el principio. Los indicadores de servicios ecosistémicos se deberían elegir en base a las necesidades de usuarios específicos. El establecimiento de un diálogo con los proveedores de datos y con los usuarios finales de los indicadores es crucial. Una amplia participación de las partes interesadas también ayudará a definir los indicadores de la forma más específica posible para evitar interpretaciones erróneas. Además, el proceso de desarrollo de indicadores requiere la colaboración con otros sectores. El alineamiento resultante de esta colaboración es un componente clave del desarrollo de indicadores. Resulta clave identificar puntos de entrada para el alineamiento de los indicadores de servicios ecosistémicos en las evaluaciones. El vincular los indicadores a los planes de desarrollo nacional resulta de ayuda.

### 10. Céntrese en la comunicación

La comunicación de los indicadores es importante pero a veces se deja de lado. Puede incluir la concienciación del público además de involucrar a quienes toman las decisiones. Es importante usar los indicadores que más probablemente sean de interés para los tomadores de decisiones, y presentar las historias de la forma más relevante posible para las políticas. Los servicios ecosistémicos se extienden a través de diferentes sectores, los cuales pueden requerir comunicación a medida. Algunos mensajes clave de comunicación incluyen:

a. Sea claro sobre lo que le dicen los indicadores: Use lenguaje común. Puede necesitar poner algo de esfuerzo en las definiciones de términos importantes para comunicar esa historia.

b. Sea transparente sobre la incertidumbre: Mantenga en mente los límites de los indicadores, y la incertidumbre. Use terminología clara. Proporcione una interpretación precisa de la historia.

c. Use mapas (datos explícitos espacialmente) en la medida de lo posible: Cuando resulta posible y relevante, éstos pueden ser de ayuda en la comunicación y el análisis. Asegúrese de presentar los resultados a la escala más relevante para los tomadores de decisiones.

d. Evite las simplificaciones excesivas: los servicios ecosistémicos no co-varían necesariamente, y por lo tanto la agregación presenta desafíos y se necesita más trabajo en esa dirección. Agrupar los indicadores en paquetes/historias relacionadas puede ayudar con la comunicación.

e. Las métricas económicas son útiles pero no ignore los valores no monetarios: cuando es posible, el uso de métricas económicas ayuda al alineamiento con otros sectores. No resulta práctico determinar todos los indicadores en términos monetarios, pero eso no disminuye su utilidad.

10- التركيز على التواصل: يتم إهمال التواصل في المؤشرات أحياناً على الرغم من أهميتها، وقد تتضمن زيادة الوعي العام وإشراك صانعي السياسة حيث أنه من المهم استخدام المؤشرات التي يهتم بها صانعو السياسة مع مراعاة تقديم القصة بالطريقة الأكثر ارتباطاً بالسياسة. خدمات النظام البيئي تتقاطع عبر معظم القطاعات المختلفة ويختلف التواصل بحسب القطاع.

فيما يلي بعض رسائل التواصل الهامة:

1- كن واضحاً فيما تخبرك به المؤشرات: استخدم لغة مشتركة ستحتاج في بعض الأحيان للقيام بتعريف المصطلحات الرئيسية لتوصيل تلك القصة.

2- تعامل بشفافية مع كل ما هو غير مؤكد: خذ بنظر الاعتبار حدود المؤشرات وغير المؤكد – استخدم مصطلحات واضحة وراعي الدقة في تقديم القصة.

ج- استخدم الخرائط (بيانات مكانية واضحة قدر المستطاع: حيثما يكون ذلك ممكناً ومناسبا، نجد أن الخرائط من الوسائل المفيدة للتواصل والتحليل، تأكد من تقديم النتائج بالمقاييس المناسبة لصناع القرار.

د- تجنب التبسيط المبالغ به: ليس بالضرورة أن تكون خدمات النظام البيئي مختلفة، ولهذا فإن التجميع يعتبر تحدياً ويتطلب المزيد من العمل. تجميع المؤشرات في حزم /قصص ذات علاقة قد يساعد على التواصل.

المقاييس الاقتصادية مفيدة ولكن يجب أن لا تتجاهل القيم غير النقدية: يساعد استخدام المقاييس الاقتصادية في التعميم على لقطاعات الأخرى حيثما يكون ذلك ممكناً. نجد أنه ليس كل المؤشرات يمكن أن تحدد بشكل عملي القيم النقدية لها ولكن هذا لا يقلل من امكان استخدامها.

8- تقييم التوجهات وأخذ التآزر والمقايضات في عين الاعتبار: بعض المؤشرات تكون عبارة عن لقطات مصورة لكن المقاييس القابلة للتكرار مهمة لمراقبة التغيرات ومتابعة التقدم، رصد الخدمات المتعددة بمرور الوقت يسمح بفهم أفضل لحالات التآزر والمقايضات .

9- إشراك أصحاب المصلحة منذ البدء: يجب أن يشترك جميع أصحاب المصلحة في تحديد وتطوير المؤشرات من البداية، يجب اختيار مؤشرات خدمة النظام البيئي بما يناسب احتياجات المستخدم. ويعتبر الحوار بين مزودي البيانات والمستخدم من العوامل الأساسية والمهمة. وكلما ازداد اشراك أصحاب المصلحة كلما ساعد في تحديد المؤشرات بشكل أدق وذلك لتجنب التفسير الخاطئ. بالإضافة إلى ذلك تتطلب عملية تطوير المؤشرات تعاوناً مع قطاعات أخرى ويعتبر التعميم مكون أساسي لتطوير المؤشرات. ويعتبر تحديد نقاط الدخول لتعميم مؤشرات خدمة النظام البيئي،أمراً أساسيا في التقييمات. ويساعد أحياناً ربط المؤشرات في خطط التنمية الوطنية.

## التوصيات:

4- استخدام البيانات والبدائل المتوفرة (مع مراعاة الحدود): أفضل منظور لتطوير مؤشرات خدمة النظام البيئي هو باعتباره عملية تكرارية , ابدأ بالفاكهة المتدلية على ارتفاع بسيط (أي أفعل المستطاع) وقم بتحسينه مع مرور الوقت، استخدم المعرفة والمؤشرات المتاحة كنقطة بداية لك وإذا لم تتوفر بيانات حالية ممكن اللجوء للبدائل الجيدة، واعلم أنه ليس من السهل قياس كل خدمات النظام البيئي حيث يمكن الاستفادة من المقاييس النوعية بقدر مقاييس الكمية.

5- التفكير في إمكانية الاستدامة - تضمين مؤشرات الأنظمة البيئية وفوائدها: قم بقياس مزود الخدمة (بما في ذلك حالة النظام البيئي أو مكوناته) وفوائد هذه الخدمة وآثارها على الرفاهية.

6- تضمين التنوع البيولوجي: نظراً لأن مؤشرات التنوع البيولوجي يتم تطويرها بشكل أفضل، وأن التنوع البيولوجي يعزز سبل توصيل خدمات النظام البيئي، فإنها تستخدم أحياناً كبدائل لخدمات النظام البيئي. ولكن، على الرغم من أن بعض تصنيفات التنوع البيولوجي مصنفة كخدمة للنظام البيئي، إلا أنها ليست قابلة للتغيير فيما بينها. من المهم أن لا تنسى أهمية التنوع البيولوجي وذلك بالتركيز على فوائد خدمة النظام البيئي.

7- الحساسية في المقياس: يجب مراعاة المقياس المستخدم لقياس خدمات النظام البيئي وإعداد التقرير عنها ليكون مناسباً لسياق اتخاذ القرار، حيث نجد أن بعض الأشياء تكون أكثر ملائمة للمقاييس من غيرها. لا يمكن تحجيم كل شيىء.

هنالك نشاط متزايد لتطوير واختبار مؤشرات خدمة النظام البيئي وعلى نطاق واسع، بدءاً بمبادرات إعداد الخرائط واسعة النطاق إلى تطوير أدوات التقييم المحلية على نطاق المواقع. سنعرض في نهاية هذا التقرير أمثلة عن خدمات النظام البيئي والطرق المستقاة من مجموعة تقييمات شبة عالمية مع مبادرات أخرى كنشرات وقائع المؤشرات .

على الرغم من الثغرات التي يتم ملؤها والتقدم الذي يتم إحرازه، مازال عدم التيقن من كيفية قياس الخدمات المتعددة للنظام البيئي وكيفية استخدام المعلومات التي يتم تقديمها. تم استخراج بعض الرسائل الهامة من أجل تطوير واستخدام مؤشرات خدمة النظام البيئي في هذا المشروع:

1- التأكد من وضوح الأهداف:

تتطلب عملية تحديد وتطوير المؤشرات خطة إرشادية أو اطار عمل: هنالك مؤشرات للإجابة عن أسئلة محددة أو تقييم أهداف السياسة والتي من الممكن تطويرها في سياق هذه الأسئلة أو الأهداف، تساعد الأهداف والمساعي الواضحة على التعرف وتحديد المؤشرات بشكل محدد قدر المستطاع لتفادي التفسير الخاطئ.

2- تبني مجموعة صغيرة من المؤشرات المتعلقة بالسياسة: لا تحاول أن تفعل كل شيء، يجب استخدام الموارد لتحديد العناصر الأساسية والثغرات في المعلومات (العناصر الأكثر ارتباطا بالسياسة)، حيثما يكون ممكناً، قم بتضمين المؤشرات المرتبطة والتي تغطي أكبر قدر ممكن من جوانب إطار تقييم النظام البيئي (النظام الاجتماعي البيئي) (على سبيل المثال الحالة والاتجاه، القوى الدافعة، وفعالية السياسة).

3- التطلع إلى ما هو أبعد من خدمات التموين: إنشاء مؤشرات لأنواع مختلفة من خدمات النظام البيئي قدر المستطاع، يتم في الوقت الحالي الاعتماد بشكل أكبر من اللازم على المؤشرات التي تحدد بعض الأصناف والأنظمة البيئية المتعلقة بإنتاج الطعام والألياف والتي نادرا ما تكون بدائل مناسبة لأنواع أخرى من الخدمات أو للمرونة.

## قضايا وتحديات

هنالك اهتمام متزايد لاستخدام المقاييس الاقتصادية لوصف خدمات النظام البيئي، يجذب هذا النوع من القياس صناع القرار ويسهل تحليلات المقارنة للعديد من الخدمات. هنالك مجموعة متنامية من الأعمال لتطوير تقنيات تقييم خدمات النظام البيئي وخصوصاً رسم خرائط التوزيع المكاني لقيم خدمات النظام البيئي. ولكن نجد أنه ليس كل خدمات النظام البيئي ممكن قياسها بالمقاييس الاقتصادية أو المالية وبالأخص الخدمات الثقافية التي تمثل تحدياً كبيراً.

يتطلب فهم العوامل المؤثرة على صيانة خدمة وتزويد النظام البيئي، نهج نظامي يستخدم مؤشرات مرتبطة ومجمعة و يتعقب الضغوط على النظام البيئي في آن واحد بالاضافة الى حالة النظام والخدمات والتأثيرات على الرفاهية ومع سياسة وإدارة الاستجابة للتغيير. كل ذلك ممكن أن يضيف تعقداً ملحوظاً ولذلك نجد أهمية كبيرة لطرق تبسيط تواصل مؤشر المعلومات.

بناءاً على مدى الخدمات التي يقدمها النظام البيئي وحقيقة أن خدمات النظام البيئي ليست بالضرورة أن تكون مختلفة فإن مؤشر واحد فقط لن يكون مفيداً لمعظم أغراض التقييم. يتم تحديد الخدمات الواجب تقييمها والمؤشرات الواجب استخدامها بناءاً على أهداف السياسة وتوفر البيانات. يتأثر توفر البيانات بنقص الرصد المستمر لمعظم خدمات النظام البيئي في معظم الأماكن، ومن المهم التأكد من أي بدائل مقاييس يتم استخدامها لتكون بدائل ذات معنى وأن أي تغيير في بدائل المقاييس يعكس بشكل دقيق التغيير في هذه الخدمة. وجود ثغرات في البيانات المتوفرة يؤدي إلى عدم التيقن من مؤشرات وتقييمات خدمة النظام البيئي.

من المهم فهم كل ما يقوله كل نوع من مؤشرات ومقاييس خدمات النظام البيئي، فمثلا نجد أن المعلومات عن حالة النظام البيئي بما فيها مقاييس التنوع البيولوجي والمواطن والمدى والمخزون من مكون معين تخبرنا عن قدرة النظام البيي على توفير الخدمات ولكن لا يخبرنا بالضرورة عن فوائد هذه الخدمات، وكذلك المعلومات عن الاستهلاك توفر المعطيات عن تدفق المزايا لكن تخبرنا القليل عن استدامة تدفق هذه المزايا بدون مقارنة المعلومات عن حالة ومدى النظام البيئي.

# ملخص تنفيذي

## الخلفية

يعتمد الناس على الأنظمة البيئية لتزويدهم بمجموعة من الخدمات الازمة لبقائهم ورفاهيتهم، وتكمن أهمية مؤشرات خدمات الأنظمة البيئية في معرفة ما إذا كان يتم الحفاظ على تلك الخدمات ومدى استخدامها بطريقة مستدامة وبالتالي مساعدة صناع القرار لاتخاذ التدابير والإجراءات الازمة لإدارتها بطريقة أفضل. ولذلك تتزايد أهمية هذه المؤشرات بين الحكومات وما بين الحكومات بما في ذلك اتفاقية التنوع البيولوجي وأهداف "أيتشي" الواردة ضمن خطته الإستراتيجية للأعوام 2011-2020 فضلا عن المبادرة الناشئة، المنبر الحكومي الدولي بشأن العلوم والسياسات في مجال التنوع البيولوجي وخدمات النظام الايكولوجي(IPBES) .

على الرغم من الطلب المتزايد على مؤشرات خدمات الأنظمة البيئية، غالباً ما يعوق نقص المعلومات والبيانات من تقييم وتطوير حالة النظام البيئي. استجابة لذلك، قام المركز العالمي للرصد البيئي التابع لبرنامج الأمم المتحدة للبيئة وعدد كبير من الشركاء الدوليين وبدعم من البرنامج السويدي الدولي للتنوع البيولوجي بإنشاء مشروع يهدف إلى الاستفادة من الدروس الهامة التي تم التوصل إليها في استخدام وتطوير مؤشرات خدمات الأنظمة البيئية في سياق مجموعة من التقييمات.

يعالج هذا المشروع طرق ومقاييس ومصادر البيانات المستخدمة في توصيل مؤشرات خدمات الأنظمة البيئية، الاستفادة منها في تطوير المؤشرات المستقبلية. يعرض هذا التقرير النتائج الرئيسية لهذا المشروع.

## ما الذي يتم قياسه الآن؟

هنالك العديد من خدمات النظام البيئي، وبالتالي أنواع عديدة مختلفة من المؤشرات المستخدمة لرصدها، فالمؤشرات الجيدة التطوير والواسعة الانتشار تعود إلى خدمات التموين حيث توجد أكثر البيانات. وتم تطوير بعض مؤشرات الخدمات التنظيمية بشكل جيد ومن ضمن الخدمات الثقافية تعتبر المعلومات الخاصة بالسياحة والاستجمام من أكثر المعلومات التي يتم جمعها.

معظم المؤشرات مشتقة من هيكل البيانات للعناصر الأساسية للنظام البيئي (مساحة، حالة، مخزون) أو بيانات توفير واستخدام الخدمات. في العديد من عمليات التقييم، يتم استخدام المعلومات الخاصة بالمواطن والتنوع البيولوجي كبدائل لخدمات النظام البيئي. هنالك مقاييس قليلة لوظائف النظام البيئي أو إمكانية استدامة استخدام الخدمات المختلفة.

يتم استخدام العديد من مصادر البيانات المتنوعة لتجميع مؤشرات خدمات النظام البيئي، بما في ذلك الدراسات المنشورة وغير المنشورة وكذلك البيانات المأخوذة من تقارير ومبادرات الرصد.

تعتمد التقييمات التي تقوم بتحليل البيانات الموجودة أصلاً على دراسات تجري لمرة واحدة والتي تقدم بيانات أساسية عن حجم وتوزيع خدمات النظام البيئي من دون أن تشمل التغيرات على هذه البيانات مع مرور الزمن.

يعتبر رسم خريطة خدمات النظام البيئي من الطرق المفيدة والواسعة الانتشار لعرض المعلومات، على الرغم من كثافة البيانات عادة والاعتماد على نماذج تحتاج إلى تحقق. يختلف مقياس استخدام وتطوير المؤشرات وهناك طرق ومقاييس مختلفة يمكن تطبيقها على مستويات مختلفة. قد يكون استخدام المؤشرات التي يتم تطويرها على مستوى عالمي محدوداً بالمستوى المحلي والعكس صحيح.

# 1. INTRODUCTION

This report arises from a research and development process led by the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) with the support of the Swedish International Biodiversity Programme (Swedbio) and involving a wide range of collaborating partners from around the world. The overall objective of this initiative is to enhance the development, uptake and utility of ecosystem service indicators at global and national scales, as a means of better tracking change in natural systems and better demonstrating its significance for society and human well-being.

This section introduces the concept and different categories of ecosystem services. It highlights the importance of ecosystem services to human well-being and makes the case for the need to monitor and assess ecosystem service status and trends for better management of these services. The section concludes by highlighting the objectives and structure of this report, which is to review experiences and lessons from the development of ecosystem service indicators in a range of assessment processes and research initiatives.

## BACKGROUND

Ecosystem services have been defined as the benefits people obtain from ecosystems[1], such as food, fuel, clean air, fresh water, flood and disease control and the pollination of crops, as well as opportunities for cultural, spiritual and recreational experiences. Human survival and well-being is utterly dependent on these ecosystem services, and thus on the health of the ecosystems that provide them (Daily 1997; Costanza *et al*. 1998; **Box 1**).

The ecosystem services concept has a long history although the term itself is relatively new (Daily 1997). The concept was mainstreamed and popularised by the Millennium Ecosystem Assessment (MA) which made the first attempt to assess the state of the world's ecosystem services and its implications for human well-being (MA 2005a; Huitric *et al*. 2008; Shackleton *et al*. 2008). The MA found that most ecosystems and their associated services are declining globally and suggested that biodiversity loss and deteriorating ecosystem services contribute - directly or indirectly - to worsening health, higher food insecurity, increasing vulnerability lower material wealth, worsening social relations, and less freedom of choice and action. Such loss of ecosystem services at global and sub-global scales means it is unlikely that the UN's Millennium Development Goals (MDGs) will be met (MA 2005a).

Since the publication of the MA in 2005, researchers and policy makers have demonstrated increasing interest in the concept of ecosystem services, resulting in a wide range of new research that is intended to help characterise, quantify, measure, track and in some cases value – in monetary or non-monetary terms – ecosystem services across a range of scales (Chen *et al*. 2006; Metzger *et al*. 2006; Naidoo *et al*. 2008; Nelson *et al*. 2009; Bateman *et al*. 2010).

The importance of ecosystem services in supporting economic activity and human well-being calls for action to quantify, value and monitor trends in these services, so as to ensure that they are adequately considered in decision making processes. Robust ecosystem service indicators, based on reliable metrics and measures (**Box 2**) are critical to knowing whether or not these essential services are being maintained and used in a sustainable manner (Layke 2009; TEEB 2009; Walpole *et al*. 2009). Ecosystem service indicators are therefore of increasing interest and importance to a variety of users at a range of scales.

**Footnote**

*[1] In this report we consider services to be the outputs of ecosystems from which, when used, benefits are derived (see Section 2, p35).*

**Box 1. The link provided by ecosystem service indicators between biodiversity and human well-being.**

The two diagrams in **Figure 1** illustrate the linkages between the four categories of ecosystem services and constituents of human well-being. Human well-being is partly dependent on the availability of ecosystem services. Underlying the provision of these services are supporting ecosystem processes such as nutrient cycling, hydrology and climate. Ecosystem services may be affected by direct factors such as pollution and land cover change, and indirect factors such as population and economic policies. Ultimately, the drivers of change are themselves influenced by human well-being. Feedbacks occur at all scales, from an individual household to the entire globe, and interventions at key points can influence these feedbacks in beneficial ways. The linkages between human well-being and ecosystem services are complex and although some of these links are recognised, many remain poorly understood.

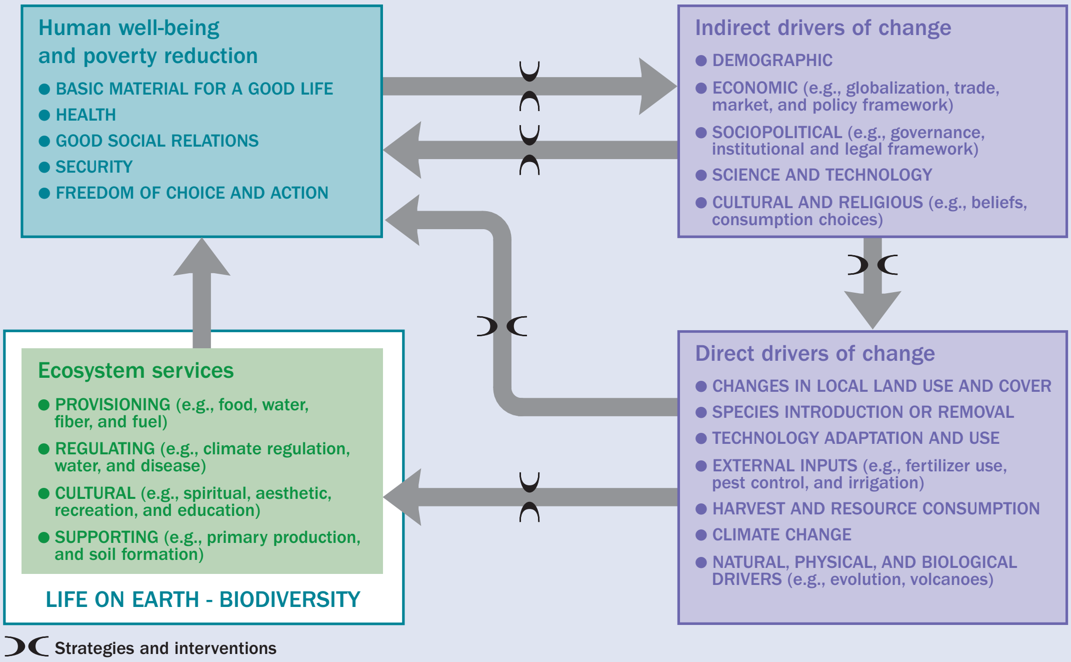



**Figure 1a. Millennium Ecosystem Assessment conceptual framework.** Source: Millennium Ecosystem Assessment (MA 2005b).

**Box 1. *Continued***

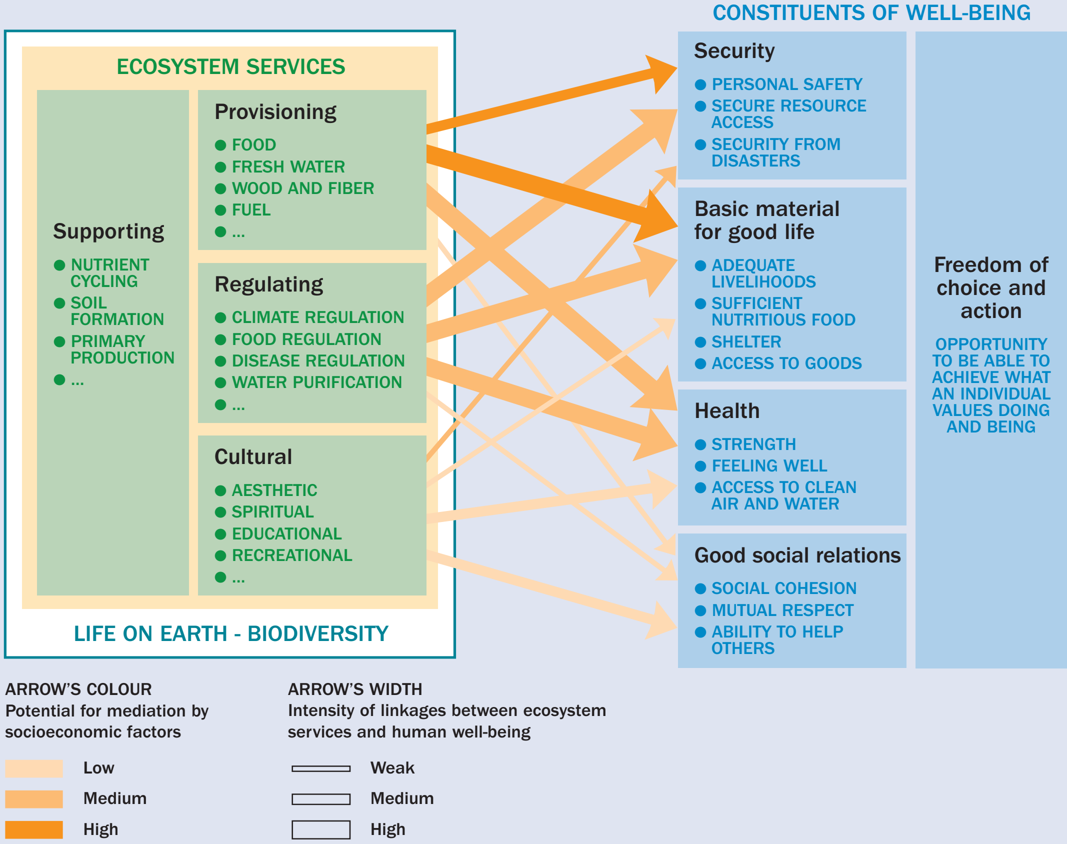



**Figure 1b. Links between biodiversity, ecosystem services and human-being.** Source: Millennium Ecosystem Assessment (MA 2005b).

**Box 2. Definitions of indicators, metrics and measures.**

**Measure:** a value that is quantified against a standard at a point in time.

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

**Indicator:** a measure or metric based on verifiable data that conveys information about more than itself. It is information packaged to communicate something important to decision-makers.

**Index:** a numerical scale used to compare variables with one another or with some reference number.

Source: 2010 Biodiversity Indicators Partnership (2010b).

At the international level, users of ecosystem service indicators include Parties to multilateral environmental agreements (MEAs) such as the CBD and other Rio conventions (UNFCCC and UNCCD) and biodiversity-related conventions such as the Ramsar Convention on Wetlands, as well as other international processes such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the Millennium Development Goals process (MDGs). At national and local levels, ecosystem service indicators will be important for national planning, reporting and decision-making (e.g. national development plans) and local decision-making (e.g. watershed management, Payment for Ecosystem Services (PES) schemes, and district development plans). Ecosystem service indicators will also benefit businesses and private companies in cases where ecosystem services are needed to produce a product. The diversity of users shows that developing ecosystem service indicators will benefit not just the biodiversity community but also the development community as well as governments and agencies managing services at the delivery level (such as water departments and protected areas agencies) and the private sector.

Despite this range of potential and actual users of ecosystem service indicators and the growing demand for information on ecosystem services, assessing status and trends and developing robust indicators is often hindered by a lack of data (Feld *et al*. 2009; Layke 2009; UNEP-WCMC 2009, 2010; Walpole *et al*. 2009; DIVERSITAS 2010). In response, increasing attempts to measure and monitor status and trends in ecosystem services are taking place. Important lessons for future indicator development can be learnt from these efforts.

## ECOSYSTEM SERVICE INDICATORS: EXPERIENCE AND LESSONS

This report arises from a research and development process led by UNEP-WCMC with the support of the Swedish International Biodiversity Programme (Swedbio) in collaboration with IUCN, the World Resources Institute (WRI) and a wide range of collaborating partners from around the world. The overall objective is *to enhance the development, uptake and utility of indicators of biodiversity and ecosystem services at global and national scales, as a means of better tracking change in natural systems and better demonstrating its significance for society and human well-being*.

Part of this work has focused on improving ecosystem service indicators. The objective was to take stock of the key lessons learnt in developing and using ecosystem service indicators in a range of assessment contexts, and in particular to examine the methodologies, metrics and data sources employed, so as to inform future ecosystem service indicator development.

The project has reviewed the use of ecosystem service indicators in MA sub-global assessments (SGAs) and in the wider literature, and has supported pilot work to explore how ecosystem services can be examined at different scales from local site-based assessments to global mapping exercises. It has also convened two international workshops to review the evidence and its implications for ecosystem service indicator developers.[2] These workshops, amongst other objectives, attempted to develop inventories of potential indicators and to identify priority candidates for development, with particular reference in the second workshop to ecosystem service indicators that may be of relevance to the Aichi targets for 2020 that were adopted by the 10th Conference of the Parties (CoP) to the CBD in Nagoya in October 2010 (CBD 2010).

## OBJECTIVES AND STRUCTURE OF THIS REPORT

This report synthesises the main findings of the reviews and expert consultations undertaken within the project focusing on ecosystem service indicator development and use. Its intention is to raise awareness and understanding of what can be measured to assess ecosystem services and on which to base ecosystem service indicators. It also aims to describe some of the important issues to consider when choosing and developing ecosystem service metrics and indicators, and to provide a concise set of recommendations for users. The report does not deal in detail with methods of ecosystem service valuation. Although some economic metrics are described, much of the content focuses on bio-physical metrics and on the advantages and disadvantages of different approaches to assessing and quantifying ecosystem services.

This report is divided into six major parts. After this introductory section, *Section 2* presents a review of existing indicators and metrics from assessment processes and the published literature. It aims to answer the question 'what is currently being measured?' *Section 3* considers the main issues confronting those wishing to develop ecosystem service indicators or assessment methods. These are compiled from reviews of current practice, interviews with practitioners and the outputs of workshop discussion sessions. *Section 4* offers a way forward for ecosystem service indicator development, presenting a series of key recommendations for practitioners and policy-makers. *Section 5* and *Annex 1* present the results of an evaluation of the potential relevance of existing and future ecosystem service indicators to the Aichi targets within the CBD strategic plan 2011-2020. This output is intended as a contribution to support the considerations of the Parties to the CBD when agreeing a framework of indicators with which to track progress and report against the Aichi targets at both national and global scales. Finally, a series of illustrative fact sheets describing some existing ecosystem service indicators are provided in *Annex 2*.

**Footnote**

[2] *Both were held in Cambridge, UK, the first in September 2009 and the second in November 2010. Further details on workshop outputs can be obtained from UNEP-WCMC.*

# 2. REVIEW OF EXISTING ECOSYSTEM SERVICE INDICATORS AND METRICS

This section presents the findings from in-depth reviews of the use of ecosystem service indicators in MA sub-global assessments and the wider literature on the development of metrics and indicators for ecosystem services over the past twenty years. It aims to answer the question 'what is currently being measured?' It is illustrated with case studies presented during expert workshops. Although there are many different kinds of service, and many different possible kinds of indicators and metrics, the most common and well developed indicators are for provisioning services. Most indicators are derived from data on the structure (extent/condition) of underlying elements of an ecosystem, or on the supply or use of services, with few measures of ecosystem functioning or sustainability. Assessments often include only baseline data, while the magnitude and distribution of ecosystem services often relies on modelled data. The scale at which indicators are developed and used varies, and different methods and metrics may be applicable at different scales.

## CLASSIFICATION OF ECOSYSTEM SERVICE INDICATORS AND METRICS

In order to examine what is currently being measured it is important to be able to classify indicators and metrics in a consistent way. Yet there is no single agreed method of categorising all ecosystem services, and many different classifications exist to meet different needs (see MA 2005a; Boyd and Banzhaf 2007; Wallace 2007; Balmford *et al.* 2008; Fisher and Turner 2008; De Groot *et al.* 2010a,b).

In this section we describe the classification of ecosystem service types and then consider the different ways in which measurements for ecosystem service indicators can be derived from the elements of a framework linking biodiversity via ecosystem services to human well-being.

The classification framework for ecosystem service assessment proposed by the MA is perhaps the most well known. The MA report categorises ecosystem services into four different classes: provisioning, regulating, cultural and supporting services (MA 2005a; see **Box 1**, p32-33). The four ecosystem service categories can each be broken down into a variety of sub-categories. The framework used by The Economics of Ecosystems and Biodiversity (TEEB) initiative, which is based on the MA, describes 22 service types under four key ecosystem service categories (**Table 1**).

**Table 1. The TEEB classification of ecosystem services (after de Groot *et al.* 2010b).** The main difference with the MA is that supporting (of Habitat) services are limited to the nursery and gene pool function and that biodiversity is not recognised as a separate service.

| Service category | Service types |
|---|---|
| Provisioning | 1. Food<br>2. Water<br>3. Raw materials<br>4. Genetic resources<br>5. Medicinal resources<br>6. Ornamental resources |
| Regulating | 7. Air quality regulation<br>8. Climate regulation (including carbon sequestration)<br>9. Moderation of extreme events<br>10. Regulation of water flows<br>11. Waste treatment<br>12. Erosion prevention<br>13. Maintenance of soil fertility<br>14. Pollination<br>15. Biological control |
| Habitat/Supporting | 16. Lifecycle maintenance (e.g. migratory species, nursery habitat)<br>17. Maintenance of genetic diversity |
| Cultural [provide opportunities for:] | 18. Aesthetic enjoyment<br>19. Recreation and tourism<br>20. Inspiration for culture, art and design<br>21. Spiritual experience<br>22. Cognitive development |

For any ecosystem service, there are various attributes that could be measured, from the state of the underlying system, through the functioning of the system, to the services it provides and the benefits gained by society. The terms used for different elements of the system by different authors are diverse and potentially confusing, but in essence ecosystems, as a result of their structures and processes, deliver things that, when experienced or consumed by people, provide benefits that individuals and/or society values.

A widely used framework for linking ecosystems to human well-being is shown in **Figure 2**. As the figure depicts, ecosystem services are generated by ecosystem functions which in turn are underpinned by biophysical structures and processes called 'supporting services' by the MA. Ecosystem functions, in the context of this framework, are thus intermediate between ecosystem processes and services and can be defined as the "capacity of ecosystems to provide…services that satisfy human needs, directly and indirectly" (De Groot, 1992).[3] Actual use of a good or service provides benefits (e.g. nutrition, health, pleasure) which in turn can be valued in economic terms.[4] It is worth noting that any individual service will be supported by a range of ecosystem structures and processes, and that individual structure and processes will support a range of services (Balmford *et al.* 2008).

**Footnote**

*[3] Note that the normative use of the term 'ecosystem function' as a source of human benefits taken in this report is only one of the ways in which the term is used in the wider literature (Barkmann et al. 2008).*

*[4] Economists argue that only the final product (benefit) of the ecosystem service should be valued so as to avoid double counting (over-estimating the benefits from a service by including values for the process as well as the product) (Defra 2007; Fisher and Turner 2008; UNEP 2009). However from an ecosystem management perspective the state and performance of the system, and sustainability of consumption, may be just as important to measure (de Groot et al. 2010a).*

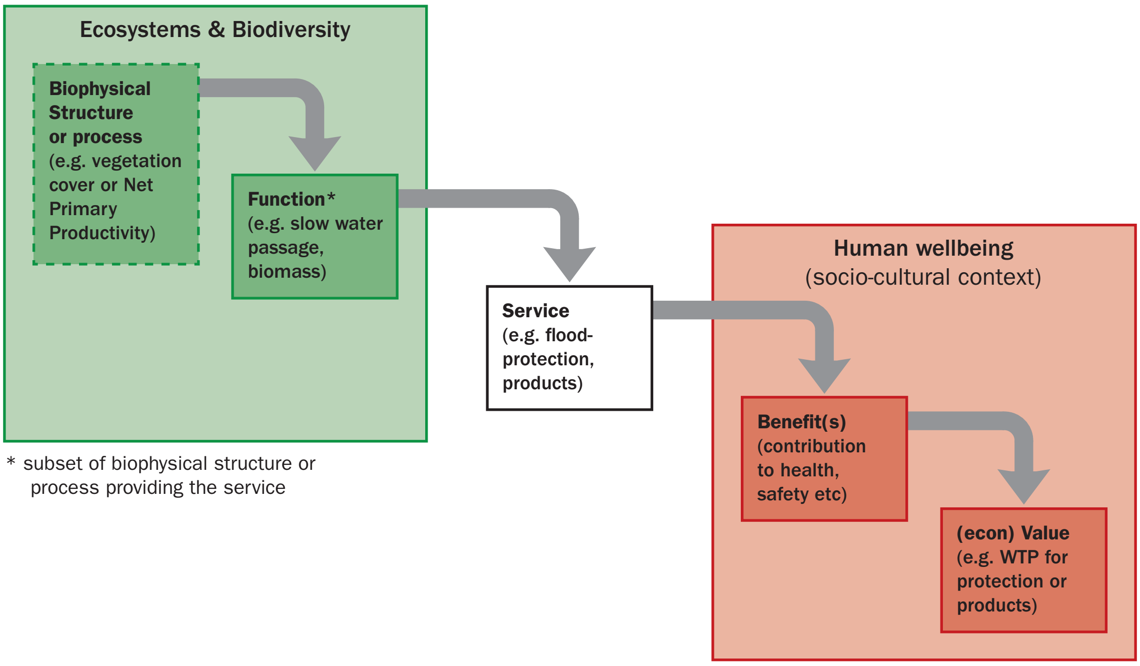



**Figure 2. Framework for linking ecosystems to human well-being.** Source: De Groot *et al*. (2010a; modified from Haines-Young and Potcshin 2010).

Indicators for ecosystem services can be defined for different aspects of this 'flow' from the ecosystems that provide services to the benefits that are captured by people. These range from measures of the structure of the system or particular elements of it (including ecosystem extent and condition), measures of ecosystem process and functions, measures relating to services and measures of use (benefit) and impact (De Groot 1992; Balmford *et al*. 2008; Tallis and Polasky 2009; De Groot *et al*. 2010a,b).

## ECOSYSTEM SERVICE INDICATORS AND METRICS USED IN SUB-GLOBAL ASSESSMENTS AND ELSEWHERE

Our analysis covered 11 SGAs from Central America, South America, South-Eastern Asia, Southern Asia, the Caribbean, Northern Europe, Eastern Europe and Southern and Eastern Africa (**Box 3**). Information was collected from SGA reports and via a questionnaire survey distributed to SGA focal points.[5]

Information was received on a total of 150 indicators, of which 137 were included in the analysis. Thirteen indicators were ambiguous and therefore omitted from the analysis. Ecosystem service indicators used in SGAs were classified according to the MA/TEEB framework of 22 service types under four key service themes presented in **Table 1**. Metrics were categorised according to the elements of **Figure 2**.

**Footnote**

[5] *Further information on this study is available from UNEP-WCMC.*

**Box 3. What are sub-global assessments?**

Sub-global assessments (SGAs) were carried out for the global Millennium Ecosystem Assessment (MA) as part of the process of building the knowledge base on the links between ecosystem services and human well-being at local, national and regional scales. The scope of individual SGAs varied widely, from topic-specific assessments to those dealing with multiple ecosystem services, and from local to regional scales. Some SGAs from the MA are still ongoing, while a number of new SGAs based on the MA framework are being initiated in various parts of the world. A manual, intended to be the 'how to' guide for undertaking ecosystem assessments has been developed to support future SGAs (Ash *et al.* 2010).

Thirty-four regional, national and local scale assessments (or SGAs) were included within the MA. The SGAs included in the analysis presented in this report are: Mexico (Central America); Argentina, Colombia (South America); Philippines (South-Eastern Asia); India (Urban) (Southern Asia); Trinidad and Tobago, Caribbean Sea Ecosystem Assessment (Caribbean); United Kingdom National Ecosystem Assessment, Norway (Northern Europe); Altai-Sayan Ecoregion (Eastern Europe) and Southern Africa SGA (Southern and Eastern Africa) (**Figure 3**).


**Figure 3. Location of Sub Global Assessments surveyed for this report.**

## Indicators used in Sub Global Assessments and elsewhere

The analysis shows that currently all four MA ecosystem service classes – provisioning, regulating, cultural and supporting - are being assessed in SGAs. Ecosystem services that have high, demonstrable value for supporting human livelihoods (Chazdon 2008) tend to dominate. Examples include food, fuel wood, freshwater, biological raw materials, climate regulation, water regulation and tourism and recreation.

The majority of the indicators were found to be for provisioning and regulating services followed by supporting and cultural services (**Table 2**). These results confirm findings from earlier studies (Layke 2009; UNEP-WCMC 2009). Among the provisioning services, the provision of food, biological raw materials, freshwater and (fuel) wood are frequently addressed. The bulk of food provisioning indicators address capture fisheries, crop and livestock production and wild foods.

Among regulating services, water regulation, climate regulation, erosion regulation and natural hazard regulation are frequently addressed. Examples included carbon stocks and sequestration, water quality, erosion control, economic costs of controlling diseases caused by crop pests, number of deaths with natural hazards and potential flood risk as a consequence of deforestation.

The majority of cultural indicators are related to recreation and tourism. For instance, revenue from tourism, number of visitors to national parks, number of jobs related to tourism and number of spiritual sites. Recreation and tourism play an essential part in the economies of most wildlife and biodiversity rich areas of Southern Africa, the Caribbean and the Americas, amongst others.

Indicators underpinning more than one ecosystem service (i.e. biodiversity and ecosystem indicators) were also commonly used in SGAs. These tended to be measures of the amount or condition of the system and included the status and trends of change in vegetation cover, number of species, area and distribution of ecosystems, ecosystem diversity and biodiversity intactness (**Box 4**). The majority of these are biodiversity indicators which either indirectly or directly underpin services such as food, biomass fuel, biological raw materials, water regulation, natural hazard regulation, climate regulation, erosion regulation, water purification, soil formation, nutrient cycling and ecotourism.

**Table 2. Frequency of indicators per ecosystem service category.** n: sample size.

| Ecosystem service type | Number of ecosystem service indicators | Proportion of total indicators in service category (%) |
|---|---|---|
| **PROVISIONING** | **n=54** | |
| Food | 29 | 53.7 |
| Biological raw materials | 10 | 18.5 |
| Biomass fuel | 4 | 7.4 |
| Freshwater | 9 | 16.7 |
| Biochemicals, natural medicines and pharmaceuticals | 2 | 3.7 |
| **REGULATING** | **n=34** | |
| Air quality regulation | 1 | 2.9 |
| Climate regulation | 4 | 11.8 |
| Water regulation/water quality | 14 | 41.2 |
| Water purification and waste treatment | 2 | 5.9 |
| Erosion regulation | 4 | 11.8 |
| Pest regulation | 1 | 2.9 |
| Pollination | 2 | 5.9 |
| Natural hazard regulation | 4 | 11.8 |
| **CULTURAL** | **n=16** | |
| Recreation and tourism | 16 | 100 |
| **SUPPORTING** | **n=18** | |
| Soil formation | 6 | 33.3 |
| Nutrient cycling | 4 | 22.2 |
| Primary production | 6 | 33.3 |
| Water cycling | 2 | 11.1 |

**Box 4. The Biodiversity Intactness Index (BII) from the South African Sub Global Assessment.**

The Biodiversity Intactness Index (BII) is a measure of the change in abundance across all well-known elements of biodiversity, relative to their levels prior to some predetermined point in time (Scholes and Biggs 2005; Biggs *et al.* 2006). It is an indicator of the average abundance of a variety of organisms in a given geographical area, relative to their reference populations (Scholes and Biggs 2005; Kirton 2008).

Using 'protected area' as an index of biodiversity conservation ignores 90% of the landscape, where people live and where most biodiversity changes are occurring. For this reason, and to avoid the insensitivity of extinction-based measures, the Southern African Millennium Ecosystem Assessment (SAfMA) developed a new index, called the 'Biodiversity Intactness Index'. The BII measures the remaining fraction of the original populations of all species that occurred in a given area, integrating across all land uses and the well-described categories of biodiversity (plants, mammals, birds, reptiles and amphibians) (**Figure 4**).

The BII is an aggregate index. Three basic input factors are needed to calculate the BII: Richness (*Rij*), area (*Ajk*) and relative population size (*Iijk*), defined in terms of specific taxa (*i*), ecosystems (*j*) and land uses (*k*) (Biggs 2005). It is weighted by the area subject to each activity, which range from complete protection to extreme transformation (e.g. in the case of urbanization), and the number of species occurring in the particular area (Scholes and Biggs 2005). The advantage of using the BII is that it can be disaggregated at any level. Therefore it can be expressed at an ecosystem or political unit, at the level of a taxonomic group, functional type, or land use activity, and this provides the BII with transparency and credibility (Biggs *et al.* 2004; Scholes and Biggs 2005). The BII can be used to describe the past or project into the future, and it can also have an associated error bar, allowing the user to monitor the range of the uncertainty (Biggs *et al.* 2004; Scholes and Biggs 2005; Kirton 2008).

The BII gives the average richness and area weighted impact of a set of activities on the population of a given group of organisms in a specific area, therefore providing the average population size of a wide range of organisms relative to their baseline populations in a given area (Biggs 2005; Scholes and Biggs 2005; Kirton 2008).

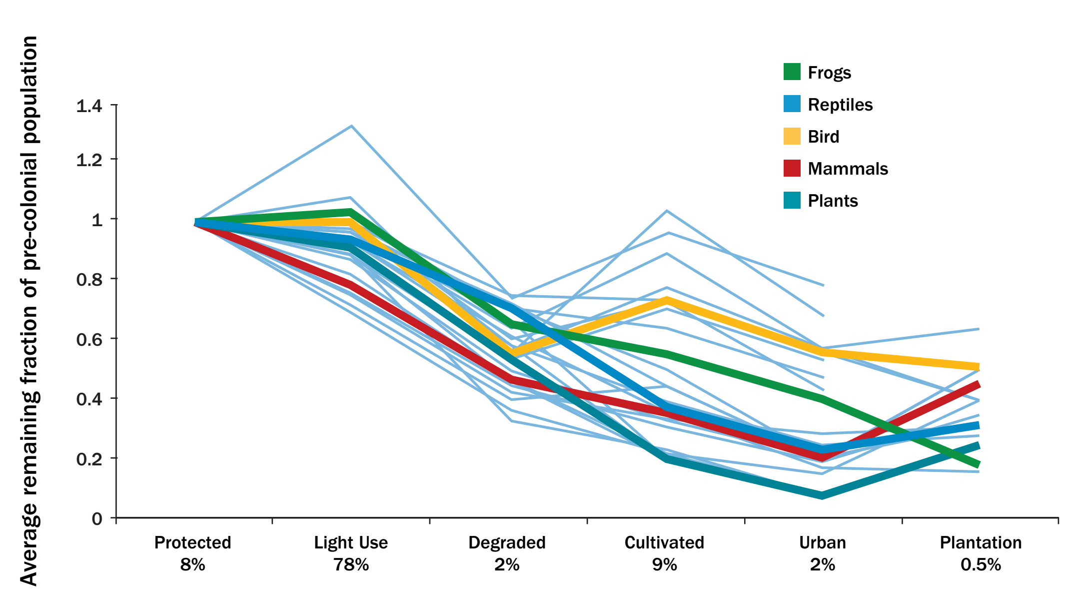



**Figure 4. The effect of increasing land use intensity on the inferred original population.** These estimates, averaged over biomes and functional types, were derived from independent structured interviews with 16 taxon specialists. Some general patterns are evident: non-mobile species such as plants are more adversely affected than mobile species such as birds. Larger organisms and predators are more affected by human activity than are smaller, non-predatory species. Mammals and reptiles tend to track (plant) habitat changes, whereas birds and frogs show marked non-linearities in their response. The x-axis percentages refer to the percentage of southern Africa under the respective land uses. Grey lines show the range of estimates. Source: Scholes and Biggs (2004).

### Metrics used in Sub Global Assessments and elsewhere

Various metrics were used to quantify ecosystem services (see **Annex 2** for more detailed descriptions of individual indicator metrics and methods). Provisioning services with direct market values are addressed by metrics such as *area* planted with maize, beans and sorghum in hectares; *area* covered by fish cages in hectares; *number* of exploited species; *number* of fisheries management units by status of exploitation; *number* of fish species reported at major fish landing sites; *number* of animals used for pharmaceutical derivates by species; *mass* and *proportion* by taxonomic group of vertebrate biomass in kilograms and percentage, *percentage* of animals used for hunting by species; *mass* of total fish catch; *average annual growth* of employment in the marine products sector, *mass* in tonnes of fish produced from aquaculture; *volume* of wood production by tree types, *volume* of timber harvested in cubic metres; *currency* - real 2000 $USD value of fish harvest and total dietary intake of carbohydrates and proteins from cereals- *Kcalories/ person/day* and *Proteins- grams*)

Regulating services were addressed by metrics such as *mass* of $CO_2$ emissions from deforestation; *dissolved oxygen* (*DO*) in water; *pH* of water; *salt content* in water; *currency and mass* - economic costs of controlling diseases caused by crop pests and total consumption of pesticides; and *number* of deaths associated with natural hazards. Cultural services were addressed by metrics such as *number* of visitors per year to sites of interest, *revenue* from tourism and *number* of jobs related to tourism (**Box 5**).

Supporting services were addressed by metrics such as *stock* of total mineralisable nitrogen and *soil pH*. Indicators underpinning more than one ecosystem service were addressed by metrics such as *area* of vegetation cover; *number* of species per hectare; t*otal forest cover*; *percentage* change in live coral cover; *annual % change* in total mangrove area and *land area* in square kilometres.

**Box 5. Nature-based tourism and recreation indicators.**

The most common measure of cultural services relate to nature-based tourism and recreation. These are frequently collected by protected area authorities or tourism offices, either through visitor books and financial accounts or entry/exit surveys and include measures of visitation, revenue and sometimes employment. The Northern Range Assessment in Trinidad provides a good example (**Figure 5**). Although commonly collected at the site level, different measures and methods of data collection pose challenges to comparisons between sites or countries and to scaling up to global level, although attempts are beginning to be made to meet these challenges (Balmford *et al.* 2009).

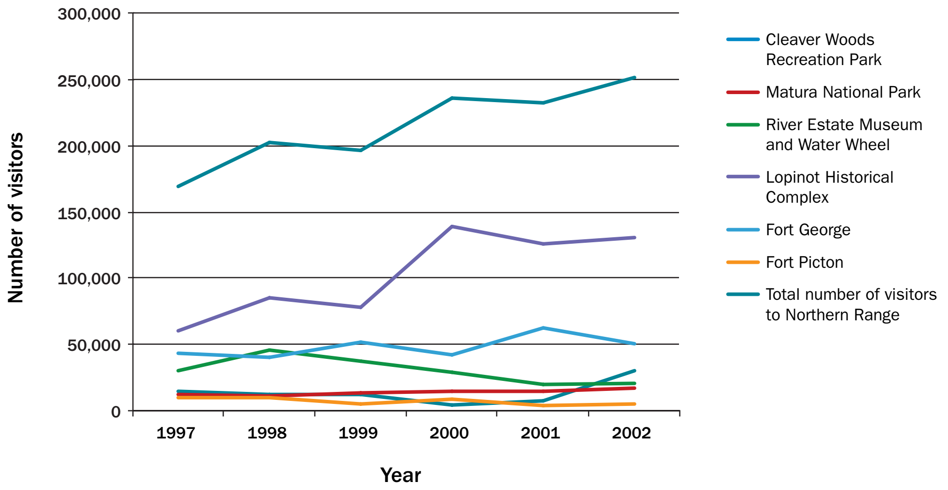



**Figure 5. Summary of visitor numbers to Northern Range Sites (Trinidad) for 1997–2002.** Source: Northern Range Assessment (2005).

The findings from the peer-review literature were similar to the findings from the survey of SGAs. The majority of the indicators were found to be for regulating and provisioning services (across all ecosystem types). Among provisioning services, examples included the provision of (fuel) wood from forests and fresh water from lakes and rivers. The examples of regulating services included water retention, primarily addressed by studies on forest and grass ecosystems. The majority of soil, flood plains and wetland-related indicators referred to the supporting service of nutrient cycling. The provision of fibre and fuel (energy) was particularly linked to indicators in forest ecosystems. Among the cultural services, most indicators related to recreation, education and knowledge systems.

### Classifying metrics

The majority of metrics used in SGAs related to ecosystem structure (extent/condition), followed by metrics of benefit and value. There were some measures relating to the output/service delivered by the ecosystem, but very few relating to ecosystem functioning.

Amongst the indicators used in SGAs there are only a handful of underlying metrics – i.e. things actually measured. The majority of indicators relied on metrics relating to the extent/condition of the habitat or ecosystem such as forests, grazing land and watershed, area planted with crops such as maize or area covered by fish cages in hectares, the condition of habitats or ecosystem and stock of, for example, carbon stored. Ecosystem services are outputs of the ecosystem, and benefits are derived from those services.

Other indicators relied on metrics relating to outputs including the amount of goods (e.g. tonnes of wheat harvested, mass of total fish catch, volume of timber harvested, volume of water consumed, number of visitors to protected areas and economic values (e.g. dollar value of tourism (or jobs created) and value of commodities such as fish, timber and non timber forest products). This pattern is likely due in part to what is easily measurable but also to what is actually measured and available (**Box 6**). In many cases there are major gaps in data availability.

There is a growing academic literature dealing with quantifying multiple ecosystem services from local (patch level) to national and regional level. Three common trends found in the literature are: i) those reporting on the extent of ecosystems; ii) those reporting on the condition of ecosystems; and iii) those reporting on the quantities of some flows of ecosystem-oriented goods (food, fibre, water). This also reflects the findings of the SGA review.

Dale and Polasky (2007) propose that ecological indicators for ecosystem services focus mainly on composition and structure rather than function. They argue that, typically, structure and composition are easier to measure than function, and they often reveal information about function. For example, identifying a plant's size (structure) or species (composition) is easier than determining such functional attributes as the plant's influence on carbon sequestration, nutrient cycling, or enhancement of soil properties. Hence, indicators often are structural or compositional attributes. This approach is useful as long as structural or compositional attributes accurately represent the functional attributes of the system that relate to the provision of ecosystem services (e.g. dominant vegetation types accurately reflect the amount of carbon storage). However, despite significant progress in the last decade in developing indicators and methods, de Groot *et al*. (2010a) argue that the quantitative relationship between ecosystem components and processes and services is still poorly understood. As a result some measures of ecosystem structure/composition and process may be poor indicators of ecosystem service.

**Box 6. Datasets and sources of data used to develop indicators within Sub Global Assessments.**

The principal sources of data for *developing* ecosystem service indicators that were used in SGAs included national statistics, government databases, regional and international agencies (e.g. FAO, CITES, World Travel and Tourism Council (WTTC) and 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 services* 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 presents 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

### Supply, demand and sustainability

An important distinction can be made between metrics indicating supply, those indicating consumption and those that indicate sustainability or risk of unmet demand. For example, the metrics *number and distribution of edible insects*[6] and *total annual wood production*[7] can be categorised as indicators of ecosystem service supply or 'potential benefits' as they reflect the amount the system or service can provide. These have to be captured and used to become benefits. To illustrate the distinction further, consider freshwater provision. The water available and provided by a system (*e.g. freshwater storage in lakes* and *freshwater storage in glaciers*) represents the ecosystem service. This is not the same as *water consumption* by the population, which would be a measure of use or demand. In the same way, both of these measures are different from *water scarcity*.[8] This is a measure derived from information on both availability and demand and is a measure of sustainability or risk/vulnerability (also see **Box 8**, p46). Another example of a sustainability metric is the *fishing in balance index*.[9]

### Measuring change

Not all indicators are indicators of change (i.e. measured at multiple times). Some are in fact baseline indicators of magnitude or importance. For example, *percentage of planted crop area dependent on (wild) pollinators*. These only become indicators of change if they are measured repeatedly over time. The presence of these indicators could be explained by the objectives of a particular SGA (which may have been a baseline study) and the fact that much of the data presented in SGAs is from one-off studies rather than ongoing monitoring. Many ecosystem service maps (see below) are snapshots or baselines indicating spatial variability but not temporal change.

### Modelling and mapping ecosystem services

Not all ecosystem service metrics are directly measured. Some are modelled, often by applying a *production function* equation to an underlying dataset containing information on the properties of an ecosystem such as its extent or condition, for example total forest cover. This information is then used to model other ecosystem variables that describe functions or services. Examples include *carbon storage* and *watershed quality* (**Box 7**). To achieve this requires good scientific understanding of the link between the condition of the system and the provision of the service, either from research studies or expert knowledge. It is worth noting that modelling and measurement support each other and meet different needs. Models can provide information at times and places where it would be impractical or impossible to measure. Measurements feed model development and evaluate model predictions.

Modelled metrics are often used in SGAs to generate maps of ecosystem service supply or demand (see **Box 7** and **Box 8**, and examples in **Annex 2**). Ecosystem service mapping is also becoming increasingly common in the academic literature. Examples of indicators where maps were created included provisioning services (e.g. reed and fish production, agricultural production, water provision); regulating services (e.g. carbon storage, carbon sequestration, pollination, water retention, flood control, soil conservation), cultural services (e.g. recreation) and supporting services (e.g. soil accumulation) and biodiversity (existence value and bioprospecting).

#### Footnote

[6] *From the Mexico SGA*

[7] *From the Southern Africa SGA*

[8] *From the Colombia SGA*

[9] *From the Caribbean Sea SGA*

**Box 7. Examples of modelled indicators.**

**Carbon stored in habitat types: Little Karoo, South Africa**

Carbon storage is the number of tonnes of carbon locked up in above and below ground biomass of plants; most of this carbon would be released if these intact ecosystems were transformed or degraded. In mapping this service, similar to Chan *et al.* (2006), the authors in the study featured here, focused on carbon storage rather than sequestration as an ecosystem service, mostly because of the data gaps and uncertainty in estimating sequestration. Most Little Karoo habitat types were assigned zero carbon storage values due to their arid and/or fire prone nature (**Figure 6**). For the remainder carbon storage values were extracted for the habitat types of Arid Thicket with Spekboom, based on research on carbon storage in the region (Mills *et al.* 2005; Mills and Cowling 2006). Through a process of expert consultation the more mesic Thicket with Spekboom types were assigned higher values based on higher predicted biomass. Similarly arid Thicket types without spekboom (*Portulacaria afra*) were assigned lower values owing to the large contribution of this species to carbon stocks (Mills *et al.* 2005). Three remaining habitat types (Randteveld, Gravel Apronveld and Thicket Mosaics) were assigned small values to reflect the small amount of carbon they potentially store. The ecosystem service was mapped as tonnes of carbon stored per hectare per habitat type. We assign a high certainty to the carbon storage values of the Arid Thicket with Spekboom type, and low certainties to the remaining values where scientific understanding is still in development.

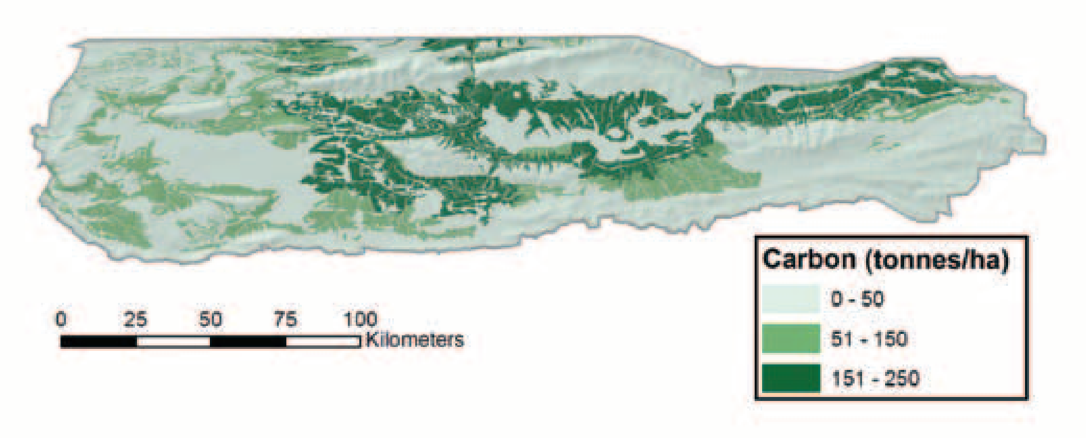



**Figure 6. Potential carbon storage (tonnes per hectare) of each habitat type in the Little Karoo of South Africa.** Source: Reyers *et al.* (2009).

**Watershed quality: Northern Range, Trinidad and Tobago**

Data used to calculate the indicator was from an assessment of watershed quality of Northern Range watersheds based on expert judgement (Northern Range Assessment 2005). The quality of watersheds is based on expert estimates on the area of forest cover in the Northern Range which is assumed to have implications for hydrological processes and health of the aquatic ecosystems. Data collected was then used to produce a map (**Figure 7**). In this case, the expert assessment concluded that the area of forest cover has declined in the Northern Range resulting in disruption to hydrological processes and negative impacts on health of the aquatic ecosystems.

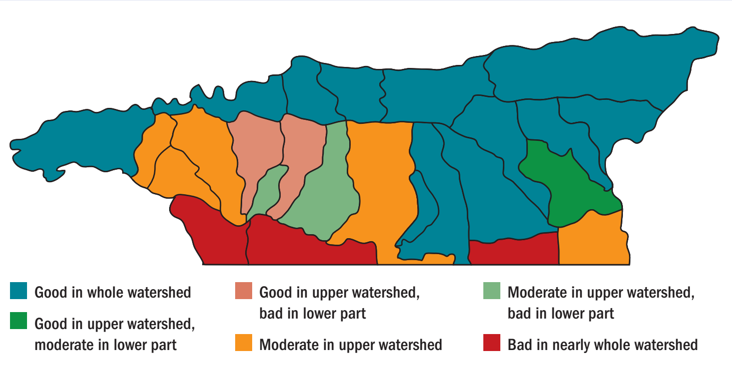



**Figure 7. The quality of Northern Range watersheds in Trinidad and Tobago.** Source: DHV Consultants BV (1999) and Northern Range Assessment (2005).

**Box 8. Ecosystem service maps from the Southern Africa Sub Global Assessment.**

In the Southern African SGA, ecosystem service maps were created for indicators such as total dietary intake of carbohydrates and proteins (a map showing production versus demand for the region), water availability (seasonal maps of surface water availability) and wood and charcoal use in Southern Africa (maps of wood fuel demand versus production to show areas of potential shortage; **Figure 8**).

Total annual wood production was calculated by scaling a maximum annual increment of 10 tonnes/hectare/ year by a function of the number of days available for tree growth and the percent tree cover at a particular location. All data are for 1995 and displayed at a 5x5 km resolution (Corbett and O' Brien 1997; CIESIN 2000; DeFries, 2000; Hutchinson *et al.* 1995).

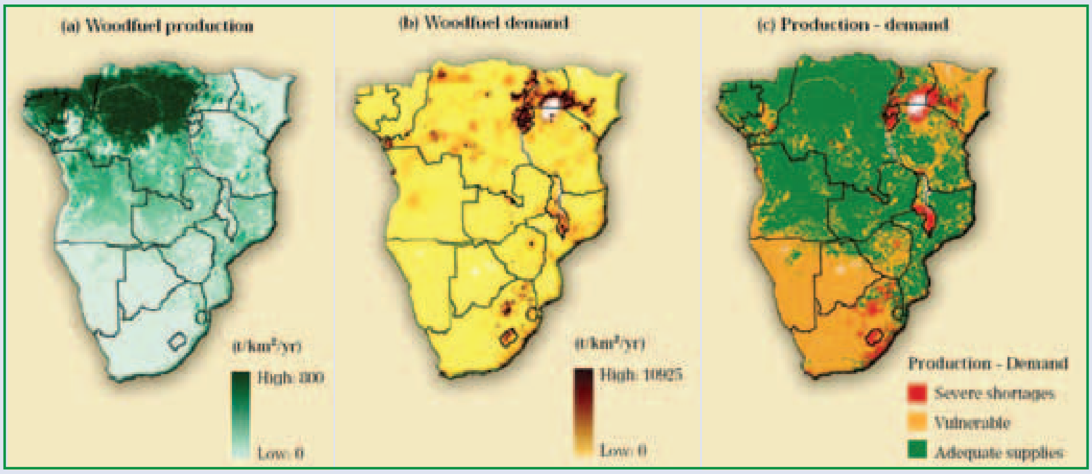



**Figure 8. Map of wood fuel demand versus production in Southern Africa.** Source: Scholes and Biggs (2004).

While maps are regarded as very effective ways to present information, they consume enormous amounts of data and it is very difficult to represent uncertainty in maps. Eigenbrod *et al.* (2010) argue that progress in the development of spatial mapping as a tool for assessing ecosystem services is hampered by a lack of data for most services across most of the world. This has led to many maps of ecosystem services being based on crude estimates, though the quality of data varies widely between studies and services.

In general, the methods used to produce ecosystem service maps can be broadly divided into: i) those that are based on at least some primary data from within the study region, and ii) those that are not (proxies). The former category can be further subdivided into maps based on representative sampling across the whole study region and modelled surfaces based on primary data, while the latter can be broadly divided into land cover based proxies and prior knowledge driven modelled surfaces as summarized in **Table 3**.

Eigenbrod *et al.* (2010) showed that land cover based proxies provide a poor fit to primary data surfaces for biodiversity, recreation and carbon storage, and that correlations between ecosystem services change depending on whether primary or proxy data are used for the analyses. They argue that good-quality proxy maps can be useful for mapping broad-scale patterns in ecosystem services but may be too crude for spatial planning or to select priority areas for multiple ecosystem services.

Nevertheless increasingly sophisticated ecosystem service mapping is taking place, with more and more focus on mapping and comparing the economic values of different ecosystem services across landscapes (see Section 3, **Box 13**, p57-58).

**Table 3. Major approaches to producing maps of ecosystem services (after Eigenbrod *et al.* 2010).**

| Methodology | Advantages | Disadvantages | Examples |
|---|---|---|---|
| **Requires primary data from within the study region** | | | |
| Representative sampling of entire study region (e.g. atlas data; region-wide survey) | Provides the best estimate of actual levels of ecosystem services<br><br>Well suited to heterogeneous ecosystem services | Expensive or difficult to obtain, so often unavailable<br><br>Degree of error will depend on sampling intensity | Recreation<br>Biodiversity<br>Reed and Fish production |
| Modelled surface based on sampling from within study region | May require far fewer samples than representative sampling<br><br>Smoothing will overcome sampling heterogeneity | Smoothing will mask true heterogeneity in the service<br><br>Error will depend on sample size and fit to modelled variables | Carbon storage<br>Biodiversity<br>Biodiversity 'hotspots'<br>Carbon sequestration<br>Agricultural production<br>Pollination<br>Water retention<br>Recreation |
| **Does not require data from within the study region** | | | |
| Land cover based proxy (e.g. benefits transfer) | Enables mapping of ecosystem services in regions where primary data are lacking | Fit of proxy to actual data may be very poor | Biodiversity (existence value and bioprospecting)<br>Recreation<br>Carbon storage<br>Flood control<br>Soil conservation |
| Proxy based on logical combination of likely causal variables | Can offer a major improvement on performance of land cover based proxies alone, without the need for much additional data | Potential for large error is still high if assumed causal variables are not in fact good predictors | Recreation<br>Flood control<br>Water provision<br>Soil accumulation |

## Spatial scale of indicators and metrics

The spatial scale – both grain and extent – of ecosystem service indicators varies,[10] and this affects what each one can tell us (Saisana *et al.* 2005; Dobbs and Escobedo 2009; Feld *et al.* 2009a,b). For example the wide geographic extent of global indicators means that they provide a valuable overview that may permit analysis at regional or national scales, but the coarser grain (resolution) of most global indicators or the limited data upon which they are based limits their value at finer scales (**Box 9**). Alternative methods and metrics may be required for more localised decision-making (see Section 3, **Box 12**, p56).

### Footnote

*[10] Our analysis of ecosystem service indicators used in SGAs revealed that the majority of indicators for provisioning services were applied at the national scale. The majority of regulating service indicators were applied at the regional and national scale. Regulating service indicators such as climate regulation and air quality regulation generally refer to broader scales, for example multiple landscapes, sub-global and global scales. Supporting services were mainly addressed at national and regional scales. Cultural services were principally addressed at the national scale.*

**Box 9. Examples of two global ecosystem service indicators.**

Both temporal and spatial ecosystem service indicators have been developed at global scale, and examples of each are illustrated here.

**Red List Index for pollinators**

Birds are important providers of particular ecosystem services, through their role as scavengers (e.g. vultures, which are important for consuming carrion), pest control (by rodent-hunting birds of prey and insect-eating species such as warblers), seed dispersal (by frugivores such as hornbills and parrots) and as pollinators (for which at least 50 crop and medicinal plant species rely on birds). Tracking trends in the status of such species can help to monitor the provision of ecosystem services. The Red List Index shows trends in the extinction risk of sets of species, based on data from the IUCN Red List. The index can range from 1.0 (if all species are classified as Least Concern) to zero (if all species have gone Extinct). The RLI for pollinators (BirdLife International 2010; **Figure 9**) shows that overall they are less threatened than other bird species (with higher index values on average), but are declining at a similar rate. As pollinating bird species slip towards extinction, they typically become less abundant and therefore their delivery of this ecosystem service declines. This has important consequences for those crops and products that rely on pollination by birds.

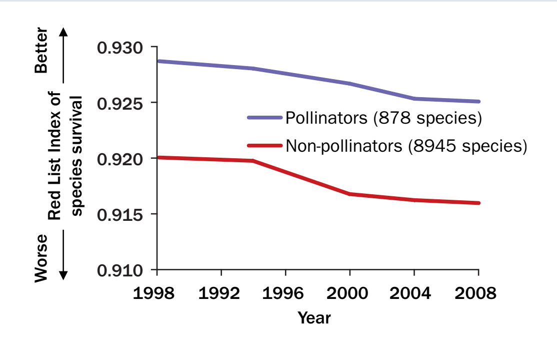



**Figure 9. Red List Index (RLI) for pollinators.** Source: Analysis of data held in BirdLife's World Bird Database (BirdLife International 2010).

**Global terrestrial carbon stocks**

UNEP-WCMC has been working to upgrade the global map of carbon stocks used in the original publication *Carbon and Biodiversity: A Demonstration Atlas* (UNEP-WCMC 2008). The most urgent aspect of this process was to improve upon the rather coarse data on soil carbon included in the original map. This has been done using the Harmonized World Soil Database (HWSD) version 1.1 (FAO/IIASA/ISRIC/ISS-CAS/JRC 2009), which has enabled UNEP-WCMC to incorporate improved values of soil carbon to 1 m depth at a nominal spatial resolution of 1 km (many of these data are based on the FAO 1974 soil mapping units, which are much larger polygons that have been rasterised at 1 km resolution).

Data in the HWSD represent 16,107 uniquely identified soil mapping units, each containing between 1 and 10 different soil typological units. UNEP-WCMC generated a global map of estimated soil carbon stocks to 1 m depth based on the soil organic carbon and bulk density values included in this data set, adjusting for gravel content and taking account of variations in soil depth. These estimates reflect inherent soil properties at the time of the original survey, but do not take account of land use change.

This new soil carbon map has been combined with the biomass carbon map developed by Ruesch and Gibbs (2008) using IPCC Tier 1 methodology and GLC2000 landcover data to provide a new global map of terrestrial carbon stocks (**Figure 10**). This map can provide a useful basis for global and regional scale analysis and a point of reference for national scale work.

**Figure 10. Global map of terrestrial carbon density, including vegetation and soil carbon pools.** Source: FAO/IIASA/ISRIC/ISS-CAS/JRC (2009); Ruesch and Gibbs (2008); Scharlemann *et al.* (in prep).

# 3. ISSUES AND CHALLENGES

Despite the growing body of literature on ecosystem services there are still many challenges to the development of robust ecosystem service indicators. This section highlights the key issues identified by participants during expert workshops. Generally a single indicator will not be sufficient since different ecosystem services do not necessarily co-vary. Choice of indicators is determined by policy objectives and data availability, although it is important to ensure proxies are meaningful and uncertainties are made explicit. There is an increasing focus on economic metrics which can facilitate comparative analyses for many, but not all, services. Spatially explicit indicators are useful although indicators developed at global scales may have limited use at local scales and vice versa. Better understanding of the factors influencing ecosystem service maintenance and delivery requires a systems approach and linked or bundled indicators. Means to simplify communication of indicator information, and to mainstream ecosystem service indicators and assessment techniques, are important.

## KEY ISSUES TO CONSIDER IN USE AND DEVELOPMENT OF ECOSYSTEM SERVICE INDICATORS

In an ideal world, policy objectives and priorities related to ecosystem services would be clearly defined, achievable and neatly integrated across all socio-ecological systems. Likewise, the connections between biodiversity, ecosystem function and the delivery of services would be well understood and observed changes easily interpreted. Consequently, selection of indicators to monitor progress towards targets would be a simple procedure, and everything that needed to be measured could be measured. Additionally, there would be uniform, wide-scale adoption of the indicators selected, but with the scope to adapt the indicators used to meet changes in objectives. Assessment outcomes would be simple but effectively communicated across different sectors, and uncertainties and unknowns would be well represented and understood.

In reality, it is a challenging process to select, develop and use ecosystem service indicators. Not only are there logistical challenges associated with both long- and short-term ecological monitoring programmes (primarily time and budgetary constraints), but there are also technical issues to confront including:

- How to prioritize indicator choice;
- What to measure, given that there is often a lack of data and/or only a limited understanding of the links and relationships between systems, services and sectors;
- Whether ecosystem services and indicators should be 'bundled' into aggregate groups or indices; and
- How to apply indicators at different scales to meet varying objectives.

Communicating and mainstreaming ecosystem service indicators and assessment techniques at all levels of decision making (i.e. local, regional, national and global) also pose considerable challenges. In this section we will discuss these key issues, highlighting where the biggest challenges lie.[11]

## PRIORITISING INDICATOR CHOICE: WHAT TO MEASURE?

Ultimately indicators will be used to track progress towards targets and form the basis of socio-ecological decisions. It is recognized that policy contexts (including targets) will vary over temporal and spatial scales. Hence the ecosystem services chosen to be included in an assessment, and the indicators used to monitor trends, will be determined on a case-by-case basis and be dependent on the overall objectives and scope of the assessment and the information needs and priorities of decision-makers. With that in mind, a key issue that needs to be taken into consideration when prioritising which indicators to use or develop is how to best allocate available resources so that key elements and information gaps are addressed.

**Footnote**

[11] *The content in this section is derived from the two expert workshops undertaken as part of this project.*

This may vary according to a number of factors, including what data is currently available to meet indicator requirements, the capacity (including both knowledge and resources) to apply different indicators, and the relevance or importance appointed to ensuring ecosystem service sustainability.

### Assessing single or multiple ecosystem services

It is evident that the majority of ecosystem service indicators in use are directly related to provisioning services, in particular food and freshwater provision (see Section 2). It is likely they dominate in comparison to other services because the value of provisioning services, in terms of supporting human livelihoods, is readily recognized (particularly by decision-makers), and because indicators of provisioning services are relatively straight forward to measure (e.g. the amount of crops produced) and interpret in terms of benefits to humans (e.g. the dollar value of crops produced).

However, as different services are underpinned by different features and functions of an ecosystem, as one service is enhanced, another may become degraded. Monitoring a single service will not capture the range of services provided by an ecosystem or how these services co-vary. Given there may be tradeoffs between services (e.g. Raudsepp-Hearne *et al*. 2010) there is a need to measure, model, map and assess multiple services. The exact number of indicators of intermediate or final services that are measured will ultimately be related to the objectives of the assessment (**Box 10**).

**Box 10. Indicators used by the Mediterranean Wetlands Observatory.**

The Mediterranean Wetlands Observatory (MWO; http://www.medwetlands-obs.org/) was launched in 2008 by the MedWet Initiative (http://www.medwet.org/). Coordinated by Tour du Valat (http://en.tourduvalat.org/), it is a partnership of 27 countries working together to provide quality information on status and trends of Mediterranean wetlands; track threats to Mediterranean wetlands; promote their protection, wise use and restoration; and assess if Mediterranean wetlands are taken into account in development processes.

It is widely recognized that wetlands provide a large number of services to human-kind, including the provision and purification of water, flood and climate regulation, provision of food (e.g. fish, timber, fibre), recreation and tourism. However, it is believed that services provided by wetlands have been severely depleted over the last 50-years due to degradation and loss of wetland habitat and species.

Although baseline data needed to monitor and assess the state and trends of wetland services is still largely lacking, the MWO Working Group on Ecosystem Services have identified the ecosystem services that monitoring programmes should focus on in order to meet the aims of the MWO in: 1) placing equal or greater emphasis on sustaining the bio-physical features of Mediterranean wetlands as opposed to enhancing economic value; 2) raising the awareness of the importance of Mediterranean wetlands amongst decision makers; 3) balancing the set of indicators between provisioning, regulating and cultural services; and 4) focusing on water related services because of the importance of water issues in the Mediterranean region and their potential to turn the attention of the decision makers to wetland conservation. These services include:

- Water supply
- Water purification
- Flow Regulation, and
- Tourism and Education

The MWO Working Group on Ecosystem Services has also prioritized potential ecosystem service indicators. In selecting potential indicators, the MWO has recognized the importance of ensuring that any change observed in the indicator value, should be indicative of the link between the wetland ecological function and the provision of the service. Other issues taken into consideration were whether the indicator should measure the current use of a service and/or the carrying capacity of a wetland to deliver a service without being degraded, acknowledging that carrying capacity may vary from site to site.

Source: Beltrame 2010; MWO 2011.

### Choosing metrics

One of the outcomes from the first workshop held in September 2009 was the suggestion that ecosystem services could be monitored by using different metrics for different components of the 'flow' of a service – i.e. those that capture information on ecosystem structure (condition/stock), function, and service alongside measures of the benefit and value of the service (see **Annex 2**). Further research (outlined in Section 2) found that the majority of developed ecosystem service indicators use data relating to ecosystem structure or to services and benefits.

When deciding what to measure it is important to consider what each type of metric will provide. If, in the first instance, we just consider indicators of the condition and/or stock of a system (e.g. biomass of a forest) and those that are indicators of the benefits and/or impacts that a service provides (e.g. amount and value of timber harvested) it is clearly evident that they are providing information on different components of a service (in this case, provisioning of raw materials). Both aspects are important: monitoring the condition or stock of the service over time and space will provide information on ecological growth rates and the level of sustainability of off-take (e.g. is more biomass of trees being removed than replaced), while monitoring the benefits or impacts of the service will provide information on the relative importance of the service to people (e.g. increased production may reflect increased preference for timber products).

If only one of these indicators was presented it may provide misleading information. For example, if the value of timber was viewed in isolation and was seen to increase, this could be taken as an indication that a greater volume of timber had been produced. However, it may be that the stock of timber had declined and the increase in price was actually driven by an increase in consumption pressure for the limited amount of timber products available. Without knowing the state of forests which produced the timber it would be difficult to interpret the trends in this service correctly, and without both pieces of information it would be difficult, if not impossible, to monitor the sustainability of ecosystem service delivery.

Consideration must also be given to whether it is necessary to have indicators of the function. In many cases having a comprehensive understanding of ecosystem functioning may not be needed. However, understanding these variables could help in the design of condition/stock or benefit/impact indicators. For example, understanding the process of carbon sequestration will provide insight into how changes in the stock or condition of forest relate to changes in carbon stocks and hence climate regulation. Similarly, understanding the function of water flux (e.g. through rainfall and runoff) may assist in subsequent management and mitigation of impacts on hydrological services.

De Groot *et al*. (2010b) concur that a suite of indicators is needed to comprehensively describe the interaction between the ecological processes and components of an ecosystem and their services. To overcome this, they propose two main types of indicators (**Table 4**):

i) **State *indicators*** describing what ecosystem process or component is providing the service and how much (e.g. total biomass or leaf area index), and

ii) ***Performance indicators*** describing how much of the service can potentially be used in a sustainable way (e.g. maximum sustainable harvest of biomass or the effect of leaf area index on air-quality).

**Table 4. Indicators for determining use of ecosystem services (after de Groot *et al.* 2010a,b).**

| Services comments and examples | Ecological process component providing the service (or influencing its availability) = functions | State indicator (how much of the service is present) | Performance indicator (how much can be used/provided in sustainable way) |
|---|---|---|---|
| **Provisioning** | | | |
| 1. Food | Presence of edible plants and animals | Total or average stock in kg/ha | Net Productivity (in kcal/ ha/year or other unit) |
| 2. Water | Presence of water reservoirs | Total amount of water ($m^3$/ha) | Max sustainable water extraction ($m^3$/ha/Year) |
| 3. Fibre and fuel and other raw material | Presence of species or abiotic components with potential use for timber, fuel or raw material | Total biomass (kg/ha) | Net productivity (kg/ha/y) |
| 4. Genetic materials: genes for resistance to plant pathogens | Presence of species with (potentially) useful genetic material | Total 'gene bank' value (e.g. number of species and sub-species) | Maximum sustainable harvest |
| 5. Biochemical products and medicinal resources | Presence of species or abiotic components with potentially useful chemicals and/or medicinal use | Total amount of useful substances that can be extracted (kg/ha) | Maximum sustainable harvest (in unit mass/ area/time) |
| 6. Ornamental species and/or resources | Presence of species or abiotic resources with ornamental use | Total biomass (kg/ha) | Maximum sustainable harvest |
| **Regulating** | | | |
| 7. Air quality regulation: e.g. capturing dust particles | Capacity of ecosystems to extract aerosols and chemicals from the atmosphere | Leaf area index NOx-fixation | Amount of aerosols or chemicals 'extracted'- effect on air quality |
| 8. Climate regulation | Influence of ecosystems on local and global climate through land-cover and biologically-mediated processes | Greenhouse gas-balance (especially carbon equestration); | Quantity of Greenhouse gases, fixed and/or emitted, effect on climate parameters |
| 9. Natural hazard mitigation | Role of forests in dampening extreme events (e.g. protection against flood damage) | Land cover characteristics and similar | Reduction of flood-danger and prevented damage to infrastructure |
| 10. Water regulation | Role of forests in water infiltration and gradual release of water | Water-storage (buffer) capacity in $m^3$ | Quantity of water retention and influence of hydrological regime (e.g. irrigation) |
| 11. Waste treatment | Role of biota and abiotic processes in removal or breakdown of organic matter, xenic nutrients and compounds | Water retention capacity in soils or at the surface | Max amount of chemicals that can be recycled or immobilized on a sustainable basis |
| 12. Erosion protection | Role of vegetation and biota in soil retention | Denitrification (kg N/ha/y); Immobilization in plants and soil | Amount of soil retained or sediment captured |

| Services comments and examples | Ecological process component providing the service (or influencing its availability) = functions | State indicator (how much of the service is present) | Performance indicator (how much can be used/provided in sustainable way) |
|---|---|---|---|
| 13. Soil formation and regeneration | Role of natural processes in soil formation and regeneration | Vegetation cover root-matrix e.g. bio-turbation | Amount of topsoil (re) generated per ha/y |
| 14. Pollination | Abundance and effectiveness of pollinators | Number and impact of pollinating species | Dependence of crops on natural pollination |
| 15. Biological regulation | Control of pest populations through trophic relations | Number and impact of pest-control species | Reduction of human diseases, live-stock pests |
| **Habitat or Supporting** | | | |
| 16. Nursery habitat | Importance of ecosystems to provide breeding, feeding or resting habitat for transient species | Number of transient species and individuals (especially with commercial value) | Dependence of other ecosystems (or 'economies') on nursery service |
| 17. Genepool protection | Maintenance of a given ecological balance and evolutionary processes | Natural biodiversity (especially endemic species); Habitat integrity (irt min. critical size) | Ecological value (i.e. difference between actual and potential biodiversity value) |
| **Culture and amenity** | | | |
| 18. Aesthetic: appreciation of natural scenery (other than through deliberate recreational activities) | Aesthetic quality of the landscape, based on, for example, structural diversity, 'greenness', tranquillity | Number/area of landscape features with stated appreciation | Expressed aesthetic value, for example: number of houses bordering natural areas, number of users of 'scenic routes' |
| 19. Recreational: opportunities for tourism and recreational activities | Landscape-features Attractive wildlife | Number/area of landscape and wildlife features with stated recreational value | Maximum sustainable number of people and facilities |
| 20. Inspiration for culture, art and design | Landscape features or species with inspirational value to human arts | Number/area of landscape features or species with inspirational value | Actual use number of books, paintings. Using ecosystems as inspiration |
| 21. Cultural heritage and identity: sense of place and belonging | Culturally important landscape features or species | Number/area of culturally important landscape features or species | Number of people 'using' forests for cultural heritage and identity |
| 22. Spiritual and religious inspiration | Landscape features or species with spiritual and religious value | Presence of landscape features or species with spiritual value | Number of people who attach spiritual or religious significance to ecosystems |
| 23. Education and science opportunities for formal and informal education and training | Features with special educational and scientific value/interest | Presence of features with special educational and scientific value/interest | Number of classes visiting. Number of scientific studies |

## Deciding upon scale

Ecosystem service indicators can be applied at a range of scales, from local through to global. Consequently, scale of the indicator may influence at what level the information can be used in decision making. Information reviewed from past or current SGAs revealed that the majority of indicators have been applied at the national or regional scale (see Section 2) and national scale indicators are receiving increasing attention from policy-makers (**Box 11**).

It may be fair to expect that the most useful metrics would be those that can be aggregated or disaggregate to any scale, according to the needs of the assessment. However complete aggregation or disaggregation may not always be possible, necessary, or useful. For instance, if we were to assess climate regulation, for example through carbon stocks, it may be appropriate to produce global maps. This is because carbon stocks are a common currency and an indicator of a service relevant to global human well-being. Some cultural services in comparison, such as spiritual values and meaningful places, may only be applicable at very local scales, and using a global indicator would be meaningless.

**Box 11. Indicators for ecosystem services on a national scale: a step-by-step approach and its implementation for Switzerland.**

Although the importance of ecosystem services is widely recognised, the lack of indicators implies that the welfare contribution of ecosystems and biodiversity is often neglected in political decisions.

Different, but complimentary approaches to ecosystem service account systems are in development. One approach focuses on ecosystem capacity (stock) and the sustainability of resource use. Another focuses on accounting mainly for final ecosystem services (flow) and their contribution to human well-being, thus demonstrating the value of ecosystems and environmental policy target groups that are interested in economic progress.

In Switzerland, the Federal Office for the Environment (FOEN) has concentrated on applying the second approach in a step-by-step fashion to: 1) identify and create an inventory of ecosystem services relevant to Switzerland; and 2) develop indicators of final ecosystem services (hereafter termed services).

The inventory consists of 26 services and 1-3 indicators for each service (Table 5). The services are assigned to the four policy goals of FOEN: health, security, natural diversity and production factors. The inventory and indicators are based on the Common International Classification of Ecosystem Services (CICES) by the European Environmental Agency (EEA), which establishes the link between the System of the Millennium Ecosystem Assessment (MA) and standards for national economic accounting.

**Table 5. Examples of final ecosystem services and indicators from the Swiss inventory.**

| Final Ecosystem Services | Indicators |
|---|---|
| **Recreational services** from city green areas and open spaces as well as from nearby and remote recreational areas | Size and accessibility of green areas in residential areas<br>Recreational use of forests, measured in visits per day |
| **Protection from avalanches**, rockfalls and debris flows through vegetation on steep slopes | Protected values through protective forests in Swiss francs (prevented damage potentials) |
| Natural supply of **drinking and process water** | Water supply that consists of untreated spring and ground water in million $m^3$ and percentage share |
| **Existence value of diversity*** at levels of species, genes, ecocsystems and landscapes | Indicators of the biodiversity monitoring of Switzerland |

* Non-use value of biodiversity in addition to the use value of ecosystem services.

**Box 11.** ***Continued.***

The Swiss project focussed on non-monetary (mostly bio-physical) indicators as they are generally considered more reliable and data availability is generally better. Keeping in mind that ecosystem service indicators need to be policy relevant and meaningful, the Swiss project also aimed to ensure that each indicator is ambiguously positively related to economic welfare. The indicators are about to be integrated in the online system of indicators for environmental reporting of the FOEN which can be accessed via the following link: http://www.bafu.admin.ch/umwelt/indikatoren/index.html?lang=en. They will also be part of future environmental reports on a national level. Thus, they will deliver complimentary information within existing communication instruments. This is a starting point for a more target-group focussed communication. At the same time, the set of indicators is always subject to further development (continuous improvement).

The presented indicators were developed for reporting on a national scale. Scaling down to local level or up to global level seems generally feasible, but has not yet been tested. Other countries could benefit from the Swiss experience and use the inventory and the indicators as a starting point for their own inventory and specific indicators.

The Swiss project has served to highlight that to establish national indicators there is a strong need for pragmatism and cooperation, and that facilitating the adoption and comparability of ecosystem service accounting systems at local, national or global levels will require using a 'common language' between environmental offices.

Source: Schlatter *et al*. 2010; Hauser *et al.* 2010.

### Data availability, proxy measurements and uncertainty

A major factor to take into consideration when deciding upon what to measure is data availability, for without sufficient or relevant data it will not be possible to meet objectives. Therefore consideration needs to be given as to whether baseline data is available that can be incorporated into existing indicators, whether to invest in data collection or whether to use proxy measures.

It is important to recognize that valuable data can be sourced from both peer-reviewed and grey literature: as long as sufficient information has been provided so that methodologies are transparent and reliability of the data can be judged, and that sources can be adequately traced, then any relevant data, whether from peer-reviewed or grey literature, should be considered suitable.

The paucity of existing data on ecosystem services, and lack of resources to develop new monitoring programmes, means that proxy measures may be required (including biodiversity indicators – see **Box 4**, p40 and **Box 15**, p62). Proxy measures can be useful as long as any change in these metrics accurately indicates change in the service or services that are the focus of the assessment. In many instances this is not the case since proxy indicators can vary due to factors other than change in the extent of service provision. Equally, data from one location used to model or measure ecosystem services may not be applicable in a different location. Although monitoring ecosystem services can be expensive and time consuming, toolkits are being developed to assist site managers to undertake rapid assessments and establish simple, relatively standardised monitoring systems (**Box 12**).

Data gaps and incomplete understanding of linkages between ecosystem structure, function and services means that ecosystem service indicators and assessments are likely to have relatively high uncertainty levels associated with them. Fundamentally, this does not necessarily lessen their value; however it is important for practitioners to devise methods for clearly and explicitly conveying these uncertainties to decision makers. As outlined in the MA assessment manual (Scholes *et al*. 2010), uncertainty can be presented in a number of different ways, including the presentation of confidence limits for quantitative data or an agreed set of phrases for more qualitative data, such as the statements used in the Inter-governmental Panel on Climate Change (IPCC) reports (e.g. 'Well established' for outcomes that have a high level of agreement and amount of evidence, graded through to 'Suggested but unproven' for outcomes with a low level of agreement and amount of evidence) (Moss and Schneider 2000).

**Box 12. Measuring and monitoring ecosystem services at the site scale: building practical tools for real-world conservation.**

The objective of this project is to develop a suite of rapid ecosystem service assessment tools for understanding how far conserving sites for their biodiversity importance also helps to provide different ecosystem services, relative to a converted state. The project is focussing on the sensitivity of five ecosystem services, including climate mitigation, hydrological services, harvested wild goods, cultivated goods and nature-based tourism and recreation. This toolkit aims to provide practical guidance on how to identify which ecosystem services may be important at a site, and the methods for rapidly measuring some of these for the current state of the site compared to its most plausible alternative (converted) state.

The toolkit is aimed at site managers and regional and national coordinators of site networks. In using this toolkit, it is expected that such people would then provide simple and focused instructions to staff and volunteers on how to collect or collate the data needed to measure the particular service(s) at individual sites. The aspiration is that the toolkit can provide approximate service estimates that are robust enough for effective advocacy, without necessitating investment of considerable resources or requiring specialist technical knowledge. The tools that have been developed are now being tested at three sites: in the UK (Wicken Fen), Montserrat (Centre Hills) and Nepal (Shivapuri-Nagarjun National Park). The project partners include the University of Cambridge, RSPB, BirdLife International, Anglia Ruskin University and UNEP-WCMC. Further information is available at www.conservation.cam.ac.uk.

**Forest cover in Shivapuri-Nagarjun National Park.** Photo kindly provided by Alison Stattersfield, BirdLife International.

**Village in Shivapuri-Nagarjun National Park.** Photo kindly provided by Alison Stattersfield, BirdLife International.

Source: Cambridge Conservation Initiative (2011).

## Economic valuation of ecosystem services[12]

Due to the crucial role that ecosystems play in supporting economic activity and human well-being, economic analysis is becoming an important feature of assessments (Bateman *et al*. 2010). Incorporating such analyses provides a means for quantifying the value of ecosystem services, thereby increasing the chance that they will be considered in decision making processes. Ideally, once the contribution of a service to the production of goods (i.e. any object or construct that contributes to human well-being) is isolated (e.g. contribution to timber production), economic analyses attempt to assess this value in monetary terms. Generating such values is useful as it provides a means for decision makers to compare the value of ecosystem service benefits on an equal footing with other goods that determine social well-being (e.g. healthcare or education), and hence can help break down barriers in communication between different sectors.

While monetary values can be derived for some ecosystem service goods and benefits (especially those that have a market value, such as timber production), it can be more difficult for others (such as the aesthetic views generated by the natural landscape). Broadly speaking, provisioning and regulating services are more amenable to economic valuation whilst many of the values of cultural services require non-economic approaches (Abson and Termansen 2011). Many economists consider the value of supporting services to be expressed via other services and so these tend not to be valued directly.

There is a growing body of work centred on developing and improving non-market valuation techniques (Bateman *et al*. 2010), and increasingly ecosystem service values are being examined spatially so as to explore trade-offs and compare the benefits of different land use choices (**Box 13**). However this is a data-intensive undertaking, and whilst customisable tools for mapping ecosystem service values such as InVEST[13] exist, they require significant parameterisation for local application.

**Box 13. Principles of economic analysis for ecosystem service assessments: a case study derived from the UK National Ecosystem Assessment.**

Ecosystem services and the other benefits that we derive from the natural world are critically important to local, national and global economies and to human well-being. Hence there is an expanding literature and interest in the application of economic analysis within ecosystem service assessments as a guide for decision making. Such analyses have to deal with the complexities of both the natural world and individuals preferences and values for the goods to which it contributes. A number of methods have been developed to address these complexities and these form the tools employed within the various economic analyses conducted for the UK National Ecosystem Assessment (UK NEA).

To demonstrate how the economic values of ecosystem services can be incorporated into decision making, the UK NEA considered the case of rural land use in Wales (UK NEA 2011a). **Figure 11** summarises the main economic values that would arise from a change of land use from farming to multi-purpose woodland, including both the market and non-market values generated and their variation across space. Working from left to right along the maps given, the first illustrates variation in the market value of agricultural output (**Figure 11a**). As can be seen, this varies very markedly across the country, being low along its mountainous central spine and higher in lowland areas. These values would be lost in any area where land was converted out of agriculture and into woodland; therefore these are shown as negative values in the first map. The second map shows the single market value generated by woodland: timber (**Figure 11b**). As these values would be gained under a shift from agriculture to woodland they are shown as positive amounts. However, comparison of the market value of agricultural losses, shown in the first map, with the market value of timber, shown in the second, shows that the former are almost always greater than the latter. Hence, left to the market we observe the current situation, with agriculture dominating almost all of rural Wales and woodland confined to upland areas where land prices are low. The third map brings in our first non-market value; the change in carbon storage arising from a switch towards woodland (**Figure 11c**). This is almost always positive (woodlands store more carbon that farmland) except for some upland areas where tree planting dries out peatlands and can release large quantities of carbon. In the fourth map (**Figure 11d**) we see the change in recreation values, which are again almost always positive (i.e. higher for woodland than agriculture) and now show the influence of population distribution, being greatest around cities and in areas with good road infrastructure. (Note that, unlike other values which are on a per hectare basis, the recreation is valued using one site per 5 km grid; this captures the fact that once a woodland site is established the per hectare recreational value of establishing a second site is not constant but diminishes significantly and to air on the side of caution that marginal value is taken as being zero). **Figure 11e** sums together all preceding values (i.e. losses of agricultural production are taken as negatives

**Footnote**

[12] *This report does not offer a comprehensive treatment of this complex topic, but does provide an overview of some key issues.*

[13] *'Integrated Valuation of Ecosystem Services and Trade-offs', a spatially explicit tool developed by the Natural Capital Initiative (www.naturalcapitalproject.org/InVEST.html), which is being tested, developed and applied in increasing numbers of projects and assessments worldwide.*

**Box 13. *Continued.***

and gains of woodland goods are taken as positives), both market and non-market, and removes all subsidies (which are transfer payments within society) to obtain the net benefits to society of a move from agriculture to woodland. Here, areas coloured in shades grading from yellow to purple indicate locations where such a move would impose net losses to society. This includes areas relatively far from major populations in the west of the country (where farming yields high values and new woodlands would not generate substantial recreation benefits) and peatland areas along the central mountain spine where afforestation would result in major carbon emissions due to such wetlands drying out. Green shows locations where a shift to multi-purpose woodland would generate net benefits. As can be seen, these are predominantly around areas of high population in the south-east (around Cardiff) and north-west of the country (the latter reflecting the high populations just over the border in England within Merseyside and Greater Manchester). This pattern stands in stark contrast with that illustrated in the last map (**Figure 11f**), which shows where market forces have consigned forests to be located; away from lowland areas (and hence cities) and in remote uplands where land values are low. Perversely, this includes some peatland areas where forests may contribute to global warming through the drying of peat and emissions of carbon.

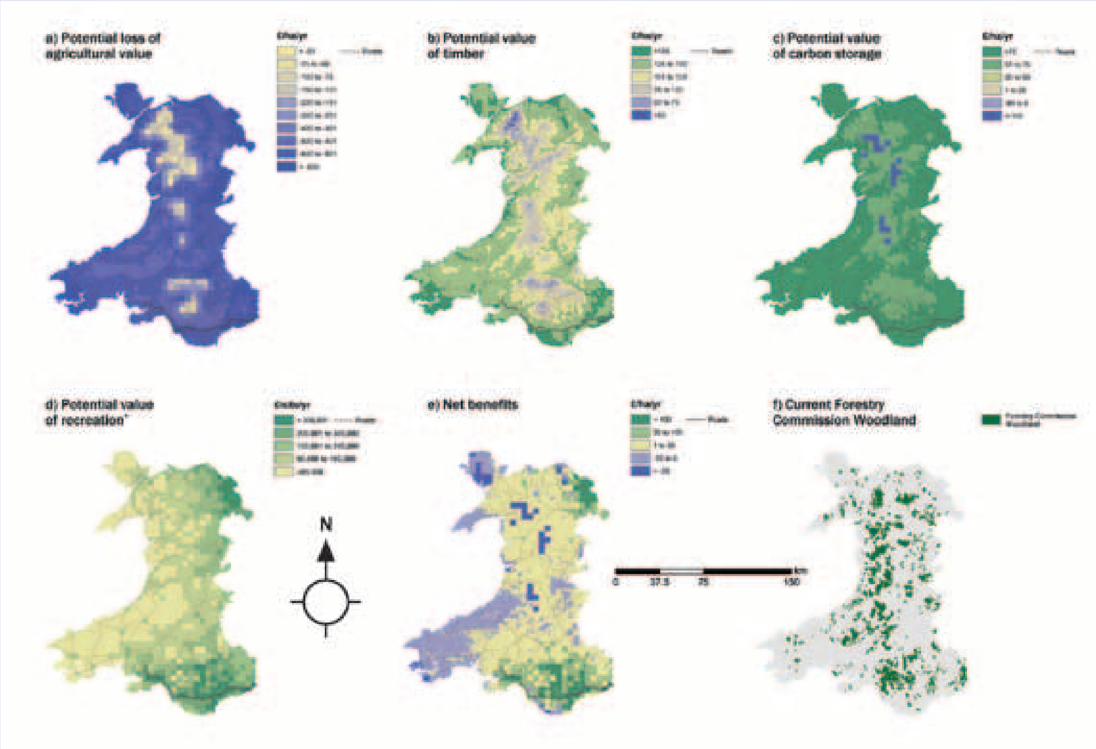



**Figure 11. Social values for various land uses (£ per annum).** Source: Adapted from Bateman *et al.* (2002, 2003) and Bateman (2009). Copyright (2009) reproduced with permission from Elsevier.

This case study shows that if the economic and social values of ecosystem services are not taken into account by decision makers, the allocation of resources could be dictated by the market alone. While markets can efficiently allocate goods whose market prices roughly reflect social values, they fail to provide the socially optimal allocation of unpriced non-market goods, including many ecosystem services. Only by directly addressing this failure will markets be corrected to the point that they can be left to provide the goods and services that society both wants and needs.

Full details of the economic analyses conducted for the UK NEA can be found in Chapter 22 and 26 of the UK NEA Technical Report (UK NEA 2011b).

Source: UK NEA (2011a).

## ADOPTING A SYSTEMS APPROACH TO ECOSYSTEM SERVICE INDICATORS AND ASSESSMENTS

As outlined, viewing an ecosystem service in isolation is unlikely to provide a complete or thorough picture of the range of services that an ecosystem provides. It has therefore been suggested that a social-ecological systems[14] approach should be adopted, which argues for the development of indicators for the major components of the system rather than just on isolated components in order to understand and interpret system dynamics and drivers. Understanding the dynamic interactions and trade-offs among ecosystem services and the factors that influence them requires a systems approach (**Box 14**).

**Box 14. A systems approach to ecosystem services indicators.**

A fundamental element of the ecosystem services paradigm is that ecosystem services are co-produced by social and ecological systems (Link 1 in **Figure 12**). Production functions capture our understanding of how social-ecological systems generate ecosystem services, and how changes in social-ecological systems will affect the provision of ecosystem services. Ecosystem services are by definition contributions of social-ecological systems to human well-being (Link 2). Management decisions are often contingent on perceptions of problems, with indicators playing an important role as triggers of action (Link 3) and management actions influence social-ecological systems (Link 4). For example, land clearing and habitat modification, changes in species populations from harvesting activities (hunting and fishing), changes in nutrient flows from fertilizer application and runoff, changes in the hydrological cycle from water withdrawals and operation of dams, changes in local air and water quality from discharge of pollutants, and changes in global climate from emissions of greenhouse gases all impact social-ecological systems, and in turn the ecosystem services they produce.

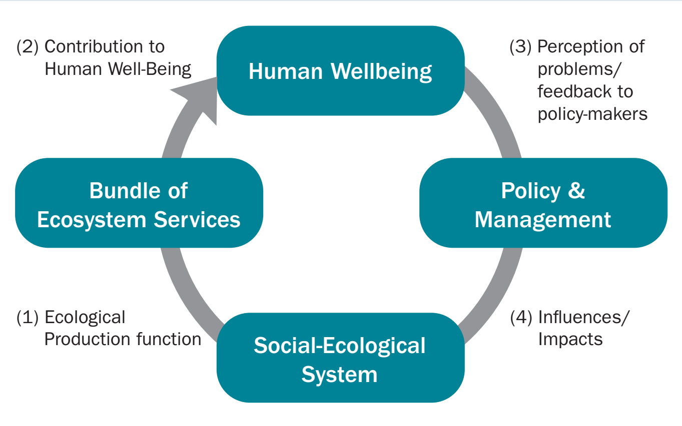



**Figure 12. A systems approach to ecosystem service indicators.** Source: DIVERSITAS (2010).

In principle the contribution of ecosystem services to human well-being can be evaluated by measuring the contribution of services to constituent components of well-being (e.g. health, nutrition), or by using an economic framework that measures contributions in a common metric (monetary value), which facilitates comparisons of desirability (utility) of different services. In an ideal world with full understanding of the drivers (Link 4), the production function (Link 1), and the contribution of services to human well-being (Link 2), the best and simplest indicators of the provision and value of ecosystem services (Link 3) would simply be the direct measures of the provision and value of ecosystem services. However, our understanding of drivers, production functions, or contributions to well-being is often incomplete. In this case, additional indicators of social and ecological processes, social and ecological conditions, governance and institutional structures are needed to understand the system. In addition, we need forward-looking indicators of the likely future provision of ecosystem services and their contribution to human well-being. Predicting future provision requires indicators of important drivers and other measures of change in the underlying social-ecological system that generates ecosystem services.

**Footnote**

[14] *DIVERSITAS (2010) describe socio-ecological systems as complex, dynamic systems where the societal (human) and ecological (biophysical) components are strongly inter-connected and thereby capture interactions between people, biodiversity and ecosystems. Socio-ecological systems generate multiple services and changes in socio-ecological systems usually affect multiple services simultaneously.*

A systems approach implies a need to consider more than single services in isolation. However, gathering information on every single service, the factors likely to influence them and their impacts on well-being is impractical and unlikely to provide information that is easily interpreted. One way around this is to consider bundles of linked services and related metrics.

The concept of compiling ecosystem service bundles is that each bundle is built around a particular topic or issue of concern by grouping or combining selected ecosystem services (plus other relevant variables if necessary) and matching appropriate indicators. For example, a 'Water Security' bundle, used to explore issues of water efficiency and water governance, may consist of the following service categories and variables:

- Supply (provisioning service)
- Quality (regulating service)
- Ecological reserves (supporting service)
- Use (indicators of human well-being)
  — Drinking and sanitation (health)
  — Recreational
  — Irrigation
- Irrigation Quality of water infrastructure (other variable)
- Water policy and governance (other variable)

In comparison a 'Food Security' bundle may consist of:

- Crop and animal production (provisioning service)
- Forage production (provisioning service)
- Water for irrigation (provisioning service)
- Pollination (regulating service)
- Pest control (regulating service)
- Soil fertility (supporting service)
- Genetics of crops and animals (biodiversity indicator)

Bundles may also be defined for specific sites or landscape features. For example, the services provided by a river, such as water for irrigation of agricultural crops, fish production and hydroelectric power could be considered as an ecosystem service bundle. Any changes to policy that affect the river system could impact on several of these services simultaneously, in-turn affecting human well-being. This may then initiate the implementation of new or altered policies for managing the underlying social-ecological system, which again will affect the bundle of services. Analysing the tradeoffs that often exist among services will also require services and the interactions between them to be considered. For example, construction of a dam might increase water storage for agricultural and improve hydroelectric capacity, but result in reduced fish production further downstream.

The bundling of thematically or causally linked indicators can create clearer, integrated storylines that may be more easily interpreted and communicated, as well as aiding our understanding of social-ecological systems (Sparks *et al*. 2011). However the extent to which indicators within bundles could be combined into single indices requires further thought. In theory, messages conveyed by indicators could be simplified (and the incorporation of indicators into policy processes and decisions made easier), if individual ecosystem service indicators could be combined into a single index that depicts trends in ecosystem service flow (in much the same way that GDP, a compound index providing a simple message about economic productivity, does).

However, creating ecosystem service bundles or aggregated indices is a challenging exercise. Currently, gaps in our understanding of the science underpinning the relationship between services hinders our ability to adopt these approaches. Further, a greater understanding of covariance (i.e. a measure of how two variables, observed at the same time, change together) and identification of confounding factors (i.e. variables that are not being studied or controlled for but which can affect the factor of interest, and can bias results if not accounted for) is needed if relationships are to be quantified in a statistically robust way.

Nevertheless, the issues surrounding the creation of indices that combine multiple features have been the focus of considerable attention recently. For example the Organization for Economic Co-operation and Development (OECD), and the European Commission Joint Research Centre (JRC) and the Commission on the Management of Economic Performance and Social Progress (CMEPSP) have released reports that address these conundrums in depth (Nardo *et al*. 2008; Stiglitz et al. 2009). Future development of ecosystem service bundles and aggregate ecosystem service indicators could build on the foundation of this work.

## COMMUNICATION, MAINSTREAMING AND STAKEHOLDER ENGAGEMENT

There is no doubt that the perceived need to incorporate ecosystem service indicators into policy and decision making frameworks is growing, and while the ecosystem services concept is now relatively well established, communicating the practicalities of ecosystem service indicator development is challenging on two fronts.

First, ecosystem service indicators are by their very nature inherently interdisciplinary and, although cross-disciplinary initiatives are becoming more conventional, finding a language common to all participants is not easy, particularly when combining differing philosophies, paradigms and research techniques.

Second, objectives, methods and outcomes may need to be communicated to a number of different audiences, from the lay-person through to specialists and policy makers. Again establishing a common language poses a significant challenge.

Likewise strategies to assist in mainstreaming the idea of ecosystem services and the use of ecosystem service indicators across different sectors, particularly those that traditionally have had very little interaction with each other (e.g. the agricultural and education sectors) or indeed with the ecosystem services concept, may need further consideration and development. For example it may be important to involve policy makers and the economic sector early in the process. As end-users and targets of the conservation message, the latter, in particular, can help focus which are key policy-relevant indicators. In turn this may help to embed ecosystem services into national development and planning processes, such as National Biodiversity Strategies and Action Plans (NBSAPs) and Poverty Reduction Strategy Papers (PRSPs). A key issue highlighted by workshop participants will be to ensure ecosystem services are considered alongside, and not as an alternative to, biodiversity (**Box 15**).

Extensive stake-holder engagement throughout the whole process may also help to mainstream ideas and principles. However, so that effective collaborations are formed, consideration needs to be given to a number of different factors, including: what the interests of the different stakeholder groups are, which groups have data and what form this data is in, and what will the relevance of outputs be to each group. Involving stakeholders therefore provides another important element which needs to be considered at all levels of interaction – i.e. providing a means for two-way communication between practitioners and end-users, so that ideas, opinions, needs, and information on what is and what is not possible, can be exchanged.

**Box 15. Biodiversity and ecosystem services.**

A key issue that has been raised in relation to ecosystem service indicator development and use is the role of biodiversity and biodiversity indicators in the assessment process. There is concern, particularly amongst the biodiversity community, that the growing impetus on decision-makers to consider ecosystem services will take precedence over conservation and management of biodiversity itself. However the two are inextricably linked.

Biodiversity is considered to underpin the provision of all ecosystem services, including ecosystem resilience to future change. Indeed, it has been suggested that biodiversity should be assessed as a service itself, similar to the approach of TEEB which used 'Habitat Service' as a main category. However, the extent to which biodiversity loss affects ecosystem services is complex, variable and often poorly understood. Although there are examples of management options that deliver favourable outcomes for both ecosystem services and biodiversity, the empirical and theoretical evidence that higher biodiversity leads inevitably to more ecosystem services is still relatively weak. Further to this, it is unlikely that the link between the two will be simple and managing one to deliver the other may result in perverse outcomes. As outlined elsewhere in Section 3 of this report, whole-system and multi-sectoral approaches will be necessary to understand biodiversity and ecosystem service interactions, as well as analyses of the trade-offs and synergies between different ecosystem services in different political and socio-economic contexts.

On the other hand, however, our knowledge of the trends and drivers of change in biodiversity and economic consequences of biodiversity loss on human well-being has improved significantly over the last decade (Balmford *et al*. 2008). It has been shown that there is a continuing trend in the decline of biodiversity (Butchart *et al*. 2010) and such losses will not only affect the flow of services and the benefits delivered from them, but also the resilience of ecosystems. Although the direct links between biodiversity and human well-being are still being elucidated, it is clear that the provision of benefits often depends on the condition and extent of ecosystems, measures of which encompass many species and the interactions both amongst them and their environment. For example, fisheries production is influenced by the condition of coral reefs and mangroves, which amongst other things provide nurseries and food for juvenile life stages of some marine fish.

Therefore there is potential for employing many biodiversity indicators (which are generally more well-developed) as proxies to indicate something about the flow of an ecosystem service (which is often difficult to measure or lacking in data), as long as the linkages between the two are well understood. Strategies for increasing the awareness of the links between the two may need to be considered to ensure both are adequately taken into account by policymakers.

# 4. THE WAY FORWARD FOR ECOSYSTEM SERVICE INDICATORS

Uncertainty remains regarding how to measure many ecosystem services and how to interpret and use the information provided, although gaps are being filled and progress continues to be made. This section includes consolidated key messages from the material presented in Sections 2 and 3, distilled during the second expert workshop on ecosystem service indicators that took place in November 2010. Some of these messages are relevant to indicator development regardless of the topic, whilst others are more specific to the development and use of ecosystem service indicators.

## KEY MESSAGES FOR INDICATOR AND ASSESSMENT PRACTITIONERS

1. **Ensure objectives are clear**
   The process of defining and developing indicators requires a guiding plan or framework. Indicators are there to answer specific questions or to assess policy objectives and can only be developed in the context of those questions/objectives. Clear objectives and targets help to identify and define indicators as specifically as possible to avoid misinterpretation. A useful resource for indicator planning and development is the framework and guidance developed by the Biodiversity Indicators Partnership **(Box 16)** which is available in multiple languages from www.bipnational.net.

2. **Adopt a small set of specific, policy-relevant indicators**
   Don't try to do everything. Resources should be used to address key elements (i.e. those most policy relevant) and information gaps. Where possible include linked indicators covering as many aspects of the ecosystem assessment framework (socio-ecological system) as possible (state and trends, driving forces, policy effectiveness).

3. **Go beyond provisioning services**
   Where possible, create indicators for different types of ecosystem service. Currently there is an over-reliance on indicators that capture the value of a few species and ecosystems relevant to food and fibre production, which are rarely good proxies for other kinds of service or for resilience.

4. **Utilise existing data and proxies (but recognise limits)**
   Developing ecosystem service indicators is best viewed as an iterative process. Start with the low hanging fruit (i.e. do what it is possible) and improve over time. Use available knowledge and indicators as a starting point. Where direct measures are not yet developed or where there are no data, good proxy indicators can be used. Note that not all ecosystem services are easily quantifiable. Qualitative metrics can be as useful as quantitative ones.

5. **Think about sustainability – include indicators for both ecosystems and benefits**
   Measure both the supply of the service (including state/condition of the ecosystem or its relevant components) as well as the benefits from services and impacts on well-being.

6. **Include biodiversity**
   Since biodiversity indicators are better developed, and biodiversity underpins the delivery of ecosystem services, they are sometimes used as proxies for ecosystem services. However, although in some categorisations biodiversity is classified as an ecosystem service they are not inter-changeable. It is important not to lose sight of the importance of biodiversity by focusing only on ecosystem service benefits.

7. **Be sensitive to scale**
   The scale at which ecosystem services are measured and reported should be appropriate to the decision-making context. Some things are more appropriate at certain scales and not others. Not everything can be scaled up.

8. **Assess trends and consider synergies and trade-offs**
   Some indicators are snapshots or baselines, but replicable measures are important for monitoring change and tracking progress. Monitoring multiple services over time allows a better understanding of synergies and trade-offs.

9. **Engage stakeholders early**

Defining and developing indicators should involve all relevant stakeholders from the outset. Ecosystem service indicators should be chosen to meet the needs of specific users. Establishing a dialogue with data providers and end users of indicators is crucial. Wide stakeholder engagement will also aid in defining indicators as specifically as possible to avoid misinterpretation. In addition the process of developing indicators requires collaboration with other sectors. Mainstreaming is a key component of indicator development. Key to this is to identify entry points for mainstreaming ecosystem service indicators in assessments. Linking the indicators to national development plans helps.

10. **Focus on communication**

Communicating indicators is important but sometimes neglected. It may incorporate raising public awareness as well as engaging policy-makers. It is important to use indicators that policymakers are likely to be most interested in, whilst presenting storylines in the most policy-relevant way. Ecosystem services cut across different sectors, all of which may require tailored communication. Some key communication messages include:

a. **Be clear about what indicators are telling you.**
Use a common language. Some work may be required on definitions of key terms for communicating that story.

b. **Be transparent about uncertainty.**
Keep in mind the limits of indicators, and uncertainty – use clear terminology. Provide accurate interpretation of the storyline.

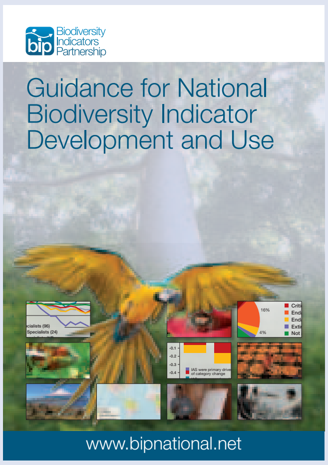
c. **Use maps (spatially explicit data) where possible.**
Where possible and relevant, these can be useful aids to communication and analysis. Be sure to present the findings at the scale most relevant to decision-makers.

d. **Avoid over-simplification.**
Ecosystem services do not necessarily co-vary, and so aggregation is challenging and needs further work. Bundling indicators into related packages/storylines may aid communication.

e. **Economic metrics are useful but don't ignore non-monetary values.**
Where possible, using economic metrics helps mainstreaming in other sectors. Not all indicators are practical to determine in dollar values but that does not lessen their utility.

**Box 16. Framework for national indicator development and use.**

The framework shown in **Figure 13** is designed to help in the development and use of national indicators. While specifically developed and applied in the context of biodiversity, the Indicator Development Framework can also be applied to the development of ecosystem service indicators. By adopting a participatory approach and focusing on building the capacity of important national stakeholders, the framework fosters ownership and effective use of the indicators at the national level. The recently published '*Guidance for national biodiversity indicator development and use*' (Biodiversity Indicators Partnership 2011) comprehensively describes the key steps in the production of successful national indicators. Whilst it is not a requirement to include all of the steps in the development of environmental and socio-economic indicators, the more of the steps that are covered in the process of developing and using indicators the more likely it is that the indicators will be successful.



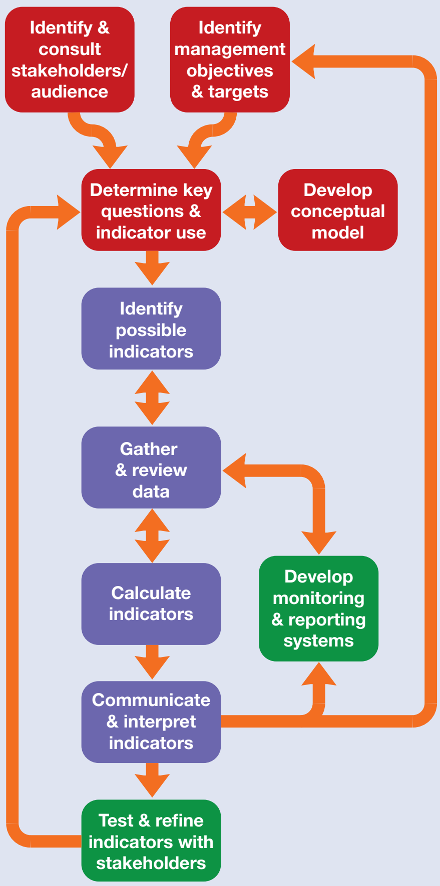




**Figure 13. Framework for national indicator development and use.**
Source: 2010 Biodiversity Indicators Partnership (2010b).

# 5. ECOSYSTEM SERVICE INDICATORS AND THE AICHI TARGETS FOR BIODIVERSITY IN THE CBD STRATEGIC PLAN 2011-2020.

In 2011 the international community will consider the indicators required to track progress towards the 20 Aichi targets adopted at the 10th meeting of the Conference of the Parties to the CBD (CoP10) in Nagoya, Japan, and included in the Strategic Plan for the period 2011-2020. Ecosystem service indicators are of relevance to a number of these targets. As a contribution to the process for defining an indicator framework for the targets, this report presents some thinking of the kinds of ecosystem service indicators which may be relevant, and their level of development. Other multilateral environmental agreements and intergovernmental processes are likely to require similar indicators and efforts to harmonise indicator use would ensure efficient use of resources and strengthen the links between processes.

At CoP10, Parties adopted an updated and revised strategic plan for the post 2010 period (CBD 2010), with a vision of a world of "*living in harmony with nature*", where "*By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people*". This vision is encapsulated within five strategic goals and 20 headline targets for 2020, set out in the revised strategic plan intended to address the underlying causes of biodiversity loss, reduce the pressures on biodiversity, safeguard biodiversity at all levels, enhance the benefits provided by biodiversity, and provide for capacity-building. These represent global aspirations, to be adapted and adopted at regional and national scales. Parties are invited to set their own targets within this flexible framework, taking into account national needs and priorities, while also bearing in mind national contributions to the achievement of the global targets.

Parties will be expected to report progress against their adopted targets in fifth and sixth national reports during the period 2011-2020, and the CoP will be expected to review progress in implementation of the strategic plan. As with the 2010 biodiversity target, a wide range of indicators will be required to monitor, assess and report progress towards the 2020 targets. Some of these may already exist whilst others may require development. At CoP10, Parties called for an Ad Hoc Technical Expert Group (AHTEG) on indicators for the strategic plan (meeting in June 2011) to provide advice and guidance on a flexible framework of appropriate indicators and their development at national and global scales (*CoP 10 Decision X/7*).

The framework of indicators that will be adopted by the CBD for the 2011-2020 period is likely to include ecosystem service indicators more prominently than was the case for 2010 (Walpole *et al*. 2009). Although such indicators may be relevant to a wide range of Aichi targets, some of the most explicit references to ecosystem services are found in Strategic Goal D (*Enhance the benefits to all from biodiversity and ecosystem services*) and it's associated 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*).

As part of the preparation for the indicator AHTEG, a review of observation capacities for each of the Aichi targets was undertaken by members of the Global Earth Observation Biodiversity Observation Network (GEO-BON). This included a focus on observations related to ecosystem services under Target 14 (GEO-BON 2011; **Box 17**), concluding that a range of possible metrics were available or could be developed.

As an additional contribution to the preparation of the AHTEG, participants at the second workshop on ecosystem service indicators, convened as part of the current project in Cambridge in November 2010, considered which ecosystem service indicators may be relevant (directly or indirectly) to a wider range of the Aichi targets including Targets 1, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16 and 19. Participants considered whether the proposed indicators were available in 2011 or could be developed in time for 2020, and also whether the proposed indicators were considered cost effective to be used at either national or global scales. While not an exhaustive list, it is apparent that countries could use some existing measures to begin to track progress in a cost effective manner (**Annex 1**).

Although the table is structured around the Aichi targets adopted under the CBD, the topics included in these targets (and hence the indicators identified in the table) are of relevance to a wide range of multilateral environmental agreements and other intergovernmental processes. There is value in considering how various processes might streamline or harmonise their choice of metrics and indicators in order to improve efficiency and maximise the benefits of any investment in indicator development.

The table in **Annex 1** is presented largely un-edited as a resource for use in further discussion. Attention to different targets was uneven and so this should not be considered an exhaustive list. It should also be noted that the table does not include an extensive list of readily available provisioning services measures, since the intention was to highlight indicators for under-emphasised services.

**Box 17. GEO-BON observation adequacy assessment for ecosystem service indicators for Aichi Target 14.**

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.*

Prioritising ecosystem services to be monitored is a difficult choice. Different services contribute to human well-being in a variety of different ways: provision of food or water is essential for having access to the basic materials for a good life; the regulation of disease vectors, water quality or climate regulation are tightly related to health and security; and cultural services deal with non-material but still essential aspects of human well-being.

Different actors value the various ecosystem services in different ways: subsistence farmers rely directly on the local provision of food, timber or biofuels, while urban populations benefit from food produced elsewhere, and regulation of water quality in places far removed from the place they live.

A critical task is to understand the complex tradeoffs among and between services. Trade-offs occur among ecosystem services, such as those between planting crops for biofuel versus crops for food; across space, such as increasing agricultural yields through fertilizer use at the cost of decreasing water quality downstream; across time, such as increasing agricultural yields through increased irrigation at the cost of soil salinization several decades later; and also occur across groups of people, when increased use by a one group implies a decrease in availability to other groups.

The list of services to be monitored will evolve through time as a result of changes in societal needs, development of new indicators, and changes in data accuracy and availability. The first efforts should focus on compiling the readily available information.

Sources of information will include that derived from remotely sensed data, national and sub-national statistics, local quantification of services in a network of sites, as well as models developed at multiple spatial scales.

The services included aim at including a wide range of types of services. Different societies within and among countries will prioritise them differently, depending on their circumstances. Some, such as the availability of clean water and adequate food, will probably be of universal concern.

In order to emphasize the needs of women, indigenous and local communities, the poor and vulnerable, all measures of ecosystem services would need to cover both the average supply and demand, as well as the distributional (equity) dimension in relation to the component of the target regarding the particular foci groups of people. In some cases it is possible and useful to estimate of the value of the services. This helps in evaluating tradeoffs and setting priorities. A preliminary assessment of the value of ecosystem services would provide a baseline against which to measure any changes.

There are several existing datasets but many gaps. The ecosystem service research and monitoring community is of the opinion that the gaps can be filled within five years through a combination of aggregation of nationally-held datasets, targeted capacity development and network development, the expansion of site-based assessments, and modelling activities. Key elements of the observing system exist (particularly those relating to marketed provisioning services), but the models and supplemental datasets needed for global coverage still need development.

Source: GEO-BON (2011).

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# LIST OF ACRONYMS AND ABBREVIATIONS USED

| | |
|---|---|
| **AHTEG** | Ad Hoc Technical Expert Group |
| **ASEAN** | Association of Southeast Asian Nations |
| **BIP** | Biodiversity Indicators Partnership |
| **CBD** | Convention on Biological Diversity |
| **CIESIN** | Centre for International Earth Science Information Network |
| **CITES** | Convention on International Trade in Endangered Species of Wild Fauna and Flora |
| **CMEPSP** | Commission on the Management of Economic Performance and Social Progress |
| **CICES** | Common International Classification of Ecosystem Services |
| **CONABIO** | Comisión Nacional para el Conocimiento y Uso de la Biodiversidad |
| **COP** | Conference of the Parties |
| **DIVERSITAS** | International Programme of Biodiversity Science |
| **EC** | European Commission |
| **EEA** | European Environment Agency |
| **ESPA** | Ecosystem Services for Poverty Alleviation |
| **FOEN** | Swiss Federal Office for the Environment |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **GBIF** | Global Biodiversity Information Facility |
| **GBO** | Global Biodiversity Outlook |
| **GDP** | Gross Domestic Product |
| **GEO** | Global Environment Outlook |
| **GEOBON** | The Group on Earth Observations Biodiversity Observation Network |
| **HWSD** | Harmonized World Soil Database |
| **IPBES** | Intergovernmental Platform on Biodiversity and Ecosystem Services |
| **IPCC** | Inter-governmental Panel on Climate Change |
| **IUCN** | International Union for Conservation of Nature |
| **JRC** | Joint Research Centre (of the European Commission) |
| **MA** | Millennium Ecosystem Assessment |
| **MDG** | Millennium Development Goal |
| **MEAs** | Multilateral Environmental Agreements |
| **MWO** | Mediterranean Wetlands Observatory |
| **MODIS** | Moderate Resolution Imaging Spectroradiometer |
| **NBSAPs** | National Biodiversity Strategies and Action Plans |
| **NASA** | National Aeronautics and Space Administration |
| **NGO** | Non-Governmental Organisation |
| **OECD** | Organization for Economic Co-operation and Development |
| **PES** | Payment for Ecosystem Services |
| **PRSPs** | Poverty Reduction Strategy Papers |
| **SCBD** | Secretariat of the Convention on Biological Diversity |
| **SGAs** | Sub-global Assessments |
| **SwedBio** | Swedish International Biodiversity Programme (now The Resilience and Development Programme) |
| **TEEB** | The Economics of Ecosystems and Biodiversity |
| **UBC** | University of British Columbia |
| **UK NEA** | UK National Ecosystem Assessment |
| **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 |
| **WRI** | World Resources Institute |
| **WTTC** | World Travel and Tourism Council |
| **WWF** | World Wide Fund for Nature (or World Wildlife Fund, North America only) |

# ANNEX 1.

## INDICATORS FOR THE AICHI TARGETS SUGGESTED BY WORKSHOP PARTICIPANTS, NOVEMBER 2010[15]

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| *Goal A.*<br>*Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society* | *Target 1:* By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably. | Charismatic biodiversity | Cultural | ? | | | | An example could be the Euro-barometer survey (SEBI indicator), which is a measure of people's attitude to charismatic biodiversity and a proxy for people's interest in biodiversity. |
| | | Number of visitors to an area | Cultural | ✓ | ✓ | | | Possible for a large number of countries, as many already monitor visitors to areas such as national parks, museums, visitor centres, nature reserves. It should be noted that it is likely to be a different metric for each country and it will be hard to get consistency across countries. |
| | | Number of members of environmental NGOs | Cultural | ✓ | ✓ | ✓ | ✓ | |
| | | Number of staff working at NGOs | Cultural | ✓ | ✓ | ✓ | ✓ | Could be divided into paid staff and volunteers. |
| | | Number of staff working for environment agencies | Cultural | ✓ | ✓ | ✓ | ✓ | May be difficult to decide who to include here. |
| | | Number of people taking part in recreation activities | Cultural | ✓ | ✓ | ✓ | ✓ | This would need to be broken down and potentially reported for different activities such as scuba diving and bird watching. |
| | | Volunteering (number days/year) | Cultural | ✓ | ✓ | | | Possible for some countries. |
| | | Income from nature based tourism | Cultural | ✓ | maybe | ✓ | ? | Possible for some countries and may be an issue of extent; sustainability and ecotourism may be a subset. |

*[15]The table of ecosystem service indicators in Annex 1 is presented largely un-edited as a resource for use in further discussion. Attention to different targets was uneven during workshop discussions and so this should not be considered an exhaustive list or comparable between targets. It should also be noted that the table does not include an extensive list of readily available provisioning services measures, since the intention was to highlight indicators for under-emphasised services.*

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| *Goal B. Reduce the direct pressures on biodiversity and promote sustainable use* | *Target 5:* By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced. | Degradation of natural habitats | Multiple | | | | | Linked to the ecosystem's ability to provide an ecosystem service. |
| | | Capacity for critical regulating services | Regulating | | | | | |
| | | Habitat cohesion | Supporting | ✓ | ✓ | ? | | Land use/land cover maps and fragmentation indexes could be used here but be meaningful for only specific habitats. If the maps exist then it could be cost effective. |
| | *Target 6:* By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits. | Harvested fish combined with safe ecological limits | Provisioning | ✓ | | ✓ | | The units would include tonnes and dollars. And could be expanded in 2020 to include invertebrates and plants. |
| | | Red List Index - threatened species | Provisioning | ✓ | | | | |
| | | Area of Marine Protected Areas in place to protect fish stock | Multiple | ✓ | | | | |
| | | Area based conservation measures | | | | | | |
| | | Fish and wildlife production | Provisioning | ✓ | ✓ | ✓ | ? | Trends in production. |
| | *Target 7:* By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity. | Forest certification - extent of FSC schemes | Provisioning | ✓ | | ✓ | | Has already been developed as part of the 2010 Biodiversity Indicators suite. |

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| | | Area of agro-ecosystems under sustainable management | Multiple | ✓ | | ✓ | | |
| | | Area of forest extraction from natural/plantation sources showing sustainable practices – both certification and otherwise | Multiple | | ✓ | ✓ | | Link to NTFPs and REDD+ (carbon sequestration service versus others) and Red List forest related services and bundle them to consider sustainability. |
| | | Sustainable practices of fish/shellfish/etc production | Provisioning | ✓ | | ✓ | | Need to consider both wild and farm sources. |
| | | Of farmed, what proportion is sustainably managed | Multiple | | ✓ | | | Linked to certification schemes but not exclusively and linked to nutrient loading – could be used as an indicator to demonstrate an ecosystems ability to deliver a service. |
| | *Target 8:* By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity. | Critical loads of nitrogen | Supporting | | ✓ | | | |
| | | Critical loads of phosphorous | Supporting | | ✓ | | | |
| | | Acid deposition | Regulating | | ✓ | | | |
| | | Oil spills | ? | | | | | Pollution as a qualifier for loss of ecosystem function – seen as part of a suite of factors/threats. |
| | | Ecosystem health index | Multiple | | ✓ | | | Use fish as a proxy. |
| | | Trophic integrity index (ecosystem function index) | Multiple | | ✓ | | | |
| | | Dead zones | Regulating | ✓ | | | | Linked to sustainable management and the ability for ecosystem service delivery (plus target 7). |
| | | Fish and wildlife production | Provisioning | ✓ | ✓ | ✓ | ? | Trends in production. |
| | | Soil fertility/organic matter | Supporting | ✓ | | | | However, existing maps are static and trends in application of fertilisers may be more useful and it is linked to soil fertility. |
| | | Trends in water quality per use category | Regulating | ✓ | ✓ | | | For most countries. |

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| | *Target 9:* By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment. | Dollar value impact of IAS on crops (pests/disease/ pollinators) or % yield | Regulating | | | | | Linked to loss of an ecosystem service. |
| | | Fish and wildlife production | Provisioning | ✓ | ✓ | ✓ | | Trends in production. |
| | | Dollar value of impacts of IAS on water availability | Provisioning | | ✓ | | | |
| | | Daily impacts of IAS on human health | Multiple | | ✓ | | | |
| ***Goal C:* To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity** | *Target 11:* By 2020, at least 17 per cent of terrestrial and inland waters, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape | National distribution of areas that has particular importance for ecosystem services. What about 'well connected' and protected? State indicator on protected areas and their cohesion? | Multiple | ✓ | | ✓ | | This indicator would use an overlay of maps of protected areas and components of ecosystem services. |
| | | Fish and wildlife production from protected areas | Provisioning | ✓ | ✓ | ✓ | ? | Trends in production. |
| | | Trends in mangroves and other coastal vegetation areas under protection | Regulating/Habitat | ✓ | ✓ | ✓ | ✓ | A number of coastal/marine habitats form part of the 2010 Biodiversity Indicators suite for extent. |
| | | Inland waters effectively protected | Regulating/Habitat | | ✓ | ✓ | ✓ | |
| | | Forest ecosystems effectively protected | Regulating/Habitat | ✓ | | ✓ | ✓ | |
| | | Ecosystem services provided by PAs | Multiple | ✓ | | ✓ | ✓ | Possible for some services and baselines for some countries. Datasets could include WDPA, carbon, water, tourism, spiritual sites, NTFPs. |
| | | Management effectiveness of PAs, including habitat fragmentation/degradation | Multiple | ✓ | | ✓ | ✓ | |
| | | Indicators related to Nagoya protocol on ABS | Provisioning, Cultural | | ✓ | ✓ | ✓ | |

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| | *Target 12:* By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained. | Status of pollinating species | Regulating | ✓ | | ✓ | ✓ | Red List Index for pollinating birds and mammals and by 2020 you could have a sampled insect pollinators index and a Living Planet Index for pollinating vertebrates. |
| | | Landscape configuration and suitability for pollinators | Regulating | ✓ | | | | Draw on the work undertaken by the Natural Capital Project. |
| | | Status of pest controlling species | Regulating | ✓ | | ✓ | ✓ | A Red List Index for pest controlling vertebrates could be developed now, and this could be further complemented by 2020 with a sampled pest controlling invertebrate index and a Living Planet Index for pest controlling vertebrates. |
| | | Avoided costs of not using pesticides | Regulating | ✓ | ✓ | ✓ | | |
| | *Target 13:* By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity. | Status of domesticated animals: number of native breeders | Provisioning/ Cultural | ✓ | | | | |
| | | Proportion of the total population accounted for by native breeds and non-native breeds | Provisioning/ Cultural | | | | | |
| | | Number of breeds classified as at risk and not at risk. | Provisioning/ Cultural | | | | | |
| | | Strategy: pressure or absence of breeding organisations | Provisioning/ Cultural | | | | | |
| | | Strategy: pressure or absence of national strategy | Provisioning/ Cultural | | | | | |
| | | Status and trends in other socio-economical as well as culturally valuable species | Provisioning/ Cultural | | | | | |
| | | Conservation programmes for genetic resources, using in-situ and ex-situ conservation methods (ABS) | Provisioning/ Cultural | | | | | |

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| *Goal D: Enhance the benefits to all from biodiversity and ecosystem services.* | *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 | Status of pest controlling species | Regulating | ✓ | | ✓ | ✓ | A Red List Index for pest controlling vertebrates could be developed now, and this could be further complemented by 2020 with a sampled pest controlling invertebrate index and a Living Planet Index for pest controlling vertebrates. |
| | | Human health benefits of ecosystem services | Multiple | | ✓ | | ✓ | It is envisaged that a human health indicator could be developed capturing the different ecosystem service benefits bundles such as food, clean water and air, mental health and a stable climate and including aggregations of possible human health impacts of medicinal plants, food, water, disaster prevention and recreation. |
| | | Net Primary Production (NPP) | Supporting | ✓ | | | | This indicator would be implemented as a model using remote sensing data. |
| | | Trends in area and fragmentation of ecosystems | Multiple | ✓ | | | | This indicator could focus on wetlands, forest, mangroves, areas important for ecosystem services as defined by the country. |
| | | Water security | Multiple | ✓ | | ✓ | ? | Includes measures for quality, quantity and use and water borne disease trends. |
| | | Gini coefficient for ecosystem service access and use | Multiple | | ✓ | | | Would be based on a similar approach to the Gini-coefficient of national income distribution around the world. |
| | | Fish and wildlife production | Provisioning | ✓ | ✓ | ✓ | ? | Trends in production. |
| | | Biodiversity for food and medicine | Provisioning | ✓ | | | ✓ | RLI cuts for key species. |
| | | Food web integrity/ efficiency | Supporting | ✓ | | ✓ | | Examples include the Marine Trophic Index. |
| | | Carbon stock | Supporting/ Regulating | ✓ | ✓ | | | Possible in some regions like Europe but to make this cost effective, means you would lose the detail and preciseness. |
| | | Sustainable extraction of NTFPs | Provisioning | | ✓ | ✓ | | Difficult to formulate consistent methodology and implement globally. Could be linked to local species use, forest trends and local community income and health status. |
| | | Sustainable extraction of peat stocks | Provisioning/ Supporting | | ✓ | ✓ | ✓ | Dependent on improving remote sensing methods. |

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| | | Sustainable forestry | Provisioning/ Supporting/ Regulating | ✓ | | ✓ | ✓ | Currently available for some areas using commercial datasets (e.g. FSC). |
| | | Nutrient cycling | Supporting | ✓ | | ✓ | | For some stages: nitrogen deposition, phosphorous to a certain extent. The concept might be too large as an indicator but a series of indexes though you might lose some sensitivity to be able to pick up change. |
| | | Soil fertility/organic matter | Supporting | ✓ | | | | Existing maps are static and trends in application of fertilisers may be more useful if it is linked to soil fertility. |
| | | Soil moisture content | Supporting | | ✓ | ✓ | ✓ | Based on EOS. |
| | | Trends in condition of erosion susceptible areas | Regulating | ✓ | ✓ | | | Possible for some countries. |
| | | Levels of sedimentation in water bodies | Regulating | ✓ | ✓ | | | Possible for some countries. |
| | | Number of flood events | Regulating | ✓ | | | | Indication of the failure of the ecosystem service. |
| | | Trends in water quality per use category | Regulating | ✓ | ✓ | | | Possible for most countries. |
| | | Wetland Health indicator | Regulating | ✓ | | | | Possible for a few countries. There is overlap here with work that the Ramsar STRP is currently completing. |
| | | Impact of river fragmentation | Regulating, Provisioning, Supporting | ✓ | | ✓ | ✓ | Siltation, water quantity and quality change, IAS etc. owing to dam construction, commercial water extraction and use, etc. |
| | | Extent and integrity of areas with spiritual value | Cultural | | ? | | | Big definitional issues in sorting out these measurements. It can often be about areas providing harmony and link to nature or about more 'native setting' and it can be specific cultural/ religious areas with close linkages to biodiversity. |
| | | Status of pollinating species | Regulating | ✓ | | ✓ | ✓ | Red List Index for pollinating birds and mammals and by 2020 we could have a sampled insect pollinators index and a Living Planet Index for pollinating vertebrates. |
| | | Landscape configuration and suitability for pollinators | Regulating | ✓ | | | | Draw on the work undertaken by the Natural Capital Project. |

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| | | Disease outbreaks linked to loss of ecosystem function | Regulating | ✓ | | | | Possible for a selection of water borne diseases. |
| | | Ecosystem services provided by Protected areas | Multiple | ✓ | | ✓ | ✓ | Possible for some services and baselines for some countries. Datasets could include WDPA, carbon, water, tourism, spiritual sites, NTFPs. |
| | | Aggregated value of ecosystem services provided | Multiple | ✓ | | ✓ | ? | This is possible now for some ecosystem services. The metrics and methods might be difficult to bring together monetary and other values together. It may need to be weighted for land area. One approach might be to look at the four ecosystem service groupings or aggregate in bundles e.g. hydrological values (water purification, flow regulation, aquatic recreation). Such an indicator might be a contribution to national accounting and Millennium Development Goals. Furthermore it might help in understanding the additional value ecosystem services bring to traded goods. Further development required. |
| | | Income and/or employment generated from nature-based tourism | Cultural | | ✓ | ✓ | ✓ | |
| | | Habitat connectivity | Multiple | ✓ | ? | ✓ | ✓ | This is already a biodiversity indicator developed as part of the 2010 suite with the focus on forest fragmentation. Though its relevance to ecosystem services (e.g. pollination, water and tourism) needs to be explored further. |

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| | *Target 15:* By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification. | Value of carbon ($/Tonnes C) | Regulating | ✓ | | ✓ | | In forest and ideally all natural habitats. |
| | | Extent of forest restored | Multiple | ✓ | ✓ | | | Linked to the ability of the ecosystem to deliver services and is ideally expanded out to all natural habitats. |
| | | Area of forests protected plus the percentage of 2010 degraded ecosystems restored | Multiple | ✓ | ✓ | | | Linked to the ability of the ecosystem to deliver services. |
| | | Ocean $CO_2$ flux | Regulating | ✓ | ✓ | | | |
| | | Sites of particular importance for biodiversity and carbon storage/ sequestration protected/ restored | Multiple | ✓ | | ✓ | | |
| | | Soil Carbon | Supporting | ✓ | ✓ | | | Possible in some regions like Europe but to make this cost effective, means you would lose the detail and preciseness. The indicator would need to be linked to other indicators to understand the changes in the carbon stock. |
| | | Soil fertility/organic matter | Supporting | ✓ | | | | Existing maps are static and trends in application of fertilisers may be more useful and it is linked to soil fertility. |
| | | Trends in condition of erosion susceptible areas | Regulating | ✓ | ✓ | | | Possible for some countries. |
| | | Levels of sedimentation in water bodies | Regulating | ✓ | ✓ | | | Possible for some countries. |
| | | Number of flood events | Regulating | ✓ | | | | Indication of the failure of the ecosystem service. |

| Strategic Goal | Target | Indicator | Ecosystem Service Group | Implementation | | Cost Effectiveness | | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | | 2011 | 2020 | National scale | Global scale | |
| | *Target 16:* By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation. | Proportion of countries with appropriate national legislation | Cultural/ Provisioning | ✓ | | | | |
| | | Dollar value of benefits shared | Cultural/ Provisioning | | ✓ | | | |
| | | Number of products with appropriate agreements | Cultural/ Provisioning | | ✓ | | | |
| | | Red List Index of medicinal plants | Cultural/ Provisioning | ✓ | | | | |
| ***Goal E. Enhance implementation through participatory planning, knowledge management and capacity building*** | *Target 19:* By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied. | Number of visitors to an area | Cultural | ✓ | ✓ | | | Possible for a large number of countries, as many already monitor visitors to areas such as national parks, museums, visitor centres, nature reserves. It should be noted that it is likely to be a different metric for each country and will be hard to get consistency across countries. |
| | | Number of members of environment NGOs | Cultural | ✓ | ✓ | ✓ | ✓ | |
| | | Number of staff working at NGOs | Cultural | ✓ | ✓ | ✓ | ✓ | Could be divided into paid staff and volunteers. |
| | | Number of staff working for environment agencies | Cultural | ✓ | ✓ | ✓ | ✓ | May be difficult to decide who to include here. |
| | | Number of people taking part in recreation activities | Cultural | ✓ | ✓ | ✓ | ✓ | This would need to be broken down and potentially reported for different activities such as scuba diving and bird watching. |
| | | Citizen science (number of biological records/year) | Cultural | ✓ | ✓ | | ✓ | Some countries as it indicates involvement with the environment and implies mechanisms for people to submit data – possibly use the data available through GBIF. |

# ANNEX 2.

## FACT SHEETS FOR SELECTED ECOSYSTEM SERVICE INDICATORS USED IN SUB-GLOBAL ASSESSMENTS

The following fact sheets outline 16 indicators that have been used in various Sub Global Assessments (SGAs) and other initiatives. They cover provisioning, regulating, supporting and cultural services, and are drawn from across four continents. These are not exhaustive but presented as an indicative sample of the kinds of indicators that are currently being used or developed.

Each fact sheet provides information on:

- The service type and category each indicator is applicable to
- The scale at which it could be applied (e.g. regional, national, global)
- Current storyline and status
- Data sources and methods used to generate the indicator
- Most effective means of presentation, and
- Limitations of the indicator

Each indicator is also categorized as a particular 'type' based on the 5-step classification system[1] which was devised at the first workshop on ecosystem service indicators (**Table A2**).

**Table A2: 5-step classification[1] of ecosystem-service indicators.**

| Category | Category Acronym | Definition |
|---|---|---|
| 1. Condition | C | The amount or quantity of underlying physical resources which influence the ability of ecosystems to support ecosystem processes and deliver ecosystem services. |
| 2. Function | F | The processes by which ecosystems deliver services and benefits. Most regulating and supporting services within the Millennium Ecosystem Assessment framework can be ecosystem functions in this classification. |
| 3. Service | S | These are ecosystem products that are important for supporting human well-being, but not directly consumed by people. For example, freshwater that is used for irrigation or aquaculture is classified as a service since freshwater in this instance supports peoples' livelihoods but is not directly consumed. |
| 4. Potential benefit | PB | These are tangible products from ecosystems that can potentially benefit humans if directly consumed. |
| 5. Benefit | B | These are tangible products from ecosystems that humans directly consume; the 'thing that has direct impact on human welfare' (Fisher *et al*. 2008). For example, fish produced by aquaculture would be classified as a benefit. It should be noted, however, that the term 'benefit' is often used as a synonym of 'service' in ecosystem service discussions within the context of the MA or in communication with the broader society and science-policy interface. |
| 6. Impact | I | Indicators of the state of people's physical, economic, social, and spiritual well-being. |

[1]*Expanded to six-steps during inter-sessional review. The additional category is number 4: Potential Benefit.*

# 1. FOOD AND NUTRITION: TOTAL DIETARY INTAKE OF CARBOHYDRATES AND PROTEINS IN SOUTHERN AFRICA

**Ecosystem Service Type:** Provisioning

**Ecosystem Service Sub-Category:** Food

**Type of Indicator:** Impact

**Lead Agency:** The Council for Scientific and Industrial Research (CSIR), South Africa

**Scale of Appropriate Use:** National and Sub-Global

**Key Policy Question:** What is the total dietary intake of carbohydrates and proteins in Southern Africa?

## The Indicator

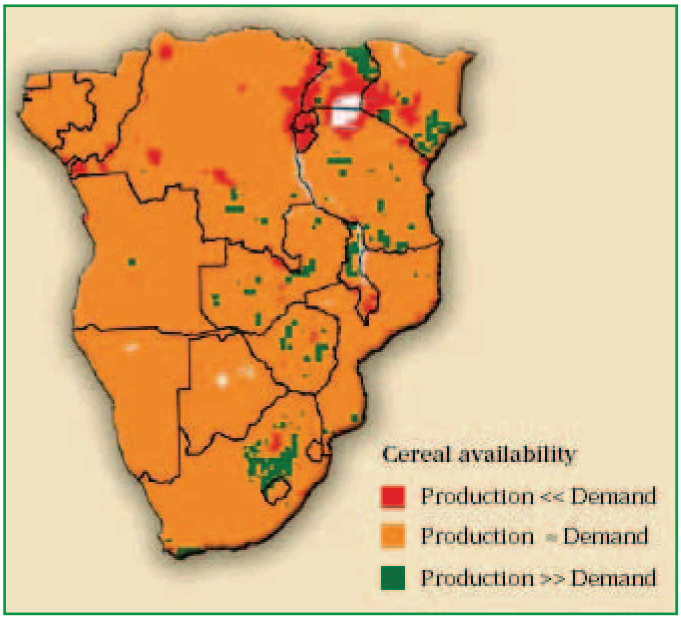


**Figure A1. Total dietary intake of carbohydrates and protein in South Africa.** Source: Scholes and Biggs (2004).

## Storyline

*The region as a whole is relatively self-sufficient in staple crops (e.g. maize, sorghum, millet) in good years. However, the spatial pattern of food supply does not match demand, resulting in food shortages in certain areas, particularly in places where distribution networks are poor.*

## Data

**Data sources, collection & management**

Data used to calculate this indicator are from The Council for Scientific and Industrial Research (CSIR), South Africa, the Centre for International Earth Science Information Network (CIESIN) at Columbia University, and FAOSTAT.

Data on crops used to calculate the indicator were obtained from FAO statistics and restricted to cultivated areas. Gridded population data were obtained from CIESIN.

## Data custodians

The Council for Scientific and Industrial Research (CSIR), South Africa.
CSIR Environmentek
PO Box 395
Pretoria, 0001. South Africa
www.csir.co.za/index.html

## Data access and availability

Data available upon request from CSIR.

## Methods

**Methods used/Calculation procedure**

This map is based on total production and nutritional contribution of carbohydrate and protein-supplying foods in the region compared with the recommended daily minimum intake of calories. Production was modelled at a 5x5 km resolution based on simple crop growth models calibrated to FAO statistics and restricted to cultivated areas. A variable fraction of maize production was distributed nationally depending on the non-agricultural proportion of the population in each country; the remainder and all millet and sorghum were assumed to be distributed within an area of 50x50 km of where it was produced. Demand was assumed to be 2,000 calories/caput*/day and the food grain calorie content 3,333 calories/kg. Gridded population data were obtained from the CIESIN.

*caput: head

### Data units

Cereals: Kcalories/person/day
Proteins: grams

### Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)

### Most effective forms of presentation

Maps accompanied by narrative

### Status

The indicator was developed by the regional-scale team of the Southern African Millennium Ecosystem Assessment led by CSIR.

### Limitations of the indicator

This is not currently a time series map (i.e. it is not an indicator of change) and is therefore a baseline map only. This is because much of the data presented in this indicator are from one-off studies rather than ongoing monitoring. Utility of this indicator as an indicator of change may be enhanced if parameters are measured repeatedly over time, and as methods for mapping ecosystem services are developed further.

### Sources/References


- CIESIN (2000). *Gridded Population of the World (GPW), Version 2*. Centre for International Earth Science Information Network, Columbia University. Palisades, New York.
- FAO (2004). FAOSTAT. [online] Available at: <http://faostat.fao.org/default.aspx>
- Scholes, R.J. and Biggs, R. (eds.) (2004). Ecosystem services in Southern Africa: A regional assessment. Council for Scientific and Industrial Research, Pretoria, South Africa. [Online] Available at: <http://www.maweb.org/documents_sga/SAfMA_Regional_Report_-_final.pdf>


## 2. WATER AVAILABILITY IN SOUTHERN AFRICA

**Ecosystem Service Type:** Provisioning

**Ecosystem Service Sub-Category:** Freshwater

**Type of Indicator:** Potential Benefit

**Lead Agency:** The Council for Scientific and Industrial Research (CSIR), South Africa.

**Scale of Appropriate Use:** National and Sub-Global

**Key Policy Question:** What was annual water availability in Southern Africa?

## The Indicator

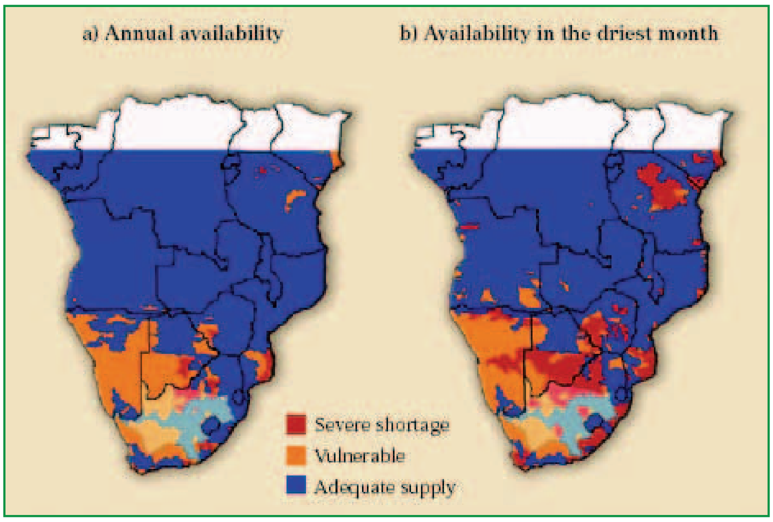


**Figure A2. The distribution of surface water abundance and scarcity in southern Africa.** Source: Scholes and Biggs (2004).

## Storyline

*Red areas on the map already experience severe water shortages, while yellow areas are vulnerable to deficits. The 'driest month' map (b) is a more conservative indicator of problem areas, given the limited water storage capacity in the region. Spatially, freshwater is unevenly distributed within and across the countries of southern Africa. The region divides roughly along the line of the Zambezi and Cunene rivers into a water-abundant north and a water scarce south, with some exceptions such as the relatively wet Lesotho highlands, and the relatively dry eastern parts of Kenya and Tanzania.*

## Data

**Data sources, collection & management**

Data used to calculate this indicator are from the South Africa Department of Environmental Affairs and Tourism, the Centre for International Earth Science Information Network (CIESIN), Columbia University, Pilot Analysis of Global Ecosystems (PAGE), and the South Africa Department of Water Affairs and Forestry's Water System Assessment Model (WSAM version 3).

## Data custodians

The Council for Scientific and Industrial Research (CSIR), South Africa.
CSIR Environmentek
PO Box 395
Pretoria, 0001. South Africa
http://www.csir.co.za/index.html

South Africa Department of Environmental Affairs and Tourism
Private Bag X447
Pretoria, 0001. South Africa
http://www.environment.gov.za/

Centre for International Earth Science Information Network
Columbia University
61 Route 9W, PO Box 1000
Palisades, New York, 10964. USA
http://www.ciesin.columbia.edu/index.html

Pilot Analysis of Global Ecosystems (PAGE)
World Resources Institute
10 G Street NE Suite 800
Washington, DC, 20002. USA
http://www.wri.org/project/global-ecosystems-analysis

Department of Water Affairs and Forestry, South Africa
Private Bag X313
Pretoria, 0001. South Africa
http://www.dwa.gov.za/

## Data access and availability

Data available upon request from CSIR.

## Methods

**Methods used/Calculation procedure**

Other indicators maps created included water availability (i.e. map of surface water availability in Southern Africa). Water supply was calculated using the water balance model (Fekete *et al*. 2002), a hydrological model which takes into account rainfall, drainage basins, topography, vegetation and soil, annual freshwater demand assumed to be 1000 $m^3$ p.a., the minimum target set by the United Nations while the demand in the driest month was assumed to be 50 $m^3$ per capita. Gridded population data were obtained from CIESIN (2000).

## Data units

$Km^3$/year
$m^3$/capita
$m^3$/annum

## Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)

## Most effective forms of presentation

Maps accompanied by narrative

## Status

The indicator was developed by the regional-scale team of the Southern African Millennium Ecosystem Assessment led by CSIR.

## Limitations of the indicator

This is not currently a time series map (i.e. it is not an indicator of change) and is therefore a baseline map only. This is because much of the data presented in this indicator are from one-off studies rather than ongoing monitoring. Utility of this indicator as an indicator of change may be enhanced if parameters are measured repeatedly over time, and as methods for mapping ecosystem services are developed further.

## Sources/References


- CIESIN (2000). *Gridded Population of the World (GPW), Version 2*. Centre for International Earth Science Information Network, Columbia University. Palisades, New York.
- Fekete, B.M., Vörösmarty, C.J. and Grabs, W. (2002). High-resolution fields of global runoff combining observed river discharge and simulated water balances. *Global Biogeochemical Cycles.* **16:** 1042.
- Scholes, R.J. and Biggs, R. (eds.) (2004). Ecosystem services in Southern Africa: A regional assessment. Council for Scientific and Industrial Research, Pretoria, South Africa. [Online] Available at: <http://www.maweb.org/documents_sga/SAfMA_Regional_Report_-_final.pdf>

## 3. WOOD AND CHARCOAL USE IN SOUTHERN AFRICA

**Ecosystem Service Type:** Provisioning

**Ecosystem Service Sub-Category:** Biomass fuel

**Type of Indicator:** Potential Benefit and Benefit

**Lead Agency:** The Council for Scientific and Industrial Research (CSIR), South Africa.

**Scale of Appropriate Use:** National and Sub-Global

**Key Policy Question:** What is the sate of wood fuel production and demand in Southern Africa?

### The Indicator

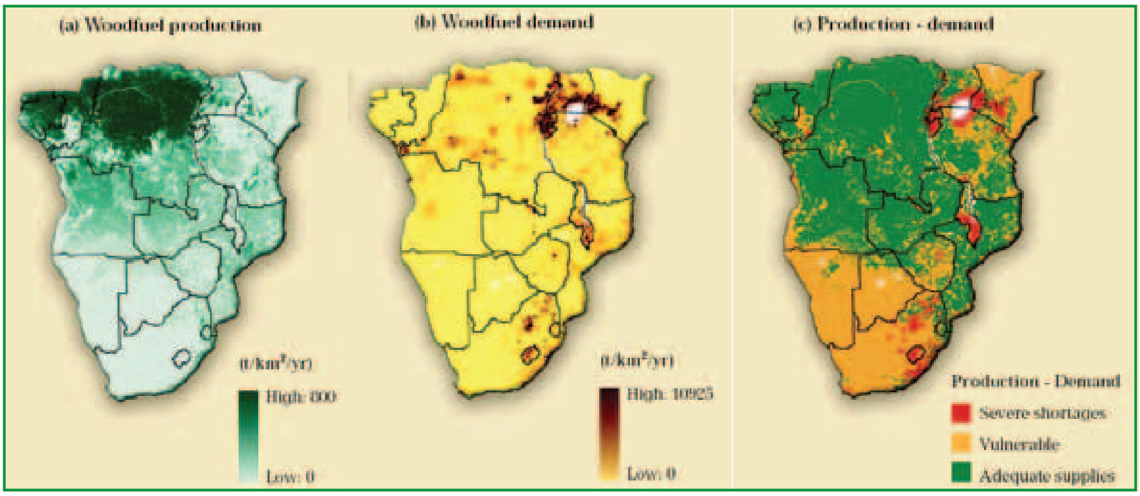


**Figure A3. Map of wood fuel demand versus production in Southern Africa (i.e. map of woodfuel demand versus production to show deficits).** Woodfuel harvesting is sustainable when the rate of wood use is less than the rate of wood growth. The rate of wood growth (a) is mainly controlled by climatic factors. Woodfuel use (b) differs between rural and urban areas and varies with climate and woodfuel availability. Where the rate of wood use is greater than wood growth (c), people cut into the woodfuel stock, resulting in deforestation or woodland loss. All data are for 1995 and displayed at a 5x5 km resolution. Source: Hutchinson *et al*. (1995), Corbett and O' Brien (1997), CIESIN (2000) and DeFries (2000), in Scholes and Biggs (2004).

### Storyline

*See caption of figure A3*

### Data

**Data sources, collection & management**

Data used to calculate this indicator are from The Council for Scientific and Industrial Research (CSIR), South Africa, and the Centre for International Earth Science Information Network (CIESIN) at Columbia University.

### Data custodians

The Council for Scientific and Industrial Research (CSIR), South Africa.
CSIR Environmentek
PO Box 395
Pretoria, 0001. South Africa
http://www.csir.co.za/index.html

### Data access and availability

Data available upon request from CSIR.

## Methods

**Methods used/Calculation procedure**

Total annual wood production was calculated by scaling a maximum annual increment of 10 tonnes/hectare/year by a function of the number of days available for tree growth and the percent tree cover at a particular location. All data are for 1995 and displayed at a 5x5 km resolution.

## Data units

Tonnes/km$^2$/year

## Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)

## Most effective forms of presentation

Maps accompanied by narrative

## Status

The indicator was developed by the regional-scale team of the Southern African Millennium Ecosystem Assessment led by CSIR.

## Limitations of the indicator

This is not currently a time series map (i.e. it is not an indicator of change) and is therefore a baseline map only. This is because much of the data presented in this indicator are from one-off studies rather than ongoing monitoring. Utility of this indicator as an indicator of change may be enhanced if parameters are measured repeatedly over time, and as methods for mapping ecosystem services are developed further.

## Sources/References


- Hutchinson, M.F., Nix, H.A., McMahon, J.P. and Ord, K.D. (1995). A topographic and climate database for Africa. Centre for Resource and Environmental Studies, Australian National University, Canberra, Australia.
- Corbett, J.D. and O'Brien, R.F. (1997). The Spatial Characterization Tool. Texas Agricultural Experiment Station, Texas A&M University System, Blackland Research Centre Report No. 97-03, CDROM Pub. Texas A&M, Texas, USA.
- CIESIN (2000). *Gridded Population of the World (GPW), Version 2*. Centre for International Earth Science Information Network, Columbia University. Palisades, New York.
- DeFries, R.S., Hansen, M.C., Townshend, J.R.G., Janetos A.C. and Lovelands, T.R. (2000). A new global 1 km dataset of percentage tree cover derived from remote sensing. *Global Change Biology*. **6**: 247-254.
- Scholes, R.J. and Biggs, R. (eds.) (2004). Ecosystem services in Southern Africa: A regional assessment. Council for Scientific and Industrial Research, Pretoria, South Africa. [Online] Available at: <http://www.maweb.org/documents_sga/SAfMA_Regional_Report_-_final.pdf>


# 4. POTENTIAL FORAGE PRODUCTION IN THE LITTLE KAROO OF SOUTH AFRICA

**Ecosystem Service Type:** Provisioning

**Ecosystem Service Sub-Category:** Livestock

**Type of Indicator:** Potential Benefit

**Lead Agency:** The Council for Scientific and Industrial Research (CSIR), South Africa.

**Scale of Appropriate Use:** National

**Key Policy Question:** What is the potential forage production (i.e. the provision of forage for grazing rangeland livestock) in the Little Karoo of South Africa?

## The Indicator

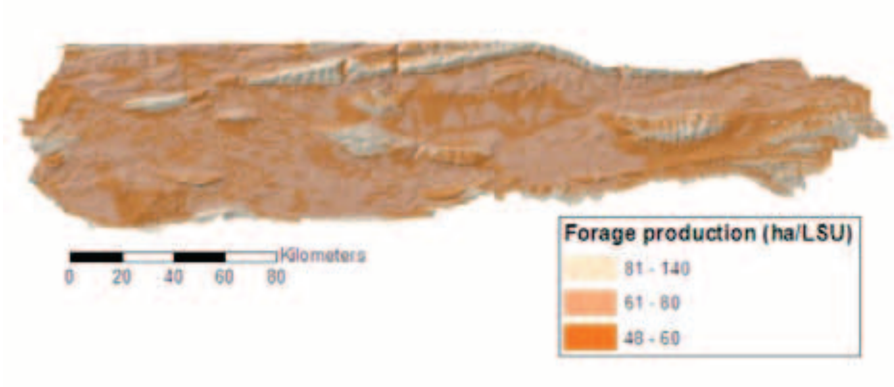


**Figure A4. Forage production: number of hectares (ha) required by a large stock unit (LSU) in each habitat type in the Little Karoo of South Africa.** The map is transposed over a digital elevation model for illustrative purposes. Source: Reyers *et al*. (2009).

## Data

**Data sources, collection & management**

The Little Karoo has been the site of much research in the last few years, which has resulted in some key databases essential to the study of ecosystem services (Vlok *et al*. 2005; Le Maitre *et al*. 2007; O'Farrell *et al*. 2008; Thompson *et al*. 2009). Of particular value to this study is a map of vegetation types mapped at a 1:50 000 scale (Vlok *et al.* 2005). This map was developed in order to inform decision making about conservation, sustainable commercial farming, and land-use planning matters in the region. Accordingly, it mapped 369 vegetation units on the basis of their floristic composition. The vegetation units were classified into 32 habitat types relevant to the agricultural and wildlife industries in the region, by considering their physiognomy as well as the floristic component of the vegetation units (Vlok *et al*. 2005). The habitat types are nested within six biomes: Subtropical Thicket, Succulent Karoo, Renosterveld, Fynbos, Aquatic Drainage, and Aquatic Source. The spatial extent of land transformation and degradation of the Little Karoo has also been mapped at a 1:50 000 scale (see Thompson *et al.* 2009). This map depicts areas of pristine vegetation and transformed (cultivated and urban) areas, and importantly, it also maps moderately and severely degraded areas.

## Data custodians

The Council for Scientific and Industrial Research (CSIR), South Africa.
CSIR Environmentek
PO Box 395
Pretoria, 0001. South Africa
http://www.csir.co.za/index.html

## Data access and availability

Data available upon request from CSIR.

## Methods

**Methods used/Calculation procedure**

To calculate ecosystem service change we used land cover data and converted land cover statistics into measures of ecosystem service change. We developed a matrix of the extent to which the transformed and degraded categories of land cover diminished the delivery of each of the quantified ecosystem services.

Carrying capacities, expressed as number of hectares required per large stock unit (LSU), for domestic stock were determined for pristine examples of the 32 habitat types defined in Vlok *et al.* (2005). This service was mapped by overlaying the carrying capacity recommendation map of the Department of Agriculture (DA) with those of the habitat map prepared by Vlok *et al.* (2005) for the Little Karoo domain. It is important to note that not all habitat types of the Little Karoo are covered by the DA map; however it does provide clear recommendations for the habitat types with the highest (Valley Thicket with Spekboom) and lowest (Proteoid Fynbos) carrying capacity, as well as several other clear recommendations at other carrying capacities (e.g. for Apronveld, Gannaveld, Sandolienveld). For habitat units not recognized by the DA map, carrying capacity recommendations for pristine examples of such types had to be interpolated. This was done by estimating the degree to which plants palatable to domestic stock would increase or decrease in the habitat type in relation to the DA recommendation for the most similar habitat type. These estimates, based on expert opinion, were reviewed in terms of the range recommended by the DA, as well as by officers from the DA. We assign a medium certainty to these reviewed and well understood data.

### Data units
Number of hectares required per large stock unit (LSU)

### Technology used/Systems in use
Statistical approaches
Geographical Information Systems (GIS)

### Most effective forms of presentation
Maps accompanied by narrative

### Status
The indicator was developed by CSIR as part of their work on mapping ecosystem services of the Little Karoo in South Africa.

### Limitations of the indicator
This is an indicator of importance or magnitude. It is not a time series map (i.e. it is not an indicator of change) and is therefore a baseline map only. This is because much of the data presented in this indicator are from one-off studies rather than ongoing monitoring. Utility of this indicator as an indicator of change may be enhanced if parameters are measured repeatedly over time, and as methods for mapping ecosystem services are developed further.

### Sources/References

- Le Maitre, D. C., Milton, S. J., Jarmain, C., Colvin, C. A., Saayman, I. and Vlok. J. H. J. (2007). Landscape-scale hydrology of the Little Karoo: linking ecosystems, ecosystem services and water resources. *Frontiers in Ecology and the Environment* **5**: 261–270.
- O'Farrell, P. J., Le Maitre, D. C., Gelderblom, C., Bonora, D., Hoffman T. and Reyers. B. (2008). Applying a resilience framework in the pursuit of sustainable land-use development in the Little Karoo, South Africa. In: *Exploring sustainability science—a Southern African perspective*. M. E. Burns, and A. V. B. Weaver (eds). Sun Press, Stellenbosch, South Africa. pp. 383–430.
- Reyers, B., O'Farrell, P. J., Cowling, R. M., Egoh, B. N., Le Maitre, D. C. and Vlok, J. H. J. (2009). Ecosystem services, land-cover change, and stakeholders: finding a sustainable foothold for a semiarid biodiversity hotspot. *Ecology and Society*. **14**: 38. [online] Available at: **<http://www.ecologyandsociety.org/vol14/iss1/art38/>**
- Thompson, M., Vlok, J. H. J., Rouget, M., Hoffman, M. T., Balmford, A. and Cowling, R. M. (2009). Mapping land transformation in a heterogeneous environment: a rapid and cost effective approach for assessment and monitoring. *Journal of Environmental Management*. **14(1)**: 38.
- Vlok, J. H. J., Cowling, R. M. and Wolf. T. (2005). A vegetation map for the Little Karoo. Unpublished Maps and Report for a SKEP Project Supported by Grant No. 1064410304. Critical Ecosystem Partnership Fund, Cape Town, South Africa.

## 5. WATER YIELD IN CENTRAL SUMATRA

**Ecosystem Service Type:** Provisioning

**Ecosystem Service Sub-Category:** Freshwater

**Type of Indicator:** Potential Benefit and Benefit

**Lead Agency:** World Wildlife Fund

**Scale of Appropriate Use:** Sub-national

**Key Policy Question:** How much water yield does each part of the landscape contribute annually in Central Sumatra?

### The Indicator

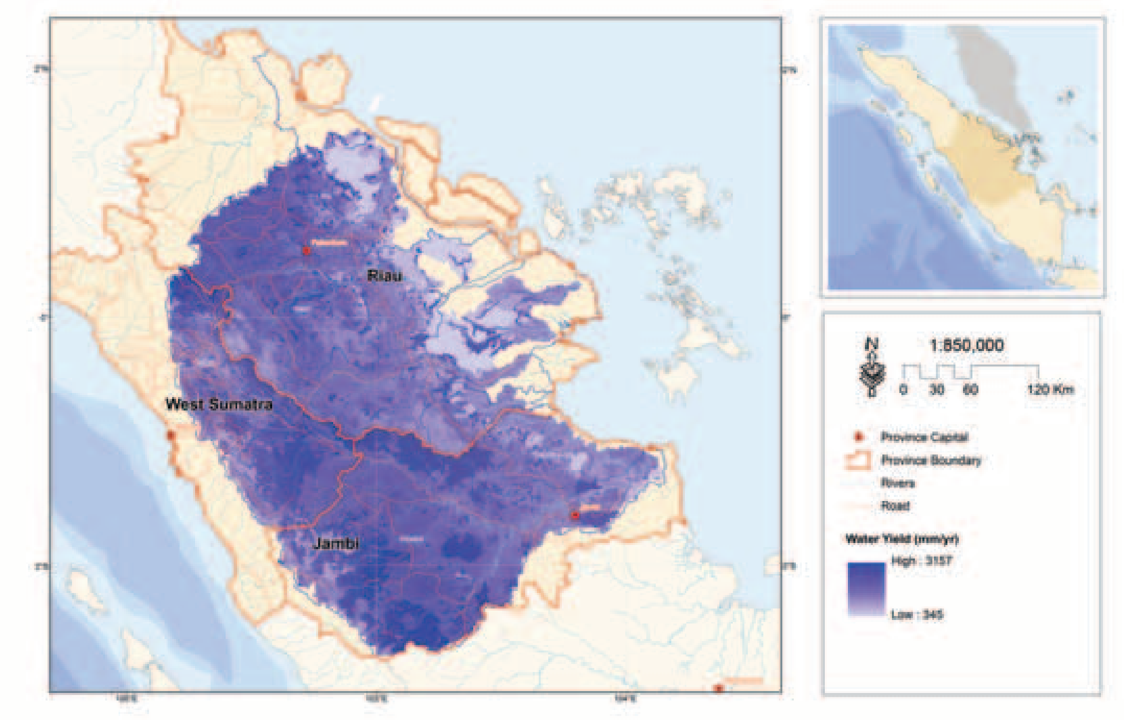


**Figure A5. Water yield based on 2008 land cover of Central Sumatra.** Source: Tallis *et al*. (2010).

### Data

**Data sources, collection & management**

The data sources used to calculate this indicator included: 1) 2008 landuse/landcover map of Sumatra based on Landsat imagery; 2) precipitation data from Worldclim (http://www.worldclim.com); and 3) soil depth, evapotranspiration and plant available water content from FAO global datasets.

## Data custodians

WWF-Indonesia
Kantor Taman A9 Unit A-1
Kawasan Mega Kuningan
Jakarta 12950
http://www.wwf.or.id/en/

WWF-USA
World Wildlife Fund
1250 Twenty-Fourth Street, N.W.
P.O. Box 97180
Washington, DC 20090-7180. USA
http://www.worldwildlife.org/home-full.html

## Data access and availability

Data available upon request from WWF-Indonesia and WWF-US.

## Methods

**Methods used/Calculation procedure**

Tier 1 water yield model of InVEST software. The model runs on a gridded map of regular cells (called raster format in GIS). It estimates the quantity and value of water used for hydropower production from each pixel. It has three components, which run sequentially in InVEST. First, it determines the amount of water running off each pixel as the precipitation less the fraction of the water that undergoes evapotranspiration. The model does not differentiate between surface, subsurface and baseflow, but assumes that all water yield from a pixel reaches the point of interest via one of these pathways. Second, it calculates the proportion of surface water that is used for hydropower production by subtracting the surface water that is consumed for other uses. Third, it estimates the energy produced by the water reaching the hydropower reservoir and the value of this energy over the reservoir's lifetime.

## Data units

mm/year

## Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)

## Most effective forms of presentation

Maps of change under alternative scenarios
Tradeoff curves

## Status

The indicator was developed as part of the Natural Capital Project (http://www.naturalcapitalproject.org/home04.html).

## Limitations of the indicator

Tier 1 estimate needs ground truthing. Annual average does not capture seasonal variation.

## Sources/References


- Tallis, H.T., Ricketts, T., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Pennington, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Lonsdorf, E., Kennedy, C. (2010). *InVEST 1.005 beta User's Guide*. The Natural Capital Project, Stanford.
- FAO (2010). FAOSTAT. [online] Available at: <http://faostat.fao.org/default.aspx>

## 6. DEMAND FOR POTABLE WATER BY ALL SECTORS IN TRINIDAD AND TOBAGO, 1997 TO 2025

**Ecosystem Service Type:** Provisioning

**Ecosystem Service Sub-Category:** Freshwater

**Type of Indicator:** Potential Benefit and Benefit

**Lead Agency:** The Ministry of Planning and Development of Trinidad and Tobago
Environmental Management Authority of Trinidad and Tobago

**Scale of Appropriate Use:** National

**Key Policy Question:** Can Trinidad's water availability (both from surface and ground-water sources) meet the island's freshwater demands at least until 2025, even in the driest months?

### The Indicator

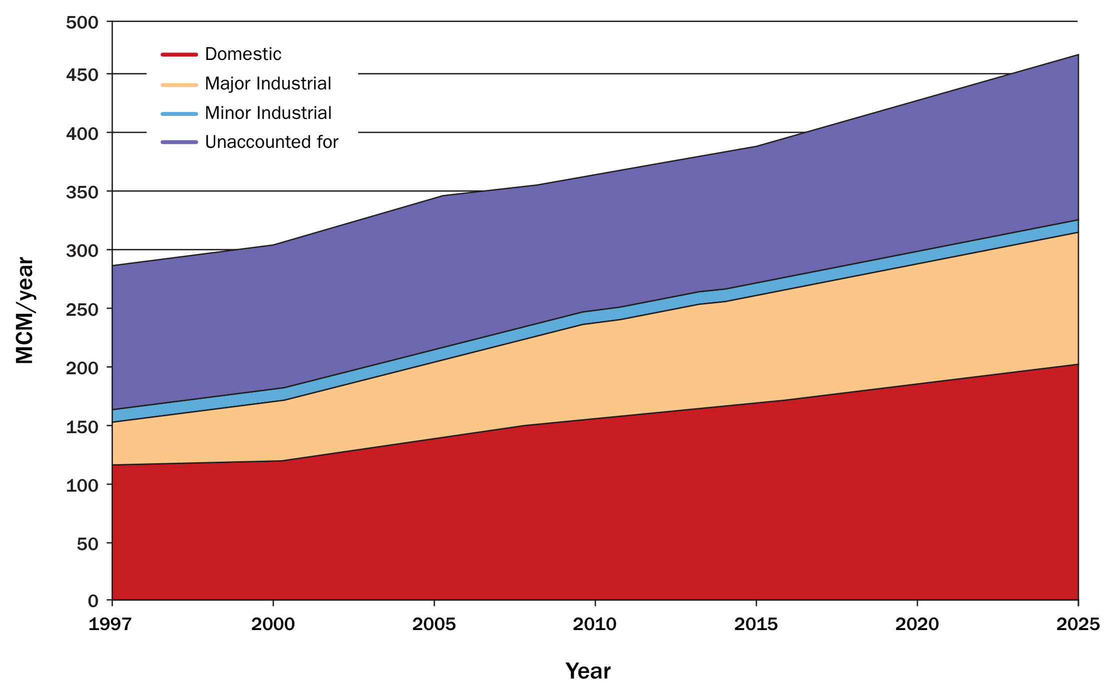


**Figure A6. Demand for potable water by all sectors from 1997 to 2025.** Source: Northern Range Assessment (2005).

### Storyline

*Trinidad and Tobago's water availability (both from surface and ground-water sources) can meet the island's freshwater demands at least until 2025, even in the driest months. The projected demand was expected to increase within all sectors, and domestic water was switched with unaccounted-for water use (40%–50%) to become the highest demand sector.*

### Data

**Data sources, collection & management**

Data used to calculate this indicator was from a study carried out by DHV Consultants BV in 1999 for the Ministry of Planning and Development of Trinidad and Tobago on the Water Resources Management Strategy for Trinidad and Tobago.

## Data custodians

DHV Consultants BV
P.O. Box 1132
3800 BC Amersfoort
The Netherlands
http://www.dhv.com/Home

The Ministry of Planning, Housing and the Environment
(Formerly, The Ministry of Planning and Development of Trinidad and Tobago)
44-46 South Quay
Trinidad and Tobago
http://www.mphe.gov.tt/home/index.php?option=com_frontpage&Itemid=1&lang=en

## Data access and availability

Data available upon request from the Ministry of Planning, Housing and the Environment (formerly The Ministry of Planning and Development) of Trinidad and Tobago.

## Methods

**Methods used/Calculation procedure**

The projected domestic demand for potable water was based on a population growth rate of 1.2%, which is higher than the rate calculated from the 2,000 population census of 0.9%. Consideration was also given to increase in average consumption per capita due to higher income and change in lifestyles, increase in access to improved water supply systems (e.g. shift from roadside standpipes to in-house connections), and widening of supply network from servicing 86% of the population in 1997 to 98% in 2010 (DHV Consultants BV 1999). The demand by commercial potable water users was based on a growth rate of 1.7% (DHV Consultants BV 1999).

## Data units

Million $m^3$/year

## Technology used/Systems in use

## Most effective forms of presentation

Area and line graphs

## Status

The indicator was developed by DHV Consultants BV in 1999 as part of a study on the Water Resources Management Strategy for Trinidad and Tobago carried out for the Ministry of Planning and Development of Trinidad and Tobago. The indicator was subsequently used by the Environmental Management Authority of Trinidad and Tobago as part of the Northern Range Sub global Assessment of the Global Millennium Ecosystem Assessment in 2005.

## Limitations of the indicator

The indicator is based on projections.

## Sources/References


- DHV Consultants BV. (1999). Water Resources Management Strategy for Trinidad and Tobago, Main Report. Submitted to the Ministry of Planning and Development, Government of Trinidad and Tobago. 167 pp.
- Water Resources Management Unit (WRMU) (2002). Draft National Water Resources Policy 2002. A Water Vision for Trinidad and Tobago. Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago. 28pp.
- Northern Range Assessment (2005). Report of an assessment of the Northern Range, Trinidad and Tobago: People and the Northern Range. State of the Environment Report 2004. Environmental Management Authority of Trinidad and Tobago. 184pp.

## 7. SAWN-LOG OUTTURN FROM STATE LANDS IN TRINIDAD

**Ecosystem Service Type:** Provisioning

**Ecosystem Service Sub-Category:** Biological Raw Materials: Timber and other wood fibre

**Type of Indicator:** Benefit

**Lead Agency:** Forestry Division (Government of Trinidad and Tobago)
Environmental Management Authority (EMA) of Trinidad and Tobago

**Scale of Appropriate Use:** National

**Key Policy Question:** What is the economic value of the sawn-log outturn from State Lands in Trinidad?

### The Indicator

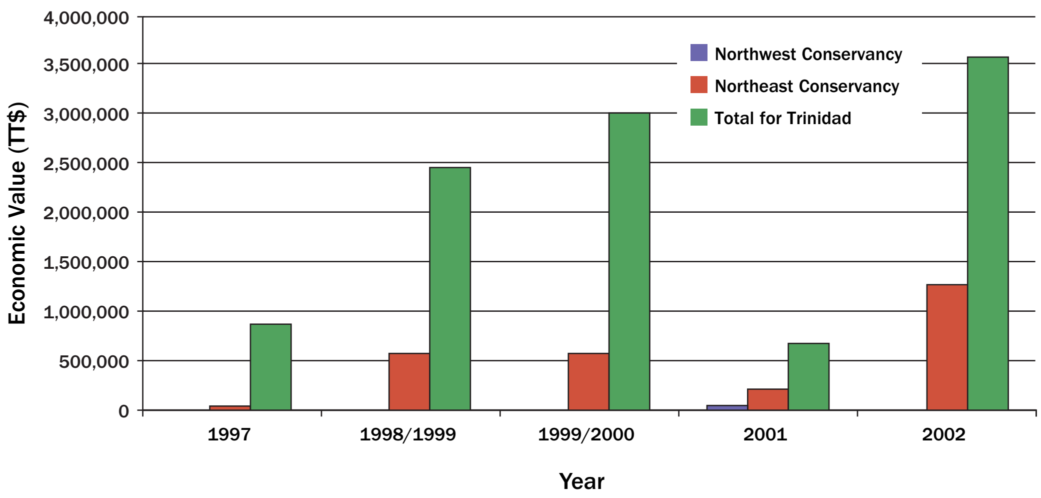


**Figure A7. Economic value of the sawn-log outturn from State Lands in Trinidad.** Source: Forestry Division (1998, 1999, 2002a, 2002b, 2002c, 2003); Northern Range Assessment (2005).

### Storyline

*The economic value of timber from State lands in the Northeast Conservancy (TT$1,280,450 in 2002) far exceeds that for the Northwest Conservancy (TT$8,540). Overall for Trinidad, the Northwest and Northeast conservancies (i.e. the Northern Range) contribute about one third of the economic value of sawn-log from State lands. Additionally, forestry accounted for 2.5% annually of the GDP between 1980 and 1988. However, this is an underestimate of the value of forests as it did not take into account the jobs created in the processing industry or a value for environmental services such as the role of forests in water cycling and replenishment, soil preservation, carbon sequestration, and flood control.*

### Data

**Data sources, collection & management**

Data used to calculate this indicator are from Trinidad and Tobago Forestry Division.
Data on revenue or economic value of the sawn-log outturn from State Lands in Trinidad is collected by the Forestry Reserve and Inventory Management Section of the Trinidad and Tobago Forestry Division.

### Data custodians

Forestry Division (Government of Trinidad and Tobago).
Long Circular Road
P.O. Box 30
St. James, Port of Spain
Trinidad and Tobago

## Data access and availability

Data available upon request from the Trinidad and Tobago Forestry Division.

## Methods

**Methods used/Calculation procedure**

Simple addition of revenue from sawn-log outturn from State Lands in Trinidad.

## Data units

Value in Trinidad and Tobago dollar (TT$)

## Technology used/Systems in use

Log books and MS Office Excel

## Most effective forms of presentation

Bar or column graphs

## Status

The indicator was developed by the Environmental Management Authority of Trinidad and Tobago as part of the Northern Range Sub global Assessment of the Global Millennium Ecosystem Assessment in 2005.

## Limitations of the indicator

The economic value of the sawn-log outturn from State Lands in Trinidad is an underestimate of the value of forests as it did not take into account the jobs created in the processing industry, or a value for environmental services such as its role in water cycling and replenishment, soil preservation, carbon sequestration, and flood control. The forest may be more valuable for these environmental services than for its contribution to employment and income. Recognition of this is an important consideration in policy choices about use and conservation.

## Sources/References


- Forestry Division (1998). Annual Report 1997. Ministry of Agriculture, Land and Marine Resources, Government of Trinidad and Tobago. 93pp.
- Forestry Division (1999). Annual Report 1998/1999. Ministry of Agriculture, Land and Marine Resources, Government of Trinidad and Tobago. 55pp.
- Forestry Division (2002a). Annual Report 1999/2000. Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago. 64pp.
- Forestry Division (2002b). Annual Report 2000. Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago.
- Forestry Division (2002c). Annual Report 2001. Ministry of the Environment, Government of Trinidad and Tobago. 59pp.
- Forestry Division (2003). Annual Report 2002. Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago. 68pp.
- Northern Range Assessment (2005). Report of an assessment of the Northern Range, Trinidad and Tobago: People and the Northern Range. State of the Environment Report 2004. Environmental Management Authority of Trinidad and Tobago. 184pp.

## 8. CARBON STORAGE IN THE LITTLE KAROO OF SOUTH AFRICA

**Ecosystem Service Type:** Regulating

**Ecosystem Service Sub-Category:** Climate Regulation

**Type of Indicator:** Condition

**Lead Agency:**The Council for Scientific and Industrial Research (CSIR), South Africa

**Scale of Appropriate Use:** Landscape

**Key Policy Question:** What is the potential carbon storage in the Little Karoo of South Africa and how has it changed?

### The Indicator

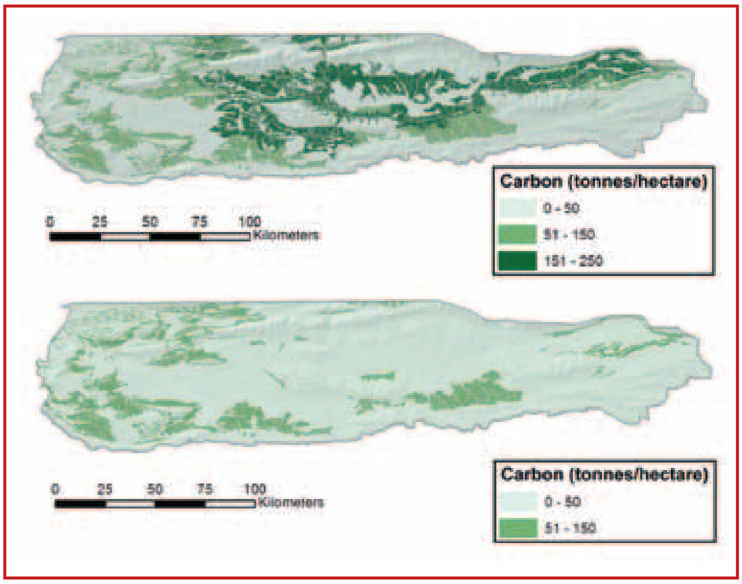


**Figure A8. Carbon storage: tonnes of carbon stored per hectare of each habitat type in the Little Karoo of South Africa for a) historic (nominally precolonial times) vs. b) current times.** Maps are transposed over a digital elevation model for illustrative purposes. Source: Reyers *et al*. 2009.

### Storyline

*Carbon storage is the number of tonnes of carbon locked up in above and below ground biomass of plants; most of this carbon would be released if these intact ecosystems were transformed or degraded. These two maps reflect the losses of carbon stored due to land cover change and overgrazing in the Little Karoo.*

### Data sources, collection & management

The base map is a Map of vegetation types at a 1:50 000 scale (Vlok *et al.* 2005). It maps 369 vegetation units on the basis of their floristic composition. The vegetation units were classified into 32 habitat types relevant to the agricultural and wildlife industries in the region, by considering their physiognomy as well as the floristic component of the vegetation units (Vlok *et al.* 2005). Carbon storage values were extracted from the literature (Mills *et al.* 2005, Mills and Cowling 2006) and through a process of expert consultation The spatial extent of land transformation and degradation of the Little Karoo has also been mapped at a 1:50 000 scale (see Figure 1 in Thompson *et al.* 2009). This map depicts areas of pristine vegetation and transformed (cultivated and urban) areas, and importantly, it also maps moderately and severely degraded areas.

Carbon storage data were extracted from relevant literature sources and expert workshops and expressed using an existing vegetation map. These data are now stored on a free access web site.

### Data custodians

The Council for Scientific and Industrial Research (CSIR), South Africa.
CSIR Environmentek
PO Box 395
Pretoria, 0001. South Africa
http://www.csir.co.za/index.html

Biodiversity GIS (BGIS)
http://bgis.sanbi.org/index.asp?screenwidth=1280

## Data access and availability

Data can be obtained online from Biodiversity GIS: http://bgis.sanbi.org/index.asp?screenwidth=1280.

## Methods

**Methods used/Calculation procedure**

Most habitat types were assigned zero carbon storage values due to their arid and/or fire prone nature. For the remainder carbon storage values were extracted for the habitat types of Arid Thicket with Spekboom based on research on carbon storage in the region (Mills *et al*. 2005; Mills and Cowling 2006). Through a process of expert consultation the more mesic Thicket with Spekboom types were assigned higher values based on higher predicted biomass. Similarly arid Thicket types without spekboom (*Portulacaria afra*) were assigned lower values owing to the large contribution of this species to carbon stocks (Mills *et al*. 2005). Three remaining habitat types (Randteveld, Gravel Apronveld and Thicket Mosaics) were assigned small values to reflect the small amount of carbon they potentially store. An assessment of change in carbon stored was conducted by analysing the percentage of four categories of land cover (pristine, moderately degraded, severely degraded and transformed) within each habitat type which was linked to a matrix of the extent to which the transformed and degraded categories of land cover diminished the delivery of each the ecosystem services. Estimates were based on a mix of expert knowledge and literature sources for carbon storage (Mills *et al*. 2005).

## Data units

Tonnes of carbon stored per hectare of each habitat type.

## Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)
Expert consultation

## Most effective forms of presentation

Maps accompanied by narrative as well as graphs of change in carbon values over time.

## Status

The indicator was developed by CSIR as part of their work on mapping ecosystem services of the Little Karoo in South Africa.

## Limitations of the indicator

This indicator originally served to highlight areas of importance to carbon storage, but together with data on land cover change has been used to measure change over time (pre colonial to current day). These data need to be measured repeatedly over time to become an indicator. Currently this sort of monitoring is not happening and so much of the data presented in developing this indicator is from one-off studies rather than ongoing monitoring. Utility of this indicator as an indicator of change may be enhanced if parameters are measured repeatedly over time, and as methods for mapping ecosystem services are developed further.

## Sources/References


- Mills, A. J., Cowling, R. M., Fey, M. V., Kerley, G. I. H., Donaldson, J. S., Lechmere-Oertel, R. G., Sigwela, A. M., Skowno, A. L. and Rundel, P. (2005). Effects of goat pastoralism on ecosystem carbon storage in semiarid thicket, Eastern Cape, South Africa. *Austral Ecology*. **30:** 797–804.
- Mills, A. J. and Cowling, R. M. (2006). Rate of carbon sequestration at two thicket restoration sites in the Eastern Cape, South Africa. *Restoration Ecology*. **14:** 38–49.
- Reyers, B., O'Farrell, P. J., Cowling, R. M., Egoh, B. N., Le Maitre, D. C. and Vlok, J. H. J. (2009). Ecosystem services, land-cover change, and stakeholders: finding a sustainable foothold for a semiarid biodiversity hotspot. Ecology and Society. 14: 38. [online] Available at: <http://www.ecologyandsociety.org/vol14/iss1/art38/>
- Vlok, J. H. J., Cowling, R. M. and Wolf. T. (2005). A vegetation map for the Little Karoo. Unpublished Maps and Report for a SKEP Project Supported by Grant No. 1064410304. Critical Ecosystem Partnership Fund, Cape Town, South Africa.

## 9. EROSION CONTROL IN THE LITTLE KAROO OF SOUTH AFRICA

**Ecosystem Service Type:** Regulating

**Ecosystem Service Sub-Category:** Erosion Control

**Type of Indicator:** Condition/Function

**Lead Agency:** The Council for Scientific and Industrial Research (CSIR), South Africa

**Scale of Appropriate Use:** National

**Key Policy Question:** What is the potential erosion control (i.e. the vital role that natural ecosystems play in ameliorating these impacts by retaining soils and preventing soil erosion) in the Little Karoo of South Africa and how has it changed over time?

### The Indicator

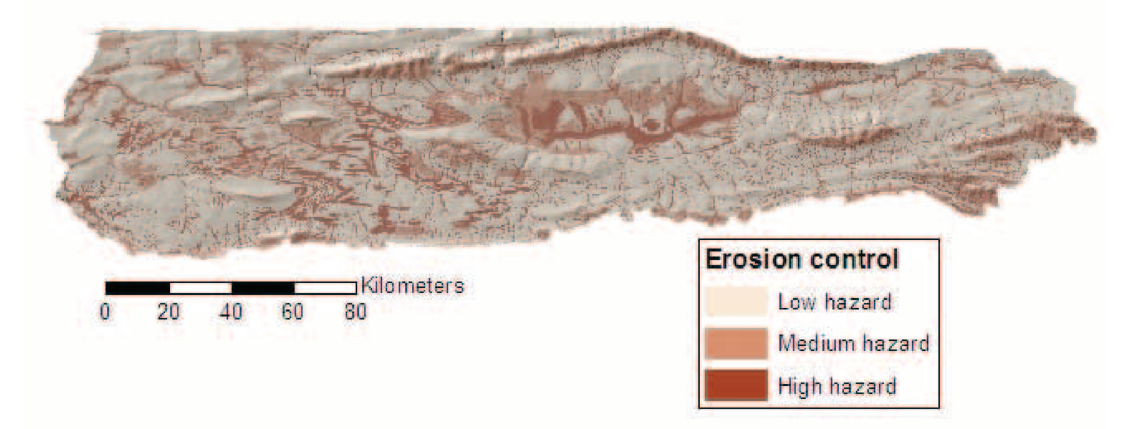


**Figure A9. Erosion control: areas of high, medium, and low erosion hazard requiring the maintenance of natural vegetation cover in the Little Karoo of South Africa.** The map is transposed over a digital elevation model for illustrative purposes. Source: Reyers *et al*. (2009).

### Storyline

*The weather patterns in the Little Karoo, most notably the cut-off lows, result in frequent floods, which have an enormous impact on the region's economy (EDM 2008). Overgrazing and subsequent degradation have resulted in increases in surface runoff, changes in flow and groundwater regimes, decreases in water quality, and increases in the severity and frequency of floods (Le Maitre et al. 2007). Natural ecosystems play a vital role in ameliorating these impacts by retaining soils and preventing soil erosion. The ecosystem service of erosion control depends mainly on the structural aspects of ecosystems, especially vegetation cover and root system and includes the protection of the soil, as well as the maintenance of water quality in nearby water bodies (de Groot et al. 2002). Areas requiring this service are those vulnerable to erosion as determined by the rainfall, soil depth and texture. We map this vulnerability as areas of high, medium and low erosion hazard, the former corresponds with areas where natural vegetation cover must be maintained to control erosion. We also analyse how this has changed since pre colonial times by calculating the area of vegetation lost out of high hazard areas. Compared with potential service supply, erosion control was calculated as declining by 44% (i.e. 44% of erosion control 'hotspots' had lost is vegetation cover; see Figure 3 in Reyers et al. 2009).*

### Data

**Data sources, collection & management**

Data used for this indicator includes a map of vegetation types produced by Vlok *et al*. (2005). Mapped at a 1:50 000 scale it comprises 369 vegetation units which have been mapped on the basis of their floristic composition. The vegetation units were classified into 32 habitat types relevant to the agricultural and wildlife industries in the region, by considering their physiognomy as well as the floristic component of the vegetation units. These habitat types were classified into high, medium and low erosion hazard areas using expert consultation. The spatial extent of land transformation and degradation of the Little Karoo has also been mapped at a 1:50 000 scale (see Figure 1 in Thompson *et al*. 2009). This map depicts areas of pristine vegetation and transformed (cultivated and urban) areas, and importantly, it also maps moderately and severely degraded areas.

In mapping this ecosystem service we assessed the interaction between rainfall, soil depth and texture for each habitat type. This information was used to assign habitat types to classes of high, medium and low erosion hazard. These classes were determined using the vegetation descriptions in Vlok *et al.* (2005) and through expert consultation.

### Data custodians

The Council for Scientific and Industrial Research (CSIR), South Africa.
CSIR Environmentek
PO Box 395
Pretoria, 0001. South Africa
http://www.csir.co.za/index.html

Biodiversity GIS (BGIS)
http://bgis.sanbi.org/index.asp?screenwidth=1280

### Data access and availability

Data can be obtained online from Biodiversity GIS: http://bgis.sanbi.org/index.asp?screenwidth=1280.

### Methods

**Methods used/Calculation procedure**

To calculate ecosystem service change we used land cover data and converted land cover statistics into measures of ecosystem service change. We developed a matrix of the extent to which the transformed and degraded categories of land cover diminished the delivery of each of the quantified ecosystem services.

In mapping this ecosystem service the interaction between rainfall, soil depth and texture for each habitat type was assessed. This information was used to assign habitat types to classes of high, medium and low erosion hazard. These classes were determined using the vegetation descriptions in Vlok *et al.* (2005) and through expert consultation. High erosion hazard habitat types as all of those belonging to the aquatic source (streams and seepage areas) and drainage (river and floodplains) biomes, as well as the *gannaveld* types which are located in valley bottoms and often form large open plains just above the river and floodplain habitat type were identified. *Gannaveld* types have deep fine-fractured soils very prone to erosion with rainstorms transferring soils to the riverine and floodplain habitats causing declines in water quality and nutrient enrichment. These habitat types are associated with high runoff (high rainfall mountain catchment areas) and high run-on areas (lowlands with vulnerable soils plus other functions, e.g. nutrient retention) and are areas where the maintenance of pristine vegetation cover is essential and form the focus of this study. Areas of medium hazard include the remaining mesic and montane habitat types, important for water runoff and drainage. High certainty was assigned to these qualitative ranks based on a sound expert understanding of the service. To determine change in this service we calculated the area of high erosion vulnerability in pristine or moderately degraded land cover categories and assumed that only these areas could provide the services currently.

### Data units

High, medium and low categories of erosion hazard.

### Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)

### Most effective forms of presentation

Maps accompanied by narrative text, and graphic indicating changes in vegetation cover in high hazard areas.

### Status

The indicator was developed by CSIR as part of their work on mapping ecosystem services of the Little Karoo in South Africa.

### Limitations of the indicator

This indicator was developed to highlight areas important to erosion control and also to assess losses of vegetation cover in areas of high importance. Data would need to be collected over time to make this indicator more useful. Furthermore work at converting the categorical data into units of measurement would also be useful.

## Sources/References


- de Groot, R., Wilson, M. A. and Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics.* **41:** 393–408.
- EDM (Eden District Municipality) (2008). Revised integrated development plan 2008/2009. [online] Available at: <http://www.edendm.co.za>
- Le Maitre, D. C., Milton, S. J., Jarmain, C., Colvin, C. A., Saayman, I. and Vlok. J. H. J. (2007). Landscape-scale hydrology of the Little Karoo: linking ecosystems, ecosystem services and water resources. *Frontiers in Ecology and the Environment* **5:** 261–270.
- Reyers, B., O'Farrell, P. J., Cowling, R. M., Egoh, B. N., Le Maitre, D. C. and Vlok, J. H. J. (2009). Ecosystem services, land-cover change, and stakeholders: finding a sustainable foothold for a semiarid biodiversity hotspot. *Ecology and Society.* **14:** 38. [online] Available at: <http://www.ecologyandsociety.org/vol14/iss1/art38/>
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- Vlok, J. H. J., Cowling, R. M. and Wolf. T. (2005). A vegetation map for the Little Karoo. Unpublished Maps and Report for a SKEP Project Supported by Grant No. 1064410304. Critical Ecosystem Partnership Fund, Cape Town, South Africa.


## 10. POTENTIAL WATER-FLOW REGULATION IN THE LITTLE KAROO OF SOUTH AFRICA

**Ecosystem Service Type:** Regulating

**Ecosystem Service Sub-Category:** Water Regulation

**Type of Indicator:** Condition

**Lead Agency:** The Council for Scientific and Industrial Research (CSIR), South Africa

**Scale of Appropriate Use:** National

**Key Policy Question:** What is the potential water-flow regulation (i.e. volume of water provided) in the Little Karoo of South Africa and how has it changed over time?

### The Indicator

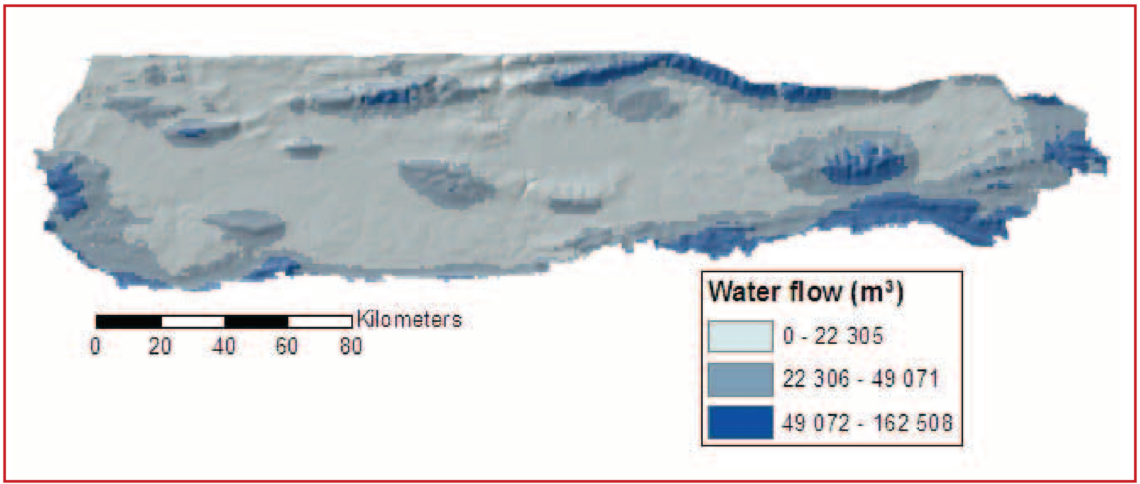


**Figure A10. Water-flow regulation: volume of water provided by a 1 km$^2$ grid in the Little Karoo of South Africa.** The map is transposed over a digital elevation model for illustrative purposes. Source: Reyers *et al*. (2009).

## Storyline

*The Little Karoo is a water limited environment with water availability restricting rangeland production, as well as dryland and irrigated farming, which are the basis of the economy (Le Maitre and O'Farrell 2008). A number of previous studies have used the volume of water as a measure of the service of water provision (van Jaarsveld et al. 2005, Chan et al. 2006), but we have used a narrower definition because the volume is largely a function of the amount and distribution of rainfall (Bosch and Hewlett 1982, Calder 1998). We focus on two distinct and interlinked roles the ecosystem plays in the service of water provision: water flow regulation and water quality regulation (de Groot et al. 2002). The ecosystem service was mapped as millions of* $m^3$ *of groundwater recharge per 1* $km^2$ *grid cell. Change in water-flow regulation was also calculated. Compared with potential service supply, water-flow regulation was calculated as declining by 18% (i.e. there had been an 18% decline in potential volume of sustained flows; see Figure 3 in Reyers et al. 2009).*

## Data

### Data sources, collection & management

Data used for this indicator includes a map of vegetation types produced by Vlok *et al*. (2005). Mapped at a 1:50 000 scale it comprises 369 vegetation units which have been mapped on the basis of their floristic composition. The vegetation units were classified into 32 habitat types relevant to the agricultural and wildlife industries in the region, by considering their physiognomy as well as the floristic component of the vegetation units. These habitat types were classified into high, medium and low erosion hazard areas using expert consultation. The spatial extent of land transformation and degradation of the Little Karoo has also been mapped at a 1:50 000 scale (see Figure 1 in Thompson *et al*. 2009). This map depicts areas of pristine vegetation and transformed (cultivated and urban) areas, and importantly, it also maps moderately and severely degraded areas. Data on groundwater recharge were extracted from DWAF (2005). Data on ground water quality were extracted from borehole water analyses stored in the Water Management System database of the Department of Water Affairs and Forestry. The results were summarized by the primary lithology taken from the 1:1 million geological data (Council for Geosciences 1997).

Data were collated from existing data on vegetation types, ground water recharge and ground water quality and were integrated to develop the indicators.

## Data custodians

The Council for Scientific and Industrial Research (CSIR), South Africa.
CSIR Environmentek
PO Box 395
Pretoria, 0001. South Africa
http://www.csir.co.za/index.html

## Data access and availability

Data can be obtained online from Biodiversity GIS: http://bgis.sanbi.org/index.asp?screenwidth=1280.

## Methods used/Calculation procedure

In mapping water-flow regulation as a service, data on both water flow regulation and water quality regulation was used. The former is a function of how much water infiltrates the soil, passes beyond the root zone and recharges the groundwater stored in the catchment (Sandström 1998). Infiltration is primarily regulated by the texture of the soils (rapid in sandy soils and slow in clays) and inputs from the vegetation and fauna which maintain the soil porosity and protect it from the erosive forces of raindrops and unhindered surface runoff (Dean 1992; Ludwig *et al*. 1997; Bruijnzeel 2004). From the human use perspective, the most important component of the water flows is the sustained flows which meet needs in the dry season and also increase yields from storage dams. One measure of sustained flows is the river baseflow which is the main component of the flow during the dry season and is typically generated by groundwater discharge (Farvolden 1963). The most appropriate dataset for estimating these flows was gridded data on groundwater recharge extracted from DWAF (2005). This estimate combines data on rainfall, geology (lithology) and estimates of recharge (e.g. from chloride profiles) to provide a grid on recharge depth at a 1x1 km resolution. These estimates take into account losses due to evaporation from the soil, interception and transpiration of soil water by plants (i.e. green water), but not the losses during the groundwater discharge into rivers (e.g. through riparian vegetation).

In mapping the water quality component of the service, data on the relationship between geology (primary lithology) and ground water quality (electrical conductivity) was used because high sodium chloride (salinity) concentrations make the water unfit for domestic use. Data on ground water quality were extracted from borehole water analyses stored in the Water Management System database of the Department of Water Affairs and Forestry. The results were summarized by the primary lithology taken from the 1:1 million geological data (Council for Geosciences 1997). Formations where the Electrical Conductivity exceeded the target water quality range for acceptability for domestic water supplies (DWAF 1996) were used to identify and exclude areas where water quality was deemed unacceptable for domestic consumption. High certainty was assigned to these well understood and peer reviewed data.

### Data units

Millions of $m^3$ of groundwater recharge per 1 $km^2$ grid cell.

### Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)

### Most effective forms of presentation

Maps accompanied by narrative text and measures of change.

### Status

The indicator was developed by CSIR as part of their work on mapping ecosystem services of the Little Karoo in South Africa.

### Limitations of the indicator

This indicator was developed to highlight areas important to water management and also to assess losses of vegetation cover in areas of high importance. Data would need to be collected over time to make this indicator more useful and complemented with field measurements to replace some of the modelled information.

### Sources/References


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- Bruijnzeel, L. A. (2004). Hydrological functions of tropical forests: not seeing the soil for the trees? *Agriculture, Ecosystems and Environment.* **104:** 185–228.
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- Council for Geosciences. (1997). *1: 1 000 000 scale geological map of the Republic of South Africa and the Kingdoms of Lesotho and Swaziland.* Council for Geoscience, Pretoria, South Africa.
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- de Groot, R., Wilson, M. A. and Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics.* **41:** 393–408.
- DWAF (Department of Water Affairs and Forestry) (1996). *South African Water Quality Guidelines: Domestic Water Use* (2nd Edition Volume 1). Department of Water Affairs and Forestry, Pretoria, South Africa.
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- Le Maitre, D. C., Milton, S. J., Jarmain, C., Colvin, C. A., Saayman, I. and Vlok, J. H. J. (2007). Landscape-scale hydrology of the Little Karoo: linking ecosystems, ecosystem services and water resources. *Frontiers in Ecology and the Environment.* **5:** 261–270.

- Ludwig, J. A., Tongway, D. J., Freudenberger, D. O., Noble, J. C. and Hodgkinson, K. C. (eds). (1997). *Landscape ecology, function and management: principles from Australia's rangelands*. CSIRO Publishing, Melbourne, Australia.
- Reyers, B., O'Farrell, P. J., Cowling, R. M., Egoh, B. N., Le Maitre, D. C. and Vlok, J. H. J. (2009). Ecosystem services, land-cover change, and stakeholders: finding a sustainable foothold for a semiarid biodiversity hotspot. *Ecology and Society.* **14:** 38. [online] Available at: <http://www.ecologyandsociety.org/vol14/iss1/art38/>
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- Thompson, M., Vlok, J. H. J., Rouget, M., Hoffman, M. T., Balmford, A. and Cowling, R. M. (2009). Mapping land transformation in a heterogeneous environment: a rapid and cost effective approach for assessment and monitoring. *Journal of Environmental Management.* **14(1):** 38.
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- Vlok, J. H. J., Cowling, R. M. and Wolf, T. (2005). A vegetation map for the Little Karoo. Unpublished maps and report for a SKEP project supported by Grant No 1064410304. (Cape Town, Critical Ecosystem Partnership Fund).


## 11. CARBON STOCK IN CENTRAL SUMATRA

**Ecosystem Service Type:** Regulating

**Ecosystem Service Sub-Category:** Climate regulation

**Type of Indicator:** Condition

**Lead Agency:** World Wildlife Fund (WWF)

**Scale of Appropriate Use:** Sub-national

**Key Policy Question:** What is the estimated amount of carbon currently stored in a landscape or the amount of carbon sequestered over time in Central Sumatra?

### The Indicator

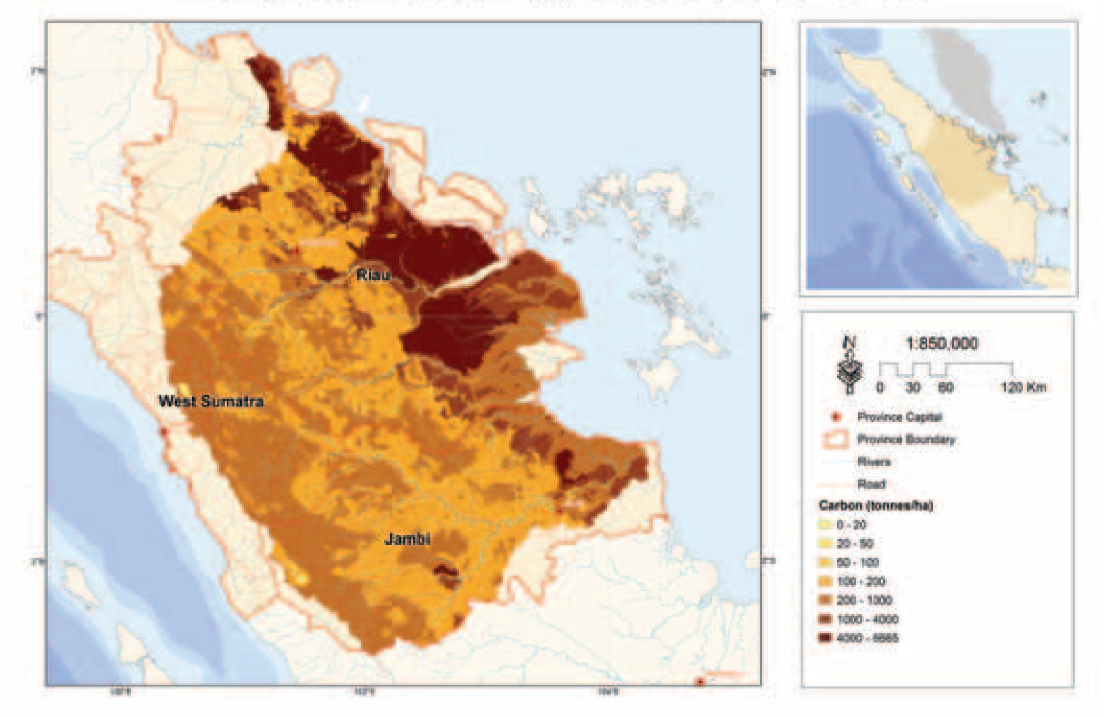


**Figure A11. Carbon stock map based on land cover in Central Sumatra.** Source: Tallis *et al*. (2010).

## Data

**Data sources, collection & management**

The data sources for this indicator include: 1) 2008 landuse/landcover map of Sumatra based on Landsat imagery; 2) Uryu, Y. *et al*. (2008). Deforestation, forest degradation, biodiversity loss and $CO_2$ emissions in Riau, Sumatra, Indonesia. WWF Indonesia Technical Report, Jakarta, Indonesia. [online] Available at: <http://assets.panda.org/downloads/riau_co2_report__wwf_id_27feb08_en_lr_.pdf>; and 3) SEAMEO-BIOTROP (1999). Distribution of above ground Biomass and C-Stock according to vegetation type in Jambi Province. Unpublished presentation.

### Data custodians

WWF-Indonesia
Kantor Taman A9 Unit A-1
Kawasan Mega Kuningan
Jakarta 12950
http://www.wwf.or.id/en/

WWF-USA
World Wildlife Fund
1250 Twenty-Fourth Street, N.W.
P.O. Box 97180
Washington, DC 20090-7180. USA
http://www.worldwildlife.org/home-full.html

### Data access and availability

Data available upon request from WWF-Indonesia and WWF-US.

## Methods

**Methods used/Calculation procedure**

Tier 1 carbon model of InVEST software. Carbon storage on a land parcel largely depends on the sizes of four carbon 'pools': aboveground biomass, belowground biomass, soil, and dead organic matter. The InVEST Carbon Storage and Sequestration model aggregates the amount of carbon stored in these pools according to the land use maps and classifications produced by the user. Aboveground biomass comprises all living plant material above the soil (e.g. bark, trunks, branches, leaves). Belowground biomass encompasses the living root systems of aboveground biomass. Soil organic matter is the organic component of soil, and represents the largest terrestrial carbon pool. Dead organic matter includes litter as well as lying and standing dead wood. A fifth optional pool included in the model applies to parcels that produce harvested wood products (HWPs) such as firewood or charcoal or more long-lived products such as house timbers or furniture. Tracking carbon in this pool is useful because it represents the amount of carbon kept from the atmosphere by a given product. Using maps of land use and land cover types and the amount of carbon stored in carbon pools, this model estimates: the net amount of carbon stored in a land parcel over time; the total biomass removed from a harvested area of the parcel, and the market and social values of the carbon sequestered in remaining stock. Limitations of the model include an oversimplified carbon cycle, an assumed linear change in carbon sequestration over time, and potentially inaccurate discounting rates. Biophysical conditions important for carbon sequestration such as photosynthesis rates and the presence of active soil organisms are also not included in the model.

### Data units

Tonnes/hectare

### Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)

### Most effective forms of presentation

Maps of change under alternative scenarios
Tradeoff curves

### Status

The indicator was developed as part of the Natural Capital Project (http://www.naturalcapitalproject.org/home04.html).

### Limitations of the indicator

Tier 1/2 estimates could be improved through direct measurements.

### Sources/References


- Tallis, H.T., Ricketts, T., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Pennington, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Lonsdorf, E., Kennedy, C. (2010). *InVEST 1.005 beta User's Guide*. The Natural Capital Project, Stanford.


## 12. SEDIMENT RETENTION MAP OF CENTRAL SUMATRA

**Ecosystem Service Type:** Regulating

**Ecosystem Service Sub-Category:** Erosion regulation

**Type of Indicator:** Condition/Function

**Lead Agency:** World Wildlife Fund

**Scale of Appropriate Use:** Sub-national

**Key Policy Question:** What is the capacity of a land parcel to retain sediment in Central Sumatra?

### The Indicator

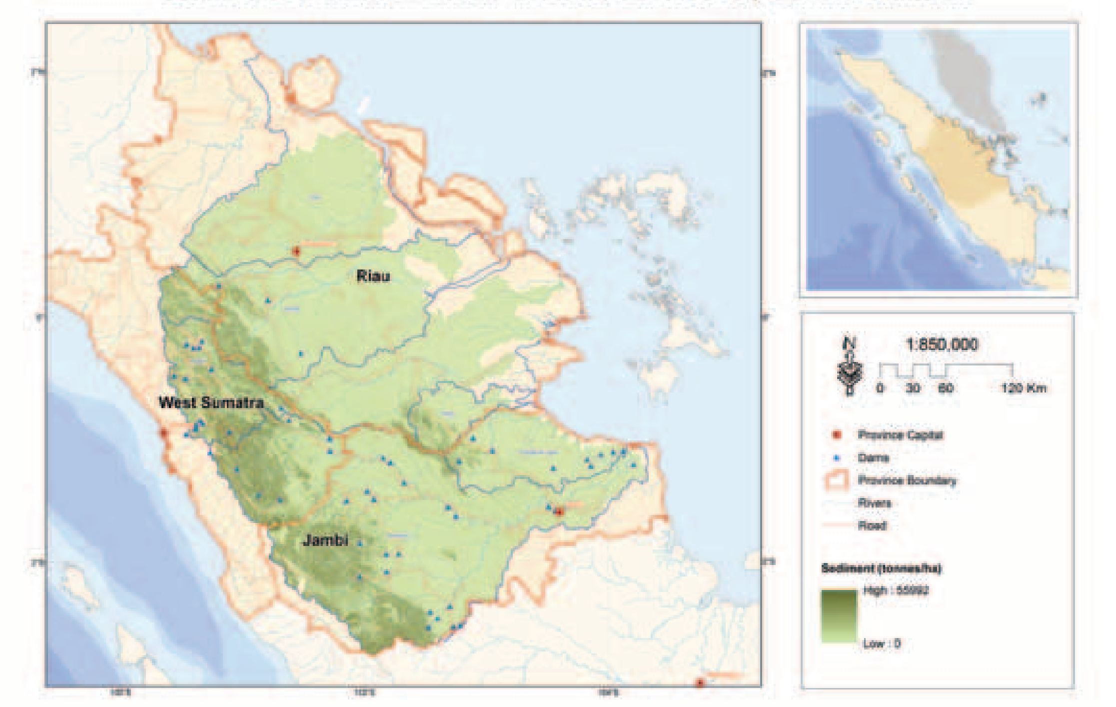


**Figure A12. Sediment retention map based on 2008 land cover in Central Sumatra.** Source: Tallis *et al*. (2010).

## Data

**Data sources, collection & management**

The data sources for this indicator include: 1) 2008 landuse/landcover map of Sumatra based on Landsat imagery; 2) monthly precipitation data from the Tyndall Centre (http://www.cru.uea.ac.uk/~timm/grid/CRU_CL_2_0.html); 3) elevation data from HydroSHEDS (http://hydrosheds.cr.usgs.gov/); 4) erosivity and erodibility from Indonesian government sources. The data used to produce the map are spatially explicit.

## Data custodians

WWF-Indonesia
Kantor Taman A9 Unit A-1
Kawasan Mega Kuningan
Jakarta 12950
http://www.wwf.or.id/en/

WWF-USA
World Wildlife Fund
1250 Twenty-Fourth Street, N.W.
P.O. Box 97180
Washington, DC 20090-7180. USA
http://www.worldwildlife.org/home-full.html

## Data access and availability

Data available upon request from WWF-Indonesia and WWF-US.

## Methods

**Methods used/Calculation procedure**

Tier 1 sediment retention model of InVEST software. The Avoided Reservoir Sedimentation model provides the user with a tool for calculating the average annual soil loss from each parcel of land, determining how much of that soil may arrive at a particular point of interest, estimating the ability of each parcel to retain sediment, and assessing the cost of removing the accumulated sediment on an annual basis. An important determinant of soil retention capacity is land use and land cover. To identify a land parcel's potential soil loss and sediment transport, the InVEST Avoided Reservoir Sedimentation model uses the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) which integrates information on Land Use/Land Change (LULC) patterns and soil properties, as well as a digital elevation model, rainfall and climate data. Using additional data on reservoir location and the avoided cost of sediment removal, it values a land parcel's capacity to retain sediments. The avoided cost of sediment removal is the savings due to the reduced need for sediment removal as a result of upland vegetation and watershed land use practices. To optimise watershed planning, the model allows comparison of avoided sediment removal costs for different land management scenarios.

## Data units

Tonnes/hectare/year

## Technology used/Systems in use

Statistical approaches
Geographical Information Systems (GIS)

## Most effective forms of presentation

Maps of change under alternative scenarios
Tradeoff curves

## Status

The indicator was developed as part of the Natural Capital Project (http://www.naturalcapitalproject.org/home04.html).

## Limitations of the indicator

Tier 1 annual average needs ground truthing. Does not show seasonal variation.

### Sources/References


- Wischmeier, W.H. and Smith, D. (1978). Predicting rainfall erosion losses: a guide to conservation planning. USDA-ARS Agriculture Handbook, Washington DC.
- Tallis, H.T., Ricketts, T., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Pennington, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Lonsdorf, E., Kennedy, C. (2010). *InVEST 1.005 beta User's Guide*. The Natural Capital Project, Stanford.


## 13. DEMAND FOR POTABLE WATER BY ALL SECTORS IN TRINIDAD AND TOBAGO, 1997 TO 2025

**Ecosystem Service Type:** Regulating

**Ecosystem Service Sub-Category:** Water Purification and Waste Treatment

**Type of Indicator:** Condition (modelled Function)

**Lead Agency:** The Ministry of Planning and Development of Trinidad and Tobago
Environmental Management Authority of Trinidad and Tobago

**Scale of Appropriate Use:** National

**Key Policy Question:** What is the quality of Northern Range watersheds in Trinidad and Tobago?

### The Indicator

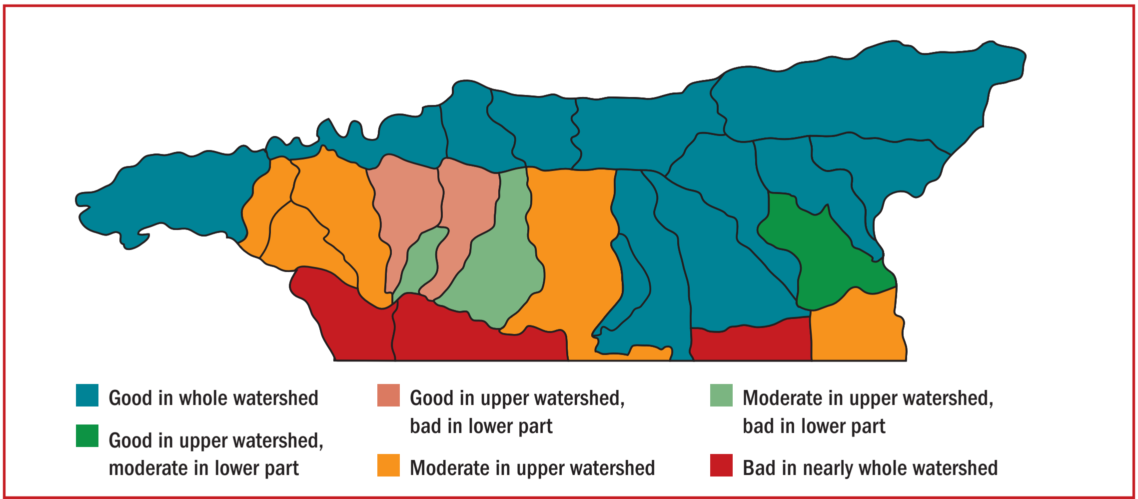


**Figure A13. Assessment of watershed quality (1999).**
Source: DHV Consultants BV (1999); Northern Range Assessment (2005).

### Storyline

*The quality of Northern Range watersheds is generally good in the eastern region and moderate towards the modified western region.*

### Data sources, collection & management

Data used to calculate this indicator was from an assessment of watershed quality of Northern Range watersheds based on expert judgement carried out by DHV Consultants BV in 1999 for the Ministry of Planning and Development of Trinidad and Tobago to input into the Water Resources Management Strategy for Trinidad and Tobago.

### Data custodians

DHV Consultants BV
P.O. Box 1132
3800 BC Amersfoort
The Netherlands
http://www.dhv.com/Home

The Ministry of Planning, Housing and the Environment
(Formerly, The Ministry of Planning and Development of Trinidad and Tobago)
44-46 South Quay
Trinidad and Tobago
http://www.mphe.gov.tt/home/index.php?option=com_frontpage&Itemid=1&lang=en

### Data access and availability

Data available upon request from the Ministry of Planning, Housing and the Environment (formerly The Ministry of Planning and Development) of Trinidad and Tobago.

### Methods used/Calculation procedure

Assessment of watershed quality based on expert judgement and mapping.

### Data units

Technology used/Systems in use
Assessment of watershed quality based on expert judgement

### Most effective forms of presentation

Map

### Status

The indicator was developed by DHV Consultants BV in 1999 as part of a study on the Water Resources Management Strategy for Trinidad and Tobago carried out for the Ministry of Planning and Development of Trinidad and Tobago. The indicator was subsequently used by the Environmental Management Authority of Trinidad and Tobago as part of the Northern Range Sub global Assessment of the Global Millennium Ecosystem Assessment in 2005.

### Limitations of the indicator

The indicator is based on expert judgement which may be subjective. Moreover, this is not an indicator and can only be considered a baseline. This is because much of the data presented in this indicator are from one-off studies rather than ongoing monitoring. Utility of this indicator as an indicator of change may be enhanced if parameters are measured repeatedly over time, and as methods for mapping ecosystem services are developed further.

### Sources/References


- DHV Consultants BV. (1999). Water Resources Management Strategy for Trinidad and Tobago, Main Report. Submitted to the Ministry of Planning and Development, Government of Trinidad and Tobago. 167 pp.
- Water Resources Management Unit (WRMU) (2002). Draft National Water Resources Policy 2002. A Water Vision for Trinidad and Tobago. Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago. 28pp.
- Northern Range Assessment (2005). Report of an assessment of the Northern Range, Trinidad and Tobago: People and the Northern Range. State of the Environment Report 2004. Environmental Management Authority of Trinidad and Tobago. 184pp.


## 14. VISITOR NUMBERS TO NORTHERN RANGE SITES IN TRINIDAD AND TOBAGO, 1997 TO 2002

**Ecosystem Service Type:** Cultural Service

**Ecosystem Service Sub-Category:** Recreation and Ecotourism

**Type of Indicator:** Benefit

**Lead Agency:** Forestry Division (Government of Trinidad and Tobago)
Environmental Management Authority (EMA) of Trinidad and Tobago

**Scale of Appropriate Use:** National

**Key Policy Question:** What was the number of visitors to Northern Range Sites for 1997–2002 in Trinidad?

## The Indicator

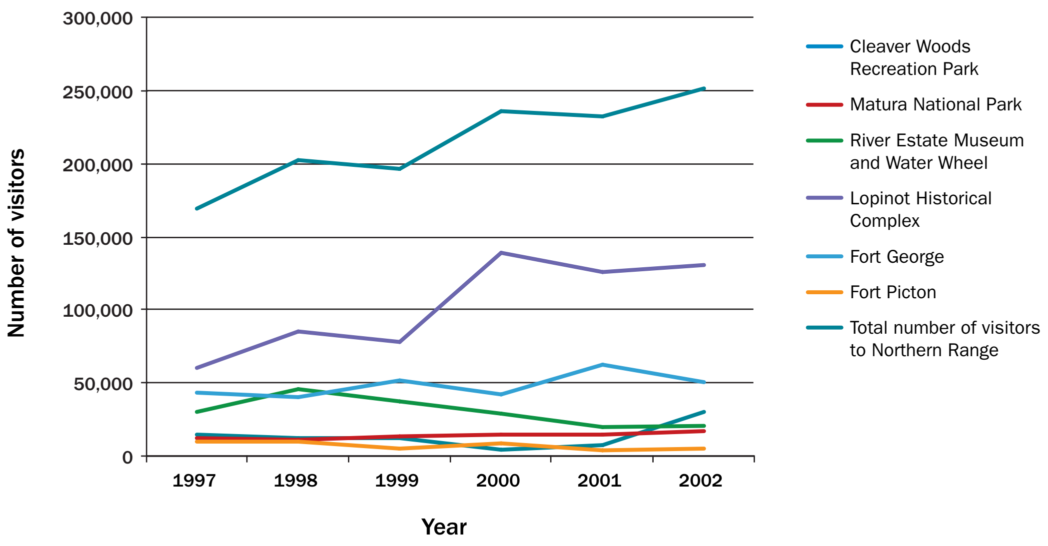


**Figure A14. Summary of visitor numbers to Northern Range Sites for 1997–2002.** These figures include schools, communities, families, foreigners, researchers, and varied groups, and thus can potentially represent the recreational value and the educational/research value of Northern Range sites. Source: Northern Range Assessment (2005).

### Storyline

*Although the number of local visitors cannot be distilled from total visitors to some of the National Parks, the figures indicate the interest and therefore value of the cultural services provided by the Northern Range. The overall number of tourists increased steadily from 1997 to 1998. This was followed by a slight dip in the total number of tourists in 1999 and then a steady increase from 1999 to 2000. In 2001, the number of visitors slightly decreased and then increased again steadily in 2002. It remains difficult, however, to compare the economic returns from such use with those from other competitive uses such as the sale of timber.*

### Data

**Data sources, collection & management**

Data used to calculate this indicator are from Trinidad and Tobago Forestry Division. The figures include schools, communities, families, foreigners, researchers, and varied groups, and thus can potentially represent the recreational value and the educational/research value of Northern Range sites. Each site takes head counts at entries to the visitors' centre at the locations.

### Data custodians

Forestry Division (Government of Trinidad and Tobago).
Long Circular Road
P.O. Box 30
St. James, Port of Spain
Trinidad and Tobago

### Data access and availability

Data available upon request from the Trinidad and Tobago Forestry Division.

### Methods

**Methods used/Calculation procedure**

Simple addition by site.

### Data units
Number of visitors per year.

### Technology used/Systems in use
Log books and MS Office Excel.

### Most effective forms of presentation
Line graph

### Status
The indicator was developed by the Environmental Management Authority of Trinidad and Tobago as part of the Northern Range Sub global Assessment of the Global Millennium Ecosystem Assessment in 2005.

### Limitations of the indicator
The number of local visitors cannot be distilled from total visitors to some of the National Parks.

### Sources/References

- Forestry Division (1998). Annual Report 1997. Ministry of Agriculture, Land and Marine Resources, Government of Trinidad and Tobago. 93pp.
- Forestry Division (1999). Annual Report 1998/1999. Ministry of Agriculture, Land and Marine Resources, Government of Trinidad and Tobago. 55pp.
- Forestry Division (2002a). Annual Report 1999/2000. Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago. 64pp.
- Forestry Division (2002b). Annual Report 2000. Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago.
- Forestry Division (2002c). Annual Report 2001. Ministry of the Environment, Government of Trinidad and Tobago. 59pp.
- Forestry Division (2003). Annual Report 2002. Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago. 68pp.
- Northern Range Assessment (2005). Report of an assessment of the Northern Range, Trinidad and Tobago: People and the Northern Range. State of the Environment Report 2004. Environmental Management Authority of Trinidad and Tobago. 184pp.


## 15. EVAPOTRANSPIRATION AS AN INDICATOR OF WATER FLUX

**Ecosystem Service Type:** Supporting

**Ecosystem Service Sub-Category:** Water Cycling: Water Flux

**Type of Indicator:** Function

**Lead Agency:** N/A

**Scale of Appropriate Use:** Regional and National

**Key Policy Question:** What is the condition, status or trends of the water cycle? How could observed changes in the water cycle impact on other services?

## The Indicator

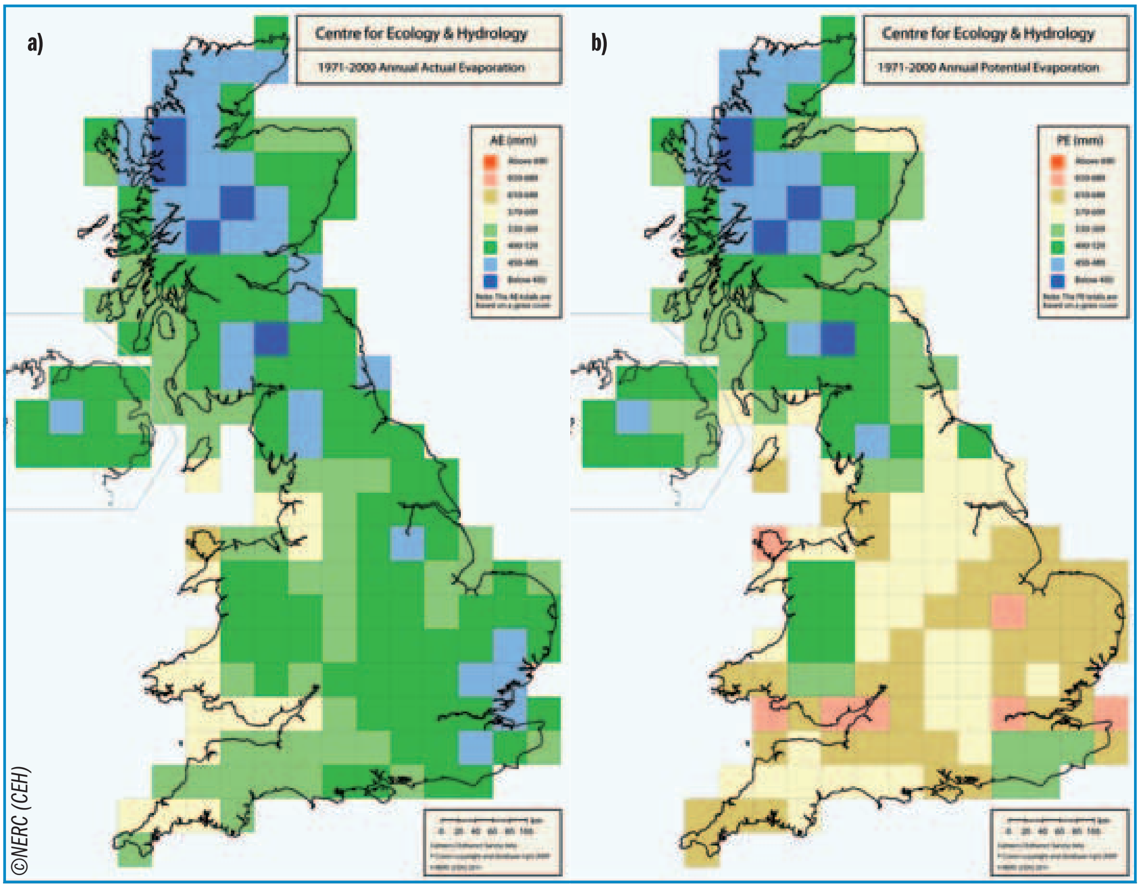


**Figure A15: Great Britain average a) annual Potential Evaporation (PE), and b) Actual Evaporation (AE) totals, 1971 to 2000.**
Source: Met Office MORECS.

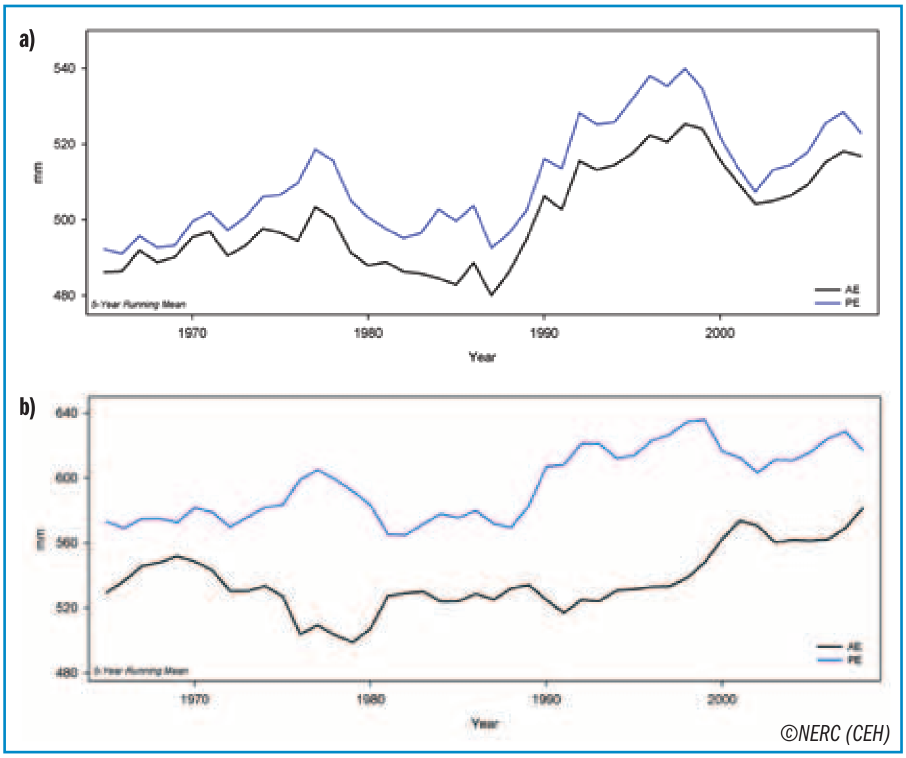


**Figure A16: Annual Potential Evaporation (PE) and Actual Evaporation (AE) totals in (a) England and Wales and (b) Scotland.** Source: Met Office MORECS.

### Storyline

*Water flux indicators (e.g. rainfall, evapotranspiration, and river flow) can be used to assess condition, status and trends of the water cycle, an important supporting ecosystem service. Estimation of the flux of water lost in gaseous form as evapotranspiration (ET) largely represents rainfall minus runoff. The flux is highly variable over the scale of a few metres and depends on factors such as plant cover and surface wetness. The UK 50 Met Office Rainfall and Evaporation Calculation System (MORECS) provide assessments of potential and actual evaporative losses for 40x40 km squares throughout Great Britain These assessments indicate that, on average, over 40% of UK rainfall is lost to evaporation, although the proportion varies greatly regionally, reaching around 80% in the driest parts of the English Lowlands (Hough and Jones 1997).*

### Data sources, collection & management

Met Office Rainfall and Evaporation Calculation System (MORECS).

### Data Collection and Management

Meteorological variables, including hours of sunshine, air temperature, vapour pressure, wind speed and rainfall, are collected by the network of weather stations throughout the UK. MORECS uses these daily synoptic weather data to provide estimates of weekly and monthly evaporation and soil moisture deficit, in the form of averages, over 40x40 km squares.

### Data custodians

Met Office
FitzRoy Road, Exeter
Devon EX1 3PB
United Kingdom
enquiries@metoffice.gov.uk

### Data access and availability

Data can be made available on request. Fees may apply.

### Methods used/Calculation procedure

Daily potential evapotranspiration (PE): is calculated for each grid square for a range of surface covers from bare soil to forest using a modified form of the Penman-Monteith equation. For more details and equations, see Hough and Jones 1997.

Actual evapotranspiration (AE): PE estimates are converted to estimates of AE by progressively reducing the rate of water loss from the potential value to zero as the available water decreased from a fraction of its maximum value to zero. For more details and equations, see Hough and Jones 1997.

### Data units

Millimetres

### Technology used/Systems in use

### Most effective forms of presentation

Maps or line graphs

### Status of the indicator

The indicator was used in the UK National Ecosystem Assessment.

### Limitations of the indicator

Models still have a degree of uncertainty associated with them.

### Sources/References


- Hough, M.N. and Jones, R.J.A. (1997). The United Kingdom Meteorological Office rainfall and evaporation calculation system: MORECS version 2.0. – an overview. *Hydrology and Earth Systems Science.* **1(2):** 227-239.
- Bardgett, R.D., Campbell, C.D., Emmett, B.A., Jenkins, A. & Whitmore, A.P. (2011). Supporting Services. In: The UK National Ecosystem Assessment: Technical Report. UNEP-WCMC, Cambridge.

## 16. NET PRIMARY PRODUCTION IN THE MARINE ENVIRONMENT

**Ecosystem Service Type:** Supporting

**Ecosystem Service Sub-Category:** Primary Production: net (marine) primary production

**Type of Indicator:** Condition (modelled F)

**Lead Agency:** Plymouth Marine Laboratory

**Scale of Appropriate Use:** Regional, National, Global

**Key Policy Question:** What are the trends in levels of primary production in the marine environment? How could this impact on other services?

### The Indicator

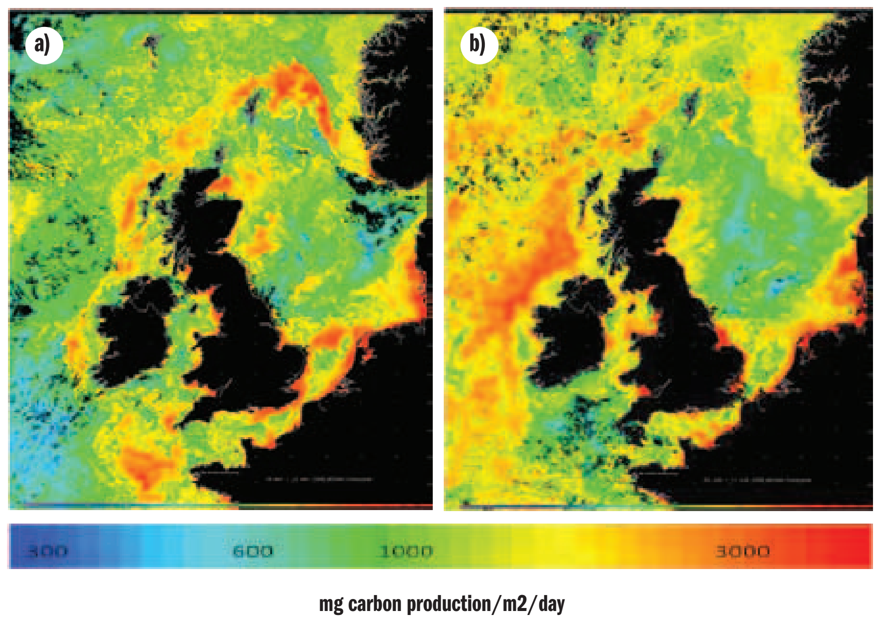


**Figure A17. Seven day 'composites' produced from the NASA MODIS Aqua instrument received at NEODAAS-Dundee and processed at NEODAAS-Plymouth for a) 16th–22nd May and b) 5–11th June 2009.** The estimates of primary production use the model of Smyth *et al*. (2005) and are probably overestimated close to the coast in the southern North Sea. Source: Plymouth Marine Laboratory.

### Storyline

*In marine systems, the patterns of primary production of coastal waters can be determined as a product from Earth observation methods, and so the spatial and temporal patterns of primary production can be identified in UK marine waters. For example, the images in Figure A17 indicate how the spring blooms of primary productivity (green areas) start on the shelf, and then move into deeper waters in the ocean as the season progresses.*

### Data sources, collection & management

In the UK, estimates of net primary production are produced from satellite-derived chlorophyll *a* and sea-surface temperatures, and measured for modelled irradiance by the Plymouth Marine Laboratory (PML).

### Data custodians

Plymouth Marine Laboratory
Prospect Place
The Hoe
Plymouth
United Kingdom
PL1 3DH
forinfo@pml.ac.uk

### Data access and availability

Data can be made available on request.

## Methods used/Calculation procedure

The estimates of primary production use the model of Smyth *et al*. (2005) which is forced by phytoplankton chlorophyll *a* which absorbs light for photosynthesis, temperature which affects the rate of growth of the phytoplankton, and irradiance on the sea-surface and its attenuation with depth which depends on the optical constituents in the water.

## Data units

milligrams carbon/m$^2$/day

## Technology used/Systems in use

Satellite remote sensing and modelling.

## Most effective forms of presentation

Satellite image maps

## Status of the indicator

The indicator was used in the UK National Ecosystem Assessment.

## Limitations of the indicator

The current model allows for in-water absorption by water, phytoplankton and its associated by-products, including co-varying coloured dissolved organic matter (CDOM). However, the model does not account for the effects of suspended particulate matter (notably in the Thames estuary, southern North Sea, Bristol Channel) nor CDOM from riverine sources (such as in the Baltic outflow along the Norwegian coast or in Liverpool Bay). In these areas, primary production is likely to be overestimated. Work at PML is aiming to improve these coastal estimates.

## Sources/References


- Smythe, T.J., G.H. Tilstone and S.B. Groom. 2005. Integration of radioactive transfer into satellite models of ocean primary production. *Journal of Geophysical research – Oceans*. **110:** C10014.
- Bardgett, R.D., Campbell, C.D., Emmett, B.A., Jenkins, A. & Whitmore, A.P. (2011). Supporting Services. In: The UK National Ecosystem Assessment: Technical Report. UNEP-WCMC, Cambridge.