Toolkit for Ecosystem Service Site-based Assessment

(TESSA)

VERSION 1.1

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Overview

Developing the toolkit

This toolkit has been developed, thus far, through three projects: a Cambridge Conservation Initiative (CCI) project entitled ‘Measuring and monitoring ecosystem services at the site scale: building practical tools for real-world conservation’; a BirdLife International / Darwin Initiative project entitled ‘Understanding, assessing and monitoring ecosystem services for better biodiversity conservation’; and an AXA Research Fund project entitled “Quantifying the risks caused by habitat loss: a practical toolkit for informed decision-making”.

The work has been coordinated by researchers and conservation biologists from: Anglia Ruskin University, Birdlife International, Cambridge University, Royal Society for the Protection of Birds and UNEP-World Conservation Monitoring Centre, with input and guidance generously provided by over 50 other individuals.

The methods and approaches presented in the toolkit have been tested at 15 sites to-date (2013), including in Nepal, Cambodia, India, UK, Montserrat, Grand Cayman, Ecuador and Fiji across temperate and tropical forest and wetland habitats. A peer-reviewed overview of the methods was published in the scientific literature in 2013 (see Peh et al. 2013 at http://dx.doi.org/10.1016/j.ecoser.2013.06.003). In 2014, there are plans for further testing at a number of additional sites.

Though the toolkit is designed with practicality in mind, the users still need scientific understanding on basic sampling principles and statistics, and computing skills. It is important that the users do not use this toolkit as a blueprint and should make adaptations according to their circumstances.

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Summary

- Ecosystem services are the benefits that people receive from nature—for example, the production of food, the provision of clean water, and the regulation of climate, as well as opportunities for cultural, spiritual and recreational experiences.

- In recent history there has been a big decline in biodiversity as a result of human activities, and species are becoming extinct much faster than at any time in the past. Ecosystem services have also changed markedly, and many are in a reduced or degraded state.

- Recognising that these changes affect us, there is a growing interest in ecosystem services, from academics and conservationists to policy-makers, economists and finance ministries. This has led to a rapid expansion of the literature seeking to define, measure and value ecosystem services.

- Measuring ecosystem services can therefore strengthen arguments for conserving important sites for biodiversity.

- This toolkit is designed to provide practical guidance on how to assess and monitor ecosystem services at the site scale without substantial technical expertise and financial resources.

Purpose and Scope

- Understanding the impacts of actual and potential changes in state at individual sites on ecosystem services is important to promote better planning decisions to support both biodiversity conservation and ecosystem service delivery.

- Until now this approach has been relatively little used because it appears that ecosystem services are technically difficult and expensive to measure.

- This toolkit is designed to overcome this obstacle by providing practical guidance for conservation practitioners on how to identify which services may be significant at a site of interest, what data are needed to measure them, what methods or sources can be used to obtain the data and how to communicate the results.

- The toolkit emphasizes the importance of making comparable estimates for the most likely alternative state of the site (for example, after conversion to agriculture) so that decision-makers can assess the net consequences of such a change, and hence the benefits of conservation for human well-being.

- One-off ecosystem service assessments may provide useful information to advocate for the conservation of a site, but repeated assessments over time permit monitoring of trends in ecosystem service delivery. The methods in the toolkit are intended to be simple enough that they could be combined with straightforward approaches for monitoring state (condition), pressures

(threats) and responses (management) at sites, as part of a monitoring programme to provide indicators about ecosystem services over time.

The toolkit has attempted to find a balance between simplicity and utility of developing convincing information for decision-makers and therefore excludes consideration of some of the more advanced concepts in ecosystem services. This is so that it can be carried out by non-experts, yet still provide scientifically robust information. For details on some of the complexities that have not been incorporated into this toolkit, refer to Annex 2.

Why use this toolkit

To date, much of the work on ecosystem services has been either global or regional often producing sophisticated maps that may or may not relate well to the situation on the ground. This toolkit focuses on the site-scale to respond to the need to bring this type of work down to the operational scale (e.g. a mountain, a reserve) using information gathered locally.

Many other projects working on similar approaches, such as the Natural Capital Project (through InVEST), require much greater technical skill and resources and are designed more for the academic user.

This toolkit is novel, useful and distinct because:

- it focuses on site-scale assessments making it relevant for local decision-making and, when scaled up, for wider communication too
- it is accessible to non-experts and conservation practitioners on the ground
- it is provided as a 'user manual' in a simple workbook structure
- it is relatively low cost to implement compared to many other methods
- it produces results that are often based on real field measurements, rather than scenarios
- it delivers scientifically robust results fit-for-purpose

What the toolkit currently covers

- Methods for assessing global climate regulation, flood protection, water provision, water quality improvement, harvested wild goods, cultivated goods and nature-based recreation
- Worked examples on how to derive a value (economic and/or quantitative) for each service
- Guidance on how to pull together the service-by-service data into an overview of ecosystem service change at a site-level

- Guidance on assessing the distributional aspects of ecosystem services provided to local, national and global communities and advice on how to disaggregate the values at the local level in to measures that reveal potential inequities in the costs borne and benefits received by individuals.

What the toolkit can and cannot do

✓ Help users with limited capacity (technical knowledge, time) and resources (money, people) to measure ecosystem services

✓ Provide insights into the overall value of ecosystem services at sites, and a way of comparing these to services at similar sites that have been altered

✓ Provide scientifically robust information on ecosystem services—*a first step* which can guide practitioners on whether more detailed studies would be useful

✓ Indicate who will be the 'winners' and who will be the 'losers' as a result of any change in state of the site and ecosystem service delivery

✓ Help decision-makers appreciate the true value of nature, and the consequences of destruction and degradation of natural habitats

✗ Assess *all* ecosystem services (five are covered so far)

✗ Provide full economic valuations (although some monetary values can be calculated)

✗ Provide ecosystem service assessments suitable for Payment for Ecosystem Service (PES) schemes and Reducing Emissions from Deforestation and Forest Degradation (REDD+) projects

What the toolkit will contain in future releases

- Improved economic valuation methodology (including discounting)
- Coastal protection services (e.g. protection from storm events)
- Classification of the methods according to different levels of uncertainty associated with each one (using a 3 code system such as very confident → moderately confident → less confident)
- More guidance on how to use this toolkit in a monitoring programme
- Time investment guidance for each method based on the field trials
- Additional case studies and examples

Who this toolkit is for

This toolkit has been designed primarily for use by conservation practitioners and those with an interest in supporting better biodiversity conservation through ecosystem service arguments. However, we acknowledge that there are multiple interests in ecosystem services as the ability to understand the impacts of land use and habitat change is critical to many sectors. We therefore recognise that the methodology here will be applicable to a wide range of users such as natural resource managers (e.g. forestry, fisheries, water managers), land use planners, development organisations (e.g. for poverty alleviation) and many others.

The methods included here are designed to be applicable to users from developing and developed countries, and across all terrestrial and wetland habitats.

Although this toolkit is designed to be accessible to non-experts, understanding ecosystem services can still be fairly technical and some training may be needed, e.g. from others who have used the toolkit before, or who have previous experience of assessing ecosystem services.

Skills required

Good understanding of English (note that the toolkit may be translated in the future)

Some scientific training – to understand basic sampling methods, statistics and production of graphs

Some training in, or understanding of, socio-economic methods if the study intends to look at the distribution of benefits and costs within communities

Competent computer skills and a good level of numeracy

Resources required

Computer

Access to the internet (LAN connection)

Field equipment (refer to individual service sections for details)

Available staff to conduct the work

Time required

This toolkit has been piloted at 15 sites to date. The time spent for data collection at these sites ranges from 13 person-days (Phulchoki mountain forests, Nepal) to 60 person-days (Parque Nacional Llanganates, Ecuador), with a mean of 37 person-days per site. This was the total time spent by all members of the survey team on planning, data collection, data entry, running rapid appraisal and co-ordinating community workshops. It does not include time spent on data analyses, writing-up of reports and communication. Therefore the estimated minimum is two months of staff time per site.

Note that for assessments that aim to take into account socio-economic issues (differentiation) at the local level, work to collect information on relevant socio-economic and cultural variables among local beneficiaries may require substantially longer.

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Section 1. Introducing ecosystem services: key concepts

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1.1. What are ecosystem services?

Ecosystem services are the aspects of ecosystems that, actively or passively, produce human well-being. They include the formation of soils, the provision of clean water, the production of crops, the regulation of climate and opportunities for recreation.

The rich variety of life on Earth—'biodiversity'—is important for human survival and well-being in many ways, from pollinating crops to providing wild-harvested fish and timber. These benefits that people derive from nature are provided by 'ecosystem services'. Ecosystem functions and processes (e.g. soil formation) underpin services (e.g. crop production), which in turn provide goods (e.g. food), often in conjunction with other inputs (e.g. labour) (see figure 1).

There are other ways of conceptualising ecosystem services, such as the framework developed by the Millenium Ecosystem Assessment (MEA 2005) which classified services into four categories: provisioning, supporting, regulating and cultural services. Although this clearly demonstrates the diversity of services that contribute to human well-being, its application risks double-counting services that may combine to provide one single benefit.

This revised framework therefore makes the distinction between services that produce 'goods', other less tangible benefits to people, and the ecosystem functions and processes that underpin the production of these services. Ecosystem services can then be valued in monetary (market and non-market) and non-monetary terms to demonstrate their contribution to economic, health and social well-being.

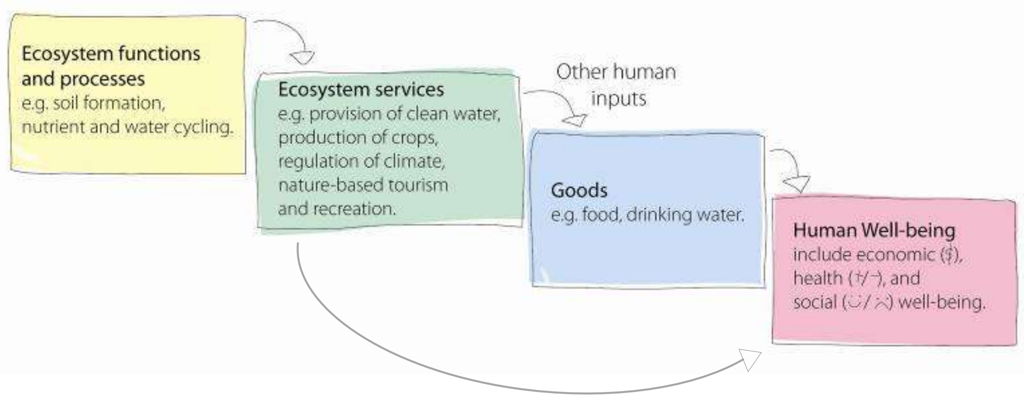

Figure 1. Conceptual framework of ecosystem services. Ecosystem services are produced as a result of ecosystem functions and processes and in turn provide goods and other benefits for human well-being. Ecosystem services represent non-use and non-material outputs from ecosystems and goods represent use and material outputs that have value for people. Adapted from Haines-Young and Potschin (2010).

Ecosystems can be seen to provide 'assets' (often referred to as natural capital). In simple terms, this is a stock which, if managed sustainably, has the ability to provide a continuous flow of ecosystem services. Although both stocks and flows can be assessed and valued, studies must distinguish between the two. Previous work has often confused this issue, with some valuing stocks and others valuing flows without explicitly noting the fundamental difference. This distinction is important when it comes to valuation studies as the relationship between stocks and flows is likely to be complex and non-linear (Vira and Adams 2009). This toolkit provides methods that quantify both stocks and flows but detailed analysis of the relationship between these two aspects of ecosystem services is beyond its scope.

1.2. Why measure ecosystem services?

Biodiversity loss and ecosystem damage is occurring at an unprecedented rate and is having a negative impact on human livelihoods. Information on ecosystem services can help to communicate the value of nature to decision-makers in the hope of reversing this trend.

Conservationists have long been advocates for the protection of biodiversity, often through the designation and effective management of key sites (a site means simply 'a management unit' with a defined boundary). These are commonly identified based on their importance for certain species, emphasising their degree of threat and/or irreplaceability (uniqueness). However, some decision-makers do not listen to these arguments, which emphasise the intrinsic value of biodiversity and associated ethical reasons for its conservation. Hence, the case for conservation can be informed if the relationship between biodiversity and ecosystem services (see figure 2), and the importance and value of ecosystem services provided by sites important for biodiversity, are better understood.

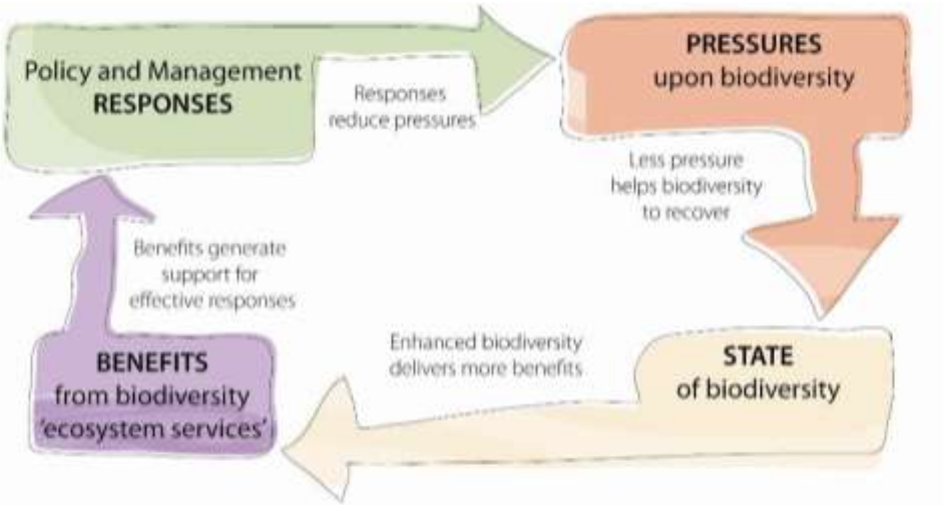

Figure 2. The relationship between ecosystem services ('benefits from biodiversity') and the state of, pressures upon and responses for biodiversity. Biodiversity provides many benefits to people via ecosystem services. The provision of these services is linked to the state of biodiversity, which is itself influenced by the largely human pressures on biodiversity. Policy and management responses from the local to the national level can reduce such pressures, and the case for implementing appropriate responses can be strengthened if decision-makers understand the importance and value of benefits from biodiversity. Reproduced with permission from Sparks et al. (2011).

Recognising this link, there is a growing interest in ecosystem services, from academics and conservationists to policy-makers, economists and finance ministries. This has led to a rapid expansion of the literature seeking to define, measure and value ecosystem services.

- For example, the Millennium Ecosystem Assessment (2001-2005), involving more than 1,360 experts worldwide, provided a state-of-the-art scientific appraisal of the condition of and trends in the world's ecosystems and the services they provide.

- More recently, The Economics of Ecosystems and Biodiversity (TEEB, 2010), a major international study, drew attention to the global economic benefits of biodiversity, and highlighted the growing costs of biodiversity loss and ecosystem degradation.

In 2010, the world's governments adopted a new strategic plan (2011–2020) through the Convention on Biological Diversity (CBD) with 20 targets for addressing biodiversity loss, including a number that relate to ecosystem services (see examples in box).

CBD Strategic Plan for Biodiversity 2011–2020

Strategic 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.

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.

Measuring and monitoring ecosystem services can:

- **lead to better planning** decisions to support both biodiversity conservation and ecosystem service delivery

- identify and inform management strategies to **enhance economic sustainability and human well-being**

- **provide information on additional benefits** from traditional approaches to biodiversity conservation

- identify those affected by land use management decisions, and so help **spread the costs and benefits** more fairly among stakeholders

- provide information to **raise awareness and build public and government support** for evidence-based policy and management decisions.

An example of where ecosystem services work has made a difference

Mabira Forest Reserve is an Important Bird Area holding around 300 bird species including the Endangered Nahan's Francolin *Francolinus nahani*. In 2007, NatureUganda (BirdLife in Uganda) conducted an economic valuation of Mabira Forest Reserve as part of a successful campaign against a proposal to convert 7,186 ha of this IBA into sugarcane. The study demonstrated that along with its high biodiversity value the combined annual value of ecosystem services from the intact forest is considerably larger than the projected annual revenue from sugar cane. It showed that this area is an important water catchment for downstream populations and provides benefits to the large population living around the forest who sustainably harvests forest products for their livelihoods. This evidence was presented to decision-makers and has resulted in the continued protection of the Forest Reserve.

A word of warning: In most situations not all ecosystem services can be maximised at once. Hence there will be 'trade-offs' between them. In some situations, ecosystem service delivery may conflict with biodiversity conservation objectives. For example, conversion or degradation of a site might enhance one especially valuable service (e.g. biofuel production) or provide an immediate one-off benefit (e.g. timber extraction) while causing population declines or local extinctions of species reliant on the site. In such circumstances, it should be emphasised that many people appreciate and value the existence of certain species. This, in addition to ethical and non-anthropocentric arguments for the conservation of species and the need for long term sustainable solutions, can also justify conservation action. Ecosystem service arguments should therefore not be considered in isolation from other arguments for conservation, but should be used as an additional tool to advocate for conservation where most relevant.

1.3. The need to consider a plausible alternative state

In some cases, conservation action can benefit both biodiversity and the delivery of ecosystem services. In others, conversion or degradation might destroy biodiversity while enhancing a particular service or providing an immediate one-off benefit. Assessments of the difference resulting from changes in land-use can be more useful to decision-makers than single state values.

Simple assessments of the value of a particular service or services at a site are a useful first step to understanding the importance of a site for delivering benefits to people. However, decision-makers are likely to be concerned with the social, ecological and economic consequences of their decisions, and so also need to know the difference between the amount of the ecosystem service(s) provided by a site in its current state compared to a plausible alternative one, where the habitat is converted (e.g. to agriculture), or in which resources are unsustainably exploited (e.g. through overfishing). This encourages them to consider whether conservation delivers greater benefits than conversion to other land-uses. If this is the case, then information on ecosystem services can be used to support the conservation of a site (e.g. when under threat from conversion or development) or the restoration of a site (e.g. rehabilitating logged forest or polluted or drained wetlands). Additionally, when aggregated at national or regional scales, data on ecosystem services at multiple sites could also support arguments for the expansion and enhanced management of protected area networks.

Economists refer to this alternative state as a ‘counterfactual’, but here we simply label it as the ‘alternative state’ of a site.

Definition of an alternative state: A plausible and often simplified description of how the future may develop based on the best available current information and a coherent and internally consistent set of assumptions about key driving forces (e.g., availability of appropriate technology, market prices) and relationships. Alternative states are usually neither predictions nor projections and sometimes may be based on a “narrative storyline”.

Identifying the most plausible alternative state will often require consideration of the impact of actions and decisions that lead to a change in management, land cover, land use or habitat quality at a site. This may affect the delivery of ecosystem services as well as the conservation of species. For example, changes may occur to habitat types (e.g. forest conversion to agriculture) or to land use (e.g. rice crops being replaced by tea plantations) or in habitat quality (e.g. pollution of waterways, climate change impacts etc.).

The policy and management context at a site, and the most likely threats, need to be well understood before any decision is taken on what the alternative state should be. Each site will have a unique set of ecological, political and social attributes that need to be considered. The main objective of this toolkit is to provide ecosystem service arguments in support of biodiversity conservation at a site, so selection of an alternative state should have this objective as the main focus. For example, there may be various threats to the site as a result of human activities in the surrounding areas. One way of arguing for conservation of the site is to explore how the delivery of ecosystem services from the site would have changed if conservation and protection measures had not been implemented in the past.

Since this toolkit is based on empirical measurements, it is important to find a real place which represents the alternative state at which to take measurements. Nearby sites that have already undergone change can be used to infer likely future changes, but it is important that the comparison site is as similar in other ways to the focal site as is reasonably possible (Figure 3). If the sites are in very different locations in the water catchment or have very different human settlement densities around them, for instance, then differences in the services they provide need not necessarily be due to differences in land-use. In some cases, no suitable alternative site will be found (e.g. suitable alternative wetland sites can be difficult to find) but it may be possible to assess the likely change in services at the site using information on projected changes (e.g. changes following an upstream water abstraction scheme at a wetland site).

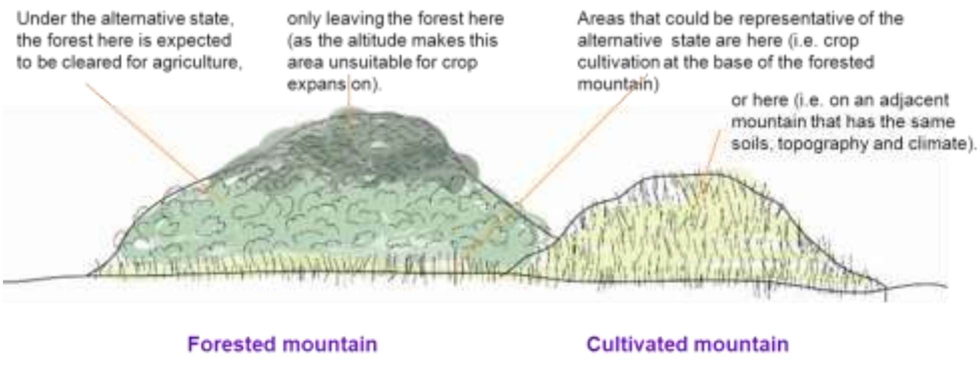

Figure 3. How to decide where to take measurements for the alternative state.

Using this toolkit in relation to climate change:

Climate change is highly relevant to work on ecosystem services as the impact that climate change has on biodiversity and habitats will directly affect the people that rely on the services that they deliver. However, since climate change models are based on theoretical projections we have not included these models into discussions about the plausible alternative state, which is based on real change in a current location that could represent the alternative at the site.

Despite this, we recognise that some users may find it useful to think of their alternative state under a climate change projection and could substitute the suggested alternative state with a climate change scenario, if appropriate.

1.4. Capturing benefits and identifying beneficiaries

An ecosystem service only exists if someone somewhere is benefitting from it. The way in which ecosystem services are captured by people depends on a number of social, political and ecological factors. Often the distribution of benefits, and the impacts of change, may not be equitable. It is essential to understand who the beneficiaries are so that the full consequences of changes in ecosystem services can be assessed.

In order to assess the value of ecosystem services at a site, the beneficiaries have to be identified, including all people who derive benefits from the ecosystem. These beneficiaries may live within the site where the service is produced, adjacent to the site, outside the natural borders of an ecosystem (e.g. people living beyond the borders of a water basin can still travel to enjoy recreation in that water basin) and even beyond regional or national borders (figure 4). The capture of these benefits also depends on a number of other factors such as socio-economic characteristics, political rules and regulations, markets, preferences and culture.

A. B. C. D.

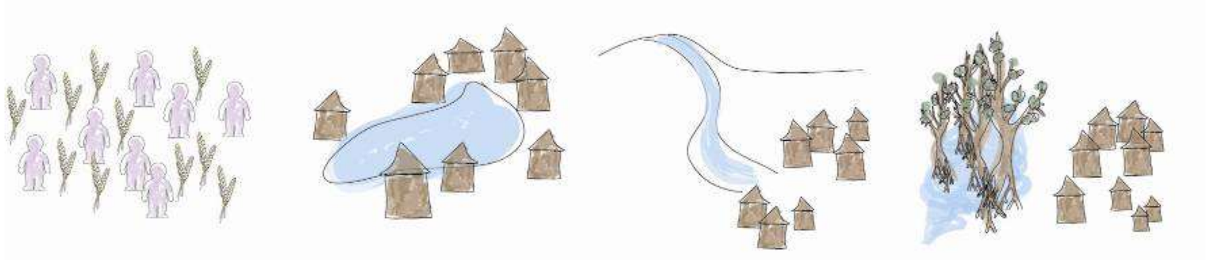

Figure 4. Diagrammatic representation of the spatial relationships between human beneficiaries and service production. (A) The beneficiaries and service production occur at the same location (e.g. soil production for farmers). (B) Beneficiaries are located around the location where services are provided omni-directionally (e.g. villagers around a lake and provision of food from the lake, respectively). In other cases the service flows in a particular direction. For example, (C) inhabitants receive fresh drinking water from the upland catchment area; and (D) mangrove forests protect landward villagers from a typhoon. This figure is adapted from Fisher et al. (2009).

Changes in the delivery of ecosystem services will therefore have different impacts on different users (beneficiaries) depending on who they are, where they live and how and when they use the services. These impacts are often overlooked but are one of the most important aspects of any assessment of ecosystem services. Although economic **valuation** is a useful indicator, many national-level decision-makers will also be interested in the **distribution** of the benefits from a particular site (see 1.6), and the **number of beneficiaries**.

Analyses should consider the equitable delivery of services, and which users stand to gain or lose from a particular land management decision. In some cases, those who bear any costs of ensuring the delivery of ecosystem services (often land owners or land managers who forego benefits from e.g. conversion of forest to farmland) may need to be compensated by those who will benefit most (often referred to as 'Payment for Ecosystem Services'), to enable a sustainable and ethically fair outcome. Considering the difference in delivery of services is not just relevant across different spatial scales (see 1.5) but also within an identified spatial group of beneficiaries (e.g. 'people living locally to the site'). Changes to the provision of ecosystem services can have very different impacts on individuals in that community, as access to and control over resources (and alternatives) is determined by factors such as land ownership, gender, culture, ethnicity and social status (Daw et al. 2011). In this toolkit we provide advice on how to assess whether there are significant differences in the benefits and costs distributed among members of the 'local' community (i.e. people living within and adjacent to the site).

1.5. Ecosystem services in space and time

Ecosystem services flow in space and time – benefits may be captured both on- and off-site and may be delayed in time. For many services, there is a finite supply related to the amount of natural capital 'stock'. It is important to consider the spatial and temporal characteristics of services and the sustainability of services when determining the scale and scope of assessment.

Ecosystem services in space

The spatial scale of analysis will often be influenced by the (political) scale of decision-making.

Nevertheless, it is important to study any site at a scale relevant to the delivery of a service. Ecosystems services may be produced and delivered both on- and off-site. For example, recreational opportunities are enjoyed on-site, while hydrological services may be delivered off-site and downstream. Hydrological services are therefore often best considered at least at a regional scale and might require consideration of processes beyond the boundaries of the site.

The spatial scale has some practical implications for ecosystem services assessment. Mitsch and Gosselink (2000) explain that local scale services–such as recreation, fishing, on-site water quality improvements–are often easier to estimate because they are more directly related to specific stakeholders at easily defined locations, whereas middle scale, regional ecosystem services–such as flood mitigation, storm break protection, agriculture–are bound to regions and large scale biosphere services. Global climate mitigation and cultural heritage are even more difficult to estimate as they may be important to the entire world. The impact of local and short-term land-cover changes may also be diluted where beneficiaries are more distant because the effects are spread over space.

Ecosystem services over time

When measuring ecosystem services in the current and alternative states, it is important to consider the sustainable delivery of ecosystem services. This is often an issue for provisioning services such as harvesting of wild species to provide food, timber, medicines and other products. Unsustainable rates of exploitation can be attractive, as they deliver immediate economic or social benefits. Sustainable use thresholds are less obvious or easy to measure for regulating, cultural and supporting services but overexploitation can also be an issue here, for example, chronic degradation of mangroves could compromise storm protection services and water sources can be overused risking future supply. For the purposes of encouraging responsible decision-making, considering the long-term delivery of these services is vital.

Sustainability

Natural capital is the term used to indicate the importance of assets provided by natural systems from which ecosystem services arise (Costanza *et al.* 1997). These capital assets have the ability to provide a continuous flow of services, provided that these flows are utilised sustainably. There are a number of definitions of 'sustainable' in the context of harvesting wild species. One useful definition is that 'harvested populations cannot show a consistent decline in numbers' (Robinson and Bennett 2004). Following the onset of harvesting, population density usually declines, but if the harvest is greater than annual production then the decline will continue and the harvest is unsustainable. The relationship between stocks and flows is complex and non-linear (Vira and Adams 2009). Sustainability will depend on a number of factors, including biological and life history characteristics of the harvested species, and the socio-economic context of the harvest. For example, small, fast growing species with high reproductive rates and short lifespans (e.g. rodents) will tend to allow a greater level of sustainable exploitation (i.e. larger harvests or greater off-take) than large, slow-growing species with low reproductive rates and long lifespans (e.g. primates). Where harvesters have strong tenure and are able to exclude others, harvested populations may be better managed than in areas where their resource is essentially open access (Tictkin 2004). The challenge for those interested in assessing the service flows from a natural ecosystem is firstly to identify whether a given extracted good is being sustainably harvested, and secondly to decide how much of the value of an unsustainable harvest to count as a service provided by the ecosystem. There is no agreed way on how to achieve this but we provide some guidance on this in Part III.

One-off benefits

It is important to consider whether there are any immediate and short-term one-off benefits that might arise from the focal site's conversion to the alternative state (such as timber obtained when a forest is cleared for farming). These benefits are of course non-sustainable, but they may be an important reason for conversion, so measuring them, and including them in the overall assessment of the consequences of conversion (alongside changes in the flows of all other measured services) is essential for understanding the overall benefits (or costs) of conservation. Use Climate method 15 to quantify one-off benefits with regard to timber felling.

1.6. Valuation approaches

Economic units are frequently used to present the value of ecosystem services in a policy relevant and accessible way. However, economic analyses can often be complex, open to interpretation, and may have inherent many assumptions, caveats and limitations which can be lost in communication. Therefore care should be taken in deciding what metrics to use. Changes in the value of ecosystem services can be represented by non-economic measures, which may be more feasible and still adequate for effective communication.

There are many components of well-being (see Figure 5). The valuation of these components is often complex and a purely economic valuation may not be the most effective way of assessing and demonstrating the benefits which society receives. Therefore, any valuation of ecosystem services should be undertaken with caution and a clear understanding of the limitations of the particular metric being used.

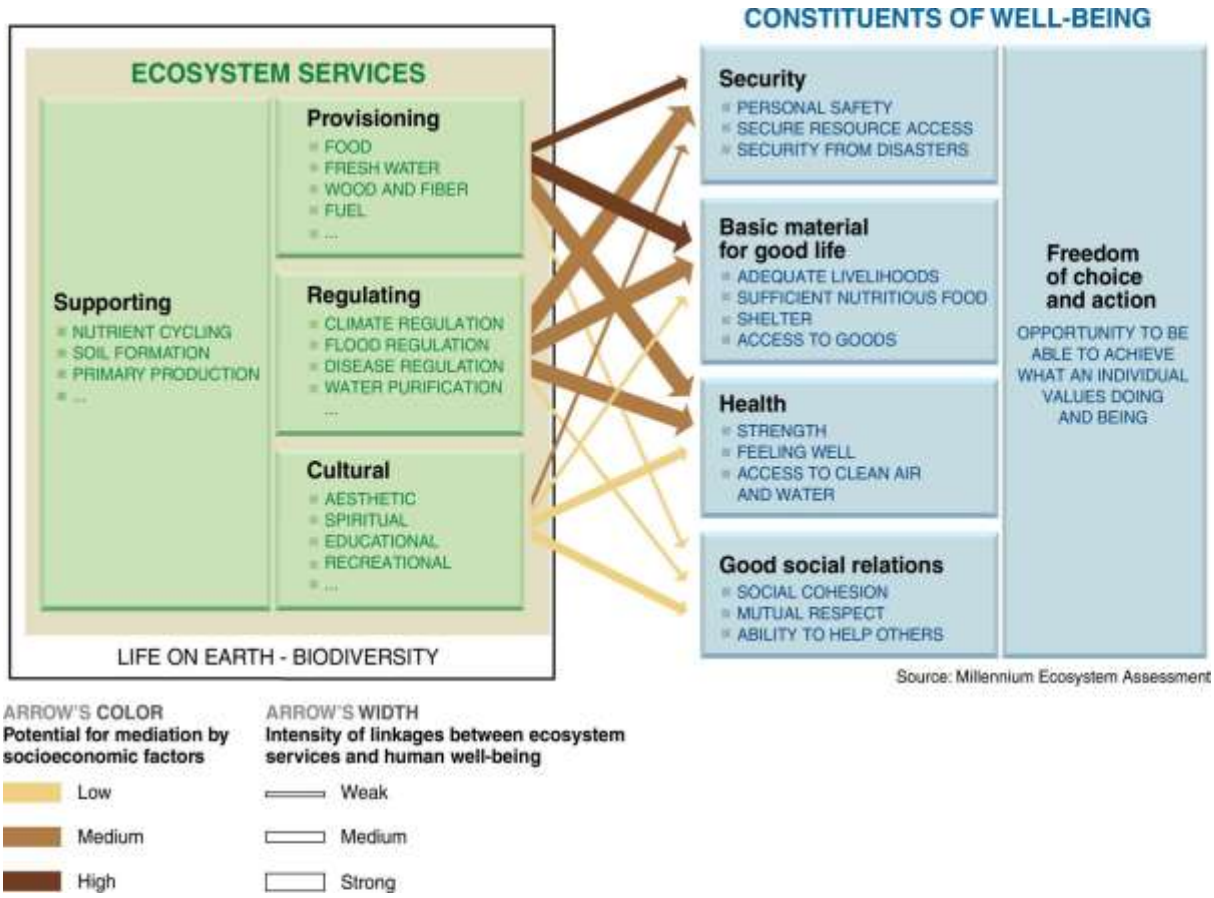

Figure 5. Contribution of ecosystem services to human well-being (adapted from the Millennium Ecosystem Assessment, 2005)

Economic valuation

We do not embrace or deter users from using economic valuation, but encourage users to be cautious with how they approach economics in this toolkit. Economic units, such as \$ ha^{-1} $year^{-1}$ for agricultural production, are frequently used in ecosystem services literature yet can often be misguided and have inherent caveats and limitations. While monetary values for ecosystem services (e.g. the dollar value of services lost or gained when the site is converted) may be most compelling for some audiences (such as finance ministries or government funders), they may be prohibitively time-consuming or expensive to obtain, and are often currently impractical to estimate for many services. In addition, comparing economic valuations of services can be problematic for detecting trends in service provision over time due to the need to consider real changes in value (not just economic) in absolute and relative terms, and changes to demand, supply, technologies, consumer preferences and need etc.

Avoiding 'double-counting'

In an ecosystem service assessment it is vital to ensure that quantification of services does not result in double-counting. This occurs if processes and services (see **Section 1.1**), as well as the ultimate goods, are considered as additive components. For example, the value of pollination and crop pest regulation (beneficial processes) are manifested through enhanced food production (a benefit) so if food production itself is being valued then pollination and crop pest regulation should not be independently valued and added to the total (Balmford *et al.* 2011). Previous studies on the valuation of services have led to so-called problems of double-counting in combining values across components. These problems can be avoided if care is taken over which services are considered for assessment (something we try to do in this toolkit).

Other units of valuation

Aside from economic valuation, changes in value can also be represented by other units such as physical units: Mg ha^{-1} for forest carbon stock; person-hours ha^{-1} $year^{-1}$ for labour employment; probabilities of events (e.g. frequency of flooding); number of people affected; or more qualitative measures such as high, medium, low. These alternative metrics may be more feasible and still adequate for effective communication (e.g. the number of days per year when a stream is flowing, the number of people whose livelihoods are impacted).

Economic valuation can be a useful indicator when looking at different beneficiaries based on measures related to socio-economic status e.g. poverty level or ethnicity. It may be useful to express economic benefits accruing to different stakeholder groups in relative terms (e.g. relative to their total income or as a percentage of their livelihood) to help highlight the dependence on ecosystem services of particular groups in society. However, in some cases the most important measurement may be the change in distribution of benefits between people (see **Section 1.4**) and it may not be appropriate or helpful to put an economic value on the service. For example, for very poor households the least commercially valuable services are often the most important and these people lack rights or access to higher value services. Very often the costs and benefits of change are distributed unevenly. For example, local people may lose out to powerful external actors living far from the site. In such cases, the data could be presented qualitatively or in terms of absolute importance to that stakeholder group. Some studies have demonstrated impact by summarising the number of people (or voters) in different categories that are impacted negatively or positively. For example, an assessment in Madagascar concluded that "continued upland **deforestation** by an estimated 50,000 slash-and-burn farmers leads to increased siltation and reduced water flows to more than 2,500,000 downstream rice farmers" (Carret and Loyer 2003).

In this toolkit, we give different options for outputting the results, some in economic terms and some in other units. In general it is often not appropriate (or possible) to sum the values of multiple services for a particular site so we advise against doing this for the purposes of this toolkit. We recognise that economic values may sometimes be essential, depending on the type of services, for estimating overall consequences of a decision, or for summing values across multiple services, to inform communication. Hence we provide some guidance in applying an economic valuation approach. We intend that further development of the methods in future versions of this toolkit will address this issue in more detail.

Section 2. Using the toolkit

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Begin the ecosystem services assessment here

This 'toolkit' has been developed to provide practical guidance on how to assess and monitor ecosystem services at the site scale. The toolkit helps the user to identify which services to assess, what data are needed to measure them, what methods or sources can be used to obtain the data, and how to communicate the results for better biodiversity conservation.

The toolkit is designed as a decision key, rather like a biological key for identifying species. It leads the user through a series of steps or questions, so that the user learns along the way. The toolkit provides specific guidance on implementing practical methods for assessing some of the services that are likely to be most important to the range of stakeholders in each ecosystem or habitat. These methods range from collecting new data from local field surveys or stakeholder workshops to using existing datasets or published studies to extract site-relevant information. **In every case, it is expected that the methods and guidance will be adapted to suit the local context.**

There are a number of important stages in applying the toolkit, each of which must be completed before moving on to the next. A key element of the process is the engagement of stakeholders from the outset and continuously throughout the study (Figure 6). Further guidance on each of these stages is provided below.

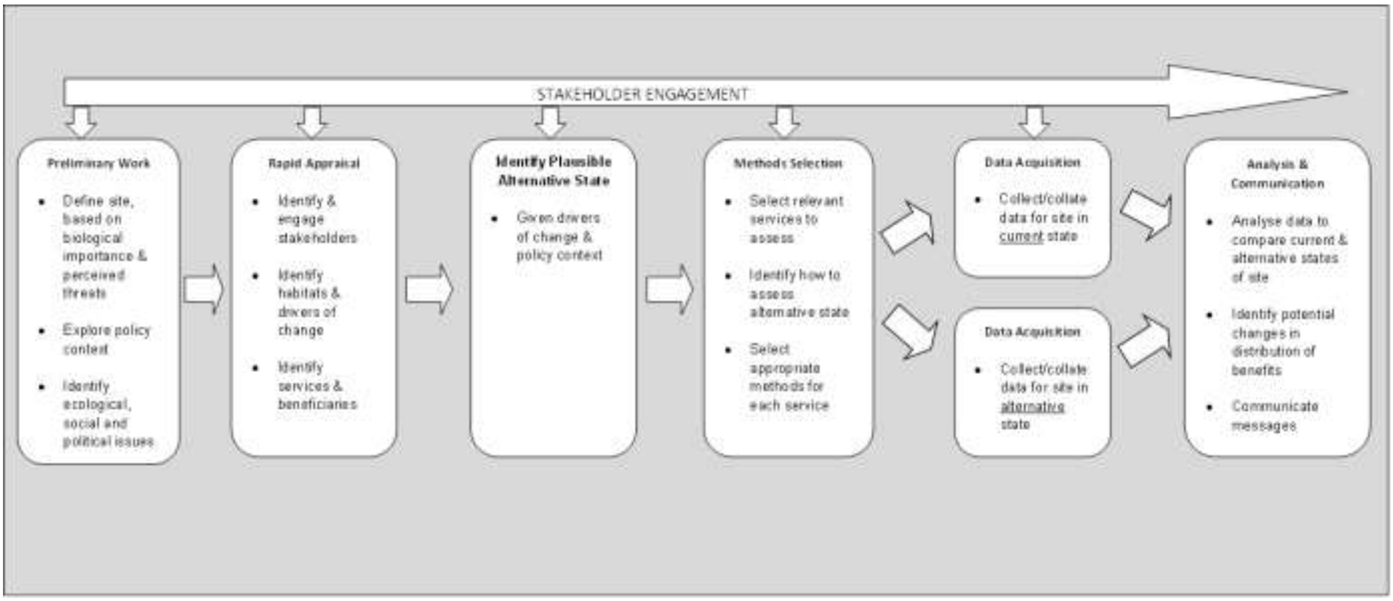

Figure 6. Outline structure of the toolkit.

The five classes of services currently covered by the toolkit are:

(i) Global climate regulation (carbon storage, greenhouse gas fluxes)

(ii) Water-related services (flood protection, water provision, water quality improvement)

(iii) Harvested wild goods (food, fibre, energy...)

(iv) Cultivated goods (crops, livestock, fish, timber…)

(v) Nature-based recreation

These services were selected because they are, in general, common across most sites where this toolkit might be used, feasible to measure, representative of a range of stakeholder interests and use and/or the best proxies for other services that at this stage are likely to be more difficult to measure. There are plans to develop similar approaches for other services in due course, but the present toolkit focuses on these classes as being both potentially important and feasible to measure with the skills and resources available to the intended users (see 'Who this toolkit is for') . Note that many other important ecosystem processes and functions will underpin these more measurable direct benefits (i.e. soil formation, nutrient cycling).

Step 1. Preliminary work

Define the site of interest. The first step in this toolkit is to define the 'site'. This is an operative or potential management unit such as a protected area, community forest, farm co-operative, Important Bird Area, Key Biodiversity Area, Alliance for Zero Extinction site etc., typically ranging in size from 100 to 1,000,000 ha (1–10,000 km^2). Note that if you have a particularly large site it is recommended that you identify a smaller area within it for your assessment and extrapolate up (if appropriate) or select several smaller, representative areas. The site must be a fixed known area with defined boundaries. A basic topographic map of the site is necessary. More detailed and technical maps will be useful if available.

Define your objective. In most circumstances, users of the toolkit (i.e. you) will not be 'neutral' unbiased participants, but will adopt a certain position. You will use the toolkit to enhance you own agenda and purpose. Start by describing your personal or professional view taking into consideration who you are and what your objectives are. What does this reflect about your own perceptions? This will help to focus attention on the objectives, and therefore the kind of information that needs to be collected and the way in which it should be communicated. Yet also based on scientific rigour, transparency and honesty.

Define your audience. Think about who you are targeting. How will that affect the data you gather, how it is analysed and the presentation of results? Depending on whom you are trying to influence, and the purposes to which you are trying to use the toolkit for, this might influence how you go about the study.

Explore policy context. Aim to get some background on the policy context. What are the local, national and international policies which are driving the decisions and processes leading to land use change at the site? These may relate to more than one sector and its associated Ministry or department (e.g. forestry, agriculture, energy, environment, transport etc.). Ministries of Finance often play a critical role across all government decisions and departments. International commitments can also drive change (e.g. under conventions on climate change [UNFCCC], biodiversity [CBD], and development [the MDGs]). Understanding this context can help you to identify who are the targets for communication (organisations and individuals), the kind of information which is needed (qualitative, economic), and the opportunities to influence decisions (planning cycles, budget processes, key meetings).

Identify ecological, social and political issues. The interactions between ecosystems and people within a site are complex. If you are not completely familiar with a site we suggest that you spend at least one week at the site in order to get to know the area, its people, rules and regulations, management programmes and biodiversity importance before you start the ecosystem services assessment as you will need to know something about the social dynamics of the site before any survey work or quantitative work is begun. For instance, at the local level resources are not always used in an equitable way.

Capturing tacit knowledge is invaluable in revealing differences between people. Talk to people regarding issues such as resources use, access and values because there may be important differences in use, access and relative importance of different services within communities. Observation is important, as well as discussion with as wide a range of local stakeholders as possible. Keep a record of observations, including the patterns of settlement, cultivation and main routes in and out of the local area. Observe the most important physical and built landmarks, and the nature of use that appears to be associated with these key features of the landscape. Find out which groups of people seem to be engaging with different elements of the landscape, and in what sorts of ways. Observe whether there appear to be any barriers to access or use, which might potentially prevent certain groups from using certain elements of the landscape.

The purpose of the ecosystem services assessment should help in deciding the most appropriate methods to use. For example, if the purpose is to inform use and management by local communities and local decision makers then a participatory approach, perhaps involving group discussions and presentation of data in qualitative terms, may be best suited. On the other hand, a different method may be more appropriate if the analysis is needed to inform policy makers at higher level (e.g. HH survey and economic analysis). In all circumstances, it is important to get the qualitative information right before collecting any quantitative data.

Step 2. Rapid Appraisal

Identifying stakeholders. Identify which are the most relevant communities of people and stakeholders to the objective of your study, as well as their main concerns, impacts and interests in the site and its services/resources. You can do this through a stakeholder analysis. The easiest way to do this is to complete a stakeholder analysis matrix, seeking input from people who are familiar with the site. Key elements to try to include in the matrix are:

- Stakeholder identity
- Their characteristics (the kind of organisation/person they are)
- Their main interests in the site
- Their main rights in relation to the site
- Their impact on the site and its services (current and future potential)
- Their priority (how important you believe they are in relation to ecosystem services and plans for the site)

In subsequent analysis and communication it makes sense to focus on the stakeholders whose interests, uses and impacts are the most important.

Engaging with stakeholders. Effective stakeholder engagement should occur throughout the entire process of doing an ecosystem services assessment. This toolkit is designed to be used in collaboration with the stakeholders at all stages of the assessment. Their contributions could include (1) identifying habitats and key services, (2) suggesting the most plausible alternative state for the site, (3) providing existing data, (4) designing data collection protocols for new data, (5) collecting new data, and (6) interpreting results.

Engaging stakeholders in the assessment process and in the interpretation of the results is vital to the effectiveness of any responses implemented as a consequence of the evaluation, as well as to more general biodiversity conservation interventions at the site. Results must be salient, credible and legitimate. We suggest that workshops or other participatory processes should be used to involve the current and potential beneficiaries from the outset as it has been shown that studies working with stakeholders, rather than portraying them as passive recipients of results are more likely to create effective uptake.

Exploring social difference. We strongly recommend that you consider issues of social and economic differentiation at site level. It is critical to understand the differentiated ways in which ecosystem services are understood, used and harnessed by stakeholders at site level. Even if you perceive that the local community around a site does not have any social differentiation, you may be surprised by what you find with a little research through simple questions.

For guidance on stratifying stakeholders (including at different spatial scales and within those spatial groupings), refer to **Guidance 1**. Identifying 'groups' – advice on how to do that (some examples of disaggregating) e.g. age, gender, ethnicity or language, caste, wealth (or basic needs assessment), residence status (migrant/resident), economic occupation, religion, land ownership/tenure, disability, level of education. Not all of these will be relevant in all cases. Make some judgement on which are most relevant in orientation stage – need to get an understanding on which of these are the important variables by which use is differentiated at the site. Use secondary information beforehand to find out some of these factors in advance. Engaging with these groups is then another skill and difficult to do.

If one of your interests is in the effect of social difference on the delivery of ecosystem services, then it will be useful to consider prioritizing important ecosystem services for which better understand socio-economic differentiation/equity issues is needed. For example, it may be relevant for cultivated or harvested wild goods which provide benefits at the local scale but be less relevant to the benefits from climate and water-related services.

Due to the nature of this toolkit, there will be a limit to how much depth a particular study can achieve within the constraints of time, cost and resources available to most users. The toolkit provides a guide only to the minimum recommended effort required to be able to say something about social differentiation between site level stakeholders. It does not replace the importance of more in-depth, embedded ethnographical methods.

Conducting a rapid appraisal. At the start of the assessment, it is important to get an overview of the site and its services through conducting a scoping assessment or 'Rapid Appraisal'. If you consider that you have enough information after this stage; or you lack the capacity in terms of time, resources or skills to continue to do the site-scale assessment work for a suite of ecosystem services, you could stop at this point and still have a good general idea of the ecosystem service value of the site.

The most basic information required by an assessment is:

- What will change in ecosystem service delivery as a result of a management or policy decision and;
- What impact will this have on different groups of people in terms of economic, health and social well-being.

For the Rapid Appraisal you will need to conduct multiple meetings with stakeholders as determined by the stratification of your groups (**Guidance 1**). Refer to **Guidance 2** on how to engage the right people at these workshops. It is particularly important to remember that not all people who use an area have an obvious 'representative' and care must be taken to discover and include such people in these workshops. It is particularly important to engage local stakeholders in this process, who live in and around the site and/or have an interest in management of the site. By holding several similar meetings with different stakeholder groups, this will be more likely to highlight areas where stakeholders have different opinions, rights, values, information etc. and which you may need to investigate further.

Different groups of beneficiaries will often value services differently. For example, local stakeholders at a tropical forest site may view the provision of bushmeat and non-timber forest products to be the most important services, and may be unaware that the site makes a significant contribution to global climate regulation through carbon storage. They may not consider this important as it is not in their immediate reality. In a similar way, other local stakeholders may view the immediate benefits of selling timber as more important than the sustained provision of harvested wild goods from the forest.

Therefore in order to begin to understand the diversity of views and relationships with a site you may need to meet with key local experts (e.g. park wardens, urban landscape planners), representatives from non-governmental organisations, representatives from government, local community representatives, user committees, etc.

The way in which you conduct the rapid appraisal with each of these groups may need to be different. For example:

a) Local users – to identify what the services/resources are that people use and then find out who has access to these. The approach you use here may be different to how you approach other groups. Use a local settlement and resource map, and ask participants to identify key features, regular routes that are used in the local area, and the main resources and their locations. Start to identify what the main ecosystem services are, and how they are accessed and used, and by whom.
b) Key informant/ site managers workshop – to understand some of the management issues at the site and some of the social and political undertones. A template for this is provided in **Section 3**.
c) Academic input / expert meeting – to understand how they view the ecological attributes of the site.

You should refer to **Section 3** when you are ready to carry out the Rapid Appraisal as it provides a template for guidance on the questions you need to ask.

The Rapid Appraisal includes the following steps:

1. **Identifying habitats and drivers of change**

   A. Determine which are the main habitat types at the site in its current state

   B. Identify the key threats currently occurring at the site that affect biodiversity and consider other drivers of change that impact on the land use and habitats in either positive or negative ways.

   C. Determine how the habitats will change in the most likely or plausible alternative state.

2. **Identify the ecosystem services at the site**

   A. Identify and rank the broad ecosystem services that are associated with the habitat types identified (using a standard list) and in the alternative state.

Standard List of Ecosystem Services (adapted from CICES available at www.cices.eu)
Global climate regulation Local climate and air quality regulation Water-related services Erosion control Coastal protection Harvested Wild Goods Cultivated Goods Biological control Recreation/ tourism Aesthetic benefits / inspiration Spiritual / religious experience

   B. Identify the most important ecosystem service benefits that are delivered by the site in the current and alternative state

   C. Get further information about the recent trends in and future perceived change in delivery of these ecosystem services under the alternative state and a preliminary assessment of how this might impact different groups of beneficiaries.

We also recommend that you obtain a list of sources of information from the group of experts that may be useful for the proceeding ecosystems services site assessment.

- Work through these steps using the template provided in **Section 3**.

Once you have completed the rapid appraisal you should decide whether to go ahead with the full ecosystem services assessment. It may be that at this stage you have a sufficient understanding of the site and the services that it delivers for your objectives. However, to continue with the full assessment, go on to Step 3 below.

It is useful to have an initial meeting to plan the approach and to develop a work plan to minimise the workload and ensure that the assessment is done as efficiently as possible.

Follow the proceeding steps and complete the workplan in **Annex 1** if this helps.

Step 3. Determine the alternative state

Define the policy change or management issue to address (Annex 1.1). The most important factor in this next stage is the consideration of a policy change or key management issue that you want to address.

Having conducted the Rapid Appraisal in Step 3 you will already have thought about the current drivers of change at the site, and this might define the 'story' that you want to communicate. If this is the case you can simply use the results from that exercise to represent the alternative state. However, there may be some other key issue or policy message that you want to highlight relating to the need for conservation at the site:

- What is the biodiversity conservation issue at this site?
- What argument do you want to make at this site?
- What policy issues do you want to address?

e.g. "How will restoration of habitats at a site impact on the value of ecosystem services delivered by the site, could this be used to persuade a company to finance the habitat's restoration, and is there an opportunity for this to be incentivised through sales of carbon credits on the voluntary market". Here, the plausible alternative state would be a place where habitat restoration has occurred.

To investigate what the key message might be, you may need a further stakeholder meeting to get expert opinion and input. The results from the Rapid Appraisal could serve as a starting point but may need to be thought through in relation to your specific objective at the site.

As stated in **Section 1.3** the conservation needs and policy implications at a site need to be well understood before any decision is taken on what the alternative state should be. Having specified the key question to address in relation to this, the characteristics of the alternative state need to be clarified.

Define the plausible alternative state (Annex 1.2). The most plausible alternative state should be a representation of a realistic and likely future change at the site based on the management or policy changes identified in Step 4 and should address the communication position that you want to make. The discussion on alternative state should always involve relevant stakeholders. When determining the alternative state, you could show images (e.g. photos) to stimulate discussion on the likely impacts of policies and processes at the site.

For example:

Q. How has community forestry impacted on the delivery of ecosystem services and biodiversity at a site over recent years?

- ➔ The current state will be the forest under community management. The alternative state will be the likely state of the forest had it not become community managed

Q. What impact would degazettement of a site have on ecosystem services in the future?

- ➔ The alternative state would be a plausible projection of how the site would change without conservation management

Q. How would restoration of a site affect ecosystem services?

- ➔ The alternative state would be a restored site

Q. How might the habitat quality of a site (e.g. wetland) change if a dam or mining operation were to be built?

- ➔ The alternative state would be an informed projection of the impact of the dam/mining on the habitats and features of the site

Note that the alternative state does not have to be land conversion per se but could be a policy change such as lifting the quota controls on fishing or installing a dam which could still have profound implications for ecosystem service flows.

A key characteristic of the alternative state is that it should be a stable state i.e. the point where the ecosystem has been altered and has reached some alternative state. Note that the time it would take to reach this end-point will be variable from relatively immediate (e.g. if a site is logged) to the longer term (e.g. if a site is subject to overharvesting of firewood causing gradual deforestation).

- ➢ Once you have agreed on this, you will need to determine the effect of this change on areas under different land cover (habitat type and use) and on habitat quality at the site. Refer back to Step 3 Rapid Appraisal (part 1C) and repeat that step.

Select where to take measurements for your alternative state (Annex 1.3). This toolkit is based on empirical measurements for alternative states rather than hypothetical scenarios. This means that as far as possible, measurements should be taken from a real place to represent the alternative condition of your chosen site. You will need to identify a site (or more than one site) that is representative of the alternative state so that real data can be gathered.

Matching sites. Although the toolkit does not provide guidance on scientific matching of sites to the level that some studies may require, it is essential that the site(s) that represent the alternative state are similar to the focal site in terms of geological and hydrological features (e.g. soil moisture regime), steepness of the terrain, rainfall intensity and pattern, proximity to beneficiaries and so on. You need to choose the substitute site carefully as there can be a number of potential differences that may not be immediately obvious (e.g., if the soil is poor in the site, it is not plausible that it will be as productive as nearby farmland with good soil; if there is a limited local market for a high-value product, it might not be plausible to assume an alternative state in which that product is grown across the entire site).

It may also be important to match the socio-economic circumstances between a site and the alternative site for comparative analysis. For this you will need to have a good understanding of the recent history (e.g. 10-20 years) of the area and know the 'direction of causality' e.g. has a change in the ecosystem led to a change in the people settled there or are changes in the ecosystem a result of differences in the communities living there (e.g. people from a different cultural or ethnic background with different customs and socio-economic practices). The latter may be unsuitable as an alternative site if communities at the study site are unlikely to adopt traditions and practices leading to an equivalent transformation of the landscape.

In many cases this will be represented by a site nearby that is under the kind of land-use that you would expect your existing site to be converted to (e.g. if some of the site is expected to be converted to rice crop production, find a site nearby that is similar to the site topographically, and which is already under rice production, and take measurements from there). If there is an area within your current site that is representative of your alternative (e.g. an area of some small-scale agriculture that you would expect to expand), this could also potentially be used as the comparison site. Refer to Figure 3 in **Section 1.3** for an example.

The comparison sites may be many small blocks of land spread over a wide area or one contiguous block of land under one land-use or mixed land-use. The site could vary in size from a few hectares to hundreds of thousands of hectares. Importantly, the spatial boundaries of the site need to be clearly defined and you need to know the area and the number of households located within that boundary. This can be done in a number of ways:

- Using Google Earth you can draw a polygon around your representative site and estimate the area. You could then estimate the cover of each habitat class within this site to get a % cover of each habitat type (see Section A2).
- If the alternative site is based on political boundaries or district boundaries it may be possible to find out from records offices what the area within your boundary is.
- Get household lists from district or village offices.

Examples of how to decide on an alternative state and where to take measurements

1. Shivapuri-Nagarjun National Park, Nepal

From field observations and discussions with the park warden and stakeholders, it was decided that the human-dominated landscapes surrounding the park represented how the land cover could potentially change if investment in park management and protection were discontinued. The most plausible alternative state of the park was agreed to be the conversion of forest (approximately c. 75%) into agricultural and residential areas. Two sites were chosen that were outside of the park boundary but within the same district. One had predominantly agricultural land use, at an altitude similar to the park; the other was mainly recent housing, in an area just outside the park boundary.

2. Phulchoki Mountain Forests, Nepal

In this study, the policy action to implement community forestry at Phulchoki in 1996 represents the ‘current state’ and the alternative state is represented by areas of adjacent national forest, which were not included within Community Forest boundaries, and which therefore indicate the ‘business as usual’ process i.e. what would have happened if no change had been made to the land tenure or management. The likely alternative state was determined through focus group discussion with participants from the local Forestry Office and Community Forest User Group members. Participants marked up a map, showing how, based on past trends, experience, and local knowledge of pressures and demands on resources, they would expect the land use and condition of different areas to change. Surveys to measure the services likely to be delivered by this alternative were conducted at two locations: one a degraded forest and one an agricultural landscape.

3. Wicken Fen Nature Reserve, UK

In this study three different types of area were used to measure ecosystem services. The site of interest at Wicken Fen includes: (a) un-drained fen habitats supporting near-natural wetland habitats on deep alkaline peats and (b) areas of peat that were drained 300 years ago and used for agriculture but have not been drained and have been returned to conservation management over the last 20 years. This second type of area is referred to as wetland restoration land but has very different biophysical characteristics to the undrained fen. Outside the site of interest at Wicken Fen there are extensive drained peat soils that continue to be drained and cultivated. Preliminary meetings with site managers, local committee members and researchers working at the site elicited a list of relevant ecosystem services. Comparisons between wetland restoration land, undrained fen and active farmland have proved useful in showing differences in ecosystem service provision by undrained peats, restored farmland and active farmland. In particular, the changes in ecosystem services that take place when drained farmland is turned into undrained wetland restoration land can be useful to support conversion of this type of land to conservation use, especially when the drained peat lands become sufficiently degraded that their agricultural value decreases.

Limitations of the alternative site approach

Using real measurements for the alternative state, wherever possible, is a unique feature of this toolkit. However, in some cases it may be difficult to find another location that represents the alternative state. In this case we suggest that you base a new assessment on projected change to your site. For example at a wetland site threatened by upstream dam construction, water inputs to the site might cause a change in water provision for people to use for cultivating crops. The site of interest could thus be re-assessed in its alternative state for cultivated goods based on plausible changes in crop species needed to cope with changed water inputs. The new alternative state may use data from modelled changes to flows included in the design report for the upstream dam to assess the likely changes to water inputs and hence crops.

For more information on the plausible alternative state, refer to **Section 1.3**.

Step 4. Methods selection

Select the relevant services to assess (Annex 1.4). The Rapid Appraisal meeting with stakeholders will provide an overview of the potentially important ecosystem services delivered by the site. However, different stakeholder groups will have different opinions and so you may find it useful to discuss the most important services with different stakeholder groups.

Note that the toolkit at present provides methods for a small subset of the ecosystem services and that not all services in this toolkit will be relevant at all sites. Careful consideration is needed to determine which services should be assessed. Besides being significant in either or both biophysical or economic terms, the services chosen should ideally be sensitive to changes in state at the site: it is less useful to measure them if their delivery is unlikely to be changed much by conversion to the most likely alternative state (see **Section 1.3**). They should also be measurable with the resources, expertise and existing data that are available, and ideally they should be monitored at repeated intervals into the future.

To decide on which services to measure, combine the information from the Rapid Appraisal with the guidance in Figure 7 below that relates the relevance of each habitat type at the site to each of the ecosystem service classes considered in this toolkit.

	Potential benefits / Ecosystem service types					
Habitat types (for definitions see Appendix 1)	**Global climate regulation** (e.g., carbon storage and sequestration)	**Water flows** (e.g., provision, regulation)	**Water quality**	**Harvested wild goods** (e.g., firewood, wild mushrooms)	**Nature-based tourism and recreation**	**Cultivated goods** (e.g., soybeans, corn, oil palm)
Natural forests (= Tree-dominated habitats)	●	●	●	●	●	○
Natural grasslands / savanna/shrublands (= Grass-dominated habitats)	○	○	○	●	●	○
Wetlands (coastal and inland)	○	●	●	●	●	●
Farmlands / agricultural lands (= Crop-dominated habitats)	○					●
Urban / built-up areas (= Developed areas)					○	○

Figure 7. Matrix showing general relationships between habitat-types and ecosystem services. This is a guide with respect to different habitats and the benefits they provide, as best available knowledge would predict. Key: black filled = high importance; black hollow = medium/low importance; blank = negligible/not relevant. Adapted from the Millennium Ecosystem Assessment (2005).

For meaningful comparisons, the evaluation of the alternative state must also include all the ecosystem services that were measured in the current state, as well as any new services the site would provide (e.g. cultivated goods - crops). Each section provides information on measuring the ecosystem services for the current state and also provides guidance on estimating the service for the alternative state.

Decide on which methods to use (Annex 1.5). There is a choice of methods for each service. Having determined which services you are going to measure, work through the relevant sections (Section B1 – B5) using the flow charts. This will direct you to the appropriate method to use. You can record this in the matrix in **Annex 1**. This means that if you need to do a stakeholder workshop for several of the services, you might consider combining this into one workshop, with sessions focusing on different services, rather than conducting a number of individual workshops which will be more time-consuming for both you and the stakeholders.

Guidance notes

Using existing data

It may be that a study has been done at the site or somewhere similar, that you can use instead of conducting more primary research that only duplicates what has been done previously. However, in using existing data, you will need to be cautious about its relevance, accuracy and reliability. There is some guidance on this in **Guidance 3**.

Consider your sampling strategy

In the majority of cases it will not be possible to survey the whole site, or whole population of users. In this case, a sample should be conducted from which you can extrapolate the data up to the whole site. For help on how to do this, refer to **Guidance 4**.

Considering uncertainty and error

Estimates of ecosystem service values or quantities provided by a site (in the current or alternative state) derived from the methods presented in this tool kit will have uncertainty associated with them. It is important to understand, quantify if possible, and communicate this uncertainty and its implications, in order for decision makers to make the best informed decisions. For further details on this, refer to **Guidance 5**.

Step 5. Collect data

Refer to Sections I – V and Section 5 for guidance and methods on how to collect the data from your site.

Step 6. Analysis and communicate the results

Refer to Section 4 for guidance on how to analyse and present your results to the relevant audience.

Once you have completed the work-plan table, go ahead to Sections 3 - 4 to measure the appropriate ecosystem services.

Section 3. Conducting the rapid appraisal

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Rapid apprasial method for site-scale ecosystem service assessments

This method will provide you with an overview of the site in relation to ecosystem services information needed for the following steps in the toolkit. It is also a good way to develop relationships with local stakeholders and to get a good initial understandins of the dynamics of the site.

After completing this appraisal, you may consider that you have enough information; or you lack the capacity in terms of time, resources or skills to continue to do the site-scale assessment work for a suite of ecosystem services, you could stop at this point and still have a good general idea of the ecosystem service value of the site.

Work through this form with you stakeholder group. We suggest that you think carefully about how to organise the meeting depending on what works best in your local context.

PART 1 – identifying habitats and drivers of change

A. Determine the most important habitat types at the site in its current state
Many (but not all) ecosystem services are delivered at the habitat level and are associated directly with particular land cover types. Identifying the area occupied by each land cover/land use at a site can therefore guide us in assessing and quantifying the ecosystem services delivered at that site.

As a first step you will need to classify the habitats at the site.
Question: Are recent land-cover / vegetation maps available for the site?

Yes – Use these maps to classify the existing habitats according to the scheme in **Appendix 1** if it is helpful. Otherwise use your own classification. BirdLife Partners refer to the IUCN Classification of habitats in Appendix 1.
No – There are a number of sources for land cover data, some of which are better than others. Three methods are outlined here:
(i) If you have GIS software you can access land cover maps from a number of sources, some of which are free to use, such as the European Space Agency Globcover Project dataset which reflects global land cover in 2005.
(ii) With access to the internet you could use Google Earth (http://earth.google.com/) to manually draw a boundary around your site and zoom in to work out the area of each habitat type.

(iii) Alternatively you could use a topographic map of the site and draw on the habitats so that their area can then be calculated.

Note: On the one hand, this map might oversimplify the actual situation on the ground; on the other, it might seem very complex. For this assessment we require a 'broad-scale' view of land cover based on your expert opinion to estimate the ecosystem services delivered by the site.

Whichever method you use, we advise that you then classify the main habitats according to the scheme in Appendix 1 and produce a table that shows the area and the percentage cover of each of the land cover classes present in the map.

Note: It is important to get as good a map as possible so this should be developed or at least verified by the group of stakeholders completing this appraisal. A bad land cover map generally means a bad / worthless product that cannot be applied at the implementation scale. Ask them to comment on the accuracy of the land cover map and associated habitat types listed in the legend, with particular reference to:

- The total area (hectares) of each land cover type
- The percentage of the site occupied by each land cover type

Complete this table which represents the agreed land cover types and areas for the site and provide a brief explanation of the site.

Land cover class	Estimated percentage cover (note these must add to 100%)	Area (ha)

Brief explanation of what the issues are (if any) with the map provided:

B. Identify the threats and drivers of change

Actions/decisions that lead to a change in management, land cover or land use at a site may affect the delivery of ecosystem services as well as the conservation of some species.

Note: Drivers (i.e. causes/factors) of change will include threats (logging etc.) but may also include impacts from management policies and positive actions by people (restoration of native tree species etc.).

Also, think carefully about how each driver of change might affect the site. Not all threats, for example, will directly influence land cover. Some will influence land use or habitat quality e.g. changing from rice crops to tea plantations, or polluting a waterway resulting in an impact on water quality and several other services affected. In addition, some threats may occur at a particular location and be spatially clear whereas others may be much more diffuse.

Describe a plausible future (10 years from now, caused by current trends at the site without intervention) by considering the following and then complete the table below[1]:

- ➔ What are the existing and potential drivers of change to the site (now or in the next 10 years)?
- ➔ How immediate are these changes?
- ➔ How likely are these changes?
- ➔ How will these drivers of change affect the habitats and biodiversity at the site in terms of area (scope)?
- ➔ How will these drivers of change affect the habitats and biodiversity at the site in terms of the magnitude of the effect within the scope (i.e. degree of habitat degradation, size of effect)

[1] Note that if an site monitoring record has been completed at the site, this information can be directly taken from the pressures that have been identified as part of that process and therefore does not need to be repeated here. However, you will need to have access to that site information to inform the remainder of this appraisal.

Table of Threats

Threats to the site (pressure)	Timing 1. Likely in long term (beyond 10 years) 2. Likely in short term (within 10 years) 3. Happening now	Scope (proportion of site affected) 0. Little of area (<10%) 1. Some of area (10-49%) 2. Most of area (50-90%) 3. Whole area (>90%)	Severity[2] (e.g. degree of habitat degradation, size of effect) 1. Low (1-10%) 2. Moderate (10-30%) 3. High (>30%)	Impact (Timing + Scope + Severity)
	(tick all that apply)			
Residential & commercial development				
Agriculture & aquaculture				
Energy production & mining				
Transportation & service corridors				
Hunting & trapping				
Logging/wood-harvesting				
Gathering terrestrial plants				
Fishing & harvesting other aquatic resources				
Human disturbance				

[2] Within the area identified by the ‘scope’ and within the next 10 years

Fire				
Water management & use				
Climate change & severe weather				
Invasive alien species				
Problematic native species				
Geological events				
Pollution				

Circle those scoring 5 or above

Conservation activities at the site **(Actions at the site)**	**Currently occurring or likely to occur in the next 10 years?**
	(tick all that apply)
Education and Awareness	
External capacity building	
Land/water management	
Land/water protection	
Law & policy	
Livelihood, economic & other incentives	
Species management	
Restoration	

C. Comparison of site under current and plausible future

This section is required in order to assess the net importance of services at your site against some alternative. The details relating to land cover areas are important for using in the next step of the toolkit which requires services to be measured according to spatial areas.

Based on the threats and actions with the greatest impact (e.g. scored at 5 and higher) identified in Table B, consider how this could affect the current land cover map over the next 10 years.

- ➔ If these changes were realised, what percentage of each habitat type would be affected?

It may help to think spatially about these changes by drawing on to the map where you think areas might be affected.

It is important to think as realistically as possible. For instance, if part of the site is very steep, or the soil very poor, agriculture may only be possible in certain areas. Or perhaps a site would be suitable for agriculture up to a certain altitude only.

In some cases, the plausible future might be the same land cover but altered in terms of quality (i.e. degraded forest or reduced wildlife populations due to over-hunting). Some of the forest area may be altered, for instance, it may become degraded to scrubland. Where this occurs may depend on the proximity to settlements.

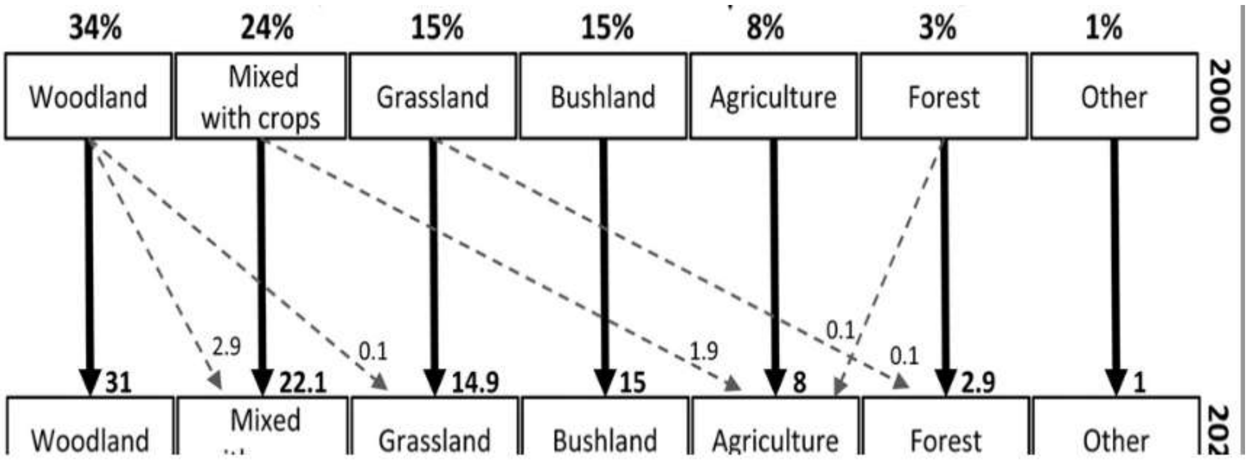
EXAMPLE

Affected current land-cover/land-use type	Expected **change** e.g. new land cover / land use / habitat quality	Main **drivers** causing this change (refer to table B threats and actions)	**Current** % cover*	**Alternative** % cover	Change in % cover
e.g. broadleaf forest	Loss of forest cover to cropland. Remaining forest quality will also decrease owing to pressures from wood harvesting.	agricultural expansion / logging / wood harvesting identified as a major threat	66%	45%	-21%
e.g. freshwater	Water of lower quality, sedimented – increasing pollution from the use of fertilisers	Pollution	34%	34%	0%

* Use the table provided or updated in A.

Affected current land-cover/land-use type	Expected **change** e.g. new land cover / land use / habitat quality	Main **drivers** causing this change (refer to table B)	**Current** % cover*	**Alternative** % cover	Change in % cover

To help visualise the changes, you could create a diagram similar to that below:



D. Overview of the site

Based on the information you entered in the previous tables in sections B and C, write a short description of the site below, using the following sub-headings:

- Current land cover
- Current and future drivers of change (in the next 10 years)
- Summary of the alternative land cover as a result of these changes
- Other important considerations for the site

This summary can be presented to the other groups(s) in the reporting back session, for discussion and verification.

PART 2 – identifying ecosystem services

The rich variety of life on Earth—'biodiversity'—is important for human survival and well-being in many ways, from pollinating crops to providing wild-harvested fish and timber. These benefits that people derive from nature are referred to as 'ecosystem services'. They can be divided into processes (e.g. soil formation) which underpin services (e.g. crop production), which in turn provide goods or 'benefits' (e.g. food), often in conjunction with other inputs (e.g. labour). In most cases, many ecosystem processes and intermediate services will underpin the provision of these final goods and benefits.

A. Determine the most important ecosystem services at the site in its current state

Firstly, identify **all** the benefits that are delivered by this site using the table below. If you think any are missing, please add them to the bottom of the list.

In the first column, score all the benefits from 0-5. 0 = not relevant; 1=of low importance; 5=highly important.

Note: 'Important' should take account of both **the number of people benefitting** and the contribution of the benefit to **economic** (the ability to earn an income and to have assets), **human** (health, education, nutrition, clean water, and shelter), **socio-cultural** (sense of place, spiritual wellbeing, recreation) and **protective** values (ability to withstand economic and external shocks). The toolkit current focuses mainly on economically important forest products. There is often a hierarchy of good that exist and it is important to understand what is meant by 'important' and for whom. Different stakeholder may rank the same service differently according to their opinion on the above elements of 'importance'.

Then, from the highest scoring benefits, agree on **five priority** benefits for the current site from your list.

Secondly, do the same for the plausible future, using your description of this and the habitats that occur, identify all the benefits that could be delivered in the plausible future and their importance (these may be the same or different to the current state, but most likely will be a combination).

As before, identify **five priority** benefits for the plausible future.

Note: The list of services below are grouped in such a way that enables you to clearly identify which services in the toolkit you may want to go on to measure. This is not the only way to classify services – there are many versions widely accepted. Please do try to follow this one for ease of use of the toolkit. There is space to add additional services if you think important ones have been missed.

Table A.

Benefits		Current state (score 0-5) 5 = highly important	Top five services in the current state (please tick five)	Plausible future (score 0-5) 5 = highly important	Top five services in the alternative state (please tick five)
Global climate regulation	e.g. carbon storage in trees				
Local climate and air quality regulation	e.g. Providing shade, removing pollutants, influence on rainfall				
Water-related services	**Water for human use** e.g. domestic human consumption, irrigation, industry, energy				
	Water flow regulation e.g. provision, natural drainage, irrigation, drought /flood prevention				
	Water quality improvement e.g. water purification, waste treatment				
Erosion control	e.g. avoiding landslides				
Coastal protection	e.g. storm protection in coastal areas				
Harvested Wild Goods	**Food** (e.g. fruit, seeds, bushmeat, fish)				
	Fibre e.g straw, timber, skins, leather, wool etc				
	Natural medicines				
	Energy e.g. firewood, charcoal				
Cultivated	**Food** (e.g. livestock, farmed				

Goods	fish, crops)				
	Fibre e.g straw, timber, skins, leather, wool etc				
	Energy e.g.biofuels				
Biological control	e.g. regulating pests and vector-borne diseases				
Recreation/ tourism					
Aesthetic benefits / inspiration					
Spiritual / religious experience					

B. Detailed description of the major ecosystem services identified

For all of the prioritised benefits identified in table A (for either the current or plausible future or both), complete the table below. You will have between 5 and 10. Discuss the questions in this table and write brief answers.

Table B.

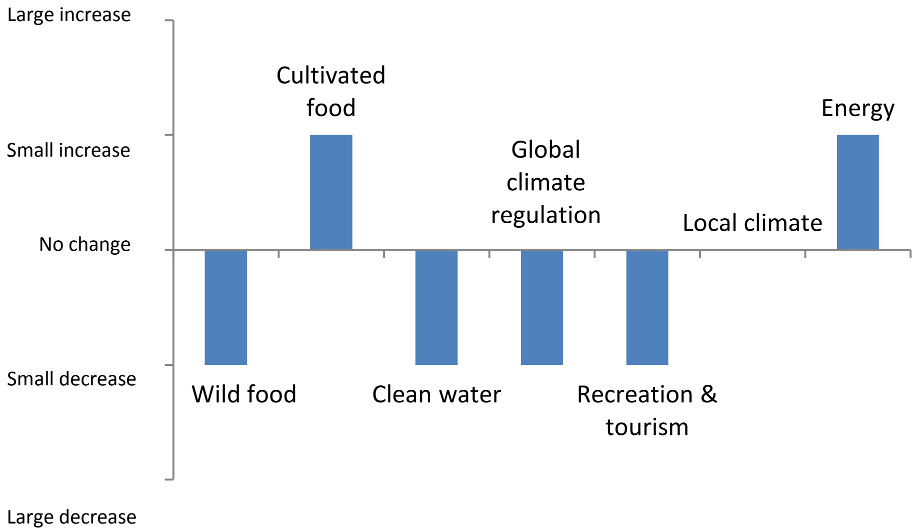
Benefit from table A	How has availability changed over the past 5 years? ↑ increased ↔ stable ↓ decreased	How will this benefit change in the plausible future? ↑ increase ↔ stable ↓ decrease	Who benefits from this service? **L**ocal/**D**istrict/**N**ational **G**lobal (select all that apply and circle the category that benefits most)	What are the main drivers (causes/factors) of this change? (select all that apply from the list in Part 1 table B)

C. Representing ecosystem service change

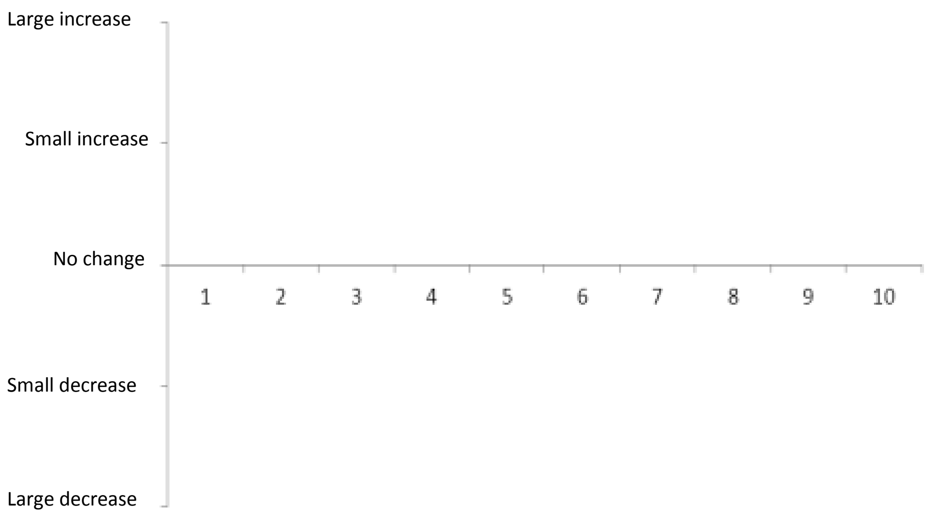
Using the results in Table B for 'How will this benefit change in the plausible future', draw bars for each one to represent the direction and scale of change.

EXAMPLE

	Benefit
1	Wild food
2	Cultivated food
3	Clean water
4	Global climate regulation
5	Recreation & tourism
6	Local climate
7	Energy



	Benefit from your list
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	



D. Overview of benefits from ecosystem services

Based on the information you entered in the previous tables in sections A, B and C, write a short description of the benefits from the site including:

- Current benefits with some explanation on those prioritised - why these? Give some details about them.
- A summary of the changes in benefits as a result of the plausible future
- What these changes might mean for people (who will benefit, who will lose out)
- What these changes might mean for biodiversity and habitats at the site

This summary can be presented to the other groups(s) in the reporting back session, for discussion and verification.

Sources of information for this site

Type of source (report, scientific paper, thesis, CD, map…)	Authors and publisher	Title	Available from	Relevant information held (e.g. data on annual value of mushroom harvest at site)	

Part I. Assessing global climate regulation

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PURPOSE OF CHAPTER

1. To estimate above- and below-ground carbon stocks.
2. To estimate carbon sequestration
3. To estimate greenhouse gas emissions
4. To compare (1-3) between current and alternative state

OVERVIEW

Key Tasks	For the current and alternative state, respectively; 1. Calculate carbon storage 2. Calculate carbon sequestration 3. Calculate carbon dioxide (CO_2) emissions 4. Calculate methane (CH_4)emissions 5. Calculate nitrous oxide (N_2O) emissions 6. Synthesize (2-5) into a single figure on flux of greenhouse gas Then; 7. Compare (1) and (6) between current and alternative state
Outputs	For each of the current and alternative state, an estimate of; • Carbon stocks, in tonnes • Annual flux of greenhouse gases, in tonnes of 'carbon dioxide equivalents'
Datasets required	• Habitat classifications • Area of each habitat type
Processes	• Stakeholder workshops • Mapping • Data collation from existing statistics • Field survey
Methods	• Climate M1: Classifying areas of different levels of disturbance, within a habitat type • Climate M2: Estimating above-ground live biomass carbon stock using IPCC tier 1 estimates • Climate M3: Direct measurement of above-ground live biomass carbon stock in grass-dominated habitats and non-forested wetlands • Climate M4: Direct measurement of above-ground live biomass carbon stock in tree-dominated habitats • Climate M5: Estimating below-ground biomass carbon stock using IPCC conversion factors • Climate M6: Estimating dead organic matter (litter and dead wood) carbon stock using IPCC tier 1 estimates

	• Climate M7: Estimating soil organic carbon stock in mineral and organic soils • Climate M8: Estimating loss of biomass carbon stocks due to disturbances • Climate M9: Estimating emission of carbon dioxide from organic soils using IPCC tier 1 emission factors for tree-dominated, grassland-dominated and crop-dominated habitats • Climate M10: Estimating emission of carbon dioxide using IPCC tier 1 emission factors for managed wetlands, in particular peatland extraction sites • Climate M11: Estimating methane emissions from wet soil and grazing animals, using IPCC and other Tier 1-type methods • Climate M12: Estimating nitrous oxide emission using IPCC tier 1 method for managed peatland and habitats with managed land • Climate M13: Estimating carbon sequestration for bogs and mires, using equation • Climate M14: Calculating the overall greenhouse gas flux of your site • Climate M15: Estimating the value of the timber harvested from the site of interest

Climate Section 1. Approach and key issues to consider

By global climate regulation, we mean the exchange of carbon dioxide and other greenhouse gases between the atmosphere and the plants, animals and soil within ecosystems. Different habitats and land uses have different potential influences on the service of global climate regulation. Therefore, we treat each habitat/land use separately in this section of the toolkit, because different measurements and/or methods are appropriate for different habitats. As stated earlier in Section A2, this might require the user to identify zones with different levels of disturbance within each defined habitat or land-use.

Data can be obtained from two main sources, depending on the resources and time available: existing databases and studies, and local field survey. If possible, local field survey is preferable (especially in forested habitats) for the improved accuracy it can generate for estimates. **The series of steps below should be followed separately for the conservation and alternative state, in order to make a comparison.** Ideally, comparisons between states should use the same methods of data collection or the same data sources for each flux or stock, to attempt to 'even-out' relative error.

When considering the alternative state, it should be a plausible state change (see Section 1.3). For global climate regulation services, the figures that you obtain for the current state can be directly transferred to the same land-cover types found in the alternative state to work out the amount of carbon stored or greenhouse gas emissions. New land-cover types will require further data collection.

For each habitat or land use you have identified in **Section 2** of the toolkit, we must assess three factors which might affect global climate regulation. These are;

1. The carbon stored in the plants (above-ground biomass, AGB, and below-ground biomass, BGB), dead organic matter (litter and dead wood) and soil;

2. The carbon sequestered (taken in from the atmosphere) over time by the plants and soil (negative flux);

3. The greenhouse gases (carbon dioxide [CO_2], nitrous oxide [N_2O], methane [CH_4]) emitted by the plants, soil and animals over time (positive flux). This emission can arise from, for example, respiration, burning, decay or other forms of disturbance.

The importance of these factors to climate regulation varies between different habitats or land uses. Furthermore, different levels of human intervention or management within a habitat may also alter their relative importance. Therefore, we must define both habitat types and, within these, different degree of disturbance (if present) and use these as the individual units for service assessment.

Having defined the habitats, you can then start to use the methods. So;

- Is the habitat tree-dominated, such as natural forest or woody crop plantations/orchards (whether the crop is the wood itself or, for example, fruit)? This includes flooded forests, forests on peat and mangroves. Go to **Climate Section 2.**

- Is the habitat grass-dominated, such as pastoral agricultural systems, steppe or savannah? Go to **Climate Section 3.**

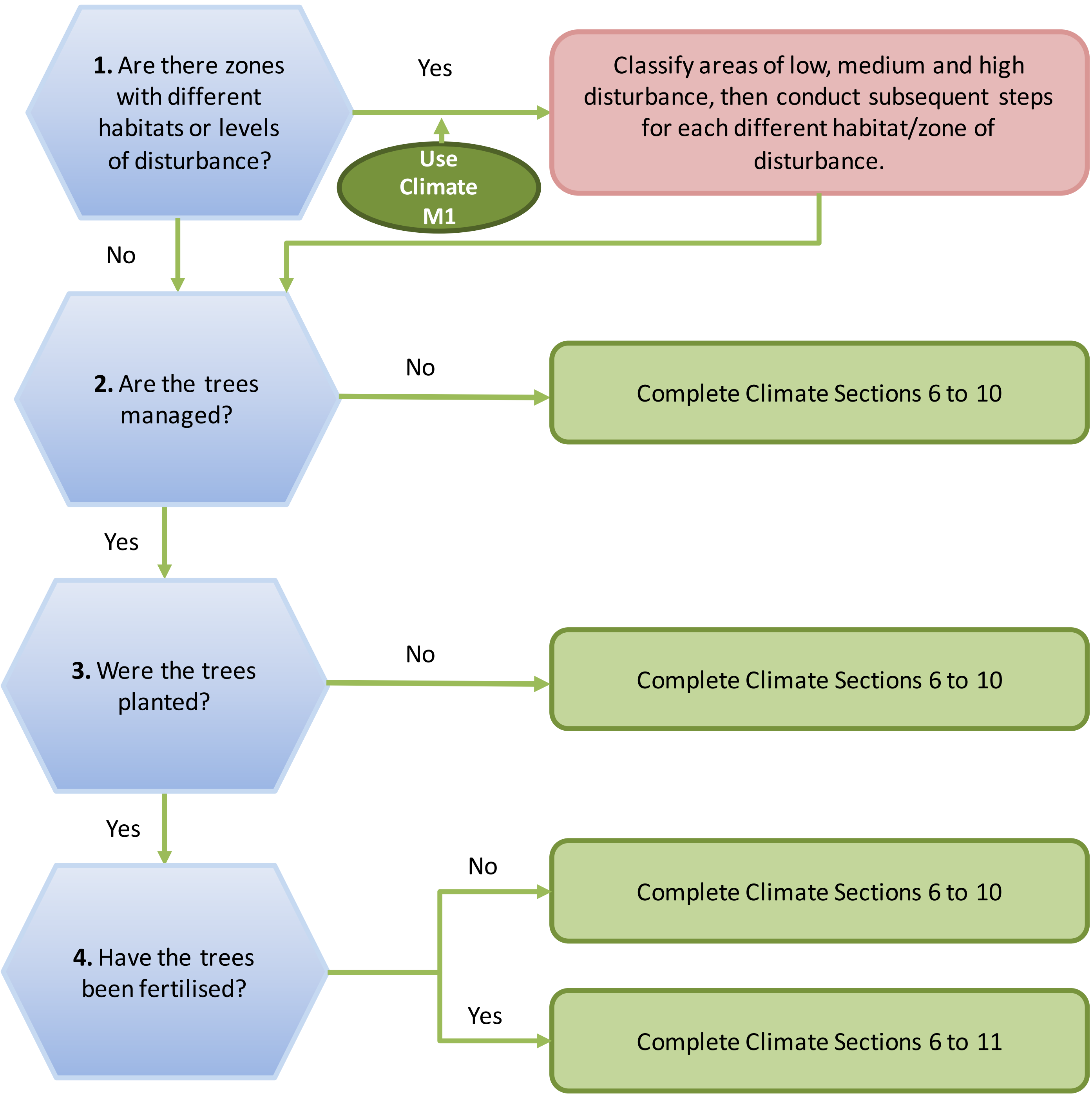
- Is the habitat crop-dominated, such as arable, rice-paddy or horticultural? Go to **Climate Section 4.**

- Is the habitat an inland or coastal wetland? Go to **Climate Section 5.**

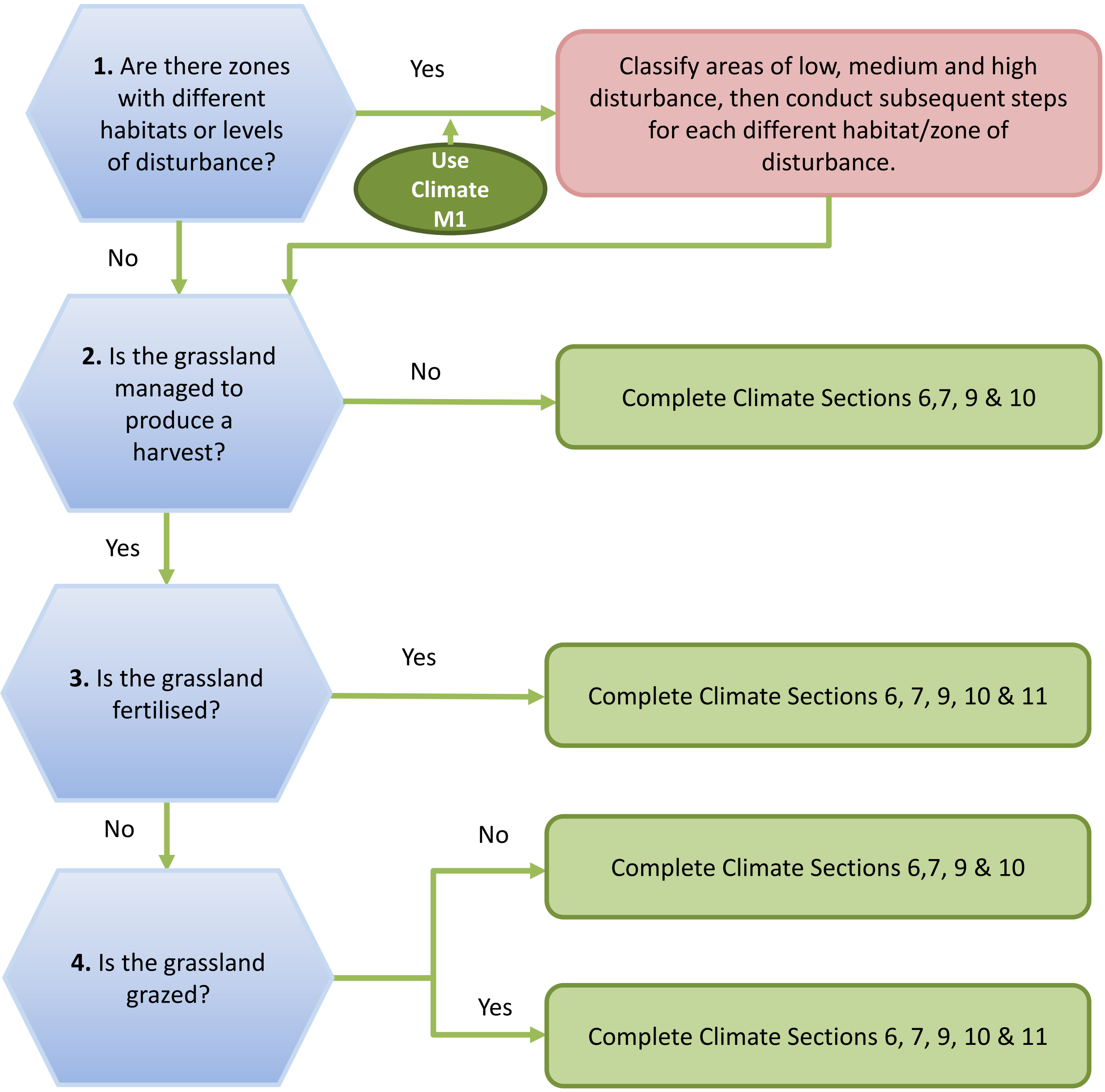
Further guidance: For an area that has mixed vegetation, you can assess each of the major habitat types within the area. For example, to assess an area of grassland with many big trees, you can go to both Climate Sections 2 and 3.

Climate Sections 2, 3, 4 and 5 provide decision trees which help you to start the process of determining which stocks of carbon or types of greenhouse gas flux you need to consider, directing you to further sections for detailed guidance. In these further sections, **Climate Section 6** gives details on how to calculate carbon stock. **Climate Sections 7, 8, 9, 10 and 11** then give detailed guidance on how to calculate fluxes in carbon and greenhouse gases. Finally, in **Climate Section 12**, guidance is provided on how to present together the figures on carbon stock and greenhouse gas flux for both the current and alternative states.

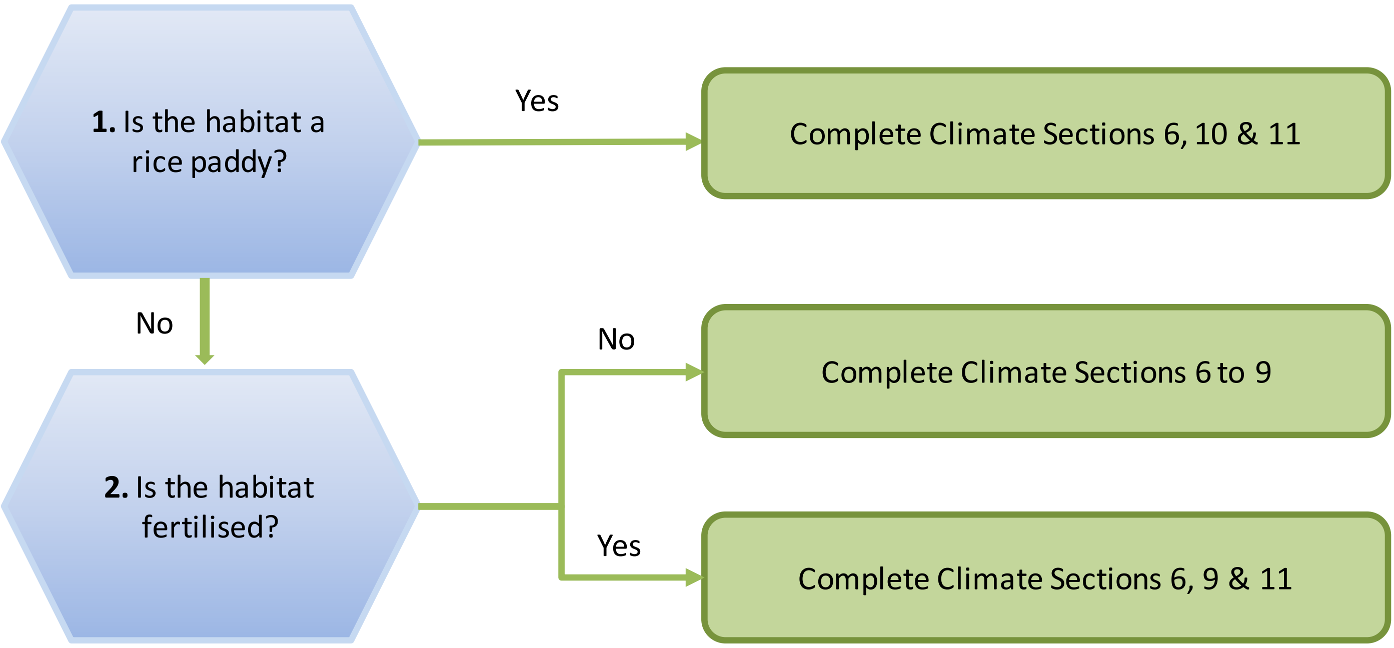
Climate Section 2. Tree-dominated habitats, such as natural forest or woody crop plantations/orchards



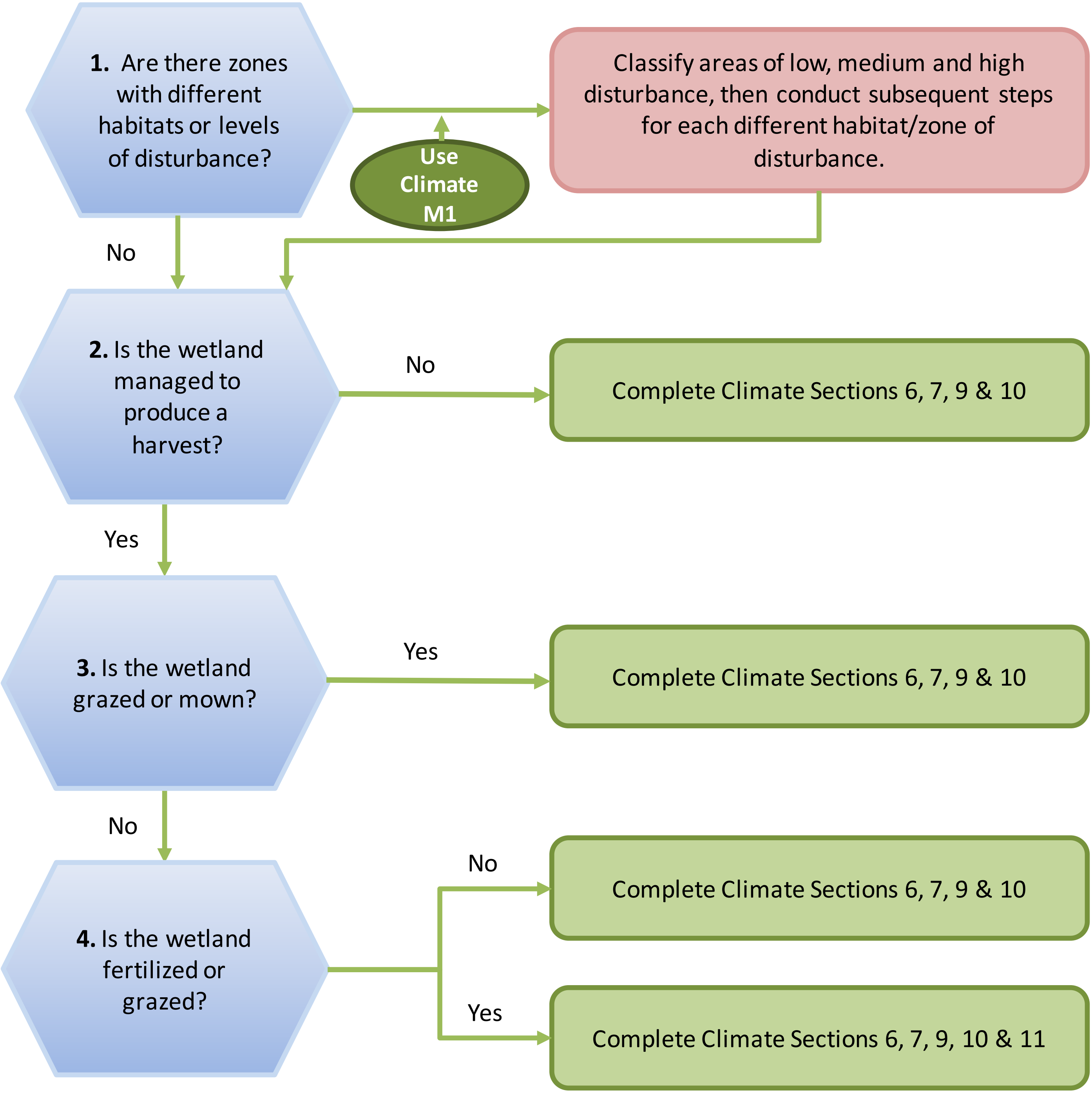
Climate Section 3. Grass-dominated habitats, such as pastoral agricultural systems, steppe or savannah



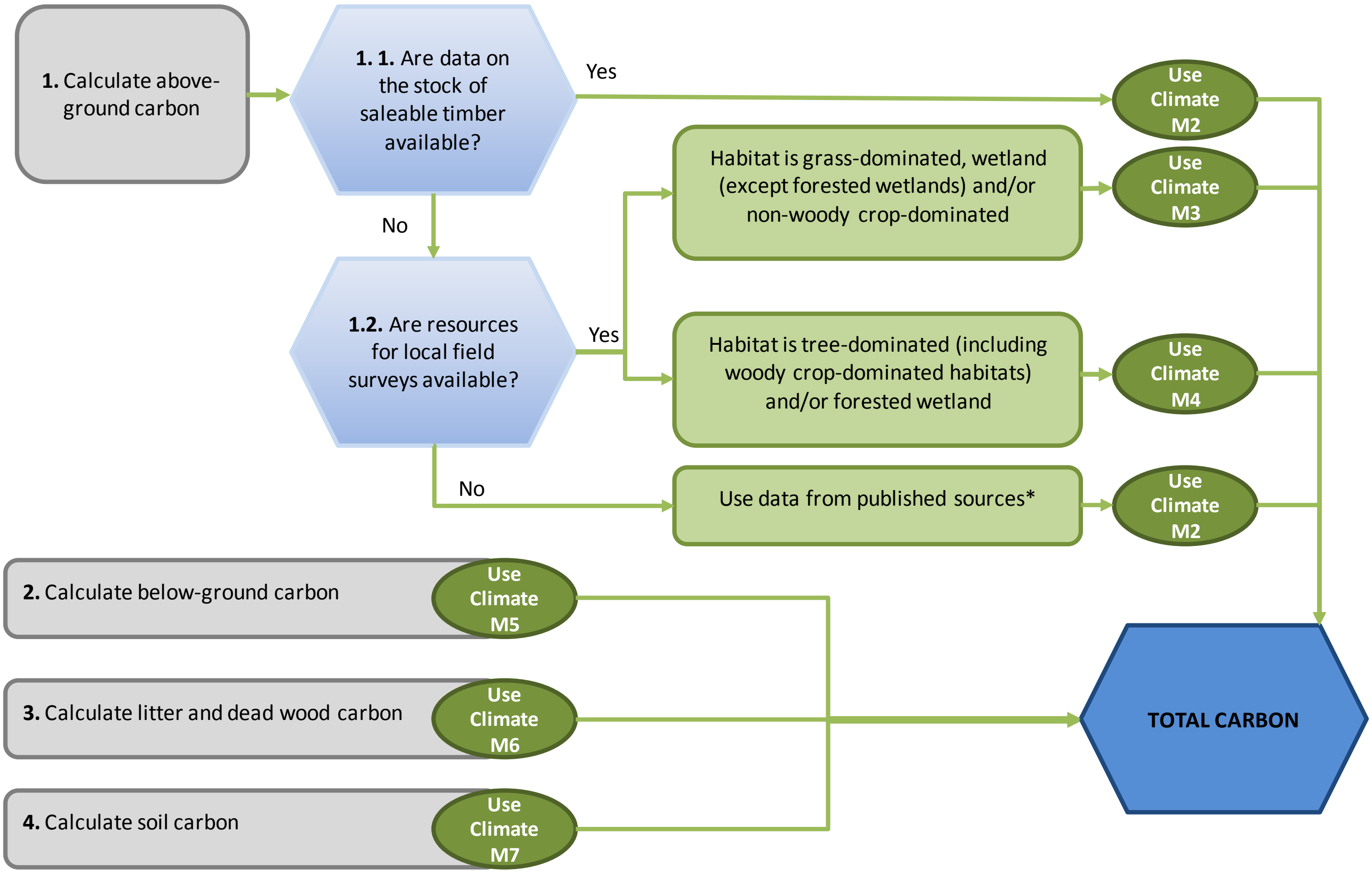
Climate Section 4. Crop-dominated habitats, such as arable, rice-paddy or horticultural



Climate Section 5. Inland or coastal non-forested wetland habitats, such as intertidal habitats, lakes, rivers, bogs and fens



Climate Section 6. Estimating total carbon stock



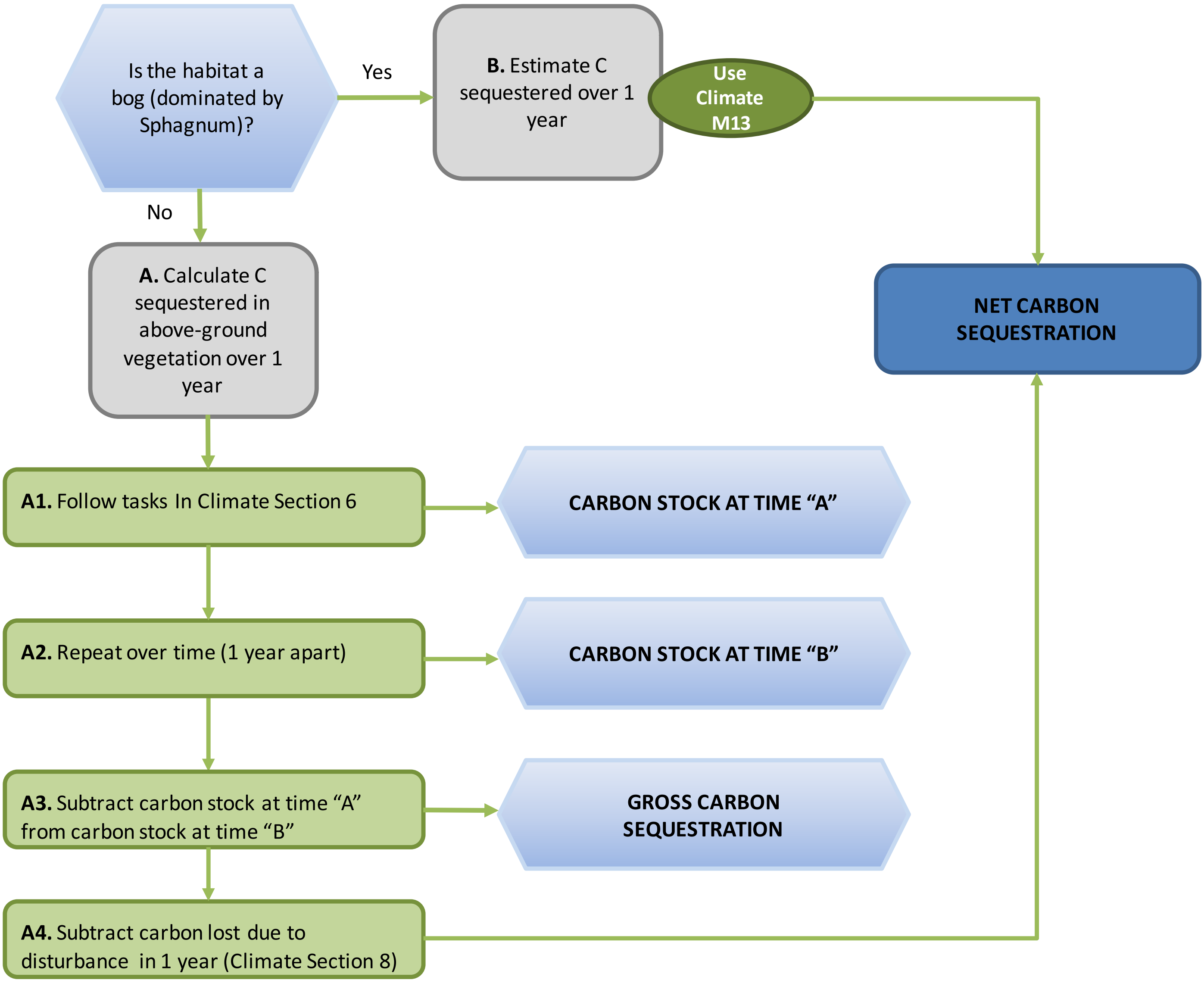
* 1. Published values from peer-reviewed journals from studies at the site or at a suitably similar site – Use Google Scholar (http://scholar.google.com) or Web of Knowledge (http://isiknowledge.com), if available, to search for these journals (search keywords: above-ground biomass, carbon stock).

2. Published values in grey literature, if available.

Climate Section 7. **Estimating carbon sequestration**

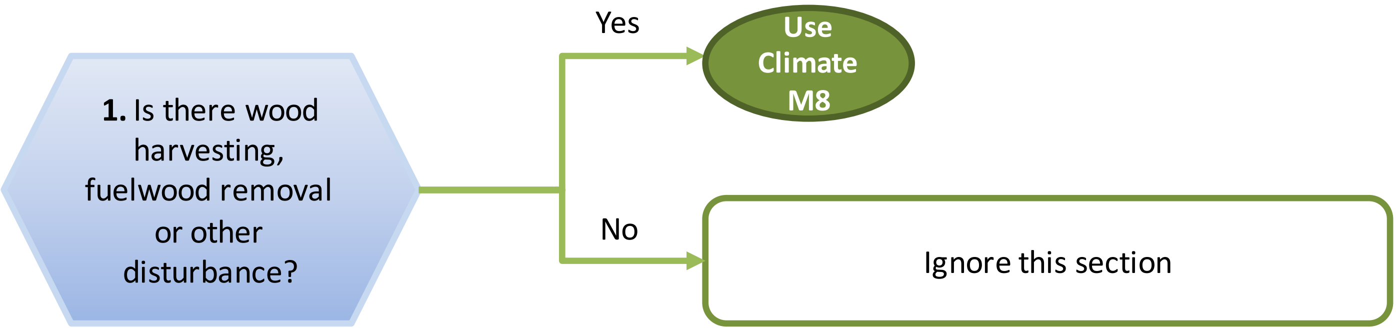
Follow A to estimate C sequestration in wooded or other habitats with standing vegetation (including wetlands with large stands of reed, sedge or trees) is suitable only if the data source for above-ground live biomass carbon stock is from local field surveys.

Use B if your habitat is a bog dominated by peat-forming bryophytes (may have

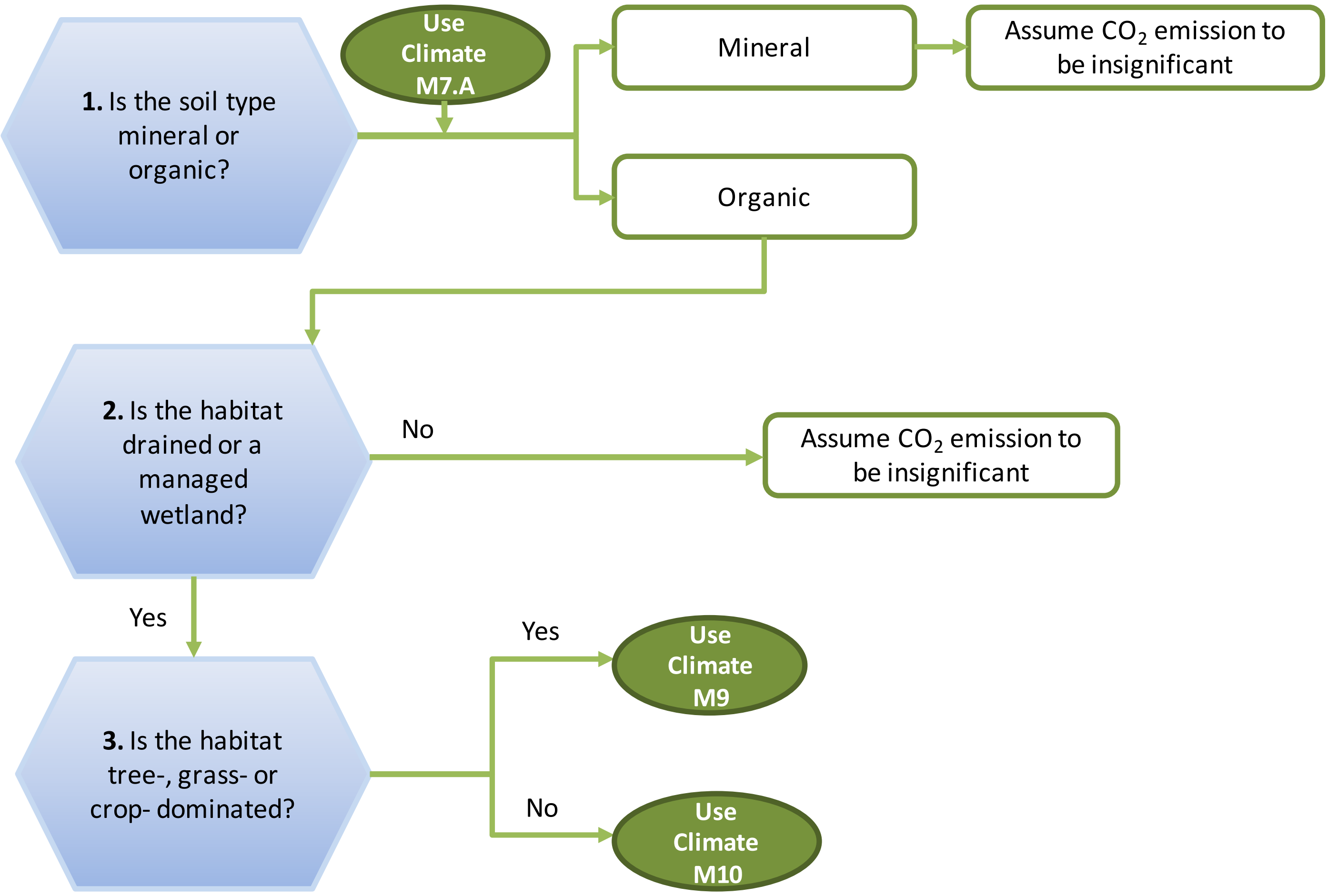


Climate Section 8. Estimating loss of vegetation carbon stock due to disturbances

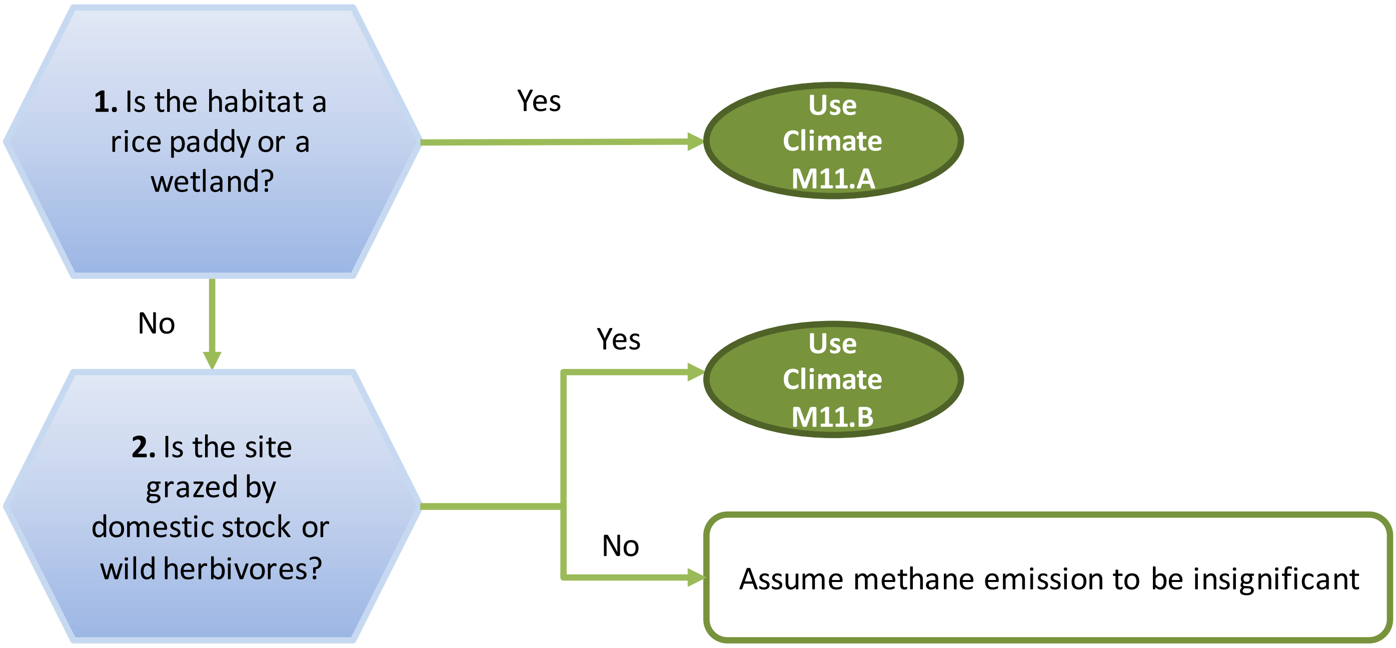
This method is necessary only if the data source for above-ground live biomass carbon stock is from published sources. Loss estimates from (1) wood harvesting, (2) fuel-wood removal and (3) other disturbances (e.g., fire, insect, drainage) are needed to calculate carbon stock change. This can help to determine if the habitat is subjected to carbon loss at a sustainable rate (i.e., whether the rate of carbon loss due to disturbances over a year is less than the rate of carbon dioxide accumulation over a year).



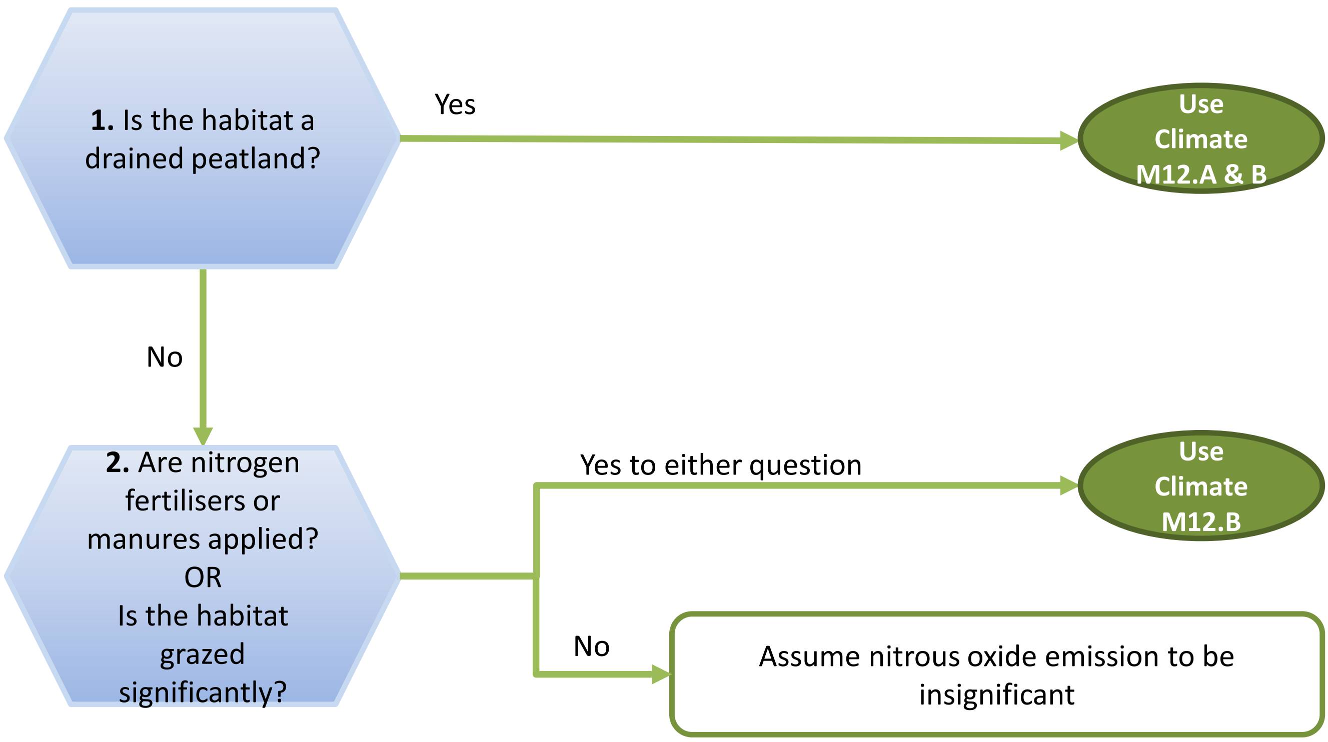
Climate Section 9. Estimating carbon dioxide (CO_2) emissions from soil



Climate Section 10. Estimating methane (CH_4) emissions



Climate Section 11. Estimating nitrous oxide (N_2O) emissions



Climate Section 12. Summarising the information

The steps below need to be done separately for the current and alternative state.

a) Add the carbon stocks (calculated in **Climate Section 6**) for each habitat at the site, to derive the total carbon stock at the site (expressed as tonnes of carbon).

b) Separately, for each habitat at the site, pull together all your data on annual greenhouse gas fluxes and express in a single figure (tonnes per year), using **Climate Method 14**.

c) Add the annual greenhouse gas fluxes for each habitat, to derive the total annual greenhouse gas flux for the site (expressed as tonnes of carbon dioxide equivalents per year (CO_2Eq y^{-1}).

For useful ways to present this information, see **Section 4** of the toolkit.

Part II. Assessing water-related services

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Reviewers: Helen Moggridge, Lucy Emerton, Charlie Stratford

PURPOSE OF CHAPTER

1. To assess flood protection .
2. To estimate water quantity provision for domestic and industrial purposes.
3. To measure water quality improvement.
4. To compare (1-3) between current and alternative states.

OVERVIEW

Key Tasks	• Determine who benefits from water-related services • Assess flood protection • Quantify domestic and/or industrial water use and periods of water shortage • Estimate water quality improvement
Resources and datasets that may be required	• Boundary of the site of interest • Map of water catchment • Hydrological data • Online access to WaterWorld Policy Support System (PSS) • Online access to Costing Nature Policy Support System
Processes	• Meeting with technical experts and /or people with statutory responsibilities
	• Meeting with beneficiaries
	• Mapping
	• Data collation from existing sources
	• Individual household questionnaire survey
	• Calculations using hydrological data
	• Web-based modelling
	• Field-based measurement of water quality
Methods	• Water M1: Obtaining information on flooding, water use and water quality from stakeholder meetings • Water M2: Using Costing Nature to identify the location of beneficiaries and contribution of • water from the site • Water M3: Assessing flood protection services • Water M3.A: Determining if the site offers flood protection services • Water M3.B: Quantitative approaches to assessing flood protection • Water M3.C: Examples of alternative states for assessing flood protection • Water M4: Assessing water supply services • Water M4.A: Sources of water supply data and calculating water use • Water M4.B: Household survey of water use • Water M4.C: Estimating water supply using the WaterWorld PSS • Water M4.D: Assessing water supply in the alternative state for wetlands, using hydrological data • Water M5: Assessing water quality improvement services

	• Water M5.A: Measuring the contribution of a wetland site to water quality improvement • Water M5.B: Estimating water quality improvement using the WaterWorld PSS • Water M5.C: Assessing water quality improvement in the alternative state	
Output metrics	• Flood protection	E.g. Number of days not flooded; Number of households not flooded; Number of months with reduced/increased flood risk
	• Water provision	E.g. Number litres per year
	• Water quality improvement	E.g. Mg/l of nutrient removed

Water Section 1. Approach and key issues to consider

This section helps you to identify and estimate some of the water-related services that may be provided by a site. It covers three main types of water-related services:

- **water provisioning services** (e.g. providing water)
- **water regulation services** (e.g. preventing flooding, maintenance of flows during low runoff season)
- **water quality improvement services** (e.g. maintaining or improving the quality of drinking water)

However, within these service categories, the methods described will only work at some kinds of sites and guidance is given on how to make this assessment. This limitation is due to the practical difficulties involved in assessing water-related services at many sites, without substantial time, resources and long-term monitoring efforts.

It is important to be aware that water-related services are complex both to identify and quantify. The type of water-related services provided by a site results from the complex interplay between climate, soils, topography, vegetation and human land use and, crucially, on the exact location of the site within the water catchment. Thus, the site of interest may be influenced by hydrological processes occurring a long way upstream from it and in turn it may provide water-related services to beneficiaries who live a long way downstream or down-slope from it. It is therefore essential to determine at an early stage where the beneficiaries are located (see guidance below).

Very different types of sites may provide water-related services. For example, sites on hilly terrain, whether they are covered in grassland or forested habitats, may influence the transfer of rainwater to stream or river courses that provide drinking water. In this example, it is critical to determine how much of the water supply to downstream beneficiaries is provided by the site of interest. In large water catchments where rainfall may vary considerably across the catchment, a small site may supply a large percentage of the water flowing within a river from which beneficiaries draw water. Therefore the area of catchment occupied by the site is not always a good indicator of the percentage of the water supply that it provides. Where rainfall is more evenly distributed, a small site may only be important for populations in the immediate vicinity downstream and may not play a significant role within the major basin in which is sits. However, where the site occupies a very large part of the water supply catchment, it is likely to play a significant role in water supply to beneficiaries downstream.

Many low-lying, flat sites are occupied by wetlands (e.g. lakes, pools, rivers, marshes, swamps etc) and these often also provide a variety of water-related services. In wetlands that have obvious water inflows and outflows, water-related services can be relatively straightforward to measure and many of the methods described in this part of the toolkit are designed to be used in wetlands with these characteristics.

Water often underpins other services such as harvested goods, irrigated cultivated goods, carbon storage and water-based recreation, especially in wetland sites. These ecosystem services are dealt with in other parts of this toolkit. Whenever non-consumptive water use upstream (e.g. water supply to a factory that then discharges the same amount of water back into the river) does not impede the underpinning of these other services, you can value both the non-consumptive use and the other services that water underpins. For the latter, water is only part of the value of those “underpinned” services (e.g. irrigated crops need soil and other inputs as well as water).

For all three water-related services we recommend field approaches wherever possible at the site scale. However, where these are not possible or the study is at a scale greater than the site scale, then modelling approaches can and should be used.

Who are the beneficiaries of water-related services?

It is important to determine whether there are any beneficiaries of water-related services from the site, and if so, where these beneficiaries are located (e.g. within the site, further downstream etc)

Referring to the rapid appraisal (**Section 3**) carried out at the start of your assessment, the stakeholder input should have given an indication of whether water-related services are recognised as important i.e. whether there are any beneficiaries, and if so, their spatial distribution. It is important when dealing with water-related services to make sure that the beneficiaries who live a long way downstream of the site or who use water seasonally (e.g. pastoralists) are not overlooked.

Stakeholder meetings: **Water Method 1** provides guidance on how to collect information from stakeholders on water-related services and how these might change in an alternative state. If you require detailed information, this can be asked of different types of stakeholders through additional meetings with either individuals or groups. Cross-check with them that they agree with the water-related services identified as important based on the rapid appraisal.

Using modelled data: As well as getting information about beneficiaries through meetings, there is a useful online tool called **‘Costing Nature’** (see **Water Method 2**) that can be used to establish preliminary information on the likely locations and numbers of beneficiaries, and on the likely contribution of the site of interest to both the provision of water quantity, quality and some regulating services. Beneficiaries are identified on the basis of the mapped locations of features (dams, urban areas) and of the identification of downstream populations on the basis of global population datasets. Costing Nature separates ecosystem services for which beneficiaries are not identified (‘potential services’) from those which are received by beneficiaries (‘realised services’).

Once you have obtained information from one or more meetings or run the Costing Nature analysis, answer the following questions:

Q1 Are there any downstream or local beneficiaries identified?

Q2 Are the water-related services of the site important to the beneficiaries?

If YES to both questions – Continue to **Water Sections 2, 3 and 4**;

If NO to either question – Then water-related services are probably unimportant at the site.

Assessing the alternative state

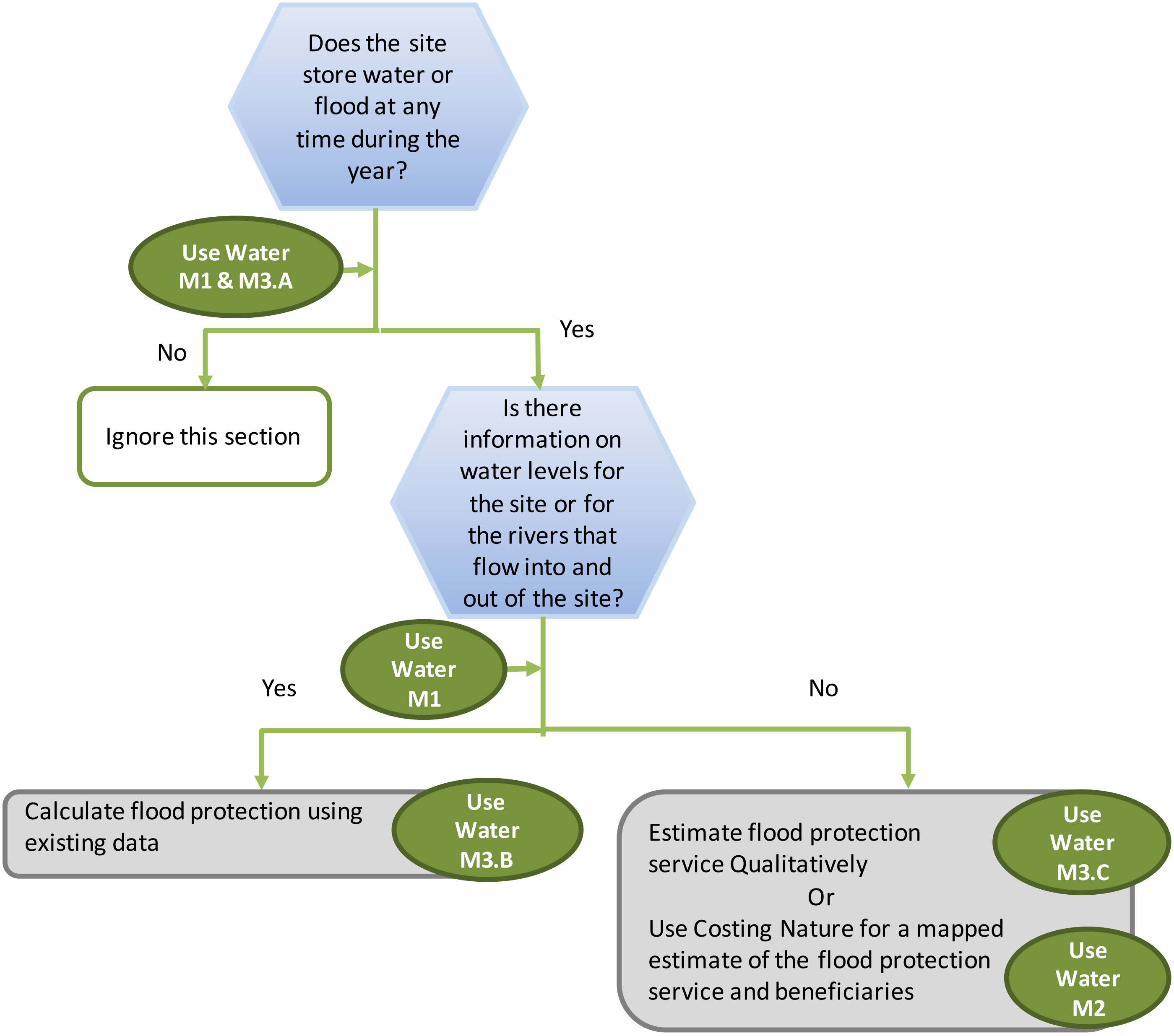
For water-related services, the alternative state is not often measurable at an alternative site because differences in hydrology that might be attributable to ecosystem state will be confounded by other differences between the sites (for example in climate or terrain). Only paired catchment studies or large experimental approaches within catchments can overcome this confounding. Such studies require long term and significant investment. Instead, the most likely change in the current state of the site has to be identified followed by a re-assessment of the relevant water-related services that might be apparent from that state. In this toolkit, help with assessing the water-related services provided by the most plausible alternative state for the site is given through examples. Where change is gradual, for example as a result of piece-meal increases in water abstraction from the regional aquifer in the area near a wetland site, change can be very difficult to assess. Where change is sudden and drastic, for example the construction of a barrage upstream of a wetland, it is often easier to find out the likely changes because the engineering plans will usually include modelled expected changes to flows downstream of the barrage. At many wetland sites there are multiple threats either from multiple sources or from a single source which might impact on several different water-related services. For example, reduced water input to a wetland could affect both water provision and water quality by reducing dilution effects. The most likely alternative state will influence the perception by beneficiaries of which water service is most threatened and this could help to direct decisions on which services to spend time measuring. For sites that are not wetlands we suggest using an online modelling tool called **WaterWorld** that allows a hydrological baseline for the current state to be compared with outcomes for the alternative state for some water-related services. It does so through the use of global and remotely sensed datasets available for any site and an understanding of the physics of how hydrological fluxes change with land cover change.

Finally, in **Water Section 5**, guidance is provided on how to summarise all the information on water-related services for both the current and alternative states.

Water Section 2. Water regulation: Flood protection

(In this part of the toolkit we deal with flood protection away from coastal areas. Flood protection in coastal areas will be dealt with separately in the next version of the toolkit.)

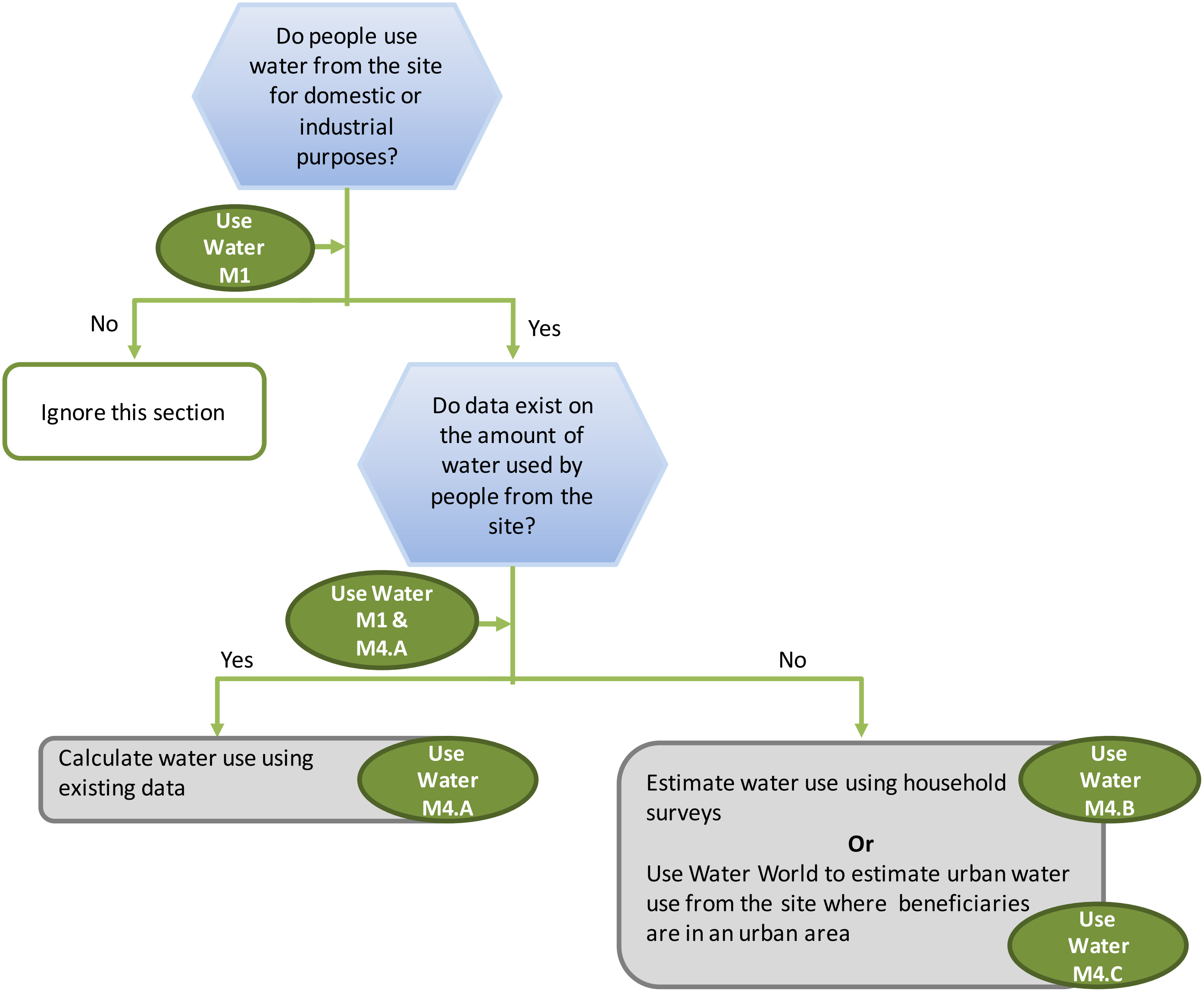
Flood protection can be provided by sites with vegetated sloping land and by wetland sites (e.g. lakes, pools, rivers, marshes, swamps etc) as they are each capable of both short- or long-term retention of water as well as reducing rates of water movement and thus reducing the risk of flooding for downstream beneficiaries. However, flood protection services are only readily assessed in the field at wetland sites that have obvious inflows and outflows and/or obvious flood periods. Qualitative assessments or modelling tools can also be used at wetland sites. The following decisions should be made:



Assessing alternative state - Use information from stakeholder meetings or background research to define most likely future changes to the site. Then use **Water Method 3.C** to choose an appropriate approach to assess flood protection services in the alternative state. These may be field-based (qualitative or quantitative) or modelled.

Water Section 3. Water provision: Domestic water supply or supply to industrial facilities

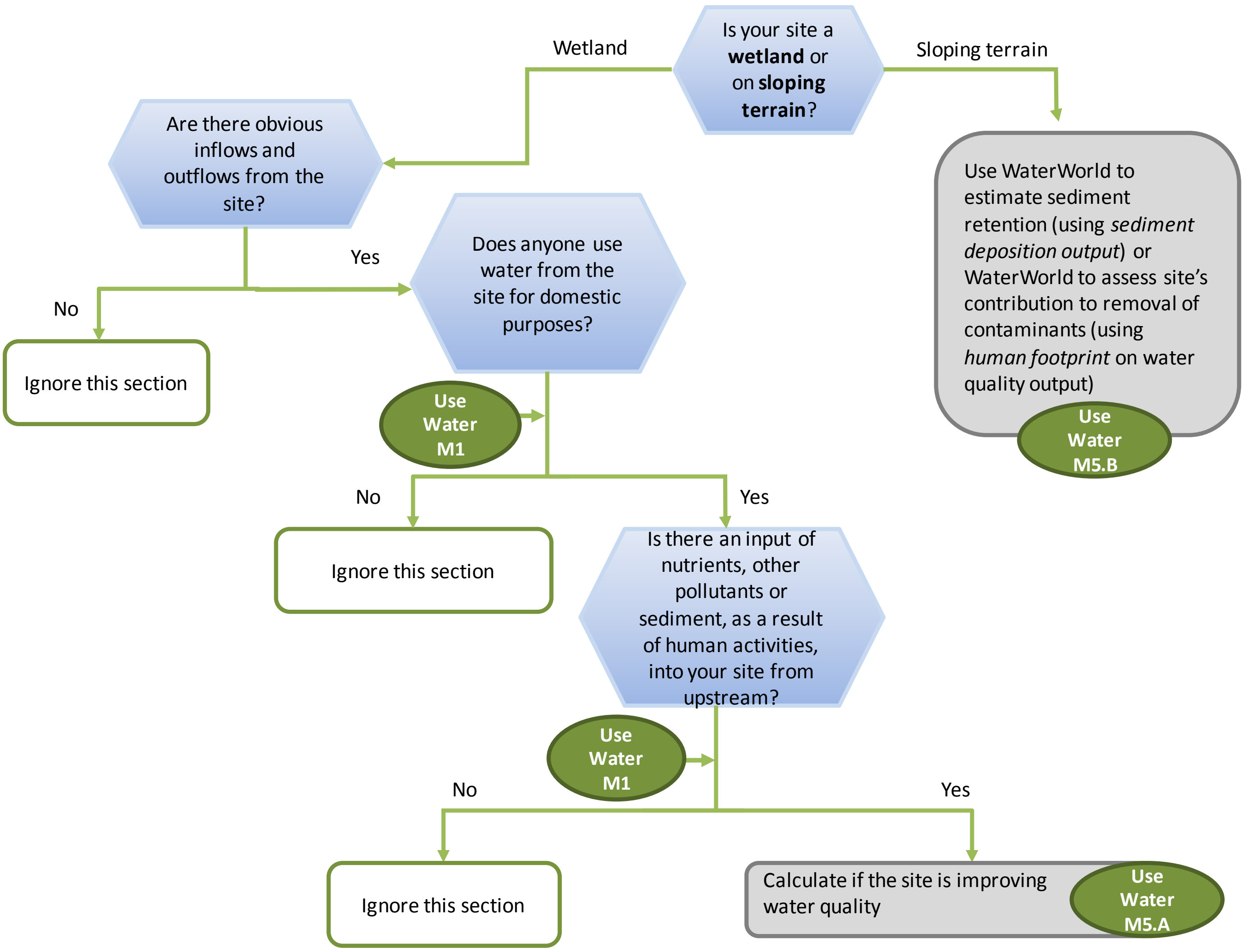
Much of the water provided by a site of interest may be used for cultivating crops, growing pasture or fodder for grazing animals, or may be used by species that provide harvested wild goods (e.g. timber trees). Methods for estimating benefits from these final services are provided elsewhere in this toolkit though there is no method for estimating the proportion of these final services that is attributable to water. In this section we provide a method for assessing the amount of water provided by the site for direct domestic use (e.g. for drinking water or washing), and for industrial use (e.g. for factories or businesses).



Assessing alternative state - Use information from stakeholder meetings or background research to define the most likely future changes to the site. In many cases, although the amount of water at a site may change under various scenarios of, for example, land use change or hydrological management, the amount of water at the site remains sufficient for domestic use. In other cases, there may be increases or decreases in the intensity and/or duration of seasonal shortages, changes in the distances people have to travel to collect water, or changes in water quality through changes in dilution effects (see section 4.4). At some sites it may be possible to assess the water provision changes that are likely to take place through meetings and using household questionnaires (see **Water Method 1 & 4.B).** Then use **Water Method 4.D** to choose an appropriate approach to assess changes in water supply services in the alternative state. These may be field-based (qualitative or quantitative) or modelled.

Water Section 4. Water quality improvement

Water quality maintenance and improvement can only take place if water quality is currently insufficient to provide services. Sites with hilly terrain and/or wetlands within them can offer water quality improvement services through the control of levels of nutrients or sediments entering water courses that are used by people. On hilly terrain, the habitat present will greatly influence the rate of runoff from the site and thus the delivery of both nutrients and sediments downstream or down-slope. Wetlands can store or remove excess nutrients (e.g., nitrogen and/or phosphorus from agriculture or heavy metals from mining upstream) or excess sediment, via biogeochemical cycling and sedimentary processes. Field measurements of water quality improvement are most easily made at wetlands with obvious inflows and outflows whereas estimates of some of these water quality services from hilly terrain and lowlands are most easily obtained using models such as WaterWorld and Costing Nature.



Assessing alternative state **-** Use information from stakeholder meetings or background research to define most likely future changes to the water quality of the site. This may be a qualitative assessment or, in some cases a quantitative estimate based on existing data or modelled data. **Water Method 5.C** provides examples of how to assess future changes to water quality improvement.

Water Section 5. Summarising the information

By now you should have the following information:

For flood protection at wetland sites

a) An assessment of whether or not the wetland provides flood protection by storing water at any time during the year (**Water Method 3.A**)

b) For any individual flood event, the difference in flood height and duration upstream and downstream of the wetland site. Your calculation of the flood protection service of an individual flood event will be calculated as the number of people or houses that have not been flooded downstream of the wetland as a result of the wetland being there (**Water Method 3.B**).

c) Information on the number of times flooding has taken place upstream and downstream of the wetland site. The difference in flood risk can be calculated from these data by finding the ratio of the number of years in which flooding has taken place and the number in which it has not taken place for the period of years over which data exist. If the wetland performs a flood protection function then e.g. upstream there may be a 1 year in every 10 years flood risk whereas downstream of the wetland this may be reduced to a 1 in 20 year flood risk. The calculation of service per annum is the replacement value of the downstream properties (or commodities) that have not been flooded divided by the number of years between floods.

For useful ways to present this information, see **Section 4**.

For water provision

a) The monthly water production of the site of interest (using a combination of **Water Method 4.A** and **4.B**).

b) The monthly household water supply under the current state (using **Water Method 4.A** and **4.B**).

c) The baseline data for the monthly water balance of the site of interest under the current state (using **Water Method 4.C**).

d) The monthly water balance of the site of interest under the alternative state (using **Water method 4.C**).

   The steps below need to be done to quantify the effect of the alternative state.

   i. Separately, for each month, calculate the average of all your data on water balances (using **Water Method 4.C**) and express in a single figure (mm hr^{-1}) for the current state, and then repeat for the alternative state (using **Water Method 4.C**).

   ii. Again separately for each month, calculate the proportional differences between the current and alternative state.

   iii. Adjust the monthly current water production data accordingly to the proportional changes obtained from the above step to derive the estimated monthly water production of the area under the alternative state.

e) For useful ways to present this information, see **Section 4**.

For water quality improvement (wetland) -

a) The value of each water quality parameter (A) at the inflow of a wetland (using **Water Method 5.A**).

b) The value of each water quality parameter (B) at the outflow of the wetland (using **Water Method 5.A**).

The step below needs to be done to assess the water quality improvement service by the wetland

i. Separately, for each water quality parameter, calculate the percentage change between the inflow and the outflow by subtracting A from B, and then divide by 100. Positive value usually means the wetland is not removing pollutants from the water, negative value means that the wetland is removing pollutants from the water. The service calculation can only be in terms how the change in pollution level changes the water use as a result of improved quality. For example, improved potability of the water may reduce need to buy water from a different source. The cost of buying water is an estimate of the service provided by the wetland.

c) For useful ways to present this information, see **Section 4**.

Part III. Assessing harvested wild goods

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Reviewers: Julia P G Jones, Chris Sandbrook, Bill Adams, Ruth Swetnam, Sebastian Buckton, Lucy Emerton

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PURPOSE OF CHAPTER

1. To quantify the amount and net economic value of the major wild goods harvested from the site under its current and alternative state - including timber and feed for livestock
2. To quantify the amount and net economic value of any 'windfall' from products obtained during the site's state change.
3. To determine (where appropriate) the relative value of wild goods to different stakeholder groups
4. To identify which stakeholder groups (or individuals, based on social differences within communities) would gain benefits and which groups (or individuals) would lose benefits as a result of the site's state change.
5. To compare net benefits, and beneficiaries, between current and alternative states of the site of interest

OVERVIEW

Key tasks	• Identify categories that differentiate stakeholders at the local level • Characterize the most important harvested wild goods at the site, under both current and alternative states (socially differentiated where relevant) • Characterize the most important harvested wild goods obtained through the site's state change (socially differentiated where relevant) • Calculate amount harvested and net economic value of each harvested wild good • Evaluate the relative value of each harvested wild good for different stakeholder groups(net economic value or qualitative measures) • Estimate overall net economic value across all main goods (where appropriate)
Outputs	• Benefits from harvested wild goods, from the current site and the site in its alternative state, expressed in $ ha^{-1} year^{-1} • Quantification or description of how different, socially differentiated stakeholders, will be affected by a change in the site's state.
Datasets required	• Total area of site • Area of each habitat type, under both current and alternative states • The location and area which the respondents access for harvested goods (for example if it is a community forest that is just a part of the site being assessed) • Map of site - under current and alternative states - to ensure

	respondents are answering questions with reference to the right area • Categorisation of stakeholders according to social difference
Processes	• Holding stakeholder workshops • Resource mapping and participatory rural appraisal • Collating existing data • Conducting a questionnaire survey • Analysing results
Methods	• Wild Goods M1. Stakeholder meeting for quantifying the benefits obtained from harvested wild goods • Wild Goods M2. Individual questionnaire to estimate quantity and value of harvested wild goods

Wild Goods Section 1. Approach and key issues to consider

This section provides information about how to estimate the volume, economic value (net of inputs) and relative importance of harvested wild goods to people. Harvested wild goods include plants for food and medicine; animals hunted for food (including fish) or decoration (e.g. feathers); materials and fibres such as timber, bamboo and rattan; and feed from an uncultivated area used for livestock, whether the animal is taken to the site, or the feed is gathered and transported. Note that timber from cultivated species (which involves planting or other cultivation costs) is dealt with in Section IV, as is livestock feed from cultivated areas. Data collection involves a workshop, followed by use of existing data or (more usually) a questionnaire survey of harvesters.

Data are needed about both the current site and its most likely alternative state, though it may be possible to collect both sets of information through the same exercises. Information is also needed on any products harvested during the process of state change of the site. Information about how much different groups of people benefit from harvesting is obtained during the workshops. It is important to note that social difference is often highlighted in the access, use and trade of harvested wild goods. This section should therefore be used with a view to identifying where dependencies on these products vary according to social factors (status, gender, ethnicity, age etc.). Refer to **Guidance 1** for details.

Another issue to consider is that harvesting may be illegal; for guidance on quantifying illegal activities see the box in **Wild Goods Method 1**.

Workshop: general information. The first step in applying this section of the toolkit is to collect general information on harvesting wild goods at the site, usually through a workshop (or several separate workshops) of informed individuals (such as forest officers, wardens, development workers) and harvesters. Detailed guidance on what to ask is given in **Wild Goods Method 1**; for disaggregating your stakeholders into groups if necessary, refer to **Guidance 1**; for general information on running a workshop see **Guidance 2**. For practical reasons it will usually be necessary to focus attention only on a selection of harvested wild goods (e.g. 3-5 products). It is important that the goods chosen reflect 'importance' appropriately for different stakeholder groups e.g. it is often the case that provisioning services with low commercial value are of most significant value to the poorest people (Vira and Kontoleon 2012).

The workshop should also be used to establish the availability of existing data (see below) and then for each of the goods in turn, approximately how many households harvest it, whether they are from particular groups (e.g. richer land-owners, or women, certain ethnic groups), and some general background on when and from where it is harvested, how it is used, and whether the harvest patterns are changing over time. This information is essential for targeting more detailed data collection, understanding the results, providing an idea of who benefits from the harvest, and indicating whether it is sustainable.

Using existing information. There are two options for obtaining the necessary data on net production of each of the main harvested goods. Where the collection and/or marketing of harvested wild goods is well organised, or of significant commercial value, there may be records kept by government, producer organisations (cooperatives) or traders. The workshop might be a good place to find out whether this information exists (see **Guidance 3)** for general guidance on the use of existing data).

Questionnaire surveys. If no previous records exist or they are inadequate, the other way of obtaining detailed data on the main harvested goods is to conduct a questionnaire survey of individual harvesters. How many people to interview, where, and when, will depend on the seasonality of harvesting and the extent of variation in who harvests what, so will be context-dependent and the answers from the workshop should be used to guide sampling design. For example:

- If your workshop respondents report that there are 300 harvesters of a product but that there are only four middle-men who buy the product from them and sell it on, you could target just those four individuals to get the required information.
- If there is no such system, but the harvesters are a fairly small or easily identified sub-set of the community, you may be able to conduct a survey of a random sample. This requires information on the total number of harvesters of the product, and their identity.
- If the majority of households within the site are harvesting a product (i.e. there isn't a smaller and more discrete group of identifiable harvesters), or if harvesters are not easily identified you may need to survey a random sample of the households in the area.

Wild Goods Method 2 provides more guidance and a basic template for a questionnaire, which can be adapted to local circumstances.

Harvested wild goods from the alternative state. It may be possible to obtain basic information on the most important harvested wild goods from the alternative state at the same community using the questions outline in **Wild Goods Method 1**. Where the alternative state would lead to significant changes in the condition of the habitat and the resources available it may be necessary to replicate the questionnaire survey (**Wild Goods Method 2**) at another site where the conditions comparable to the plausible alternative state are already present (see **Section 1.3**).

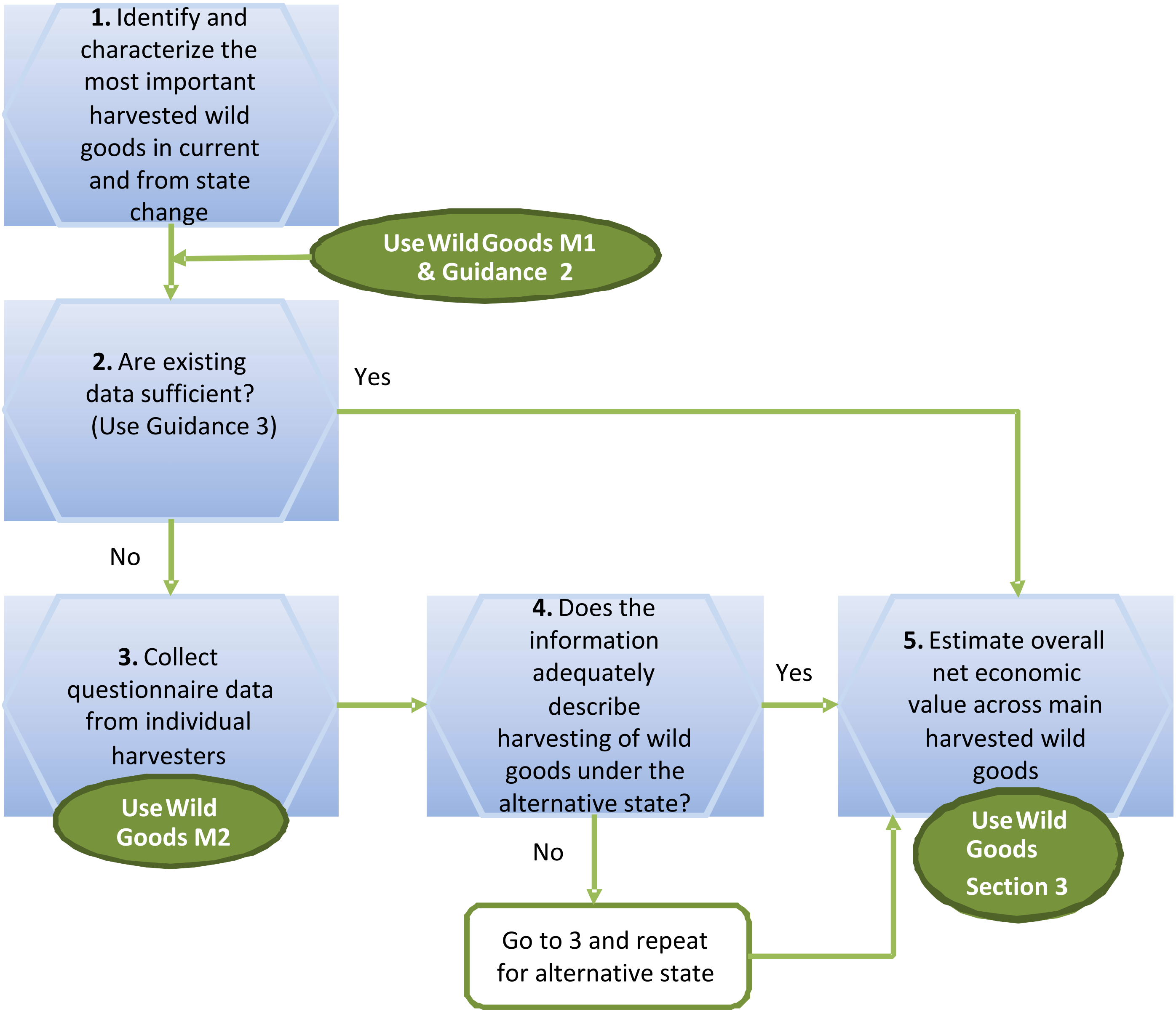
Next, use the data on number of harvesters, harvested amounts and costs of collection, processing etc. to estimate the net value of each of the main harvested wild goods across the site and how it may differ between current and alternative states. The data collected should also yield information on who benefits from harvesting, about the sustainability of harvesting, the social differentiation of benefits from harvesting within communities and about how far focusing on the selected goods underestimates the value of wild harvested goods as a whole.

Products from state change of the site. In some situations there may be significant harvest of wild goods during state change of the site to the alternative state - for example timber from a forest, charcoal from a woodland or peat from a wetland. You should ask key informants at a separate meeting whether they would expect any significant one-off harvest at the time of state change and derive estimates of the volume, value and beneficiaries of this one-off harvest based on their responses (see **Wild Goods Method 1**).

Sustainability of harvests. Declines in availability can be expected to indicate that harvest rates are not sustainable. This information can be checked by talking to informed individuals in the area. The value of production will need to be adjusted according to estimates of how sustainable current harvest rates are deemed to be. If responses indicate a large decline in availability (attributable to over-harvesting) we suggest reducing the calculated total net volume/value of production by 30%. If responses indicate only a slight decline we suggest reducing by 15%. However, these figures are largely arbitrary, and this should be noted in the presentation of results.

Illegal harvesting. In many countries, and despite laws protecting species or limiting the time and place for harvesting, some wild products will be harvested illegally. A number of methodological and ethical issues may then arise, especially where harvesters have reason to fear authorities. These are described below. Ultimately it will be up to you to decide whether it is safe, ethical and necessary to gather information on illegal use in the context of the site which you are studying. Refer to the note in Wild Goods Method 1 for guidance.

Wild Goods Section 2. Steps to estimate the volume and net economic value of harvested wild goods



Wild Goods Section 3. Summarising the information

Estimating overall net economic value of the main Harvested Wild Goods

The following worked example uses a fictitious site to show how information collected through methods described in this section can be analysed to arrive at the net economic value of the main harvested wild goods.

During a stakeholder workshop, the community identified **fuelwood**, **fodder** and **wild mushrooms** as the most important products they harvest from the site, which has a **total area of 10,340 ha**.

Census data obtained from the local government offices showed that there are **5,400 households** living around the site. However, according to participants at the stakeholder workshop access to natural resources is restricted to members of a Community Forest Management Organisation (CFMO), which has **749 household members**.

The stakeholder workshop also established that rates of unemployment were very high (and therefore the opportunity cost of family labour can be rated as zero), and that local units used for fuelwood are 'bundle' (**1 bundle of fuelwood = approximately 20 kg**) and for fodder 'basket' (**1 basket of fodder = 15.5 Kg**).

Participants at the workshop also told us that they had to travel slightly further from the village, and work harder to meet their needs for fuelwood, compared to 5 years ago.

Using a list of members provided by the CFMO, a subset of 50 respondents was randomly selected for the questionnaire survey (the potential list comprised more than 30 in case some respondents returned a negative response). In the end **45 households were interviewed**.

Based on the results of the questionnaire survey, the net annual benefit for each respondent was calculated, taking into account the amount collected, its market value, and costs of collection, processing, marketing etc. A worked example for fuelwood is shown below:

Quantity and value of product		Fuelwood
a.	Total quantity collected **from the site** in last 12 months* ⭘	4+4+3+1+1+2+3+2+4+5+4+5 = 38 (information provided per month for ease of recollection)
b.	Unit ⭘	Bundles
c.	Percentage for own use	80%
d.	Percentage sold/ bartered	20%
e.	Average price obtained per unit** ⭘	$5 per bundle
Family labour		
f.	Annual time taken by respondent and family members (unpaid) to harvest and process the product (person days)* ⭘	2+2+1.5+1+1+1+1.5+1+2+3+2+3 = 21 days (collection time per bundle varies e.g. takes longer during rainy season)
Hired labour		
g.	Annual input of hired labour for harvesting and processing (person days)* ⭘	1+1+1+2 = 5 (hire labour to help with fuelwood collection during peak farming periods)
h.	Typical daily wage rate paid for hired labour	$2 per day
Equipment costs****		
i.	What capital items (tools, materials, equipment) do you need for harvesting and processing this product? ⭘	Axe
j.	How long do you expect each of these tools etc. to last? ⭘	5 years
k.	How much did each item cost to buy? ⭘	$10
Transport and marketing costs		
l.	What are the annual costs of transport and marketing this product?* ⭘	Zero – fuelwood sold from home

- Annual value of fuelwood collected is 38 bundles x $5 per bundle = $190
- Annual cost of collection = 5 days of hired labour at $2 per day = $10
- Annual cost of equipment = cost of axe ($10) spread over 5 years = $2
- Therefore for this household annual benefit from fuelwood is 190 – (10 + 2) = $178

Repeating this calculation using information provided by each of the 45 households in the survey the **mean benefit per household** for each of the 3 products was calculated:

- Mean annual benefit per household from Fuelwood = 41 bundles/820 Kg/$205
- Mean annual benefit per household from Fodder = 200 baskets/3100 kg/ $4650
- Mean annual benefit per household from Mushrooms = 26 Kg/$299

Because responses indicated that the harvest of fuelwood was not at sustainable levels (people are travelling slightly further to gather household needs) the benefit for fuelwood was reduced by 15%. (It should be noted that this reduction is largely arbitrary). Therefore:

- Mean annual benefit per household from fuelwood, **adjusted for sustainability** = 35 bundles/700Kg/$175

Therefore total annual benefit per household from harvested wild goods from the site = $(175+4650+299) = $5124

And therefore total HWG benefits from the site (which is used by 749 members of the CFMO) = 749 x 5124 = $3,837,876 = **$371 per hectare**

The site is threatened by agricultural encroachment, and discussions at the stakeholder workshops established that the most plausible alternative state would be marginal agriculture on the lower slopes, and degraded forest in less accessible areas. An area with very similar physical and socio-cultural characteristics which had already undergone such a conversion was identified nearby. The boundaries to this area were clearly defined (demarcated by a dry river bed, a road and a mountain ridge). The area had an area of 5600 ha (determined from maps of the area). Using census data provided by the local government authority a random sample of 45 households was selected, from a total of 1500 households, and interviewed using the same questionnaire form, and referring to the harvest of harvested wild goods from the degraded forest/farmland. The HWG benefit per hectare was calculated based on their responses, in exactly the same way as described for the site in its current state (above), to arrive at a figure of **$158 per hectare**.

The stakeholder workshop, and a subsequent feedback session, explored who was using the resources, to understand better who would be affected. These meetings established that those most dependent on harvested wild goods are **landless** households, and **female-headed** households (especially for collection of wild mushrooms which provide important cash income).

<u>One-off benefits from conversion</u>

Respondents also indicated that conversion would be expected to yield a one off harvest of timber and fuelwood – most of which would be sold in local markets or to middle-men coming from the city.

These benefits would accrue to the farmers who cleared the land for their new farms, using their own labour (zero opportunity cost) and mainly hand tools. However, some hired labour would be needed to carry or drag large logs to the roadside.

Respondents estimated that on average one hectare of forest would yield a one-off harvest of 45 bundles of fuelwood (worth $225) and a one-off harvest of timber worth $520. Labour to help drag large timber to the roadside would cost $38/ha. Therefore total one-off benefits from clearance would be $(225+520-38) = $707/ha.

Part IV. Assessing cultivated goods

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PURPOSE OF CHAPTER

1. To quantify the amount and net economic value of the major cultivated goods grown in the area under its current and alternative state - including crops, livestock, plantation timber and biofuels.
2. To determine (where appropriate) the relative value of cultivated goods to different stakeholder groups based on social differences within communities
3. To identify how much different stakeholder groups (or individuals) gain these benefits and which groups (or individuals) lose benefits when there is a change in state.

OVERVIEW

Key tasks	• Identify categories that differentiate stakeholders at the local level • Characterize the most important cultivated goods at the site, under both current and alternative states (socially differentiated where relevant) • Calculate amount produced and net economic value of each product • Evaluate the relative value of each cultivated good for different stakeholder groups (net economic value or other qualitative measures) • Estimate overall net economic value across all main goods (where appropriate)
Outputs	• Benefits from cultivated goods, from the current site and the site in its alternative state, expressed in $\$$ ha^{-1} $year^{-1}$ • Quantification or description of how different, socially differentiated stakeholders, will be affected by a change in the site's state.
Datasets required	• Map of site - under current and alternative states - to ensure respondents are answering questions with reference to the right area
Processes	• Categorisation of stakeholders according to social difference • Holding a stakeholder workshop • Collating existing data • Resource mapping and participatory rural appraisal • Conducting a questionnaire survey • Analysing results
Methods	• Cultivated Goods M1. Meeting with cultivators or other informed individuals to characterize the most important cultivated goods and who the beneficiaries are • Cultivated Goods M2. Individual questionnaires with cultivators.

Cultivated Goods Section 1. Approach and key issues to consider

This section provides information about how to estimate the volume, economic value (net of inputs) and beneficiaries of cultivated goods. The goods might include food crops, livestock, products from aquaculture and plantation forestry, and biofuels; note that timber from non-cultivated species (which does not involve planting or other cultivation costs) is dealt with in Section III. Data collection involves workshops, followed by use of existing data or (more usually) a questionnaire survey of cultivators. Data are needed about both the current site and its most likely alternative state, though it may be possible to collect both sets of information through the same exercises. Information about how much different groups of people benefit from cultivation is obtained during the workshop, which also considers sustainability by asking about recent changes in cultivation. One other issue to consider is that cultivating some areas (e.g. inside reserves) or crops (e.g. narcotics) may be illegal; for guidance on quantifying illegal activities see Wild Goods Method 1. It is important to note that the access, use and trade of cultivated goods may be socially differentiated. This section should therefore be used with a view to identifying how dependencies on these products vary according to social factors. Refer to **Guidance 1** for details.

The first step in applying this section of the toolkit is to collect general information on cultivation within the site, usually through a workshop of informed individuals (such as agricultural extension officers) and/or producers (e.g. farmers or foresters). Detailed guidance on what to ask is given in Cultivated Goods Method 1; for general information on running a workshop see **Guidance 2**. For practical reasons it will usually be necessary to focus attention only on a selection of cultivated goods. It is important that the goods chosen reflect 'importance' appropriately for different stakeholder groups.

The workshop should also be used to establish the total area under cultivation and the number of households involved; the availability of existing data (see below); and then for each of the selected goods in turn, how many households cultivate it, whether they are from particular social groups (e.g. richer land-owners, or women, or part-time-farmers from the city), and some general background on how it is cultivated and used, and whether cultivation patterns are changing over time. This information is essential for targeting more detailed data collection, understanding the results, providing an idea of who benefits from cultivation, and indicating whether it is sustainable.

Having established the main cultivated goods, for each one we then need information about the contribution of the ecosystem to its production. Most cultivated goods (such as rice, or fish produced by aquaculture) are usually fairly straightforward to assess - they tend to have a single use (so are not too difficult to value) and quantifying and subtracting inputs from outside the ecosystem (such as labour or fertiliser) to estimate the value contributed by the ecosystem is reasonably simple.

Valuation of livestock can be more complicated, as they might simultaneously provide many different, sometimes non-marketed benefits (meat, milk, power, dung, or acting as financial security) and often have varied inputs (they may be brought in as juveniles, receive food from outside the area in question, and so on). We therefore suggest a different approach to estimating the net benefits of livestock cultivation in the area, which involves estimating the value of the fodder obtained from it (equivalent to the approach adopted in Section III to estimate the benefits of fodder obtained from non-cultivated areas).

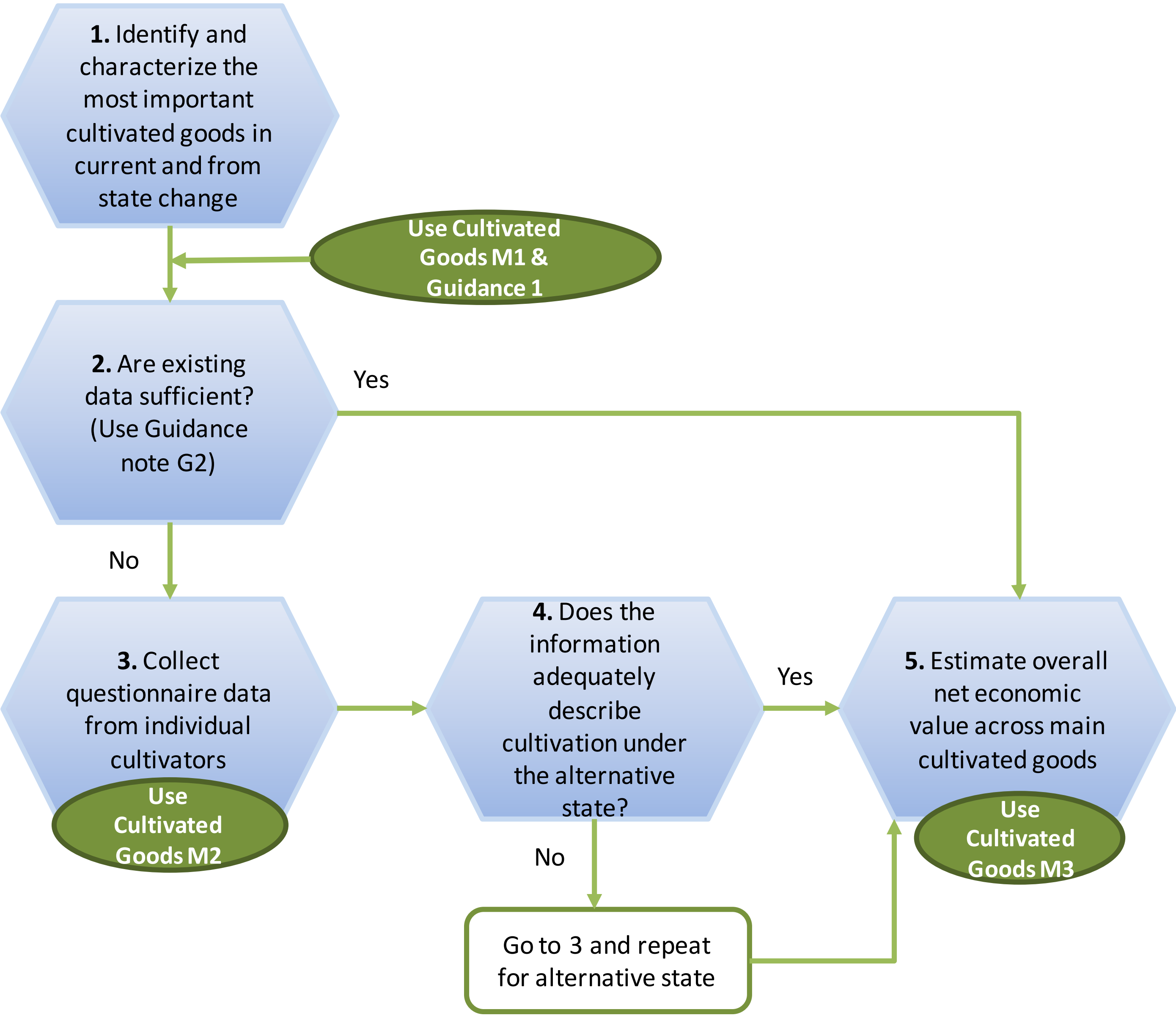
There are two options for then obtaining the necessary data on net production of each of the selected cultivated goods. One is to use information available in existing databases (e.g. kept by government, extension officers, businesses or cooperatives) or previous studies (e.g. academic research, project reports, etc.). The workshop, or a preliminary meeting, might be a good place to find out whether this information exists. If it does, be sure to critically review the methods used and check whether the data are really what you need (see **Guidance 3** for general guidance on this). It may also be necessary to speak to informed individuals to establish whether there have been any major changes (e.g. in production methods, prices, markets or competition) that have significantly affected cultivation in the area since the results were published which may mean they need to be adjusted or are no longer useful.

If no previous records exist or they are inadequate, the other way of obtaining detailed data on the main cultivated goods is to conduct a questionnaire survey of individual cultivators. From knowing what individual cultivators do, and the number of cultivators, it is then possible to calculate total production across the entire site. How many people to interview, where, and when, will depend on the seasonality of production and the extent of variation in who cultivates what, so will be context-dependent. Cultivated Goods Method 2 provides more guidance and a basic template for a questionnaire, which can be adapted to local circumstances.

The next step is to check that the information obtained from the workshop, existing data sources, and questionnaire surveys is adequate to describe cultivation under the site's most plausible alternative state, as well as its current state. In many cases the workshop should be able to provide the necessary background information for both circumstances, and the goods and cultivation methods may be sufficiently similar for questionnaire surveys within the area to enable estimation of net production under the alternative state. However, where the alternative state would include introduction of important new goods or cultivation techniques it may be necessary to replicate the survey at another site where these practices already occur (see Section 1.3).

The final step is to use the data on number of cultivators, cultivation methods, yields and inputs to estimate the net production and economic value of each of the main cultivated goods across the area and how it may differ between current and alternative states. Where relevant (e.g. where a crop is grown for several years before harvesting) it is important to take into account variation in production and inputs over the entire lifecycle of the cultivated good; provided enough cultivators are interviewed and some have recently planted perennial crops while others have mid-aged or old plantings the yield data should be representative of the average across the life cycle, but this should be checked. The data collected should also yield information on who benefits from cultivation (i.e. identifying any social differentiation of benefits within the surveyed population), about the sustainability of cultivation, and about how far focusing on the main goods underestimates the value of cultivation as a whole.

Cultivated Goods Section 2. Steps to estimate the volume and net economic value of cultivated goods



Cultivated Goods Section 3. Summarising the results

Estimating overall net economic value across main cultivated goods

The following fictitious example shows how data collected with the methods set out in this chapter can be analysed to estimate how the net economic value of cultivated goods might differ between the current and alternative state of a site.

The meeting with farmers established that there are three important cultivated goods in the area - **olives, wheat** (which is grown beneath the olive trees), **and cattle** (which are brought there for three months each year to feed on the wheat stubble). All are cash crops; other crops are very minor. **At present there are 12 farms in the site, covering a total area of 74 hectares** (out of the total site area of 3224 hectares). All the farms are run and owned by local farmers, who are nearly all over 60 years old.

Olive production is done on a roughly 25-year cycle, with no olives produced for the first 5 years. The farmers sell their olives and wheat before processing, and also receive a government subsidy based on how many hectares they farm, worth $120/hectare. Cattle are owned by farmers from outside the area who pay local farmers a monthly rental for the food they eat in the fields; the cows' owners pay other costs (such as veterinary treatment) themselves.

Because there are only 12 farmers at the site each was asked to complete a questionnaire survey. 10 did so. Here is one example of the main results:

2. Crops			
What is your **total** size of the land you farm in the area (use local units of area if appropriate):	8 hectares		
Which of the top five cultivated goods do you grow? ⭘	Olives	Wheat	
Unit of measurement for that crop ⭘	tonne	tonne	
Last year, how much of that crop did you produce? ⭘	23.1 tonnes	17.6 tonnes	
Last year, what was the average price obtained per unit** ?⭘	1765	240	
Percentage for own use	0%	0%	
Percentage sold/ bartered	100%	100%	
Did you, or family members, spend (unpaid) time cultivating/ harvesting/ processing this crop? (Yes/No)	Yes	No	
If yes, how many person-days did you or your family spend cultivating/ harvesting/ processing this crop last year*?⭘	45		
Did you hire people to cultivate/harvest/process this crop? (Yes/No)	Yes	Yes	
If yes, how many person-days did hired people spend cultivating/ harvesting/ processing this crop last year*? ⭘	126	15	
What is the average daily wage rate you paid these hired people (outside of any reciprocal arrangements)?	$78	$78	
Cost of other inputs for this crop (seed, fertiliser, pesticide, water, fuel for machinery)*? ⭘	$868	$150 (includes hired machinery)	
What capital items (tools, materials or equipment) do you need for cultivating/ harvesting/ processing this crop? (e.g. tools, machinery)? ⭘	Baskets, various hand tools	Tractor, plough, seed drill	
How long do you expect each of these tools / machines to last (years)***? ⭘	15 years	20 years	
How much did each tool / machine cost to buy? ⭘	$420 total (adjusted to 2012 prices	$22000 total (adjusted to 2012 prices	
Last year, what was spent on transporting and marketing this crop*?⭘	$760	none	
If the crop is a perennial crop (e.g. fruit trees, vines, nut bushes, perennial herbs) ask the following:			
How much did it cost to establish the crop	$22300		

For this farmer:

Value of olives produced last year = 23.1 tonnes @$1765/tonne) = $40,772

Annual cost of labour used to produce olives = 126 days @ $78/day = $9,828

Other costs of producing olives = $868 on inputs + $760 on transport + $28 on equipment [$420 spread over 15 years] + $912 establishment costs [$22,800 spread evenly over 25 years] = $2,568/year

So net annual benefit from olives = $40,772 - [$9,828 + $2,568] = $28,376

Applying the same methods to wheat (slightly simpler because it is an annual crop):

Value of wheat produced last year = 17.6 tonnes @$240/tonne) = $4,224

Cost of labour used to produce wheat = 15 days @ $78/day = $1,170

Other costs of producing wheat = $150 on inputs + $1,100 on equipment [$22,000 spread over 20 years] = $1,250/year

So **net annual return from wheat = $4,224 - [$1,170 + $1,250] = $1,804**

Similar calculations can be done for cattle (data not shown in detail). The farmer has a contract for grazing 25 cattle for three months each year, for which their owner pays $32/cow/month. The farmer himself looks after the cattle so incurs no hired labour costs.

So the **net annual return from cattle = 25 x 3 x $32 x = $2,400**

and the **total net return to the farmer from all 3 products = $28,376 + $1,804 + $2,400 = $32,580/year**.

Note that the farmer also receives a government subsidy of $960/year (= $120/hectare x 8 hectares) but this does not count as part of the return from cultivation.

Repeating these calculations for the other 9 farmers at the site who completed the questionnaire (and who together farm 68 hectares) meant that the total net return of cultivation for the site could be calculated:

Total net return for all 10 farmers interviewed = $243,615/year, summed across 68 hectares

So net return from cultivation per unit area = $243,615 / 68 hectares = $3,583/hectare/year (less than on the first farm, partly because the sample includes two farms whose olives are not yet in production).

And the **total net return from cultivation across the entire site** (taking into account the farms for which questionnaire data could not be obtained) = $3,583/hectare/year x 74 hectares **= $265,110/year**.

Finally, turning to the alternative state, an earlier stakeholder workshop has suggested that the most **plausible alternative state would involve expansion of farming to cover around 1200 hectares, producing the same crops but on larger farms** (as is already the case on similar hillsides to the west of the site). Because these might be expected to have profit margins that differ from those of the smaller farms at the site a new survey is conducted which involves interviewing 30 randomly chosen farmers who operate larger farms close to the site. These farmers produce the same crops as the farms within the site, but in 19 cases the farm itself is owned by (and the profits go to) businesses in the provincial capital. All but one of the 30 farmers is less than 60 years old.

The **total net return of cultivation on the 30 larger-scale farms** (calculated in exactly the same way as above) **= $4078/hectare/year.** Note that because of economies of scale and increased use of machinery and chemicals this is greater than on the smaller farms.

Hence the **total net return from cultivation across the entire site under the alternative state** can be estimated as = $4078/hectare/year x 1200 hectares = **$4,893,600/year**.

As well as noting the difference in net returns from cultivation between the current and alternative state it is also important to report the **likely change in ownership patterns and in the age structure** of the farming community that might be expected if the site changes to the alternative state.

Part V. Assessing nature-based recreation

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Reviewers: Julia Jones, Ruth Swetnam, Chris Sandbrook, Lucy Emerton, Jo Elliot

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PURPOSE OF CHAPTER

1. To estimate the annual number of visits
2. To estimate annual total income from tourism and recreation
3. To estimate annual tourism income from nature-based activities
4. To compare (1-3) between current and alternative state

OVERVIEW

Key Tasks	For the current and alternative state, respectively; 1. Estimate the number of visits 2. Estimate the average spend per visit 3. Estimate the percentage of visits that would occur under the alternative state 4. Synthesize (1-3) into a single figure on the value of the site for nature-based recreation
Outputs	For each of the current and alternative state, an estimate of; • number of visits per year • spend per visit ($)
Datasets required	• Habitat classifications • Visitor data, if exists
Processes	• Expert interviews • Data collation from existing statistics • Field survey / questionnaire
Methods	• Recreation M1: Census for estimating number of site visits • Recreation M2: Questions for estimating economic value of tourism and recreation at the site

Recreation Section 1. Approaches and key issues to consider

This section deals with how to measure the volume and wherever possible the economic value of nature-based tourism and recreation (referred to as nature-based recreation). We focus on quantifying the benefits that people obtain from nature-based recreation (tourism based on the natural environment) and/or recreation (using one's free time to engage in some activity) at the site of interest.

Data could be obtained from three main sources: existing databases and studies, expert interviews, and new field surveys. The key information we want is the annual total number of visits. [Note that this is not the same as the number of visitors, as repeat visits will be included. Obtaining the actual number of visitors is far harder to estimate.] For economic valuation, some way of measuring the value of a visit is required. Here we suggest using a simplified travel cost method combined with visitation data to estimate the economic value of tourism and recreation at a site. Negative impacts of tourism on ecosystem service provision are not directly included in the analysis, making assessment of this ecosystem service slightly different from others (e.g. extractive resource uses) which incorporate considerations of sustainability. If sustainability is to be investigated, some measure of whether current activity levels are sustainable will also be needed (see below).

Using existing information. In some instances previous studies may have been conducted (e.g. by researchers, NGO staff, site managers or government officials) to estimate the extent and/or economic value of nature-based visits to a site. If not it may still be the case that government staff, tour operators, site officials, tourist visitor centres, hotels or local tourism co-operatives have compiled the data that you need. Identify who might be involved in tourism at the site and conduct interviews with them (note that some of this information could be gathered at a general workshop of national level stakeholders and key informed individuals). This may provide sufficient data on the number of visits to a site and maybe on their economic value.

Interviewing key informants. You also need to know what would happen to the number of visits to the site - or the mean spend by visitors – under the change in state. The best approach is to ask a cross-section of visitors, although key informants may be able to provide a good estimate. You can then adjust your total visit or spend figures accordingly, as described in the <u>Recreation Method 1</u>. Some useful information that could be derived from the key informants include: (1) how the number of visits to the site (or the mean spend by visitors) would be expected to change if it had changed in state; and (2) by what proportion the total would change. If you cannot obtain reliable answers to these questions from people who work with visitors you could instead consider asking similar questions of a sample of visitors directly (see <u>Recreation Method 1</u>).

Questionnaire surveys. Where existing documentation is inadequate, two sorts of field surveys to sample the visitors at a site may be undertaken. These can be done relatively efficiently if visitors are concentrated in areas where sampling efforts can then be focused (e.g. at the entrance to a site, at a hotel, in an airport), though consideration should be given to whether this might lead to an unrepresentative sample (e.g. because few of a site's local visitors will get there by air). Also be cognisant of the fact that visitor numbers typically fluctuate greatly between seasons and years.

Census: If only data on total visit numbers are needed, then a census of visitors might be undertaken. This requires staff or volunteers to conduct a count of the people visiting the site (e.g. at the site entrance, or from points that give a vantage over a frequently visited area). Alternative ways of doing this, taking into account the problems of estimating visit numbers across an entire site and an entire year, are given in Recreation Method 1.

Economic survey: If data are also required on visitor spending, then a short questionnaire can be undertaken. This should aim to target a socio-economically, spatially and temporally representative sample of, as a rough guide, between 50 – 200 visitors, where possible using information from stakeholders to guide aspects of sampling design such as when, where and who to sample. Some guidelines for doing this are provided in Recreation Method 2.

Tourism and recreation from state change of the site. For nature-based tourism and recreation, estimating how visit rates and values might change in the alternative state is harder than for some other services because places already under these conditions might differ from the focal site in important ways (such as in provision of visitor infrastructure, or accessibility): we therefore recommend that these changes are instead estimated by asking people how they think visitation might change, rather than by trying to measure it directly in a place already in the alternative state. However, if the alternative state still holds some attraction to tourists, it might be possible to find an appropriate site and collect data on visitation levels directly. Refer to Recreation Method 2.

Differentiation of beneficiaries. The economic benefits from recreation and tourism will be received differently among different stakeholder groups. Benefits may be received at the national or global scale (for instance, when international holiday packages are booked in the country of origin or all payments are made to a national tour operator). In some cases, benefits may be received directly by local communities at the site (e.g. eco-tourism ventures, local accommodation, guides etc). Equally, at the local level, the distribution of benefits may be influenced by social circumstances. It is therefore good to identify the spread of the total economic benefit across socially differentiated groups. Use **Guidance note x** to inform how you might do this.

Sustainability. In popular areas there may be concerns about the sustainability of current levels of tourism. If you think the site might be under threat from tourism you could ask some specific questions to groups of people:

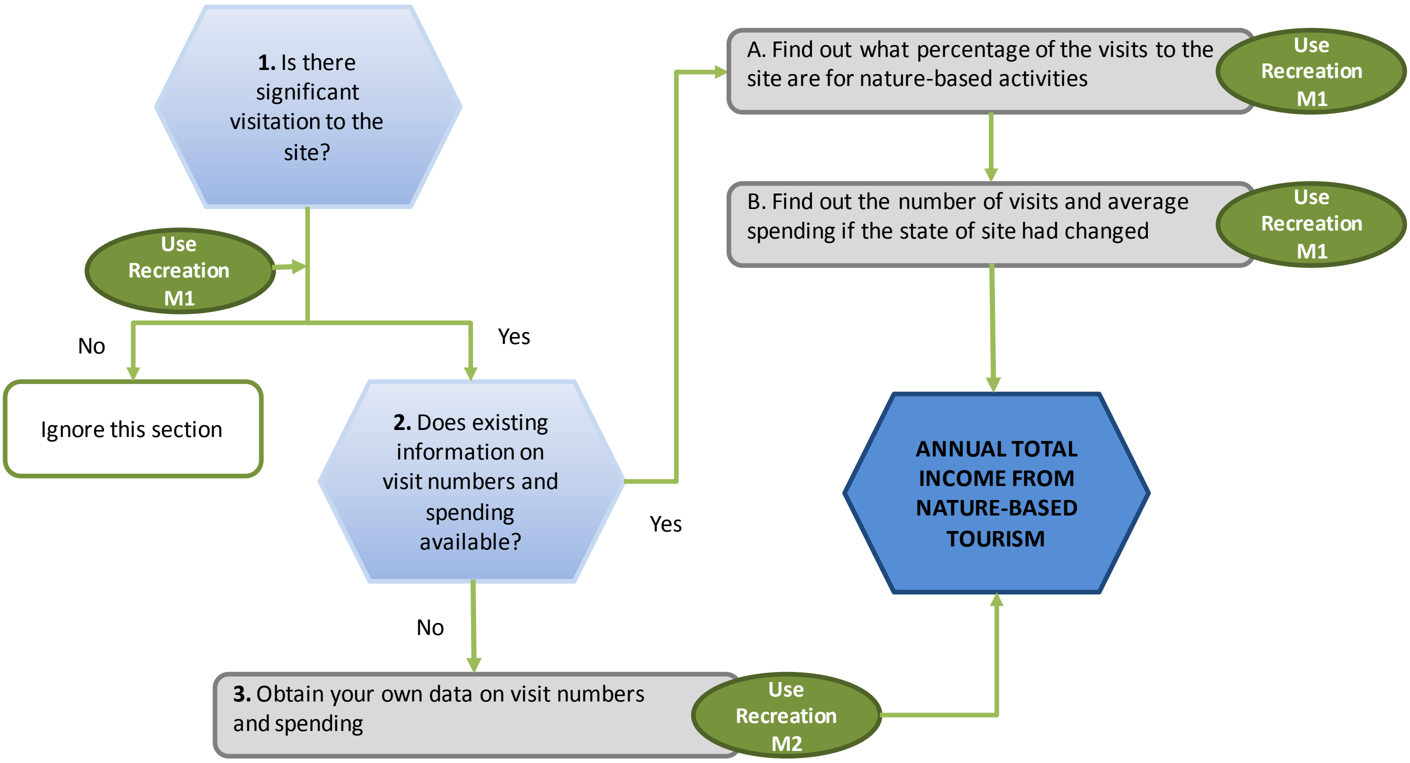
Visitors - is the area too crowded?

Site managers - do they think tourism is a problem? Do they consider the number of visitors received currently to be damaging to the site? Do they have evidence for this (e.g. eroded trails, disturbance of animals, damage to plants etc.)?

Host population/local communities – do they think there are too many tourists? Is it damaging their local environment? Is it affecting their well-being?

Where the evidence points to tourism being damaging you should make this clear in interpreting your findings and communicating them to stakeholders. An example of this kind of approach is given in the wild foods section of the toolkit (see Section III).

Recreation Section 2. Steps to estimate the number of visits and nature-based tourism economic value of sites



Recreation Section 3. Summarising the information

The steps below need to be done separately for the current and alternative state.

a) Separately, for international and local visitors, multiply the annual visits (expressed as number of visits per year) with their mean spend per day to derive the annual total spend (expressed as $ per year for the current state).

b) Separately, for each visitor group (e.g. national and international visitors), multiply the total spend with the percentage of people in each group who reported they would return in the alternative state (expressed as $ per year).

c) The difference in value between **a** and **b** reflects the nature-based recreation value of your site in the current state (expressed as $ per year).

d) Where relevant, divide the economic income between spatial and/or social groups (e.g. benefits received at the local, national and global levels, or benefits received to distinct individuals within the local community based on social status).

For useful ways to present this information, see **Section 4** of the toolkit.

Section 4. Presenting and Communicating the Results

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Introduction

In this section we provide some guidance and issues to consider when presenting and communicating the results obtained by applying the toolkit to assess ecosystem services *for the purposes of supporting the case for conserving a site.* There are other possible purposes for which one might want to apply the toolkit and communicate its results, but we do not focus on these here. Note that each of the sections covering methods for assessing different services contains guidance on how to calculate the values of a service, currently and under the alternative state. Here we consider how best to present these values, and communicate what they mean. Note also that effective communication requires engagement with the target audience throughout the process of planning, data collection and dissemination of results. Engaging with stakeholders from the start of the project will help facilitate more effective communication of the results. Feeding back to stakeholders is therefore a key part of this toolkit and should take place after a preliminary analysis of the results. Feedback sessions may be in the form of a group discussion with simple diagrams and graphs to represent the ecosystem service changes and implications for users. This will allow them to contribute to what is said about the place where they live and to have some power and ownership of the data.

Issues to consider

Identifying the target audience.

It is likely that users will want to communicate their results to different target audiences, including, for example, local people living in or near a site, local, provincial or national officials/decision-makers/politicians/government, NGO members, the general public, scientists etc. These different audiences will have different levels of understanding about biodiversity conservation, ecosystem services and the relationship between them. Some will require more general and less technical language, and the level of detail required will also vary. It is therefore important that users identify which audiences are of greatest priority, and then for each of these what information is most relevant, what level of technical understanding can be assumed and what level of detail is appropriate.

Choosing the appropriate format(s) and product(s) for presenting results.

Different audiences will be best informed with using different formats for presenting results. These might include scientific papers, popular magazine or newspaper articles, brochures, policy briefings, videos, presentations etc. Users should consider a variety of alternatives and decide which ones are most appropriate. Many potential audiences will have little time to devote to looking at any product in detail, so succinctness and simplicity are very important.

Economic versus other metrics, and unevaluated services.

While some ecosystem services can be readily quantified (under current and alternative conditions) using economic metrics (e.g. $), others may be capable of being expressed only in physical units (e.g. water supply in cubic metres), or in terms of number of people benefiting from the service, or even more intangible services (such as spiritual values) may simply be identified as ‘important’ by experts and local users. Such services may be greatly significant and even more important than those capable of being quantified and monetised. Hence it is essential to consider the diversity of services and metrics, and not to over emphasise only those that it is possible to express in terms of dollars. Similarly, the toolkit only provides methods to evaluate a small suite of services. At some sites, other services may be considerably more important: it is important to mention these services, even if no quantification of their value can be presented. Refer to Section 3 for details on the scoping of all ecosystem services using a rapid appraisal form.

Qualitative information.

Narrative is really important; not all aspects of differentiation need to be quantified. The explanatory narrative might suffice, and might not need quantification. Need not always be quantified differentiation. Stress importance of social science methods and reporting of results in a qualitative way.

Communicating uncertainty and accuracy.

It is important to be open and transparent about the potential sources of uncertainty and bias, and the likely level of accuracy in the results presented. For example, carbon storage values may be based on data derived from a sample of measurements in the field. Such data are likely to be more accurate (i.e. the estimated value is closer to the true value) if they are based on a larger number of samples (simply because with a smaller number of samples there is a greater chance that one may be unusually high or low by chance). The uncertainty introduced by sample size is often best communicated using error bars or confidence intervals showing ± 1 standard error around the mean, or 95% confidence intervals. When one compares the difference in values between the current and alternative state, one can then see how large these are compared to the variability of the results obtained from the sample of measurements. For example see Figure 1. This toolkit provides a rough classification of levels of confidence based on how the data were collected. Refer to Guidance 5 for details.

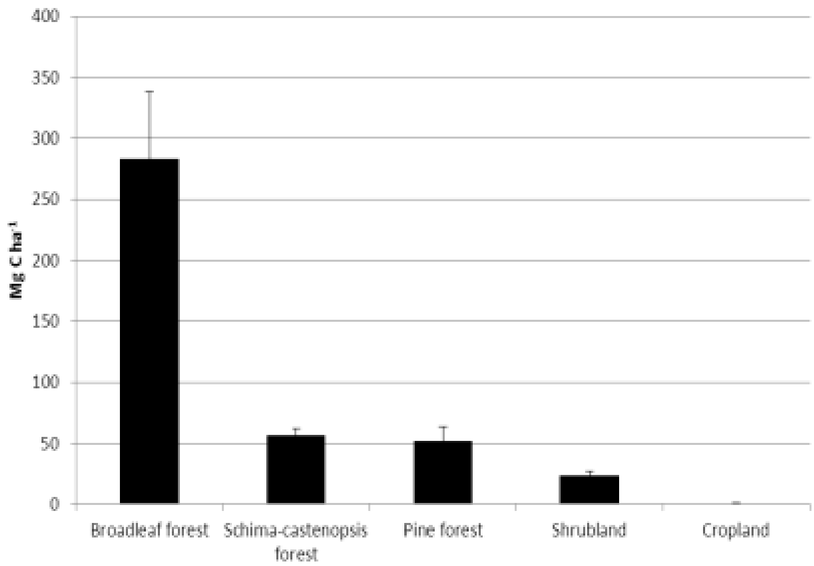


Figure 1. The carbon storage in metric tonnes per hectare for different land covers types at a site.

Users should also be open about potential sources of bias—for example, if the user bases estimates of the value of some service for a site in the alternative state, but believes these are likely to be systematically too high or too low (e.g. because of some other factor that it was not possible to control for), then this should be stated prominently.

Communicating trade-offs between biodiversity & ecosystem services.

Management and action for biodiversity conservation at a site will sometimes enhance net delivery of ecosystem services: a so-called ‘win-win’ situation. In these cases one can argue that it is worth conserving the site not only for its intrinsic biodiversity value, but also because there is a net benefit for the ecosystem services people derive from the site. However, in some cases one might find that there is a trade-off: management to benefit a particular aspect of biodiversity at the site (e.g. the population of a threatened species) leads to a net reduction in the delivery of one or more service. In these cases, the results will need to be presented carefully, considering *the intrinsic value* of the biodiversity, the long-term sustainability of ecosystem service delivery, the balance of beneficiaries (who wins and who loses), and how any inequalities might be addressed (e.g. through changes to current management practices or possible ‘Payment for Ecosystem Services’ schemes).

Communicating trade-offs between beneficiaries.

Changes in the delivery of ecosystem services will have different impacts on different users (beneficiaries) depending on who they are, what rights they have, where they live, whether they have access to alternatives and when they use the services. These impacts are often overlooked but are one of the most important aspects of any assessment of ecosystem services. Analyses should consider the equitable delivery of services, and which users stand to gain or lose from a particular land management decision. In some cases, one group of stakeholders may bear the costs of ensuring the delivery of ecosystem services to another group of stakeholders. In such cases they may need to be compensated by the users (often referred to as ‘Payment for Ecosystem Services’) to enable a sustainable and fair outcome.

Although this is only dealt with only briefly in this version of the toolkit, the distribution of benefits, and issues relating to equity and poverty alleviation are essential considerations in any ecosystem services assessment. We aim to build on this aspect in the future development of the methods.

Communicating limitations of the toolkit.

It should be reported what the limitations are of the methodology used. For example:

Positionality of people collecting the data may introduce bias into the process

Issues is translation of information collected

Misrepresentation of women and other marginal groups is a risk

Constructing a narrative

Most audiences will have a limited understanding of the issues related to biodiversity conservation and ecosystem services. Effectively communicating to such audiences will require careful explanation of the relevant facts in appropriate language. It can often help to construct a narrative to help communicate the messages. For example, one might address the following issues in sequence:

- Site X is important for Y biodiversity (e.g. threatened or endemic species, representative habitat etc)

- But site X is also important for the services ('benefits') 1,2,3 that people obtain from it

- Such people include those that live nearby (e.g. local villages), at some distance (e.g. in the capital city), or at considerable distance (the global community)

- The greatest (potential) threat to the site is X (e.g. conversion to cultivation)

- This would negatively impact not only the biodiversity, but also the delivery of some of the services people rely on

- Service 1 would decline from Y to Z (i.e. by X%), while service 2 would decline from Y to Z (i.e. by X%)

- However, service 3 would increase from Y to Z (i.e. by X%)

- X people may derive a net benefit from a change in state of the site, while Y people will be disadvantaged.

- A case for biodiversity conservation at site X can be made by taking account of the balance of ecosystem service delivery and who benefits from these

- The case can be strengthened by considering management / policy options X, Y, Z.

Alternatively, the toolkit may have been used to obtain data in order to address a specific question, or to provide information to inform arguments against a particular development. It always helps to think about who is the target, what do they need to know, in what level of detail, and then present the results as simply as possible to achieve this.

Presenting results

Graphics often tell a story more powerfully than words, so bar charts, spider diagrams and rose plots may form an important component of how the results are presented. However, beware of providing too many, or making them too complicated. The most important may be a summary graphic showing the key result for all services evaluated at the site, indicating the units and values in the current and alternative state, and % change between the two. An example is shown in Figure 2.

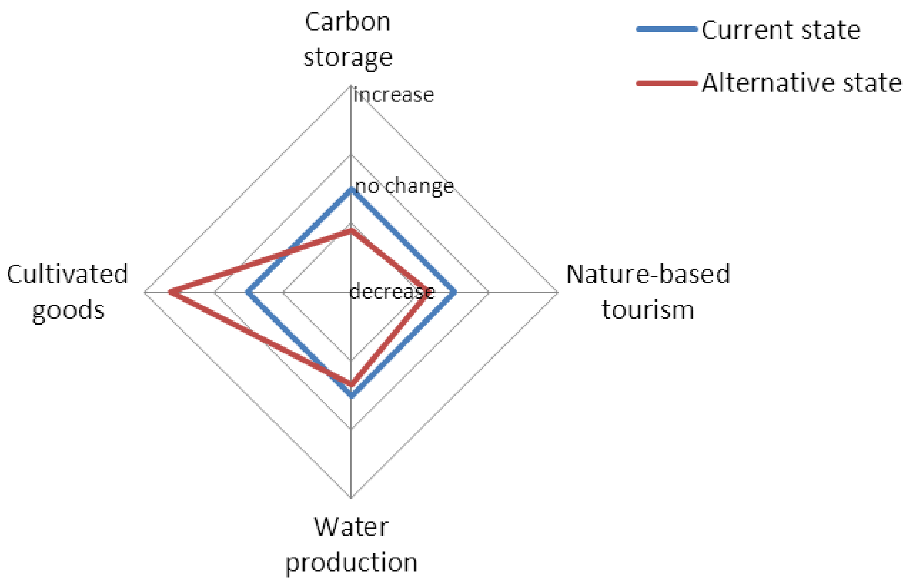


Figure 2. Summary graphic showing a comparison of the ecosystem service delivery for a hypothetical forest site, currently and under conversion to agriculture.

Alternative ways to present results include using rose plots that present the overall balance of services on a common scale of 0–1 where 1 represents the maximum value of the services between the two states. For example see Figure. 3

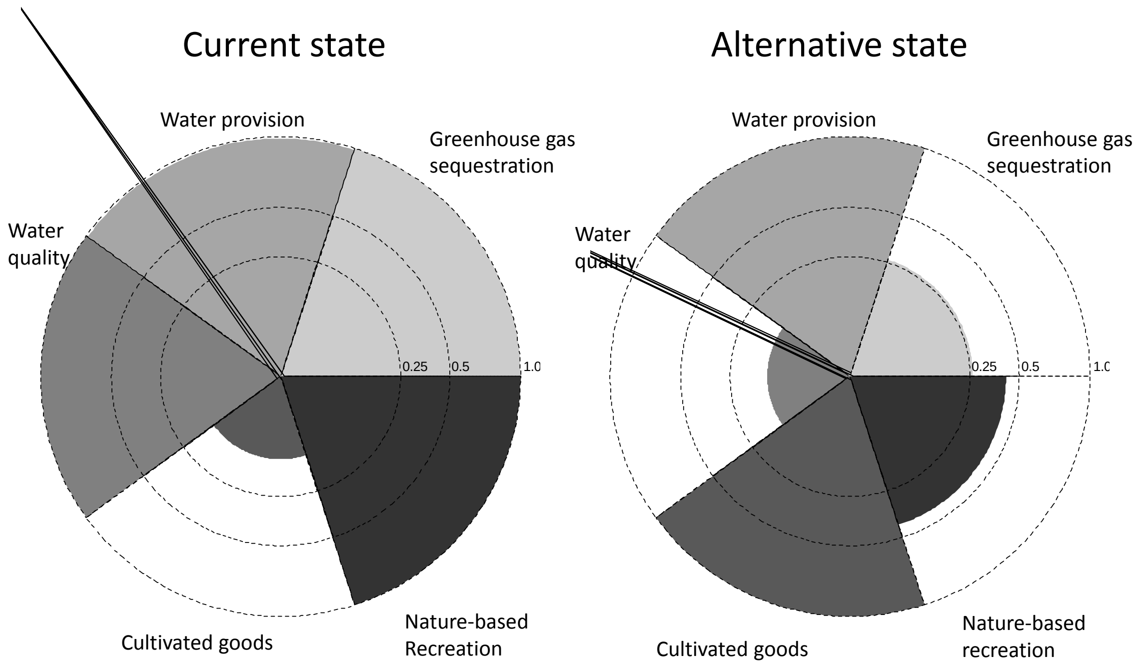


Figure 3. Rose plots showing a comparison of ecosystem service delivery between two states.

Tables could be used as a mean to present concisely the overall results. For examples, see Table 1 and 2. Table 1 shows the net consequences in ecosystem services of alternative land management at hypothetical site. Such presentation for current and plausible alternative states of a site of interest also determines the net consequences of such changes for different stakeholder groups. Often a sensitivity analysis of carbon stock is also performed using a range of carbon prices that were adjusted to a particular year based on published inflation rates (see Table 1). Table 2 shows the magnitude of change in delivery of different services and who the beneficiaries and losers are, if the site were converted.

Table 1. Net values of all services resulting from continuation of hypothetical invasive alien mammal control programme.

	Current state (with control programme)	Alternative state (without control programme	Difference
Service (flow) ($ yr $^{-1}$)			
Nature-based tourism	400,000	200,000	200,000
Harvested wild meat	200,000	100,000	100,000
Feral livestock management cost	-50,000		-50,000
Net annual benefit	**550,000**	**300,000**	**250,000**
Net annual benefit per hectare	**550**	**300**	**250**
Service (stock) ($)			
Net stock benefit from avoided carbon loss*	28,000,000	25,000,000	3,000,000
Net stock benefit per hectare			**3,000**

*Carbon values used are based on the mid-value US Government figure (see below)

Sensitivity analysis of carbon stock ($)	Current state	Alternative state	Difference
EU's Emission Trading Scheme ($56.18/Mg C)	19,000,000	17,000,000	2,000,000
US Government ($83.61/Mg C)	28,000,000	25,000,000	3,000,000
UK Government ($319.33/Mg C)	109,000,000	97,000,000	12,000,000
Tol, 2010 ($118.09/Mg C)	40,000,000	36,000,000	4,000,000

Stern et al. 2006 ($348.13/Mg C)	119,000,000	105,000,000	14,000,000
Verified Emission Reductions ($22.75/Mg C)	8,000,000	7,000,000	1,000,000

Carbon prices were adjusted to 2011 based on International Monetary Fund's inflation rates (http://www.imf.org/external/pubs/ft/weo/2012/01/weodata/weorept.aspx)

Table 2. Summary table showing a comparison of the ecosystem service delivery for a hypothetical forest site currently and under conversion to oil palm plantation

		If site is converted to alternative state:	
Ecosystem service	% change in alternative state	Who benefits?	Who loses?
Carbon storage ($)	-40%		Global community
Tourism ($)	-25%		Local and national communities
Water provision (million L/day)	-10%		Local communities
Cultivated goods ($)	+75%	National scale business	

One may also want to supplement the overall summary with graphics for individual services. For example see Figure 4.

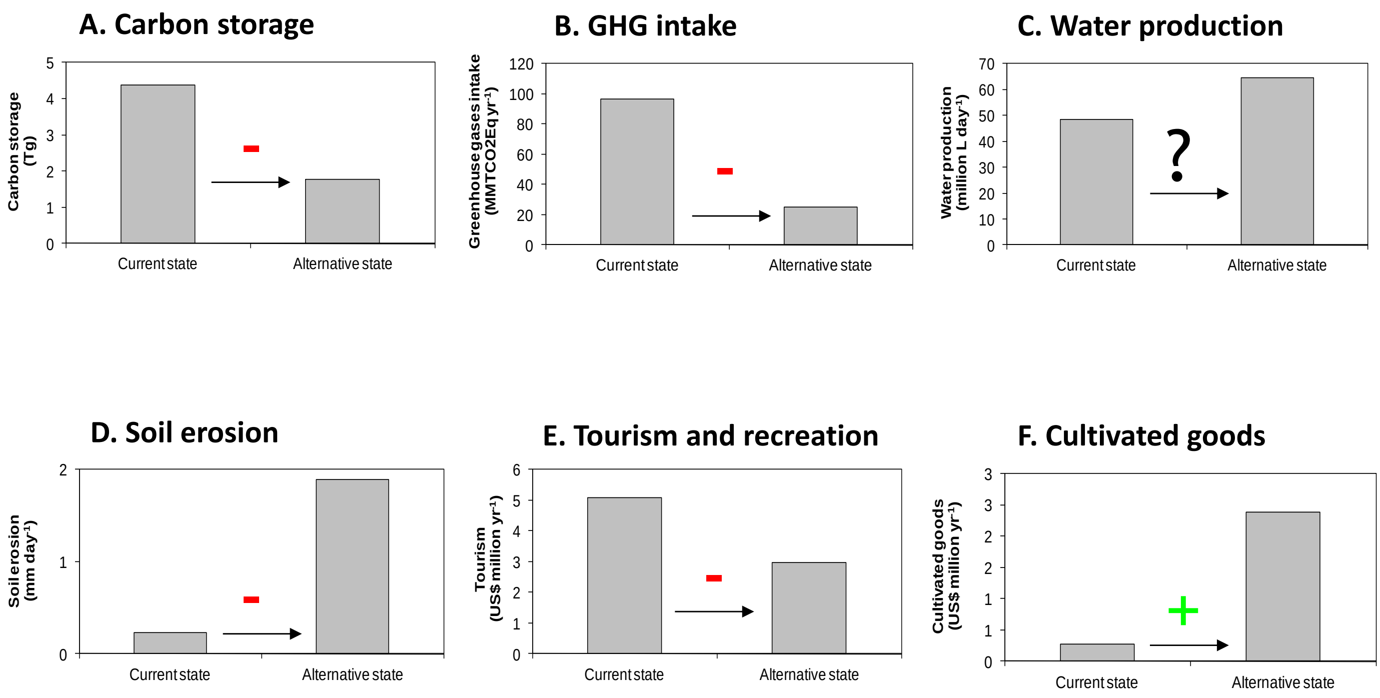


Figure 4. The differences between the current and alternative states of a hypothetical forested site for carbon storage (A), greenhouse gases, GHG, intake (B), water production (C), soil erosion - proxy indicator for water quality (D), tourism and recreation (E) and cultivated goods (F).

Alternative ways to present the overall summary include using stacked bar charts. For example see Figure 5.

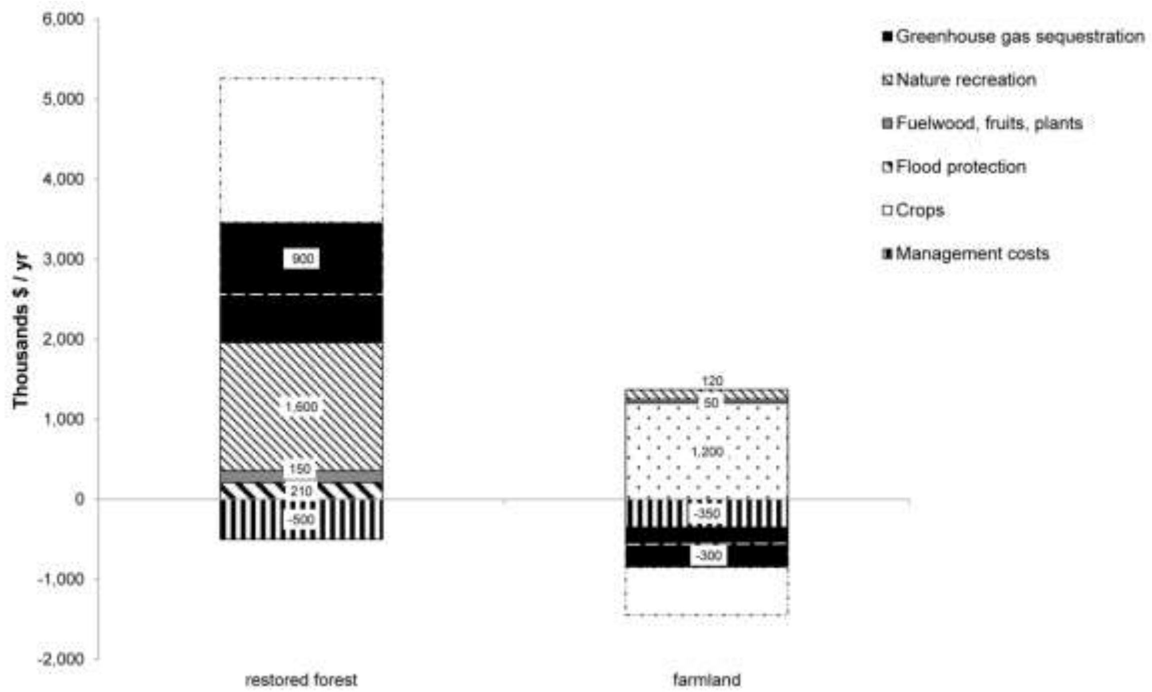
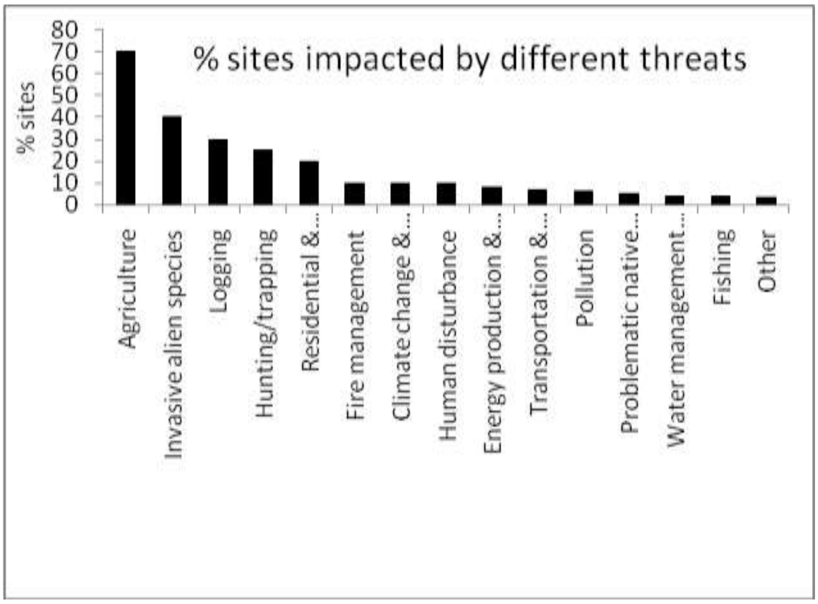


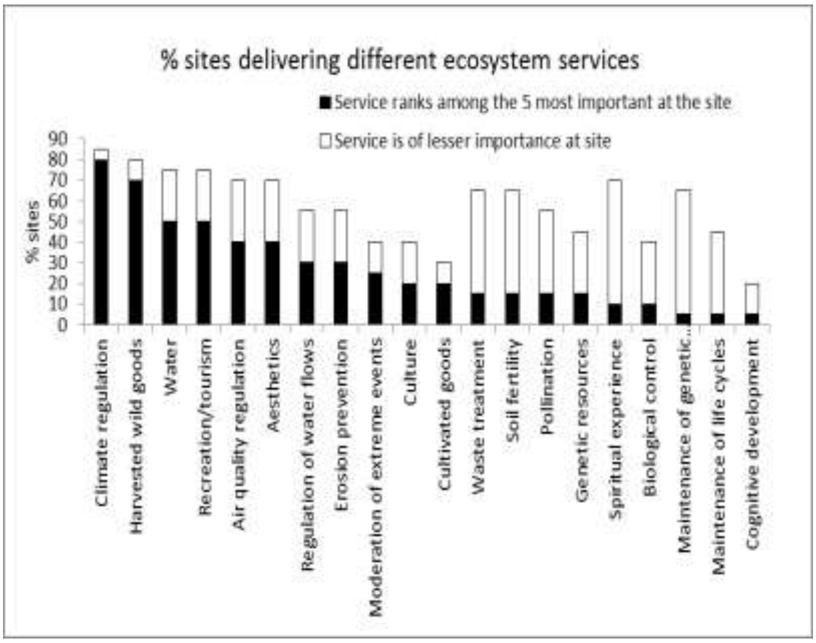
Figure 5. The differences between the current and alternative states (farmland) of a hypothetical restored wetland site for nature-based recreation, grazing (harvested wild goods), greenhouse gases, GHG, emission and flood prevention.

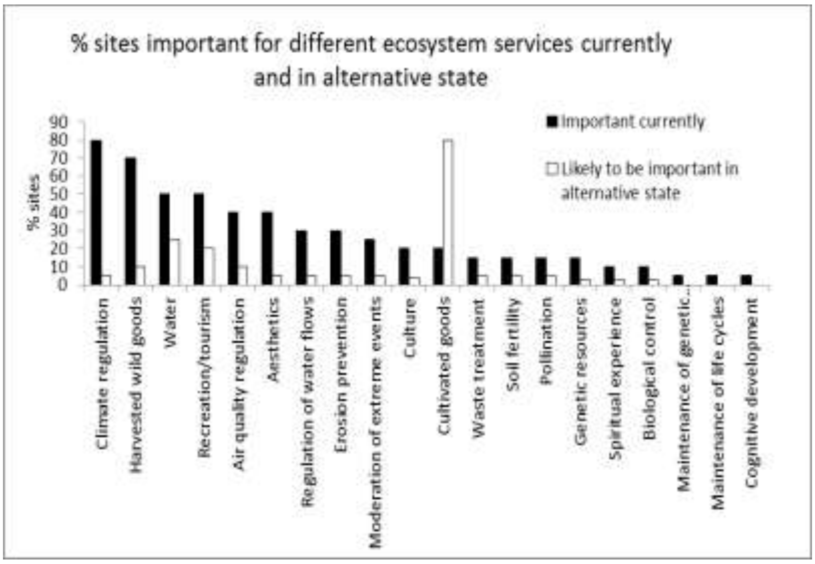
Multiple site analysis

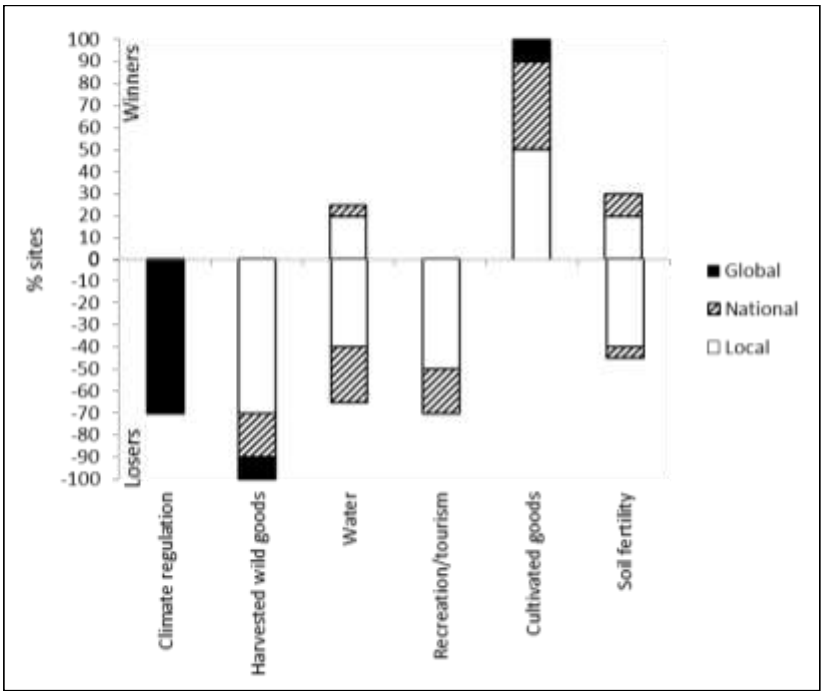
Although the toolkit is designed for site scale use, it is possible to conduct multiple site analysis by using the Rapid Appraisal form at a number of sites (for example, a national network of Protected Areas or Important Bird Areas) to assess general trends at the national level. This could also have important policy influence.

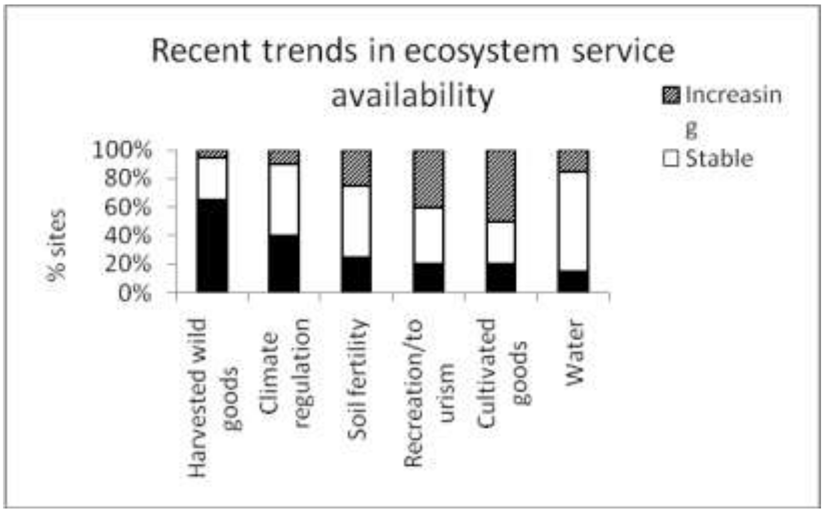
Below are some examples of the data that could be extrapolated from a multiple site analysis using the Rapid Appraisal form.

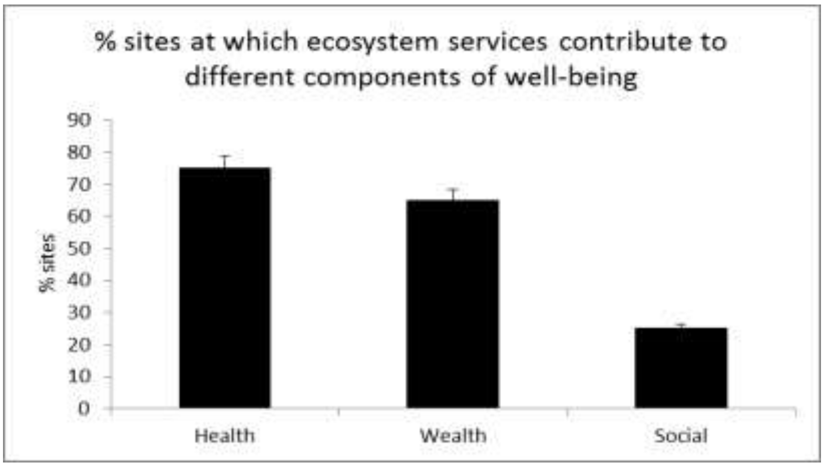




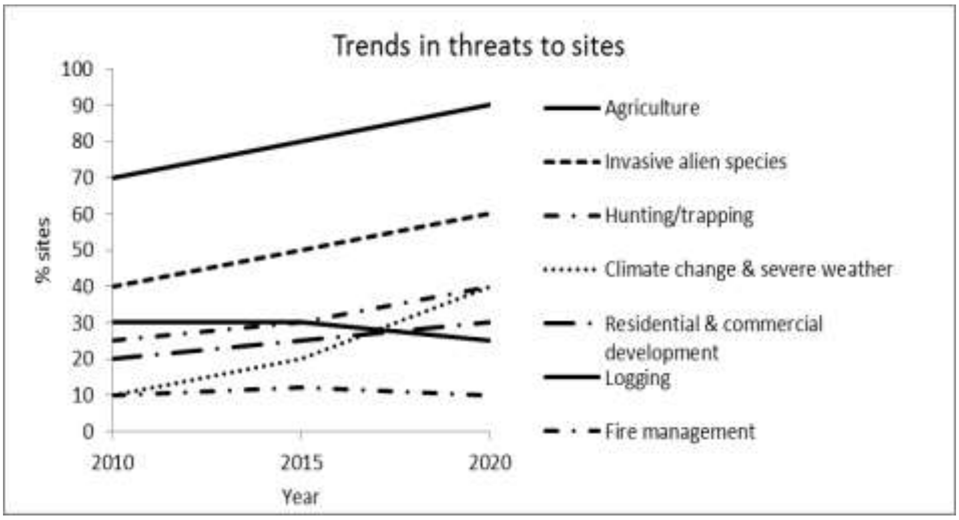

% sites important for different ecosystem services currently and in alternative state
% sites
■ Important currently
□ Likely to be important in alternative state
Climate regulation
Harvested wild goods
Water
Recreation/tourism
Air quality regulation
Aesthetics
Regulation of water flows
Erosion prevention
Moderation of extreme events
Culture
Cultivated goods
Waste treatment
Soil fertility
Pollination
Genetic resources
Spiritual experience
Biological control
Maintenance of genetic...
Maintenance of life cycles
Cognitive development

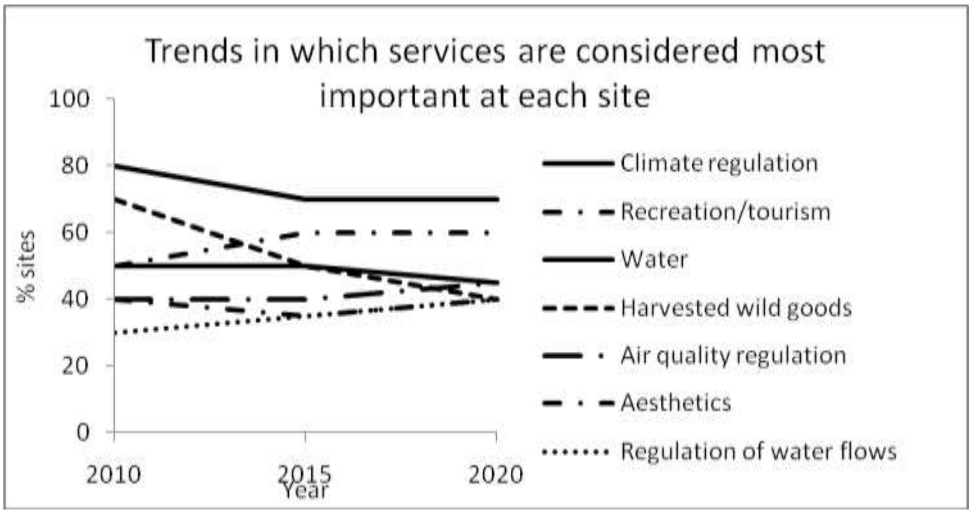

% sites
Winners
Losers
Global
National
Local
Climate regulation
Harvested wild goods
Water
Recreation/tourism
Cultivated goods
Soil fertility

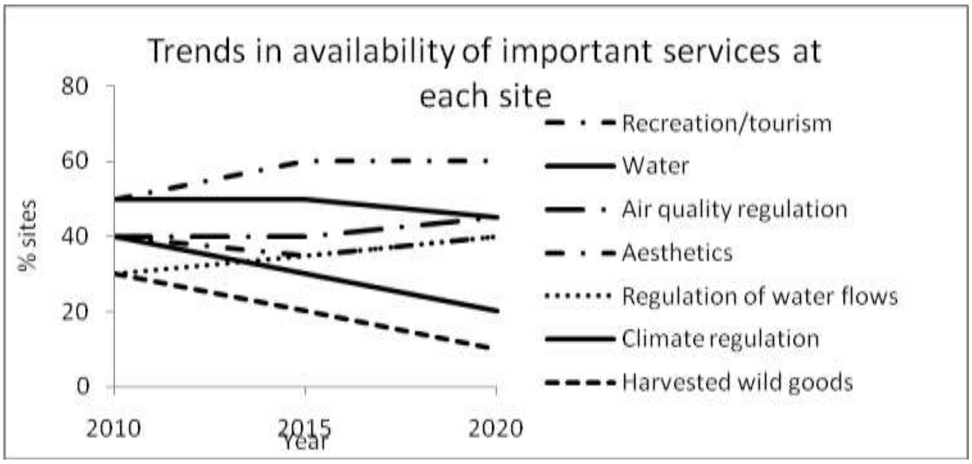




In addition, this process could be repeated over time as part of a monitoring strategy. This will allow trends to be inferred in the delivery of ecosystem services over time. Below are some examples of how this data could be presented.


Trends in threats to sites
100
90
80
70
60
50
40
30
20
10
0
% sites
2010
2015
2020
Year
Agriculture
Invasive alien species
Hunting/trapping
Climate change & severe weather
Residential & commercial development
Logging
Fire management


Trends in which services are considered most important at each site
100
80
60
40
20
0
% sites
2010
2015
2020
Year
Climate regulation
Recreation/tourism
Water
Harvested wild goods
Air quality regulation
Aesthetics
Regulation of water flows


Trends in availability of important services at each site
80
60
40
20
0
% sites
2010
2015
2020
Year
Recreation/tourism
Water
Air quality regulation
Aesthetics
Regulation of water flows
Climate regulation
Harvested wild goods

Section 5. Guidance

Guidance 1. Identifying different stakeholder groups at the local level

Identifying which groups exist within your site of interest, or interact with it on a regular basis, is important to understand how ecosystem services are accessed and used in the local landscape. The local 'community' is rarely homogenous, and there are usually important axes of difference that affect the ways in which different groups perceive, use and value ecosystem services. Prominent amongst these are:

- categories of social differentiation (religion, caste, ethnic grouping, language);
- age (young/old);
- gender (male/female);
- migration status (permanent residents, temporary residents and/or transhumant/nomadic groups);
- landownership (owners/tenants/landless);
- household size and availability of labour;
- household wealth and asset ownership;
- household level of education;
- occupational status (primarily agricultural or diversified).

These categories of difference will not always be important in all cases, and are presented here to be illustrative of the sorts of factors that might mediate the ways in which different households might access and use ecosystem services. Being aware of these differences allows for an understanding of the distributional consequences of management choices, as not all stakeholders will necessarily be equally impacted by decisions that affect the flows of ecosystem services.

You may need to make a judgement about which categories of difference are most important for the ecosystem services that are being studied.

If you believe that social differentiation is important at the local level, and there are likely to be significant differences in the ways in which different groups perceive, use and value ecosystem services, you must try and find ways to engage with the perspectives of all major groups. This might involve holding separate meetings with particular groups, especially those which might be a minority, or locally less vocal or powerful. It is quite likely that the perspectives of such 'marginalised' stakeholders may not be forthcoming in the presence of more dominant groups. Questionnaire surveys could be appropriately stratified (to ensure that responses are received from particular social groups of interest) or in randomised questionnaire surveys you could include social questions (e.g. about age, ethnicity – dependent on the differentiating factor which you believe to be important) to allow responses to be analysed according to such factors).

With time and resource constraints, it is likely that all perspectives will not be adequately captured by a rapid assessment. However, it is important to be attentive to local difference, especially if it appears that some ecosystem services benefit certain identifiable groups, but are not necessarily accessible to others.

Guidance 2. General guidelines on running a workshop

Who to invite: Focus on getting participation from a cross section of people who might have knowledge of the site and the service(s) you are focused on. Mapping or tabulating key stakeholders against each service will help to ensure all primary stakeholders have been identified. These might be local farmers, resource harvesters, people from local government with responsibility for local markets, residents from site-adjacent villages, government officers from e.g. the forest, wildlife or water department, and staff from rural-development or conservation projects working in the area. Aim for a maximum of 30 people.

Including the excluded: Special efforts may be need to get input from people who are conventionally excluded from discussions. In communal meetings people may alter their answers depending on the others around them. So for example, marginalised people (sometime but not always women) may just follow the men because that is what is expected and culturally it would be difficult for them to disagree. Often it is best to hold separate meetings for different social groups, and especially for marginalised people (women, ethnic minorities, landless).

Timing of meeting and other logistics: Consider a timing and location for the meeting that will allow stakeholders to attend. This may mean holding the meeting at the weekend, or in the evening for example. Factors such as location may also be important, especially in remote areas, and transport may need to be arranged. Consider the need to pay for the travel costs etc. of participants, and maybe also a per diem if the meeting is held during a working day and people are prevented from participating in their normal paid employment.

Language and tools for gathering information: Use methods for data collection that are appropriate for the participants in terms of language and the use of written words (where participants may not read or write). There are handbooks available giving guidance on participatory methods of data collection.

Sharing and owning information: The information you are collecting belongs to the stakeholders who are contributing it. It will be important to be transparent about the purpose of your questions, and also to feedback the results in some way (how best to do this will depend on the interests and educational level of the stakeholders: even semi-literate farmers may have difficulty interpreting a short report, so a question and answer session in a meeting will often be better). At the very least participants should know how you can be contacted if they want more information after the meeting on how 'their' knowledge will be used (see Appendix 6: Ethical Protocols).

Expectations: Surveys and meetings can lead to raised expectations – people may believe that it is the start of a process leading to support for local development (positive) or may fear that it will lead to reduced access or rights to resources (negative). It is important to be very clear about the purpose of the workshop and the larger study of which it is part, so that all participants understand how information will be used and what implications might be for themselves, their families, and their communities.

Dealing with information on illegal use: In some cases workshop participants may provide information (or may be asked about) use that is illegal. How this is dealt with will depend on the context. Wild Goods Method 1 provides guidance on illegal use.

Useful References

Chambers, R. (1997) Whose Reality Counts? Putting the First Last Intermediate Technology Publications, London.

Narayanasamy, N. (2008) Participatory Rural Appraisal, Principles, Methods and Application, Sage.

Guidance 3. Making good use of existing data

Collecting new information is often difficult, expensive and time-consuming, so existing information should be collated first. Sources of information might include local, regional and national government offices and libraries, agricultural extension services, land valuation offices, local NGOs, representatives of organisations such as FAO and the World Bank and universities. Information might be held in unpublished reports or databases, or there might be published information in the form of scientific papers, agricultural research reports, livelihood assessments or the like.

Collecting new information is often difficult, expensive and time-consuming, so the option of using existing information should be explored first. However, such data can be difficult to find, and must be interpreted critically.

Sources might include local, regional and national government offices and libraries, agricultural extension services, development agencies, NGOs, representatives of organisations such as FAO and the World Bank, and universities. Data might be held in unpublished reports or databases, or there might be published information in the form of scientific papers, research reports or theses, livelihood assessments, etc. In most countries, the only practical way to investigate these potential sources of information is by talking with as many potential contacts as possible; workshops are a good place to start.

If you find potentially useful information, it is then essential to ask whether (given that it may have been collected for another purpose) it meets your needs. Read both the details of how the existing data were collected and the section of the toolkit explaining what to do if you have to collect your own data to see if you can answer the same questions with the existing information. Also think about data quality - as a guide, figures in peer-reviewed literature, theses or widely used databases may be more reliable than those in unpublished reports. Write down any caveats or concerns. Last, consider how representative the existing data are of the site you are interested in. Does the data refer to exactly the same area, or a potentially unrepresentative part of it, or perhaps a wider area? Does it deal with all the service-related benefits or costs you want to know about? Does it provide information about all the people you are interested in, or just an unrepresentative subset? And unless the data were collected very recently, has the site changed - in terms of its population, their activities, the extent or condition of local habitats, the rules governing their use, etc.? If the data are old but otherwise fit-for-purpose and representative of the current situation prices can be adjusted to present-day values using a local currency deflator index (or else converting to US dollars [using the exchange rate at the time of study) and applying an international deflator index). For example: International Monetary Fund, World Economic Outlook Database.

Validity of using benefits transfer and precautions needed

Carbon

The ideal data source for carbon stocks is a set of local field estimates, where the above-ground biomass, below-ground biomass, litter and dead biomass and soil carbon content has been directly measured. The main source of data for carbon storage used in this toolkit is the Intergovernmental Panel on Climate Change's 2006 methodology for determining greenhouse gas inventories in the Agriculture, Forestry and Other Land Use. Note that this is a very general source, and it is advisable to use region-specific sources of carbon storage data if available. For example, Lewis et al. (2010) report above-ground biomass for 79 sample plots, located in moist forest, spanning West, Central and Eastern Africa.

When assessing fluxes of greenhouse gases (GHG), we recommend the use of look-up values that are representative of local conditions because these are not readily measurable.

Water

Some useful sources of data for the water withdrawals are:

- AQUASTAT (http://www.fao.org/nr/water/aquastat/main/index.stm) - FAO's global information database which is the most complete compilation of water resources statistics to date, according to the World Resources Institute (WRI). This provides national estimates such as annual water withdrawals per capita annual withdrawals and sectoral withdrawals for agriculture, industry and domestic uses. To use this data for the calculation of the total water withdrawals of the beneficiaries, you must know the total population of the people served by the site.

- Earthtrends (http://earthtrends.wri.org/) - free environmental information online portal maintained by WRI. This database harbours a section focusing on "water resources and freshwater ecosystems" where you can find a selection of data tables. For example, "Food and Water" (gives national estimates of the annual volume of water used for irrigation in agricultural sector per hectare of arable cropland. For this data to be meaningful, you must also know the total area of irrigation land supported by the site. You may be able to find such information at AQUASTAT's sub-national irrigation database (http://www.fao.org/nr/water/aquastat/main/index.stm)

Note that there is a major caveat to the use of this approach. When using FAO's database or other similar broad data sources, you have to consider if the national averages represent the reality of your field estimates. For example, Earthtrends' database reports that the proportion of water withdrawals in Nepal for agriculture, industry and domestic uses are 96 %, 1 % and 3 %, respectively. Clearly this is not the case for the sectoral withdrawals of water from Shivapuri National Park which serves mainly the population of the capital city, Kathmandu. Also, when using the national estimates of water use for irrigation, you must consider how the different types of crops affects water uses. For example, water used for irrigating the water demanding crops will likely be more than water withdrawal for the less demanding crops.

Harvested Wild Goods / cultivated goods

If existing data are available, be sure to critically review the methods used and check whether the data are really what you need. It may also be necessary to speak to informed individuals to establish whether there have been any major changes (e.g. in product availability, prices, markets or competition) that have significantly affected harvesting in the area since the results were published which may mean they need to be adjusted or are no longer useful.

Tourism

Visit numbers: Site officials, tour operators and others sometimes collect information on the numbers of visits to a site. The available data may not cover an entire year, nor the whole site (or visit numbers may be combined across several sites). In these cases it might still be possible to estimate annual visits across the entire site. If the information is spread evenly through the year or if it is known that the area sampled accounts, say, for roughly one-third of all visits, then it will be relatively easy to extrapolate. Ideally the data will distinguish different types of visitors (adults as well as children, nationals as well as foreigners, etc.), as spending may differ between them. Last, because rates of nature-based tourism change over time try if possible to obtain data from several recent years.

Visitor spending: Spend data are less commonly documented in most important is the total amount that visitors spend on their visit, but unless these values have been estimated as part of a study (e.g. into the value of nature tourism in an area) they are unlikely to be directly available. However you might be able to obtain existing information on particular elements of visitor expenditure. Site officials will commonly have data on entrance and other fees they collect, either in total or per person (but bear in mind in working up total spend that these will often vary between visitor groups). Tour operators may tell you about the travel or guide fees they charge, and where visitors are travelling from so you can estimate rough travel costs); you can often find out about spending on food and accommodation from hoteliers and restaurant owners. In using these figures to estimate expenditure across all visitors think about where the money goes (to local people, elsewhere in the country, or abroad ,and about whether all visitors spend this much or some pay more, less, or nothing at all during their visit. And if you only have values for a few elements of spending (say, entrance and guide fees but not accommodation) make this clear when you present your findings.

Important adjustments to both: With luck, existing data can give you a reasonable idea of the total number of visits to the site and even of the associated expenditure. However, it may well be the case that not all visitors are going there to appreciate nature (there may be other attractions, or they may simply be there for another purpose altogether). Clearly visits that are not related to nature should not count as nature-based recreation, so where possible distinguish these and exclude them.

Guidance 4. Determining sample size

This is relevant for Sections III, IV and V.

After the key harvested wild goods and/or cultivated goods are identified through meetings with informed individuals, the next step would be to quantify annual amount harvested or cultivated, the unit value and related costs by conducting random household surveys. Here we provide some guidelines on how to choose an appropriate sample size for a simple random sample. This guidance note is also applicable for determining the number of tourists for assessing the benefits from nature-based tourism and for choosing the number of forest transects or peat samples for assessing the carbon storage capacity of a stratum. Note that there is a more elaborate method for habitat with multi-strata (see Climate Method 4)

Some factors that determine your sample size include your budget (e.g. considerations to minimise cost), timeline (e.g. administrative deadlines) and desirable level of precision. It is also important to note that high variability within the population or subpopulation (e.g. stratum, local tourists) will lead to a larger sample size. Conversely, if the population or subpopulation is relatively homogenous, you will likely need smaller sample size to achieve a higher prevision level.

To determine the smallest sample size that provides the desired level of precision:

1. Specify your desired precision level. For example 20% or 0.2
2. Determine the mean and the standard deviation (s) of a preliminary survey of 10 transects or household or individuals.
3. Determine the margin of error (ME) by multiply mean with your specified level of precision:

   ME = mean * 0.2

4. Apply the following formula to determine the sample size (n):

   n = (4 x s x s)/(ME x ME)

Worked example

Level of precision: 0.1 (therefore 10%)

Mean above-ground carbon value of 10 transects of oak-dominated forest: 249.2 tonne/ha

Standard deviation of these transects: 49.3

Margin of error (ME): 249.2 x 0.1 = 24.92

The smallest sample size that provides the precision level at 10% is:

(4 x 49.3 x 49.3)/(24.92 x 24.92) = 16 transects

Guidance 5. Dealing with uncertainty in ecosystem service evaluations

Estimates of ecosystem service values or quantities provided by a site (in the current or alternative state) derived from the methods presented in this tool kit will have uncertainty associated with them. It is important to understand, quantify if possible, and communicate this uncertainty and its implications, in order for decision makers to make the best informed decisions.

In generic terms, such uncertainty derives from:

- Measurement error: observers may make errors when estimating and recording parameters such as tree diameter, river flow, counts of numbers of tourists etc. For data derived from questionnaires, measurement errors may result from respondents' inaccurate estimates of parameters such as volume or value of harvested goods.
- Sampling error: when data are taken from a sample of measurements, these may not be representative of the entire site. For example, the trees measured at a sample station may be larger or smaller than the average across the site. Larger numbers of samples (or well-stratified samples) are likely to be less biased. A special case of sampling error relevant to the toolkit arises when data are derived from a look-up table or model. Such values may not be representative for the site if the table or model is based on too few input data, or inadequately stratified data.

For estimates derived from models, errors may also arise if the model is inappropriately parameterised for the situation at an individual site, i.e., if it doesn't contain the most relevant factors.

Ideally, the user should quantify the uncertainty associated with each parameter measured or calculated using the toolkit methods. Where feasible, value estimates can be presented as minimum to maximum ranges, for example reflecting uncertainty about the price of carbon. If more than one parameter contributes to a service (e.g. above and below-ground carbon, and soil carbon, all contribute to total carbon stock) then their uncertainties will be cumulative. Ideally, these uncertainties should be combined quantitatively to derive confidence intervals for the overall estimate of the ecosystem service. However, the methods to do this are computationally difficult.

More simplistically, the user can categorise confidence as High, Medium or Low using the definitions in the table below. Such an assessment needs to consider, for example, the representativeness of any sampled data (considering the number of samples taken relative to the size and heterogeneity of the site, and whether look-up tables were used or primary data collected). Applying the scores requires the user to consider the relative contribution of different parameter estimates to the overall service estimate, and the uncertainty associated with each one.

Below we provide generic definitions of High, Medium and Low confidence for each of the services, or components of services, covered in the toolkit.

Level of confidence	Description
High	Estimate is based on (a) existing data that are recently derived from the specific site; and/or (b) data from field measurements that use protocols provided in this toolkit (or more sophisticated approaches), with large and unbiased sample sizes; and/or (c) peer-reviewed published data derived recently from similar habitat near the site; and for all three data sources based on sound methods in terms of accuracy and precision level, judged in relation to site boundary definition, area stratification, type, number and distribution of measurement plots, and measurement frequency.
Medium	Estimate is based on (a) existing data that are recently derived from reasonable sampling effort and that are treated critically with their methodological limitations acknowledged; and/or (b) data from field measurements that used protocols provided in this toolkit but are derived from relatively low sample size and precision level, or are subject to minor measurement and sampling errors; and/or (c) published data derived from similar habitat within your site's climate domain and region. Also estimate based on data from the look-up tables that used region-specific sources based on compilation of the data sources is reasonably complete. Certain types of estimate based on modelling tools would fall into this class.
Low	Estimate is based on (a) existing data that are derived from unknown methodology or poor sampling techniques (i.e., data are poorly representative, inadequately sampled, inappropriately stratified etc.); and/or (b) data derived from an area that may not be a good surrogate for the site (e.g. moderately different habitat, very distant site, very old data) or data that are highly uncertain (e.g. substantial range between upper and lower confidence limits) ; and/or estimate is based from the look-up tables that used habitat-specific sources, and not based on the region-specific; based on sparse compilation of data sources.

Section 6. Methods

Methods: Global climate regulation

Climate Method 1. Classifying areas of different levels of disturbance, within a habitat type

This section provides information on how to classify areas, using either quantitative field data or qualitative guidelines.

Classify areas within the habitat as 'low', 'medium' and 'high' disturbance, using the following observations:

Do you have some quantitative field data?

Yes: Classify areas as 'low', 'medium' and 'high' disturbance using the following rough quantitative guidelines:

1. Lots of charcoal extraction (i.e., there are ≥5 charcoal pits per hectare, or, on average, one would encounter at least one charcoal pit every 200 m in the forest assuming visibility of 5 m either side).
2. Lots of firewood extraction and/or tree debarking/ringing/other damage (i.e., on average, one would encounter signs of fire wood extraction or debarked, ringed or otherwise damaged trees every 50 m in the forest assuming visibility of 5 m either side).
3. Lots of cutting/logging (i.e. ≥20% of the trees/poles/saplings are cut).
4. Other significant disturbance (e.g. ≥5% of the area affected by drainage, mining, over-grazing, or agricultural encroachment).

If 1 or more of these above ('high disturbance categories') observations are TRUE, classify the area as high disturbance.

Otherwise, continue below:

1. Some charcoal (i.e., there are ≥1 and <5 charcoal pits per hectare, or, on average, one would encounter at least one charcoal one pit every 1000 m in the forest assuming visibility of 5 m either side).
2. Some firewood extraction and/or tree debarking/ringing/other damage (i.e., on average, one would encounter signs of fire wood extraction or debarked, ringed or otherwise damaged trees every 250 m in the forest assuming visibility of 5 m either side).
3. Highly selective timber extraction (i.e. ≥5% and <20% of the trees/poles/saplings are cut).
4. Other medium disturbance (e.g. ≥1% and <5% of the area affected by drainage, mining, over-grazing, or agricultural encroachment).

If 2 or more of these above observations are TRUE, classify the area as medium disturbance. Otherwise, classify the area as low disturbance.

No: Classify areas as 'low', 'medium' and 'high' disturbance using the following qualitative guidelines:

1. Lots of charcoal extraction (i.e., charcoal extracted is sold commercially).

2. Lots of firewood extraction and/or tree debarking/ringing/other damage (i.e., firewood or other woody products extracted are sold commercially and/or dead wood is insufficient to supply the demand and trees and shrubs are frequently intentionally debarked, ringed or otherwise damaged to increase available dry dead wood).
3. High and medium value timber removed.
4. Other significant disturbance, e.g. a lot of drainage, mining, over-grazing, or agricultural encroachment.

If 1 or more of these above ('high disturbance categories') observations are TRUE, classify the area as high disturbance.

Otherwise, continue below:

1. Some charcoal (i.e., charcoal extracted is used only locally, e.g. by villagers near the forest).
2. Some firewood extraction and/or tree debarking/ringing/other damage (i.e., firewood or other woody products extracted are used only locally, e.g. by villagers near the forest and/or trees and shrubs are only occasionally intentionally debarked, ringed or otherwise damaged to increase available dry dead wood).
3. High value timber extraction only.
4. Other medium disturbance, e.g. a little bit of drainage, mining, over-grazing, or agricultural encroachment.

If 2 or more of these above observations are TRUE, classify the area as medium disturbance. Otherwise, classify the area as low disturbance.

Climate Method 2. Estimating above-ground live biomass carbon stock using IPCC tier 1 estimates

It is highly recommended to collect local field data on above-ground live biomass (AGB), if your resources (i.e., manpower, time etc.) permit. However, when this is not possible, this section provides information on where to find existing estimates from IPCC (2006) and the appendices of this toolkit. It should though be noted that these estimates tend to be spatially coarse, and are usually global estimates. They will therefore be relatively imprecise for a given site.

You will need: A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

1. Is the habitat tree-dominated (except woody savannas) or a forest plantation?

Yes: Go to **2.**
No: Go to **3.**

2. Do you have data on merchantable growing stock volume (V), in terms of m^3?

Yes: See guidance below for using the data (V) to calculate the above-ground live biomass.

Guidance for calculating above-ground live biomass from growing stock volume

2.1. See Table 4.3 in Chapter 4 of IPCC (2006), for the appropriate default value of carbon fraction of dry matter (CF) as expressed in tonnes of C (tonne d.m.)$^{-1}$.

2.2. See Table 4.5 in Chapter 4 of IPCC (2006), for the appropriate default value of biomass conversion and expansion factor ($BCEF_S$) for expansion of merchantable growing stock volume to above-ground live biomass as expressed in tonnes of aboveground live biomass (m^3 growing stock volume)$^{-1}$.

2.3. Calculate the aboveground live biomass carbon stock, as expressed in tonnes of C, using the following formula:

Aboveground live biomass carbon stock (t C) = V x $BCEF_S$ x CF

No: See Table 4.7 (for natural forests), Table 4.8 (for forest plantations), Table 4.12 (for natural forests and forest plantations in more detailed classification) in Chapter 4 of IPCC (2006) for crude estimates of above-ground live biomass carbon stocks. Alternatively, see Appendix 2 of this toolkit.

Then go to **8.**

3. Is the habitat grass-dominated or a woody savannah?

Yes: There is no existing tabulated data from IPCC (2006). Go to Appendix 2 of this toolkit. Then go to **8.**

No: Go to **4.**

4. Is the habitat a wetland?

Yes: There is no existing tabulated data from IPCC (2006). Go to Appendix 2 of this toolkit. Then go to **8.**

No: Go to **5.**

5. Is the habitat perennial crop-dominated (including woody crops plantations, orchards and agroforestry)?

Yes: See Table 5.2 (for cropping systems), Table 5.2 (for agroforestry systems), Table 5.3 (for default values for specific types of crop-dominated habitats) in Chapter 5 of IPCC (2006). Then go to **8.**

No: Go to **6.**

6. Is the habitat annual crop-dominated?

Yes: It is assumed that there is no above-ground live biomass carbon stock because of biomass losses from harvest and mortality in that same year. Then go to **8**.

No: Go **to 7.**

7. Is the habitat a developed area?

Yes - There is no existing tabulated data form IPCC (2006). If resources allow, go to Climate Method 3 (for urban lawns) and Climate Method 4 (for urban parks) for information on rapid field measurements. Then go to **8.**

8. To calculate the total above-ground live biomass of each habitat at the site, multiply above-ground live biomass by the area (ha) of the habitat. For developed areas, multiply above-ground live biomass by the land area of the urban park or lawn within the developed area. Go to **9.**

9. To calculate the total above-ground live biomass carbon stock (t C) of your habitat, multiply the total above-ground live biomass by a conversion factor of 0.5 for tree-dominated, forest plantations, woody savannas, perennial crop-dominated habitats and urban parks, or by 0.47 for grass-dominated habitats, wetlands and urban lawn.

10. Sum all carbon stocks (t C) across the habitats present at the site.

<u>Worked example for Climate Method 2</u>
There is a 2900ha site in East Africa, consisting of 1000ha of moist forest, 1500ha of sparsely-wooded savannah, 200ha of perennial cropping and a 200ha wetland (half open water and half swamp).

Tree-dominated habitat
There is no data on merchantable growing stock volume, therefore look-up tables have to be relied on. Of the tables available (Tables 4.7, 4.8 and 4.12 on the IPCC website, and Appendix 2 of this toolkit), the most appropriate data is in Table 4.7. This gives an Africa-specific estimate for tropical moist deciduous forest of 260 tonnes of dry matter per hectare.

This value is multiplied by the area of forest (1000ha), to give 260,000 tonnes of dry matter.

This figure is multiplied by the conversion factor (0.5) to give 130,000 tonnes of carbon.

Savannah
The user is directed to Appendix 2 of this toolkit, which gives a generic value for tropical savannah of 21 tonnes of dry matter per hectare.

This value is multiplied by the area of savannah (1500ha), to give 31,500 tonnes of dry matter.

This figure is multiplied by the conversion factor (0.5) to give 15,750 tonnes of carbon.

Perennial crops
The user is directed to Tables 5.2 and 5.3 on the IPCC website. Table 5.2 gives a generic value for agrosilviculture in humid tropical Africa of 41 tonnes of dry matter per hectare.

This value is multiplied by the area of perennial crops (200ha), to give 8,200 tonnes of dry matter.

This figure is multiplied by the conversion factor (0.5) to give 4,100 tonnes of carbon.

Wetland
The user is directed to Appendix 2 of this toolkit, which gives a generic value for marsh and swamp of 150 tonnes of dry matter per hectare.

This value is multiplied by the area of swamp (approximately 100ha), to give 15,000 tonnes of dry matter.

This figure is multiplied by the conversion factor (0.47) to give 7,050 tonnes of carbon.

Total above-ground carbon stock
All the stocks that have been estimated are added together;

130,000 + 15,750 + 4,100 + 7,050 = **156,900 tonnes of carbon**

Climate Method 3. Direct measurement of above-ground live biomass carbon stock in grass-dominated habitats and non-forested wetlands

This section provides information on how to measure above-ground live biomass in grass-dominated habitats (for the list of grass-dominated habitats, see Appendix 1) and non-forested wetlands. The methods are adapted from den Hollander (2008). The items of equipment required are rolls of string (for laying out the plots), measuring tapes (for measuring the plot size), clippers, plastic bags (for collecting the clippings) and oven (for drying the samples).

You will need: A coil of rope for stringing the plot A pair of secateurs for clipping the vegetation Large zip block bags for collecting samples from the field Large paper envelops for containing drying samples in an oven An oven that is capable of maintaining a temperature at 105^{o}C A laboratory balance

1. Randomly lay out 10 sampling plots (1 m x 1 m) for each stratum (e.g. low disturbance, high disturbance area) first on the map, and then on the ground. The random location of the plots can be obtained on the map using a fixed grid that covered the entire stratum and random number tables for generating the coordinates of the grid. Clip all vegetation as close to the ground as possible for each plot, but without stem base, corms and roots. Woody plants are not included in the clipping because they contribute a relatively small proportion of total aboveground biomass. Weigh the samples within two days.

2. Measure the total fresh weight of all clippings from each plot. Separate the total clipping of each plot into three fractions: dead material, stems and green leaves. Then measure the weight of these three different vegetation components within each sample. Again, take at least five subsamples from each of the three different vegetation components and measure the fresh weight (no less than 100g) of this subsample. Then place the subsample of dead material, stem and leaf sub-subsamples in separate paper envelops and oven-dry at 105^{o}C until a constant dry weight is obtained (at least 2 days), to develop conversion factors to express the initial weights of the clippings as oven-dry mass.

3. Calculate the total dry weight of the clippings for each plot (1 m^2) using the conversion factors. Then calculate the mean dry mass of all sampling plots and divide this value by 100 to express in dry mass (t) ha^{-1}. Above-ground biomass carbon stock (t C) is then assumed to be 47% total dry mass (IPCC 2006, Chapter 6, p. 6.9; http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html).

4. Calculate the total above-ground biomass carbon stock (t C) for each stratum by multiplying by the representative land area (expressed in ha) of each stratum. The total above-ground biomass carbon stock is then the total above-ground biomass carbon stock of all strata.

Worked example for Climate Method 3

There is a 300ha temperate grassland site in northern Europe. Most of it is relatively intact, but some has been degraded by drainage which has enabled some grazing by domestic cattle. Using method 2, it was identified that 100ha of the site should be considered as a 'low disturbance' stratum, while the other 200ha should be considered as a 'medium disturbance' stratum.

The low degradation stratum was considered first. Having randomly laid out 10 sampling plots, the fresh weight of the clippings from each plot was measured, with the following results;

Plot	1	2	3	4	5	6	7	8	9	10
Fresh weight (g)	3500	2500	4800	4300	3900	4100	2900	5600	4000	3800

The clippings from each plot were then separated into the three fractions and the fresh weight again measured, with the following results (mass again in g);

Plot	1	2	3	4	5	6	7	8	9	10
Dead material (g)	1100	1000	1600	1100	1400	1000	800	1800	1400	1000
Stems (g)	1100	700	1200	1200	1000	1100	500	1500	1200	900
Green leaves (g)	1200	800	2000	2000	1500	2100	1600	2300	1400	1900

For each fraction, 5 of the plots were randomly selected and a small sub-sample taken from each. For each fraction, these sub-samples were pooled and the total fresh weight of these pooled samples measured. The sampling looked like this;

Plot	1	2	3	4	5	6	7	8	9	10	Total
Dead material (g)	40			30	30	20			30		150
Stems (g)		40	30	30			30	40			170
Green leaves (g)				20	40		30		30	20	140

After drying the sub-samples of each of the three fractions, they weighed 125g (dead material), 130g (stems) and 90g (green leaves) respectively. The conversion factors were therefore;

Dead material = 125/150 = 0.833
Stems = 130/170 = 0.765
Green leaves = 90/140 = 0.643

The fresh weight of each plot was then converted to dry mass using the conversion factors, thus;

Plot	1	2	3	4	5	6	7	8	9	10
Dead material (g)	916	833	1333	916	1166	833	666	1499	1166	833
Stems (g)	842	536	918	918	765	842	383	1148	918	689
Green leaves (g)	772	514	1286	1286	965	1350	1029	1479	900	1222

And summed, for each plot, to give;

Plot	1	2	3	4	5	6	7	8	9	10
Dry mass (g)	2529	1883	3537	3120	2896	3025	2078	4126	2984	2743

And the mean dry mass, across all 10 plots, was 2892.1g
The mean dry mass per hectare was therefore 2892.1 / 100 = 28.9 tonnes per ha
Above-ground carbon stock for the low disturbance stratum was therefore 28.9 x 0.47 = 13.58 tonnes per ha (0.47 is the conversion factor for converting dry biomass to carobn).

Following the same steps, the above-ground carbon stock for the medium disturbance stratum was calculated to be 9.34 tonnes per ha.

The total above-ground carbon stock for the low disturbance stratum was therefore 13.58 x 100 = 1,358 tonnes, and the total above-ground carbon stock for the medium disturbance stratum was therefore 9.34 x 200 =1,868 tonnes. The total above-ground carbon stock for the site was therefore 1,358 + 1,868 = **3,226 tonnes of carbon**

Climate Method 4. Direct measurement of above-ground live biomass carbon stock in tree-dominated habitats

This section provides information on how to measure above-ground live biomass in tree-dominated habitats (see Appendix 1 for definition), woody savannahs and forested wetlands (e.g., mangrove forests). The methods are adapted from Verplanke & Zahabu (2009). The variable to be measured is tree diameter at breast height (dbh), i.e. at 1.3 m from the ground, and – only for tropical forests – the tree height (optional; only if time and resources are available). The items of equipment required are rolls of string (for laying out the plots), measuring tapes (for establishing the plots), dbh meters, clinometers (for measuring tree height), ladder (for trees with large buttresses), broad paint-brush and red paint (for marking the point of measurement on the tree).

You will need:
A measuring tape
A Diameter in Breast Height (DBH) tape
A coil of rope for stringing the transect
A hammer and aluminium nails for tagging the trees (essential for measuring and monitoring carbon flux)
A clinometer for measuring the tree height and the slope of the ground
A stick of 1.3 m long for marking the point of measurement on the trunk
A tin of red paint and a brush for marking the (measured) trees
A Geographic Positioning System for marking the location of the transects
A compass
A pair of binoculars and a field guide for identifying tree species

Estimating number of transects

1. For each stratum (e.g., low disturbance, high disturbance area), preliminary data are needed in order to determine the required number of transects for the desired level of precision. Data from six to ten sampling transects distributed over each stratum are needed. Long, thin transects (5 m [2.5 m each side of a thin access path] x 100 m) are used for efficiency. See the section below for the methods for measuring trees.

2. Determination of the number of sampling transects is based on the variability of trees measured in the first six to ten sampling transects (see below for details on how to measure carbon stock in trees). The number of sampling transects (n) is calculated using the formula:

For a single-stratum habitat:
$$n = \frac{(N \times s)^2}{\frac{N^2 \times E^2}{t^2} + N \times s^2}$$

where

n = number of transects required

N = the total area, in ha (sum of all strata), divided by 0.05 ha (area of a transect)

s = standard deviation of the mean carbon stock

E = mean carbon stock (from the preliminary data) multiplied by the desired precision. The desired precision is usually set at 0.1 (i.e. margin of error at 10%). However, a precision level at 0.2 could also be used. Generally the greater the margin of error, the more difficult to ascertain that the carbon stock has changed over time.

t = the sample statistics from the t-distribution for the 95 per cent confidence level. This is usually set at 2, as sample size is unknown.

Worked example for a single-stratum habitat:

Area: 5000 ha
Transect size: 0.05 ha
Mean carbon stock: 101.6 t C/ha
Standard deviation: 27.1 t C/ha
N: 5000/0.05 = 100000
Desired precision: 10%
E: 101.6 x 0.1 = 10.16

$$n = \frac{(100000 \times 27.1)^2}{\frac{100000^2 \times 10.16^2}{2^2} + 100000 \times 27.1^2}$$

= 28 transects

For two strata:
$$n = \frac{\left((N_1 \times s_1) + (N_2 \times s_2)\right)^2}{\frac{N^2 \times E^2}{t^2} + (N_1 \times s_1^2) + (N_2 \times s_2^2)}$$

For three strata:
$$n = \frac{\left((N_1 \times s_1) + (N_2 \times s_2) + (N_3 \times s_3)\right)^2}{\frac{N^2 \times E^2}{t^2} + (N_1 \times s_1^2) + (N_2 \times s_2^2) + (N_3 \times s_3^2)}$$

Worked example for three strata:

	Stratum 1	Stratum 2	Stratum 3	Total
Area (ha)	3400	900	700	5000
Transect size (ha)	0.05	0.05	0.05	0.0
Mean carbon stock (t C/ha)	126.6	76.0	102.2	101.6
Standard deviation	26.2	14.0	8.2	27.1
N	3400/0.05 = 68000	900/0.05 = 18000	700/0.05 = 14000	5000/0.05 = 100000
Desired precision				10
E				101.6 x 0.1 = 10.16

$$n = \frac{\left((68000 \times 26.2) + (18000 \times 14.0) + (14000 \times 8.2)\right)^2}{\frac{100000^2 \times 10.16^2}{2^2} + (68000 \times 26.2^2) + (18000 \times 14.0^2) + (14000 \times 8.2^2)}$$

= 18 plots

If the habitat of interest is stratified, use this formula to allocate the calculated number of plots among the various strata:

$$n = \frac{N_h \times s_h}{\sum_{h=1}^{L} N_h \times s_h}$$

where:
n = total number of plots
n_h = number of plots in stratum h
N = number of sampling units in the population
N_h = number of sampling unit in stratum h
s = standard deviation
s_h = standard deviation in stratum h

Example using the data from the calculations above:

Stratum 1:

$$n_h = \frac{68000 \times 26.2}{(68000 \times 26.2) + (18000 \times 14.0) + (14000 \times 8.2)} \times 18$$

= 15 plots

Stratum 2:

$$n_h = \frac{18000 \times 14.0}{(68000 \times 26.2) + (18000 \times 14.0) + (14000 \times 8.2)} \times 18$$

= 2 plots

Stratum 3:

$$n_h = \frac{14000 \times 8.2}{(68000 \times 26.2) + (18000 \times 14.0) + (14000 \times 8.2)} \times 18$$

= 1 plot

However, if resources (cost and person days) are limited, follow the guidance below for allocating sampling effort:

i. 0.25% effort on stratum with the largest total area.
ii. 0.25% effort on stratum with highest likely carbon density (t C ha^{-1}).
iii. 0.25% effort on stratum under the greatest threat of rapid change under the alternative state.
iv. 0.25% effort on other strata.

Measuring plots

3. Lay out the sampling transects (5 m x 100 m transects) along an access path, with a random starting point. Do this first on the map, then on the ground. All transects should be at least 200 m apart. The trail should be a foot trail (i.e. not a road access trail). Note the start point, the bearings and the distances along the access path to the start of each transect, and mark all trees of the transect with an inconspicuous number (metal) tag nailed to the trunk. This should enable you to relocate the trees again for re-measurement in successive years, if necessary.

4. Measure diameter at breast height (dbh) of all trees with dbh ≥10 cm.

5. Identify all measured trees to family- or genus-level. For key timber species, identify them to species-level. All trees with large buttress above 1.3 m from ground are measured at the 1.3 m point on the trunk from buttresses, using a ladder, for speed and removal of major potential measurement biases (Phillips and Baker 2006).

Further guidance for tropical forest habitats

For tropical forests, we recommend the measurement of tree height for better estimates of above-ground biomass (see 'A' below). However, it is still possible to calculate the above-ground biomass without the tree height data (see 'B' below).

6. Calculate above-ground biomass for each transect (0.1 ha) using the published biomass regression equations in Appendix 3 (or see Pearson *et al.* 2005 for the list; http://www.winrock.org/ecosystems/files/winrock-biocarbon_fund_sourcebook-compressed.pdf). For more tree allometric equations, see www.globallometree.org.

Further guidance for tropical forest habitats

For better estimations of the tropical forest habitats, we recommend using the equations from Chave *et al.* (2005) together with the tree height data and wood mass density data. The values of wood mass density for each measured species could be obtained from the published literature. Wood mass density for some species are available in IPCC (2006; Chapter 4, Table 4.13 and 4.14, p. 4.64 – 4.71, http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html) and the global wood density database http://datadryad.org/repo/handle/10255/dryad.235, which is good for tropical tree species, especially in Africa. Mean genus-level wood density could be used for individual stems with no species-specific data, and mean wood density of all stems within a transect for stems for which genus-level and family-level data are not available. The first question to be asked in this Step is:

Do you have both tree height data and wood mass density data for your plots?
Yes: Go to **A** below and use the appropriate equation.

No : Go to the next question below.

Do you have wood mass density data for your plots?
Yes : Go to **B** below and use the appropriate equation.

No : Go to Appendix 3 for tropical equations that use dbh data only.

A. Tropical forest equations – if both tree height and wood mass density data available:

Dry forest:
$AGB = 0.112 \times (\rho D^2H)^{0.916}$

Moist forest:
$AGB = 0.0509 \times \rho D^2H$

Moist mangrove forest:
$AGB = 0.0509 \times \rho D^2H$

Wet forest:
$AGB = 0.0776 \times (\rho D^2H)^{0.940}$

where ρ is wood mass density (in g/cm^3), H is height (in m), and D is dbh (in cm).

B. Tropical forest equations – if only wood mass density data available:

Dry forest:
$AGB = \rho \times \exp(-0.667 + 1.784 \ln(D) + 0.207((\ln(D))^2 – 0.0281 (\ln(D))^3)$

Moist forest:
$AGB = \rho \times \exp(-1.499 + 2.148 \ln(D) + 0.207((\ln(D))^2 – 0.0281 (\ln(D))^3)$

Moist mangrove forest:
$AGB = \rho \times \exp(-1.349 + 1.980 \ln(D) + 0.207((\ln(D))^2 – 0.0281 (\ln(D))^3)$

Wet forest:
$AGB = \rho \times \exp(-1.239 + 1.9801 \ln(D) + 0.207((\ln(D))^2 – 0.0281 (\ln(D))^3)$

where ρ is wood mass density (in g/cm^3) and D is dbh (in cm).

Then calculate the mean AGB (in kg) of all sampling transects of a stratum and multiply this value by 10 to express in tonnes dry mass ha^{-1}. Above-ground live biomass is then assumed to be 50% carbon (Chave *et al.* 2005).

7. Calculate the total above-ground live biomass carbon stock for each stratum by multiplying by the representative land area (expressed in ha) of each stratum. The total above-ground live biomass carbon stock of all strata is the total above-ground biomass carbon stocks of the habitat of interest. Note that this is not the total carbon stock of the site, if the site has more than one type of habitat.

Worked example for Climate Method 4

The site is a restored pine forest of an area of 754 ha in Northern India.

To determine the above-ground biomass, diameters at breast height (DBH) of all trees ≥ 10 cm were measured along six 5 m x 100 m transects

Above-ground biomass of a pine tree was estimated using the regression models developed for temperate pine forest involving DBH: $AGB_{pine} = 0.887 + ((10486 \times D^{2.84})/(D^{2.5} + 376907))$

Here is an example of a transect which contained 9 pine trees.

Tree No.	Tag No.	Species	DBH (cm)	Biomass (kg)	Carbon (kg)	Carbon (tonnes)
1	1	*Pinus roxburghii*	29.1	385.99	193	0.19
2	2	*Pinus roxburghii*	25.4	265.73	132.87	0.13
3	3	*Pinus roxburghii*	31	458.47	229.23	0.23
4	4	*Pinus roxburghii*	13.6	46.78	23.39	0.02
5	5	*Pinus roxburghii*	15.1	62.56	31.28	0.03
6	6	*Pinus roxburghii*	13.6	46.78	23.39	0.02
7	7	*Pinus roxburghii*	19.5	127.59	63.8	0.06
8	8	*Pinus roxburghii*	14.5	55.89	27.94	0.03
9	9	*Pinus roxburghii*	32.3	512.33	256.16	0.26
Total				1962.12	981.06	0.98

Therefore the total above-ground biomass of this transect is 1962.12 kg.

The amount of carbon stored in a tree was assumed to be 50% of the above-ground biomass. Hence, the total carbon in the transect is 1962.12/2 = 981.06 kg = 0.98 tonnes.

Given that the transect size is 0.046 ha (corrected for slope), the carbon stored in this transect is: 0.98/0.046 = 21.16 tonnes per ha.

If the mean amount of stored carbon across the six transects was 51.85±19.72 tonnes per ha (precision level at 20%), the total carbon stored in this pine forest is: 51.85 x 754 = 39,105 tonnes.

Climate Method 5. Estimating below-ground biomass carbon stock using IPCC conversion factors

Estimating below-ground live biomass is an important component of biomass surveys. However, field measurements are difficult. This section provides information on how to estimate below-ground biomass carbon stock for your habitat(s). The below-ground biomass is estimated by using a below-ground biomass to above-ground biomass ratio (conversion factor) from IPCC (2006). It is highly recommended to use empirically-derived root-to-shoot ratios specific to a region or vegetation, if available. These values can be used as defaults if you do not have more specific ratios.

> You will need:
>
> A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Guidance

1. Is the habitat tree-dominated (except woody savannahs) or a forest plantation?

Yes: See Table 4.4 in Chapter 4 of IPCC (2006), for the conversion factor. To calculate the total below-ground live biomass of your habitat, multiply total above-ground live biomass of your habitat by the conversion factor. Then go to **7.**

No: Go to **2.**

2. Is the habitat grass-dominated or a woody savannah?

Yes: Either (i) see Table 6.1 in Chapter 6 of IPCC (2006), for the conversion factor, then calculate the total below-ground live biomass of your habitat by multiplying total above-ground live biomass of your habitat by the conversion factor, or (ii) see Appendix 2 of this toolkit for relevant estimate of below-ground biomass for your habitat and multiply by the area of the habitat. Then go to **7.**

No: Go to **3.**

3. Is the habitat a wetland?

Yes: There are no existing conversion factors from IPCC (2006). As a rule of thumb, the conversion factor is 0.3 for annual wetland species without rhizomes (Cronk & Fennessy 2001). For habitats with other wetland species, conduct field measurement using harvest method (see protocol immediately below) or see Appendix 2 of this toolkit for relevant estimate of below-ground biomass for your habitat and multiply by the area of the habitat, and then go to **7.**

Guidance for field measurement

Step A: Collect sediment cores (of known cylindrical area) following **Climate Method B7.C** below.

Step B: Wash and strain the materials and separate the living matter from dead.

Step C: Dry the below-ground plant structures (roots, rhizomes, tubers, corms etc.) in an oven at 105^{o}C and weigh (expressed as g dry mass ha^{-1}).

Step D: Calculate the total below-ground biomass of your habitat – multiply the dry mass (g ha^{-1}) by the land area (ha) of your habitat. Divide by 1000000 to give the dry mass in t.

No: Go to **4.**

4. Is the habitat perennial crop-dominated (including woody crops plantations, orchards and agroforestry)?

Yes: See Table 4.4 in Chapter 2 of IPCC (2006), for rough estimated conversion factors. Use the conversion factor of a system closest to your habitat. To calculate the total below-ground live biomass of your habitat, multiply total above-ground live biomass of your habitat by the conversion factor. Then go to **7.**

No: Go to **5.**

5. Is the habitat annual crop-dominated?

Yes: It is assumed that there is no below-ground live biomass carbon stock because of biomass losses from harvest and mortality in that same year.

No : Go to **6.**

6. The habitat is a developed area.
There is no existing conversion factor from IPCC (2006). Go to Table 4.4 (urban parks) in Chapter 4 of IPCC (2006), and Table 6.1 (urban lawn) in Chapter 6 of IPCC (2006), for relevant conversion factors. To calculate the total below-ground live biomass of your habitat, multiply total above-ground live biomass of your habitat by the conversion factor. Then go to **7.**

7. To calculate the total below-ground live biomass carbon stock (in tonnes) of your habitat, multiply the total below-ground live biomass by 0.5 for tree-dominated, forest plantations, woody savannas, perennial crop-dominated habitats and urban parks or by 0.47 for grass-dominated habitats, wetlands and urban lawn. Then go to **8**.

8. Sum all carbon stocks (t C) across the habitats present at the site.

Worked example for Climate Method 5

There is a 2900ha site in East Africa, consisting of 1000ha of moist forest, 1500ha of sparsely-wooded savannah, 200ha of perennial cropping and a 200ha wetland (half open water and half swamp). This is the same hypothetical site as used to illustrate Method 4.

Tree-dominated habitat
The estimated amount of above-ground carbon was 260,000 tonnes. From Table 4.4 on the IPCC website, the relevant conversion factor for tropical moist deciduous forest is 0.24.

Below-ground biomass is therefore estimated to be 260,000 x 0.24 = 62,400 tonnes.

Below-ground carbon stock is therefore 62,400 x 0.5 = 31,200 tonnes of carbon.

Savannah
Appendix 2 of this toolkit gives a generic value for below-ground biomass in tropical savannah of 39 tonnes of dry matter per hectare.

This value is multiplied by the area of savannah (1500ha), to give 58,500 tonnes of dry matter.

This figure is multiplied by the conversion factor (0.5) to give 29,250 tonnes of carbon.

Perennial crops
The estimated amount of above-ground carbon was 8,200 tonnes. Appendix 2 of this toolkit gives a generic value for below-ground biomass in tropical cropland of 2 tonnes of dry matter per hectare.

This value is multiplied by the area of cropland (200ha), to give 400 tonnes of dry matter

Below-ground carbon stock is therefore 400 x 0.5 = 200 tonnes of carbon.

Wetland
Appendix 2 of this toolkit gives a generic value for below-ground biomass in marsh and swamp of 19 tonnes of dry matter per hectare.

This value is multiplied by the area of swamp (100ha), to give 1,900 tonnes of dry matter.

This figure is multiplied by the conversion factor (0.47) to give 893 tonnes of carbon.

Total below-ground carbon stock
All the stocks that have been estimated are added together;

31,200 + 29,250 + 200 + 893 = **61,543 tonnes of carbon**

Climate Method 6. Estimating dead organic matter (litter and dead wood) carbon stock using IPCC tier 1 estimates

Estimating dead organic matter – consisting of litter and dead wood – is an important component of biomass surveys, if the habitat is forested. This section provides information on how to estimate dead organic matter carbon stock based on information from IPCC (2006). Note that there is no existing tabulated data for dead wood biomass for tree-dominated habitats. IPCC (2006) tier 1 default carbon stock values are broad-scale estimates, and considerable uncertainty will be generated if applied to your habitat.

> You will need:
>
> A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

If, as a result of the following decision tree, no value is assigned to dead wood or litter then it must be reported that a value of zero was assigned.

1. Is the habitat tree-dominated, woody savannah, forested wetland, a forest plantation (including woody crop plantations and orchards) or an agroforestry system?

Yes: See Table 2.2 in Chapter 2 of IPCC (2006), for tier 1 default carbon stock estimates for litter (tonnes C ha^{-1}). However, dead wood carbon stock is not available. To calculate the total litter carbon stock of your habitat, multiply the default value by the land area (as expressed in ha) of your habitat. It is highly recommended to use litter and dead wood data from the relevant region, from published studies, if available. From these published data, litter carbon stock and dead wood carbon stock are then assumed to be 50% and 40% total dry mass, respectively (IPCC 2006). Then go to **6**.

No: Go to **2.**

2. Is the habitat grass-dominated?

Yes: There is no existing tabulated data from IPCC (2006). It is assumed that there are no significant litter and dead wood carbon pools for grass-dominated habitats (IPCC 2006). Then go to **6.**

No: Go to **3.**

3. Is the habitat a wetland?

Yes: There is no existing tabulated data form IPCC (2006). It is assumed that there is no significant dead organic matter because most carbon in litter and dead wood returns quite rapidly to the atmosphere by decay (IPCC 2006). Then go to **6.**

No: Go to **4.**

4. Is the habitat crop-dominated (excluding woody crops plantations, orchards and agroforestry)?

Yes: It is assumed that there is little or no litter or dead wood in croplands (IPCC 2006). Then go to **6**.

No: Go to **5.**

5. Is the habitat a developed area?
It is assumed that there is little or no litter or dead wood in developed areas (IPCC 2006). Go to**6.**

6. Sum all carbon stocks (t C) across the habitats present at the site.

Worked example for Method B1.6

There is a 2900ha site in East Africa, consisting of 1000ha of moist forest, 1500ha of sparsely-wooded savannah, 200ha of perennial cropping and a 200ha wetland (half open water and half swamp). This is the same hypothetical site as used to illustrate Method 4.

Tree-dominated habitat and perennial crops

According to Table 2.2 on the IPCC website, the estimate for litter carbon stock for tropical broadleaf deciduous forest is 2.1 tonnes of carbon per hectare.

Therefore, the total litter carbon stock for the forest and perennial crop area is 2.1 x 1200 = 2,520 tonnes of carbon.

Appendix 2 of this toolkit gives a generic value for below-ground biomass in tropical forest of 20 tonnes of dry matter per hectare.

Therefore, the total dead wood carbon stock for the forest and perennial crop area is (20 x 0.5) x 1200 = 12,000 tonnes of carbon.

Savannah and wetland

It is assumed that there are no significant pools of dead wood or litter carbon in either habitat.

Total stock of dead wood and litter carbon

All the stocks that have been estimated are added together;

The total stock is therefore **14,520 tonnes carbon**.

Climate Method 7. Estimating soil organic carbon stock in mineral and organic soils

Estimating soil carbon is an important component of surveys of your habitat(s), in addition to any biomass estimates. This section provides information on how to calculate soil carbon stocks in either organic or mineral soils. Soil organic carbon (SOC) stocks for mineral soils are calculated to a default depth of 30 cm, and although depth can vary, this is to some extent accounted for by climate and regional classification and assessments can be reliably made using IPCC tier 1 soil carbon inventories, if local field surveys are not possible. However, local data are preferable for mineral soils, and vital for organic soils, since they can be very deep and hence carbon stocks very variable. Therefore, site specific assessment of SOC should be made if possible. Even though both organic and inorganic forms of carbon are present in soils, inorganic carbon is ignored because land-use and management typically has a larger impact on organic carbon stocks. The soil types within any one site may vary between organic and mineral, therefore, it may be necessary to divide a site up into separate habitat strata upon the basis of soil type. However, it is likely that vegetation type will necessarily change with soil type, so stratification by vegetation type will probably suffice on most sites.

This section is drawn from IPCC (2006) soil classification, Volume 4, Chapter 3, Annex 3A.5 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html), Schumacher (2002) and Rydin & Jeglum (2006; pp79-80).

The first stage is to determine whether the soil in your habitat(s) is mineral or organic. Refer to **A.** Depending on the result of this, then go to either **B** or **C** for each habitat. If you have both mineral and organic soils at a site, or in your alternative state, you must make assessment of both using the same method. If soil maps are available for your site, you may make a tier 1 assessment of soil organic carbon if you only have mineral soils present, using method B. If you have no soil maps, or you have both mineral and organic soils, you should use method C, unless you have access to good local soil data (e.g. peat resource maps).

A. Determining if your soil is Mineral or Organic by local sampling

You will need:

Ceramic crucibles or heat-safe beakers.

A laboratory oven capable of maintaining 440 °C

A laboratory balance.

1. Is the soil at your site(s) organic or mineral? If you know the soil type at your site(s) then go to Method **B** or **C** as appropriate. If not continue below.

To make these determinations you need to:

1.1. Dig a small pit approximately 50cm deep in an area typical of each of your habitat(s).

1.2. Measure the depth of the dark (humic) layer of the soil (directly below the surface, to the sandy or clay (paler) subsoil). If the humic zone continues below 50cm, do not dig deeper at this stage.

1.3. Fill 3 small containers (of known volume - between $1cm^3$ and $10cm^3$) with soil from the middle of this dark layer by pressing them gently into the soil. Make sure you know the volume of the containers, and that you fill them. Do not compress the soil by pushing excess into the container; you need to know the weight of the sample at its natural density.

1.4. If laboratory facilities are available, proceed with the steps below. If not, determination of soil organic carbon is a service commonly offered by commercial soil testing companies. Soil samples can be kept for up to 28 days at 4 ^oC without significant loss of organic carbon.

2. Procedure:

2.1. Weigh each crucible/beaker – Crucible weight (**CW**)

2.2. Transfer each soil sample to a separate crucible/beaker, and weigh again – **CW**+Wet Weight (**WW**).

2.2. Place samples in the oven at 105° C for 24 hrs, then weigh again – **CW** + Dry Weight (**DW**)

2.3. Place samples in the oven at between 350 °C and 440 °C for 24hrs, then weigh again – **CW** + Ashed Weight (**AW**)

2.4. Calculate the following for each sample:

Organic matter content ($\mathbf{OM\%}_{\mathbf{by\ weight}}$) = ((**DW**-**AW**)/**DW**) x 100

Organic Carbon content ($\mathbf{OC\%}_{\mathbf{by\ weight}}$) = **OM**/1.75

Once you have your results from the above samples, proceed to **3.1. to 3.3.:** If your soil(s) fulfils conditions **3.1.** and **3.2.** OR **3.1.** and **3.3.** below, then it is **organic;** if not then it is **mineral.**

3.1. Humic (organic dark surface) layer is greater than or equal to 10cm deep (if less than 20cm, must have **OC** greater than or equal to 12%).

3.2. Soil is never saturated (other than very infrequently), but has an **OC** of greater than or equal to 20% by weight

3.3. soil is regularly or constantly saturated and has either:

≥12% **OC** if there is no clay in the dark layer

OR ≥18% **OC** if there is more than 60% clay in the dark layer

OR between these limits

Worked example 1 for Method A The humic layer is 16cm deep, with no clay in it. It is not regularly saturated.

CW = 5.9
CW + WW = 11.9g Therefore WW = 6.0g
CW + DW = 8.9g Therefore DW = 3.0g
CW + AW = 7.7g Therefore AW = 1.8g

Therefore OM = ((3-1.8)/3) x 100 = 40.00
Therefore OC = 37.5 / 1.75 = 22.86

Conditions 1 and 2 are met, so this soil is **organic**.

Worked example 2 for Method A
The humic layer is just 5cm deep, with about 50% clay in it. It is not regularly saturated.

CW = 6.0g
CW + WW = 10.9g Therefore WW = 4.9g
CW + DW = 10.4g Therefore DW = 4.4g
CW + AW = 9.8g Therefore AW = 3.8g

Therefore OM = ((4.4-3.8)/4.4) x 100 = 13.63
Therefore OC = 15 / 1.75 = 7.79

None of conditions 1, 2 or 3 are met, so this soil is **mineral**.

Worked example 3 for Method A
The humic layer is 30cm deep, with about 25% clay in it. It is regularly saturated.

CW = 6.1g
CW + WW = 12.0g Therefore WW = 5.9g
CW + DW = 9.4g Therefore DW = 3.3g
CW + AW = 8.3g Therefore AW = 2.2g

Therefore OM = ((3.3-2.2)/3.3) x 100 = 33.33.
Therefore OC = 33.33 / 1.75 = 19.05

Conditions 1 and 3 are met, so this soil is **organic**.

B. Estimating Soil Organic Carbon Stock in Mineral soils using IPCC Tier 1 soil carbon inventory method

This assessment is based on IPCC (2006) default tier 1 values on mineral soil carbon stock. Note that defaults are not available for developed areas of built infrastructure.

You will need:

A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

1. You need to know the climate domain of the site. Do you know the climate type of the site?

Yes: Go to **2.**

No: See Annex 3A.5 in Chapter 3 of IPCC (2006), for the default climate classification scheme. You may also classify the climate type of the site based on your national database or international sources of climate data, such as the United Nations Environmental Program. Go to **2.**

2. You need to know the soil type under each habitat type. Do you know the soil type of the site?

Yes: Go to **3.**

No: Use local or regional soils maps (if available) to determine the soil type. If no local or regional information is available, use FAO Soils Map of the World (http://www.fao.org/ag/agl/agll/wrb/soilres.stm) Go to **3.**

3. Is the habitat tree-dominated (natural or managed), grass-dominated (natural) or wetland (natural or managed)?

Yes: See Table 2.3 in Chapter 2 of IPCC (2006), for the default reference soil organic carbon stock (as expressed in tonnes C ha^{-1}).

No: Go to **4.**

4. Is the habitat grass-dominated and managed (including lawn in developed areas)?

Yes: Follow the guidance below for the calculation of the total soil carbon stock.

4.1. Find the default reference soil organic carbon stock (SOC_{REF}) value (as expressed in tonnes C ha^{-1}) in Table 2.3 in Chapter 2 of IPCC (2006). You will need information about the climate type and the soil type of your habitat.

4.2. Find the stock change factor for land-use systems (F_{LU}) in Table 6.2 in Chapter 6 of IPCC (2006). This land-use factor reflects carbon stock changes associated with type of land-use. For grass-dominated habitat, F_{LU} = 1 for all land-use.

4.3. Find the stock change factor for management regime (F_{MG}) in Table 6.2 in Chapter 6 of IPCC (2006). This management factor represents the principal management practice specific to the land-use of your habitat .

4.4. Find the stock change factor for input of organic matter (F_I) in Table 6.2 in Chapter 6 of IPCC (2006). This input factor represents different levels of carbon input to soil.

4.5. Calculate soil carbon stock (SOC) using this formula:

$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_{FI}$

4.6. Calculate the total soil carbon stock of your habitat – multiply SOC by the land area (as expressed in ha) of the habitat (as expressed in tonnes C ha^{-1}). All land in the site should have a common climate type, soil type and management practices.

No: Go to **5.**

5. The habitat is crop-dominated and managed (including woody crops plantations, orchards and agroforestry). Follow the guidance below for the calculation of the total soil carbon stock.

5.1. Find the default reference soil organic carbon stock (SOC_{REF}) value (as expressed in tonnes C ha^{-1}) in Table 2.3 in Chapter 2 of IPCC (2006). You need information about the climate type and the soil type of your habitat.

5.2. Find the stock change factor for land-use systems (F_{LU}) in Table 5.5 in Chapter 5 of IPCC (2006). This land-use factor reflects carbon stock changes associated with type of land-use.

5.3. Find the stock change factor for management regime (F_{MG}) in Table 5.5 in Chapter 5 of IPCC (2006). This management factor represents the principal management practice specific to the land-use of your habitat (e.g., different tillage practices).

5.4. Find the stock change factor for input of organic matter (F_I) in Table 5.5 in Chapter 5 of IPCC (2006). This input factor represents different levels of carbon input to soil.

5.5. Calculate soil carbon stock (SOC) using this formula: $SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_{FI}$

5.6. Calculate the total soil carbon stock of your habitat – multiply SOC by the land area (as expressed in ha) of the habitat (as expressed in tonnes C ha^{-1}). All land in the site should have a common climate type, soil type and management practices.

Worked example for Method B

An area of 10,000 ha of habitat was crop-dominated. The FAO soils map suggests that the soil type is an Ultisol and Annex 3A.5 on the IPCC website suggests that the climate domain is tropical moist, which has a native reference stock (SOC_{REF}) of 47 tonnes C ha^{-1} (see Table 2.3 in Chapter 2 of IPCC 2006, for native reference stock).

The land-use was annual row crops, with conventional tillage, no fertilization and where crop residues are removed.

Therefore, the soil carbon stock (SOC) of this habitat was (SOC_{REF} x F_{LU} x F_{MG} x F_{FI}) = 47 tonnes C ha^{-1} x 0.48 x 1 x 0.92 = 20.8 tonnes C ha^{-1} (see Table 5.5 in Chapter 5 of IPCC (2006) for stock change factors).

Therefore the total soil carbon stock is 10,000 x 20.8 = **208,000 tonnes of carbon**

C. Estimating Soil Organic Carbon Stock in Mineral and Organic soils

Organic soils can be very deep (up to 10m or more – Rydin & Jeglum, 2006), but their depth and density can be very varied, especially when they are fully waterlogged. Therefore, to determine the total carbon stock within an area of organic soil, you need to know not only the area of soil, but the depth of the organic component, the carbon content of the soil (Soil Organic Carbon – SOC) and the density of that soil.

1. Define your soil sampling regime at your site

Using a map of your site, define a grid of soil sampling sub-sites. The density of sampling sites should be at a level that is readily achievable given the size of the sites and the manpower available. Time is needed not only to collect samples in the field, but to process them in the laboratory. If SOC is to be determined by a third party, then cost should be considered also. Go to **C.2.**

2. Determine soil depth and collect soil samples

You will need:

A semi-cylindrical soil 'gouge augur' and handle extensions for deep sampling (available to borrow from university departments or agricultural colleges, or to purchase/rent from survey companies (~ \$200). If an augur is not available, a spade and thin flexible measuring rod may suffice for relatively shallow soils, but may become impractical at depths of more than 1m – unless you have lots of digging manpower!)

A measuring tape

Soil sample containers of known volume ($1cm^3$ to $10cm^3$) as in **A.1.**

Laboratory facilities and materials as described in **A.1.**, or access to the services of a commercial soil testing company.

Once a survey grid has been agreed, field sampling should be undertaken, using a variation of **A.1**. At each sampling point, you should determine depth of organic soil, and collect soil samples to determine SOC and soil density (so-called 'bulk density').

Procedure (at each sampling point):

2.1. Push the augur into the soil to its full length, twist and remove.

2.2. Take a sample of soil, as in **A.1.**, from the top 10cm of the soil core obtained.

2.3. Examine the core – if no clay or sand subsoil layer is apparent, measure the total length of the core, and repeat the previous two steps (using augur extensions), recording additional depth of each core, until the subsoil is reached, add these together to give the total depth of the organic layer at this sampling point. If subsoil is apparent in the first core, measure the depth of the organic layer in this. Retain all cores for further steps

2.4. Take a further soil sample from the bottom 10cm of the deepest core, and one from the mid-depth of the total soil depth (this will depend on how many cores you have). You should have three soil samples from each sample point, and the total depth of organic soil. Soil samples can be kept for up to 28 days at 4 ^{o}C without significant loss of organic carbon.

Go to **D.**

D. Determine SOC and soil density for each soil sample.

If laboratory facilities are available, follow **1.** If not, follow **2.**

1. Conduct the protocol given in **A.1.** to determine organic carbon content of each soil sample. Additionally, determine the bulk density of each sample as follows:

Bulk Density (BD) = DW/wet volume (WV), in g cm^{-3}

NB. The volume of soil in each sample container should equal that of the **filled** container. Then go to **3.**

2. Send samples to a commercial soil testing company for determination of soil organic carbon and bulk density. Then go to **3.**

3. Calculating the total soil carbon stock on your site(s)

For each sample point, you need:

The depth, in meters, of the organic layer of the soil.
The mean, maximum and minimum organic carbon density (OCD) in the soil column, calculated as follows (from the three soil samples at each point):

For each soil sample,
OCD = $((OC\%_{by\ weight}/100) \times BD) \times 1000\ kgCm^{-3}$

And

$OCD_{mean} = ((\sum((OC\%_{by\ weight}/100) \times BD))/3) \times 1000\ kgCm^{-3}$

Thus, knowing the area of the site, in m^2, you can calculate the carbon stock estimates (expressed in tonnes C) based on maximum, minimum and mean soil depth over the site as follows:

Total carbon (tC)= (depth x area x $OCD_{(mean,\ max\ or\ min)}$) / 1000

Worked example for Method D

The site is a 100ha fenland in eastern England. There are 6 sampling points and laboratory facilities are available for analysis. The containers for collecting the samples (3 per core) had a volume of 1 cm^3.

The depths of the soil cores, in cm, are as follows;

Core	1	2	3	4	5	6
Depth	56	48	83	45	62	53

Therefore, mean depth = 57.83cm.

As the sampling container is 1 cm^3, so is the wet volume of soil in each sample. Therefore, the bulk density = DW / 1, i.e. BD = DW. Therefore, for each sample, % organic carbon contents and organic carbon density are calculated as follows. (a) signifies sample from the top of the core, (b) from the middle, and (c) from the bottom. ;

	CW	CW+WW	CW+DW	CW+AW	WW	DW	AW	OM	OC	OCD
1a	5.52	10.12	7.65	6.82	4.592	2.129	1.301	38.89	22.22	473.14
1b	6.43	12.45	10.48	9.68	6.026	4.059	3.257	19.76	11.29	458.29
1c	5.41	12.15	10.27	9.58	6.742	4.859	4.171	14.16	8.09	393.14
2a	5.38	10.77	6.68	5.76	5.396	1.306	0.381	70.83	40.47	528.57
2b	5.4	11.21	9.31	8.6	5.81	3.907	3.203	18.02	10.3	402.29
2c	7.12	13.5	11.47	10.72	6.375	4.343	3.594	17.25	9.85	428
3a	5.36	11.5	7.26	6.38	6.14	1.892	1.011	46.56	26.61	503.43
3b	5.34	11.62	7.72	6.86	6.278	2.382	1.523	36.06	20.61	490.86
3c	5.33	13.39	10.87	9.85	8.062	5.543	4.524	18.38	10.5	582.29
4a	5.95	12.01	9.03	8.13	6.061	3.081	2.185	29.08	16.62	512
4b	5.44	12.56	7.35	6.64	7.121	1.915	1.203	37.18	21.25	406.86
4c	5.49	11.74	8.45	7.38	6.251	2.963	1.895	36.04	20.6	610.29
5a	5.43	11.39	7.87	6.95	5.959	2.44	1.526	37.46	21.41	522.29
5b	5.83	12.22	9.21	8.39	6.391	3.386	2.567	24.19	13.82	468
5c	6.07	12.18	8.1	7.12	6.108	2.029	1.049	48.3	27.6	560
6a	5.77	11.35	8.15	7.29	5.576	2.381	1.519	36.2	20.69	492.57
6b	5.35	11.52	6.99	6.44	6.164	1.638	1.088	33.58	19.19	314.29
6c	5.42	10.86	9.08	6.56	5.447	3.664	1.147	68.7	39.25	1438.29

Mean OCD is calculated to be 532.48 kg C m^{-3}

We need to express the volume of peat in m^3. So, we first need to convert the area of the site to m^2 - 100 ha = 1,000,000m^2.

So, total carbon = (0.5783 x 1,000,000 x 532.48) / 1000 = **307,933.2 tonnes of carbon.**

Climate Method 8. Estimating loss of biomass carbon stocks due to disturbances

Estimating loss in biomass carbon stocks due to disturbances is an important component of biomass surveys of your habitat(s), particularly for those that are tree-dominated. This section provides information on how to estimate the loss in carbon stocks due to (1) wood harvesting, (2) fuelwood/charcoal removal, and (3) other generic disturbance (e.g., fire, insect) based on IPCC (2006) default tier 1 methods.

You will need: A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html A computer with access to the internet

1. Is the site experiencing wood harvesting?

Yes: Follow the guidance below for estimating annual carbon loss due to wood harvesting. Then go to **2.**

1.1 Determine the annual roundwood removals at the country level, as expressed in m^3 y^{-1} from survey of experts. If the data is not available, use statistics on roundwood production from Earthtrends (http://earthtrends.wri.org/pdf_library/data_tables/for2_2005.pdf)or FAO statistics on wood harvest (FAOSTAT; http://faostat.fao.org/site/626/default.aspx#ancor). Because the FAO statistical data on wood harvest exclude bark, you will need to multiply FAO statistical wood harvest data without bark by a default expansion factor of 1.15 to determine merchantable wood removals including bark.

1.2. Determine the annual roundwood removals (H), based on the ratio of the land area of the harvestable habitats to the land area in the country where the wood is harvested (as expressed in m^3 y^{-1}).

1.3. See Table 4.3 in Chapter 4 of IPCC (2006), for the default value of carbon fraction of dry matter (CF) expressed in tonnes C (tonne dry mass [d.m.])$^{-1}$.

1.4. See Table 4.5 in Chapter 4 of IPCC (2006), for the default value of biomass conversion and expansion factor ($BCEF_R$) for conversion of removals in merchantable volume to total biomass removals (including bark), as expressed in tonnes biomass removal (m^3 of removals)$^{-1}$.

Guidance

To choose the right BCEFR, an estimate of the current mean growing stock is necessary. It can be derived from Global Forest Resources Assessment (FRA) 2005 at http://www.fao.org/forestry/32085/en by clicking "Grow stock in forest and other wooded land" and following by choosing your country of interest.

1.5. Calculate the annual carbon loss in biomass of wood removals ($L_{WOOD-REMOVALS}$), as expressed in tonnes C y^{-1}, using the following formula: $L_{WOOD-REMOVALS} = H \times BCEF_R \times CF$

No: Go to **2.**

2. Is the site experiencing fuelwood/charcoal removal?

Yes: Follow the guidance below for estimating annual carbon loss due to fuelwood/charcoal removal. Then go to **3.**

Guidance for estimating annual carbon loss due to fuelwood/charcoal removal

2.1. Determine the annual fuelwood and charcoal removals at the country level, as expressed in m^3 y^{-1} from survey of experts. If the data is not available, use FAO statistics (FAOSTAT) (http://faostat.fao.org/site/626/default.aspx#ancor) on fuelwood and charcoal removals for your respective country. If your unit is tonnes y^{-1}, remember to convert from tonnes to m^3 y^{-1}.

Guidance
Use a factor of 6 to convert from tonnes to m^3.

2.2. Determine the annual fuelwood and charcoal removals (FG) based on the ratio of the land area of the harvestable habitats to the land area in the country where the wood is harvested, as expressed in m^3 y-1.

2.3. See Table 4.3 in Chapter 4 of IPCC (2006), for the default value of carbon fraction of dry matter (CF) as expressed in tonne C (tonne d.m.)$^{-1}$.

2.4. See Table 4.5 in Chapter 4 of IPCC (2006), for the default value of biomass conversion and expansion factor ($BCEF_R$) for conversion of removals in merchantable volume to total biomass removals (including bark), as expressed in tonnes biomass removal (m^3 of removals)$^{-1}$. Note that the unit of growing stock level in Table 4.5 should be million cubic meters (instead of just m^3)

Guidance:
To choose the right BCEFR, an estimate of the current mean growing stock is necessary. It can be derived from Global Forest Resources Assessment (FRA) 2005 at http://www.fao.org/forestry/32085/en by clicking "Grow stock in forest and other wooded land" and following by choosing your country of interest.

2.5. Calculate the annual carbon loss in biomass of wood removals ($L_{FUELWOOD}$), as expressed in tonnes C y^{-1}, using the following formula: $L_{FUELWOOD} = FG \times BCEF_R \times CF$

No: Go to **3.**

3. Does the site experience disturbances (e.g., fire, insect, etc).

Yes: Follow the guidance below for estimating annual carbon loss due to disturbance. Then go to **4.**

3.1. Determine the area affected by disturbances (A), as expressed in ha y^{-1}.

3.2. Determine the mean above-ground biomass of land areas affected by disturbances (B), as expressed in tonnes dry mass ha^{-1}.

3.3. See Table 4.3 in Chapter 4 of IPCC (2006), for the default value of carbon fraction of dry matter (CF) as expressed in tonnes C (tonnes dry mass)$^{-1}$.

3.4. Determine the fraction of biomass lost in disturbance (fd).

Guidance: In a landslide event (i.e. a stand-replacing disturbance) where all biomass is killed, fd should be set at 1. However, an insect disturbance may only remove a portion of the mean biomass C density and fd should be less than 1 (e.g. fd = 0.3).

3.5. Calculate the annual carbon loss in biomass due to disturbance ($L_{DISTURBANCE}$), as expressed in tonnes C y^{-1}, using the following formula: $L_{DISTURBANCE} = A \times B \times CF \times fd$

No: This section is not relevant to the site of interest.

4. Calculate the annual decrease in carbon stock of the site, as expressed in tonnes C y^{-1}, using the following formula:
Annual decrease in carbon stocks due to biomass loss = $L_{WOOD\text{-}REMOVALS} + L_{FUELWOOD} + L_{DISTURBANCE}$

Worked example for Climate Method 8

Gabon has an area of 21,826,000 ha of forest. Here we assumed that all of its unprotected forest (2,094,000 ha) is harvested for wood. The site is a 10000 ha forest in Gabon that experienced wood harvesting, and fuel wood and charcoal removal. But the site does not experience any disturbance such as fire or landslide.

Estimating annual carbon loss due to wood harvesting

The annual roundwood removals at the country level = 2,584,000 m^3 y^{-1} (based on the data table from Earthtrends)

The annual roundwood removals (H) from the site = (10000/21826000) x 2584000 = 1183.91 m^3 y^{-1} (based on the ratio of the land area of the harvestable habitats to the land area in the country where the wood is harvested)

The default value of carbon fraction of dry matter (CF) = 0.49 tonnes C (tonne dry mass [d.m.])$^{-1}$

The default value of biomass conversion and expansion factor ($BCEF_R$) for conversion of removals in merchantable volume to total biomass removals (including bark) = 1.05 tonnes biomass removal (m^3 of removals)$^{-1}$ (Assuming the growing stock level is >200 m^3per hectare)

Therefore, the annual carbon loss in biomass of wood removals ($L_{WOOD\text{-}REMOVALS}$) = 1183.91 x 1.05 x 0.49 = 609.12 tonnes C y^{-1}, using the following formula: H x $BCEF_R$ x CF

Estimating annual carbon loss due to fuelwood/charcoal removal

The annual fuelwood removals at the country level = 1070000 m^3 y^{-1}

The annual charcoal removals at the country level = 20168 tonnes C y^{-1}. Therefore it is 20168 x 6 = 121008 m^3 y^{-1}

Therefore, the annual fuelwood and charcoal removals at the country level = 1070000 + 121008 = 1191008 m^3 y^{-1}

The annual fuelwood and charcoal removals (FG) based on the ratio of the land area of the harvestable habitats to the land area in the country where the wood is harvested = (10000/2094000) x 1191008 = 5687.72 m^3 y^{-1}.

The default value of carbon fraction of dry matter (CF) = 0.49 tonne C (tonne d.m.)$^{-1}$

The default value of biomass conversion and expansion factor ($BCEF_R$) for conversion of removals in merchantable volume to total biomass removals (including bark) = 1.05 tonnes biomass removal (m^3 of removals)$^{-1}$

Therefore, the annual carbon loss in biomass of wood removals ($L_{FUELWOOD}$) = 5687.72 x 1.05 x 0.49 = 2926.33 tonnes C y^{-1}, using the following formula: $L_{FUELWOOD}$ = FG x $BCEF_R$ x CF

Estimating annual carbon loss due to disturbance

The annual carbon loss in biomass due to disturbance ($L_{DISTURBANCE}$) = 0 tonnes C y^{-1}. This is because the site does not experience any disturbance such as fire or landslide.

Estimating the annual decrease in carbon stock of the site

The annual decrease in carbon stock of the site due to biomass loss = 609.12 + 2926.33 + 0 = 3535.45 tonnes C y^{-1}, using the following formula: $L_{WOOD\text{-}REMOVALS} + L_{FUELWOOD} + L_{DISTURBANCE}$

Climate Method 9. Estimating emission of carbon dioxide from organic soils (only) using IPCC tier 1 emission factors for tree-dominated, grassland-dominated and crop-dominated habitats

Carbon stored in soils, especially organic soils, can decompose, releasing CO_2 to the atmosphere when drained. The degree to which this is compensated by sequestration of CO_2 from the atmosphere into plants, and hence to soils, will vary with circumstances. Drainage is a common practice in agriculture and forestry, to improve site condition for plant growth, and can enhance aerobic decomposition of organic soil carbon. In this case, losses of CO_2 may outweigh sequestration, leading to a net emission of CO_2. Thus, estimating soil carbon emission could be an important component of biomass surveys of croplands and forestry plantations. Rapid estimation of CO_2 emissions could not be easily obtained from field measurements because the methodologies involved are too laborious and may be expensive. You should use any data on CO_2 emissions at the site, if they exist. Otherwise, this section provides information on where to find the existing estimates derived from IPCC (2006). This section covers tree-dominated, grassland-dominated and crop-dominated habitats, where drainage is practised at the site. For drained wetlands which have not been converted to these habitats, see Climate Method 10. Net CO_2 emissions from other habitats are probably not significant.

You will need: A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

1. Is drainage practised at the site?

Yes: Go to **2.**

No: CO_2 emissions from unmanaged sites are not estimated in this toolkit. CO_2 emissions from such sites are probably not significant. Sites that have become degraded through climate change are also not dealt with in this toolkit.

2. You need to know the climate domain of the site. Do you know the climate type of the habitat?

Yes: **Go to 3.**

No: See Annex 3A.5 in Chapter 3 of IPCC (2006), for the default climate classification scheme. You may also classify the climate type for the site based on your national database or international sources of climate data such as the United Nations Environmental Program. Go to **3.**

3. Is the habitat tree-dominated and managed (including parks in developed areas)?

Yes: See Table 4.6 in Chapter 4 of IPCC (2006), to select the appropriate default emission factor, as annual loss of carbon (as expressed in tonnes C ha^{-1} y-^{1}). Go to **6.**

No: Go to **4.**

4. Is the habitat grass-dominated and managed (including lawn in developed areas)?

Yes: See Table 6.3 in Chapter 6 of IPCC (2006), to select the appropriate default emission factor, as annual loss of carbon (as expressed in tonnes C ha^{-1} y^{-1}). Go to **6.**

No: Go to **5.**

5. The habitat is crop-dominated. See note on Table 5.6 in Chapter 5 of IPCC (2006), to select the appropriate default emission factor, as annual loss of carbon (as expressed in tonnes C ha^{-1} $y\text{-}^{1}$). Go to **6.**

6. Follow the guidance below for the calculation of the total annual carbon emission of the site:

6.1. Estimate the area of drained organic soils under the managed habitat (A), as expressed in ha.

6.2. Calculate total annual carbon emission by multiplying A by the emission factor. If there is more than one habitat at the site, repeat the steps and sum the total annual carbon emission across habitats.

6.3. Calculate total annual carbon dioxide equivalent, see Climate Method 14.

Worked example for Climate Method 9

The site is a 1500ha drained temperate peatland in Eastern Europe, with grasses dominant.

According to Annex 3A.5 on the IPCC website, the climate domain is 'cool temperate moist'.

According to Tables 5.6 on the IPCC website, the default emission factor (for boreal/cold temperate) is 0.25 tonnes of carbon per hectare per year.

Therefore, the total annual carbon emission = 1500 x 0.25 = **375 tonnes carbon per year**.

Climate Method 10. Estimating emissions of carbon dioxide using IPCC tier 1 emission factors for managed wetlands, in particular peatland extraction sites

Wetland drainage can increase CO_2 emissions from soils. Thus, estimating carbon emission could be an important component of biomass surveys of managed wetlands. Rapid estimation of CO_2 emissions could not be easily obtained from field measurements because the methodologies involved are too laborious and may be expensive. Unless data on CO_2 emissions at the site exist, this section provides information on how to calculate CO_2 emission rates using emission factors from IPCC (2006).

You will need: A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

1. Is the site a drained peatland?

Yes: Go to **2.**

No: CO_2 emissions from other managed wetlands are not estimated in this release of the toolkit. (We hope to include them in future versions)

2. Is the peatland undergoing active peat extraction?

Yes: Estimating CO_2 emission from wetlands undergoing peat extraction has two elements: on-site emissions from the remaining, drained peat deposits, and off-site emissions from the extracted peat when used for purposes such as horticulture or fuel which rapidly oxidise the carbon. Here we follow the IPCC (2006) default methodology that covers the on-site CO_2 emissions - Go to **A, then 3;** and literature values (Cleary et al., 2005; Rydin & Jeglum, 2006) to calculate emissions from extracted peat - Go to **B, then 3.**

No: See **Climate Method 11**, according to which vegetation is now present on the peatland.

A. Estimating CO_2 emissions from dry peat at extraction sites

You need to know the climate domain of the site. See Annex 3A.5 in Chapter 3 of IPCC (2006), for the default climate classification scheme. You may also classify the climate type of the site based on your national database or international sources of climate data such as the United Nations Environmental Program. You also need to know if the site is of nutrient-rich or nutrient-poor peatlands. Nutrient-rich fens and mires predominate in temperate regions, while nutrient-poor bogs are more common in temperate region. Go to **1.**

1. Estimate the area of nutrient-rich peat soils managed for peat extraction ($A_{peatRich}$). Go to **2.**

2. Estimate the area of nutrient-poor peat soils managed for peat extraction ($A_{peatPoor}$). Go to **3**

3. See Table 7.4 in Chapter 7 of IPCC (2006), to select the appropriate default emission factors (expressed in tonnes C ha^{-1} y^{-1}) for the nutrient-rich ($EF_{peatRich}$) and nutrient-poor ($EF_{peatPoor}$) peat soils associated with the climate zone of the site. Go to **4.**

4. Follow the guidance below for the calculation of the change in carbon stocks in biomass due to vegetation clearing (ΔC_{peatB}) during the peat extraction. Then go to **5.**

   4.1. Determine the above-ground and below-ground biomass (as expressed in tonnes of dry mass ha^{-1}) at the site before the peat extraction (B_{BEFORE}). For guidance, see Climate Method 3 for above-ground biomass measurement and Climate Method 5 for below-ground biomass estimation.

   4.2. Determine the above-ground and below-ground biomass (as expressed in dry mass ha^{-1}) at the site immediately after the peat extraction (B_{AFTER}). For guidance, see Climate Method 3 for above-ground biomass measurement and Climate Method 5 for below-ground biomass estimation.

   4.3. Determine area of peat soil extracted (A_{TOTAL}) in a certain year (as expressed in ha y^{-1}).

   4.4. Calculate ΔC_{peatB} (expressed in t C y^{-1}) using the following formula:
   $(B_{BEFORE} - B_{AFTER}) \times A_{TOTAL} \times 0.47$

5. Calculate CO_2 emission (as expressed in t C y^{-1}) from the peat extraction site using this formula:

$$\mathbf{Weight}_{\mathbf{CSite}} = ((A_{peatRich} \times EF_{peatRich}) + (A_{peatPoor} \times EF_{peatPoor})) + \Delta C_{peatB}$$

B. Estimating CO_2 emissions from peat extracted from the site for fuel or horticultural use

To estimate these values, you need to know the volume of peat extracted from the site annually. Additionally, if you have values for Bulk density (BD) and proportion of Soil Organic Carbon (OC), from the extractor, or calculated locally using M9.3, use these. Otherwise, use default values from literature (Cleary et al., 2005; Rydin & Jeglum, 2006), given below.

1. Calculate the total weight of carbon extracted (in Kg) from the site annually using the formula:

$$\mathbf{Weight}_{\mathbf{CExtracted}} = \text{Volume extracted (in } m^3\text{)} \times \text{BD (in Kg } m^{-3}\text{)} \times \text{OC}$$

Where BD = bulk density (use 0.2g cm^{-3} (=200Kg m^{-3}) if no local figure available)
OC = percentage of organic matter that is carbon (use 0.5 if no local figure is available).

2. If the peat is extracted for fuel, we assume that all peat extracted is burnt, therefore, all carbon is lost to the atmosphere as CO_2, as in **M12.4.1.**

i.e. $\mathbf{Weight}_{\mathbf{CBurnt}}$ (tC) = $\mathbf{Weight}_{\mathbf{Cextracted}}$ **/ 1000**

However, if the peat extracted is used for horticulture, or soil improver, we assume that the amount lost annually to the atmosphere as CO_2 through decomposition is 5% (after Cleary et al, 2005). Therefore, if this is the case calculate the loss of carbon to the atmosphere as:

$$\mathbf{Weight_{CDecomposed}} = \mathbf{Weight_{CExtracted}} \times 0.05 / 1000 \text{ (t C)}$$

3. Obtain total carbon lost to the atmosphere as CO_2 due to peat extraction:

$$\mathbf{Total\ Weight_{CO2Lost} = Weight_{CSite} + Weight_{CBurnt} + Weight_{CDecomposed}}$$

Worked example for Climate Method 10

The site is a 2000ha drained temperate peatland in Eastern Europe, of which 500ha is being extracted (40ha per year) to a depth of 1.5m, for horticulture. Grasses dominate the vegetation on the part which is not being extracted.

The extracted and non-extracted parts of the site are separated for analysis. For the 1500ha which is not being extracted (see worked example under Method B1.11) the annual carbon emission is 375 tonnes.

Then, for the 500ha which is being extracted, see below.

Emissions from the dry peat on site

According to Annex 3A.5 on the IPCC website, the climate domain is 'cool temperate moist'

All the soil at the site is nutrient rich. So, $A_{peatRich}$ = 500ha, $A_{peatPoor}$ = 0ha.

According to Table 7.4 on the IPCC website, CO_2 emissions from nutrient rich temperate peat = 1.1 tonnes of carbon per hectare per year. So, $EF_{peatPoor}$ = 1.1.

Using methods 5 and 7, it was found that B_{BEFORE} and B_{AFTER} = 10 tonnes per hectare and 2 tonnes per hectare respectively.

A_{TOTAL} = 40 hectares per year.

Therefore, ΔC_{peatB} = (10 – 2) x 40 x 0.47 = 150.4 tonnes of carbon per year.

Then, CO_2 emissions = ((500 x 1.1)+(0)) + 150.4 = 700.4 tonnes of carbon per year

Emissions from the extracted peat

There is no local data on bulk density or proportion of soil organic carbon, so default figures are used.

Annual volume of peat extracted = 40 ha x 1.5m = 600,000m^3.

Therefore, weight of carbon extracted annually is (600,000 x 200 x 0.5) = 60,000,000 kg

Therefore weight of extracted carbon which decomposes annually = (60,000,000 x 0.05)/1000 = 3000 tonnes of carbon per year.

Therefore total weight of carbon emitted from the extraction site each year = 700.4 + 3000 = 3700.4 tonnes.

And total weight of carbon emitted from the whole site = 375 + 3700.4 = **4075.4 tonnes per year.**

Climate Method 11. Estimating methane emissions from wet soil and grazing animals, using IPCC and other Tier 1-type methods

Significant emissions of methane (CH_4), one of the most important greenhouse gases, can result from several consequences of land management. The anoxic conditions of waterlogged soils cause CH_4 to be produced in large quantities due to the anaerobic decomposition of organic material. Another important source of CH_4 is ruminant and other grazing animals. The gut flora (bacteria) and diet (containing lots of cellulose from plant cell walls) of these animals can produce significant quantities of CH_4 as a by-product of digestion, released by belching.

Rapid estimation of $CH_4$from these sources is not easily obtained from field measurements because the methodologies involved are too laborious and expensive. Therefore, unless data on CH_4 emissions at the site exist, this section provides information on how to calculate CH_4 emission rates following the Tier 1 methods from IPCC (2006) and further information from Couwenberg (2009), Couwenberg et al. (2010), Crutzen et al. (1986) and Thornton & Herrero (2009).

You will need:

A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

A. Methane emissions from wet soils

Is the site a wetland or a rice paddy?

Wetland : Go to **1**.

Rice paddy: Go to **2**.

1. Wetlands

Wetlands can be divided into two main types, naturally occurring wet areas, flooded as a result of topography and climate e.g. floodplain fens, bogs, salt marsh; and flooded lands, caused by human intervention e.g. hydroelectric or drinking water reservoirs. The CH_4 emissions of these land types are different, due to the differences in anoxic processes, vegetation communities/structures and the decomposition substrates available. They are therefore treated separately here, and by IPCC.

Is the site a manmade or natural wetland?

Manmade: Go to **1.1.**

Natural: Go to **1.2.**

1.1. Manmade, or flooded, wetlands

CH_4 emissions in flooded land could occur via (1) diffusive emission across the air-water interface by molecular diffusion; (2) gas emission from the sediment through the water column in bubbles; and (3) degassing emission which is the result of a sudden change in hydrostatic pressure. The method for estimating CH_4 emission includes only diffusion emissions during ice-free periods. Emissions during ice-cover periods are assumed to be zero.

1. Is the wetland drained?

Yes: CH_4 emissions from managed, drained wetlands are assumed to be not significant.

No: Go to **2.**

2. You need to know the climate domain of the site. See Annex 3A.5 in Chapter 3 of IPCC (2006), for the default climate classification scheme. You may also classify the climate type of the site based on your national database or international sources of climate data such as the United Nations Environmental Program. Go to **3.**

3. Estimate the length of ice-free periods, P, in terms of days y^{-1}. P = 365 for a site in tropics, or less if the site has ice-cover periods. Go to **4.**

4. See Table 3A.2 in Appendix 3 of IPCC (2006), to select the appropriate default diffusion emission, $E(CH_4)_{diff}$ (as expressed in kg CH_4 ha^{-1} day^{-1}) associated with the climate zone of the site. Go to **5.**

5. Estimate the total flooded surface area ($A_{flooded}$), including flooded land, lakes and rivers (as expressed in ha). Go to **6.**

6. Calculate CH_4 emission rate (as expressed in t CH_4 y^{-1}) using the following formula: $\mathbf{CH_{4\ Wet\ Soils}} = (P \times E(CH_4)_{diff} \times A_{flooded}) / 1000$
Multiply this figure by 0.75 if you need to obtain the amount of carbon lost as methane (expressed as tonnes C_{CH4} y^{-1}).

Worked example for Method A1.1 (flooded land)

The site is a 500ha grassland in Eastern England which has largely been flooded. The flooded area amounts to 420ha.

According to Annex 3A.5 on the IPCC website, the climate domain is ‘cool temperate moist’.

On average, the site is only ice covered on 10 days per year, so P = 355

The default diffusion emission given in Table 3A.2 on the IPCC website is 0.061 kg CH_4 ha^{-1} day^{-1}.

Therefore, the methane emission rate is (355 x 0.061 x 420) / 1000 = **9.1 tonnes of methane per year.**

1.2. Natural wetlands

CH_4 emissions from natural wetlands occur by three mechanisms. (1) Diffusion through soil pore spaces. This includes diffusion through both water-filled and gas-filled pores. (2) Plant-mediated fluxes. These include diffusive transfer and/or advective (mass) flow through the aerenchyma of certain so-called 'shunt species'. (3) Ebullition, involving movement of bubbles containing CH_4 upwards through the soil profile. Bubbles may form for a variety of reasons, including changes in atmospheric pressure.

1. Is the wetland drained?

Yes: CH_4 emissions from managed, drained wetlands are assumed to be not significant.

No: Go to **2.**

2. Is the wetland coastal or freshwater?

Coastal: CH_4 emissions from coastal wetlands are assumed to be not significant. There are no data on methane emissions of coastal wetlands in IPCC. We assume though that CH4 emissions are zero due to suppression of methane production by sulphates in sea water (eg Chapman, Chmura 2009).

Freshwater: Go to **3.**

3. Is the site boreal or temperate?

Yes: Go to **4.**

No: Only a very approximate assessment of soil CH_4 emissions can be made from Tropical wet soils, and then only for forested sites. Go to **Table A.,** but use caution!

4. Is the mean annual water table within 20cm of the soil surface?

Yes: The site is 'Wet'. Go to **5.**

No: The site is 'Dry'. Go to **Table A.**

5. Assess the site vegetation communities for the presence of CH_4 'shunt species'

Many wetland plants possess aerenchymous tissue that allows for transport of oxygen into the root zone in waterlogged soils. CH_4 is transported through the aerenchyma out into the atmosphere. Plant species displaying this CH_4 emission pathway, or 'shunt', are referred to as 'shunt species'. Examples of shunt species include *Nymphaea*, *Nuphar*, *Calla*, *Peltandra*, *Sagittaria*, *Cladium*, *Glyceria*, *Scirpus*, *Eleocharis*, *Eriophorum*, *Carex, Scheuchzeria*, *Phragmites* and *Typha*. Shunt species can facilitate a very effective mechanism for methane to bypass the methanatrophic (CH_4 oxidising) organisms in the aerobic upper soil layers, and thus increase CH_4 emissions on wet soils. Go to **Table A.** and select the appropriate emission factor based on the presence or absence of 'shunt species'.

Table A. CH_4 emission from wet soils addressing climate, soil type and vegetation (adapted from Couwenberg, 2009 & Couwenberg et al., 2010). Select the appropriate emission factor from the table and then go to **6.**

		Mean t $CH_4 ha^{-1} yr^{-1}$ (range)		
		Dry	Wet	
			Without shunts	With shunts
Boreal	Bogs	0.0086 (-0.0011 – 0.051)	0.024 (-0.0017 – 0.164)	0.012 (0.0031 – 0.059)
	Fens			0.123 (0.0066 – 0.525)
Temperate		0.0002 (-0.0040 – 0.0090)	0.050 (-0.0002 – 0.250)	0.170 (0 – 0.763)
Tropical*	Forested		0.270 (-0.037 – 0.578)	

* Limited information is available about CH_4 emissions from tropical wet soils. The estimates presented here represent a mean and range for forested wet soils only (Couwenberg et al., 2010). CH_4 emissions from tropical wet soils are apparently very variable, but generally low (indeed, often negative – CH_4 uptake from the atmosphere, Couwenberg et al., 2010). Therefore, we recommend using caution when making CH_4 assessments from tropical wet soils. Do not make any assessment where the site is substantially without trees, and where an assessment is made, present either minimum and maximum possible emissions, or, preferably make no assessment for CH_4 emissions from either the current or counterfactual state (the most conservative).

6. Multiply the CH_4 emission factor by the area of the site (in hectares) to obtain the total annual CH_4 emissions from wet soil at the site: **$CH_{4\text{Wet Soil}}$**

Multiply this figure by 0.75 if you need to obtain the amount of Carbon (as methane) lost by the site per year.

Worked example for Method A1.2 (natural wetland)

The site is a 500ha wetland in northern Spain, half of which remains wet all year and half of which dries up for over half the year. In the wet half, there is an abundance of 'shunt' species.

For the estimated 250ha which are 'dry', the default emission factor is 0.0002 t $CH_4 ha^{-1} yr^{-1}$.

For the estimated 250ha which are 'wet', the default emission factor is 0.170 t $CH_4 ha^{-1} yr^{-1}$.

Therefore, the methane emission rate is (250 x 0.0002) + (250 x 0.170) = **42.55 tonnes of methane per year.**

2. Rice paddies

Many factors can affect CH_4 emissions – such as soil type, temperature, rice variety, size of the paddies and cultivation period of the rice grown. However, our method here, following the tier 1 method from IPCC (2006), estimates CH_4 emissions by using a default daily emission factor.

1. The default CH_4 baseline emission factor (EF_C) = 1.30 (See Table 5.11 in Chapter 5 of IPCC (2006)). This value assumes that there is no flooding for less than 180 days prior to rice cultivation, and continuous flooding during rice cultivation, without organic amendments. Go to **2.**

2. See Table 5.12 in Chapter 5 of IPCC (2006), to select the appropriate default scaling factor to account for the differences in water regime during the cultivation period (SF_W). In Table 5.12, the aggregated case refers to a situation when information on flooding patterns are not available, whereas the disaggregated case refers to a situation when flooding patterns can be distinguished in the form of three subcategories. Go to **3.**

3. See Table 5.13 in Chapter 5 of IPCC (2006), to select the appropriate default scaling factor to account for the differences in water regime in the pre-season before the cultivation period (SF_P). In Table 5.13, the aggregated case refers to a situation when information on the pre-season water status is not available, whereas the disaggregated case refers to a situation when the pre-season water status can be distinguished in the form of three subcategories. Go to **4.**

4. Calculate the scaling factor using the following guidance:

4.1. Determine the application rates of the different organic amendments (ROA_i), in dry weight for straw and fresh weight for other (as expressed in t ha^{-1}).

4.2. See Table 5.14 in Chapter 5 of IPCC (2006) to select the appropriate default conversion factor ($CFOA_i$) for the different types of organic amendment.

4.3. Calculate the scaling factor for both type and amount of organic amendment applied (SF_O) using the following formula:
$SF_O = (1 + \sum_i ROA_i \times CFOA_i)^{0.59}$

4.4. Go to **5.**

5. Estimate the cultivation period (T) for rice (as expressed in days). Go to **6.**

6. Estimate the annual harvested area (A) for rice (as expressed in ha y^{-1}). Go to **7.**

7. Calculate annual CH_4 emission rate (as expressed in t CH_4 y^{-1}) using the following formula:
Annual CH_4 emission from rice cultivation $\mathbf{CH_{4Wet\ Soil}}$ = $(EF_C \times SF_W \times SF_P \times SF_O) \times t \times A \times 10^{-3}$.

Multiply this figure by 0.75 to obtain the amount of Carbon (as methane) lost by the site per year.

Worked example for Method 2 (rice paddies)

The site is a 300ha paddy in Cambodia, half of which is cultivated in each year. It is flooded for 20 days before cultivation and then continuously flooded during cultivation. The cultivation period is 150 days.

The default emission factor (EF_C) is 1.30.
According to Table 5.12 on the IPCC website, $SF_W = 1$
According to Table 5.13 on the IPCC website, $SF_P = 1.90$

Farmyard manure is applied at a rate of 2 tonnes per hectare. Therefore CFOA = 0.14

Therefore, $SF_O = (1+(2 \times 0.14))^{0.59} = 1.157$

Therefore, methane emission = $(1.3 \times 1 \times 1.9 \times 1.157) \times 150 \times 150 \times 10^{-3}$ = **64.3 tonnes of methane per year.**

B. Methane emissions from domestic or wild grazers

Ruminants (cattle, sheep, deer etc) and other herbivorous animals (horses, asses, swine) produce CH_4 as a by-product of their digestive processes. This is released by belching. The magnitude of emissions from domestic stock is affected by the species and breed of animal, and the content of their diet. Generally, more highly refined diets result in lower emissions per weight of feed/weight of animal, but often require more energy (greenhouse gas release) to produce. Since pastoral agriculture is an anthropogenic ecosystem change, CH_4 emissions from domestic animals are covered by IPCC Tier 1 methodology. Emissions from wild grazers are not covered by IPCC, but some figures are available from literature (Crutzen et al., 1986). In order to make an assessment of the CH_4 emitted by grazers at the site, you need to have a reliable estimate of the number of domestic animals present and/or a population estimate for wild grazers. The latter, particularly, may be difficult to obtain, so estimates of CH_4 emissions should be conservatively treated as an underestimate.

Procedure:

1. Obtain estimates of the number of animals at the site. These may be available as agricultural statistics locally for domestic stock, or it may be possible to ascertain animal holdings from local authorities or by questionnaire/interview. Estimates for wild grazers may be available from protected area records or from NGO/scientific institution study.

Are estimates of wild and domestic animal numbers available?
Yes: Go to **2.**

No: Obtain estimates from local sources as above. If none are available, conduct survey/interviews to obtain domestic stock numbers. Local census of wild grazer numbers as part of this toolkit is not possible, as it requires specialist knowledge, methods, and is very time consuming. Then go to **2.**

2. Are domestic or wild grazers present at the site?

Domestic: Go to **3.**

Wild: Go to **4.**

3. Domestic stock CH_4 emissions

3.1. Define the species of domestic animals present and select the appropriate emission factor (in kg CH_4 head^{-1} year^{-1}) for each species, using Tables 10.10 and 10.11in Section 10.3.2 of Chapter 10 of IPCC 2006. To select emissions for each species, identify the region most applicable to the site. For species not listed, use the method given in section 10.2.4 to estimate emissions factors.

3.2. Calculate the emissions from each species (T) of animal using the following equation:

$$\text{Emissions} = EF_{(T)} x (N_{(T)}/1000)$$

Where: Emissions = methane emissions, t CH_4 y^{-1}
$EF_{(T)}$ = emission factor for the defined animal population, kg CH_4 head^{-1} y^{-1}
$N_{(T)}$ = the number of animals of species T at the site

3.3. Calculate the total emissions from livestock at the site using the following equation:

$$\textbf{Total CH}_{4\ \textbf{Domestic}} = \sum_i E_i$$

Where: Total $CH_{4Domestic}$ = total methane emissions from domestic livestock, t CH_4 y^{-1}
E_i = is the emissions for the *i*th livestock species.

Then go to **5.**

4. Wild grazer CH_4 emissions

4.1. If significant populations of wild grazers are present (deer, gazelles, horses), and their population size is known, identify the most appropriate emissions factor from **Table B.** Then go to **4.2.**

Table B. CH_4 emissions factors for wild grazing animals, accounting for region and body size, in kg CH_4 head^{-1} year^{-1} (adapted from Crutzen et al., 1986)

Region		Size		Emission Factor(KgCH_4 head^{-1}y^{-1})	Body Weight (kg)
Boreal/Temperate	Ruminants	Large	Moose, elk	31	350
		Medium	Large deer, Caribou	15	90
		Small	Small deer	5	15
Tropical/Savannah	Ruminants	Large	Buffalo	37	500
		Medium	wildebeest	13	130
		Small	Gazelle	4	32
	Non-Ruminants	Large	Elephant	20	1000
		Medium	Zebra	5	200

Small	Wild pig	1	50

4.2. Calculate the total emissions from each species (T) of wild grazer using the equation in **3.2.** and then calculate the total CH_4 emissions due to all wild grazers (**Total CH_{4Wild}**) using the equation in **3.3.** Then go to **5.**

5. Total CH_4 emissions from grazing animals at the site

Add **$CH_{4Domestic}$** and **CH_{4Wild}** to obtain an estimate of the total emissions of CH_4 due to animal gut fermentation at the site: **$CH_{4Grazers}$**

Multiply this figure by 0.75 if you need to obtain the amount of Carbon (as methane) emitted by grazing animals at the site per year.

Worked example for Method B

The site is a 200ha grassland site in eastern England, with 200 beef cattle and 100 sheep.

For cattle, the default emission factor, according to Table 10.11 on the IPCC website, is 57 kg CH_4 head^{-1} y^{-1}.

Therefore methane emissions from cattle = 57 x (200/1000) = 11.4 tonnes per year.

For sheep, the default emission factor, according to Table 10.10 on the IPCC website, is 5 kg CH_4 head^{-1} y^{-1}.
Therefore methane emissions from sheep = 5 x (100/1000) = 0.5 tonnes per year.

Total methane emissions from domestic animals = 11.4 + 0.5 = **11.9 tonnes per year**.

Climate Method 12. Estimating nitrous oxide emission using IPCC tier 1 method for managed peatland and habitats with managed land

Nitrous oxide (N_2O), the most important non-carbon greenhouse gas, is emitted from some types of drained peatland and agricultural systems where nitrogen fertilisation is applied. N_2O is produced by bacteria in soils of these habitats through the processes of nitrification (aerobic microbial oxidation of ammonium to nitrate) and denitrification (anaerobic microbial reduction of nitrate to nitrogen gas). It leaks from microbial cells into the soils and then ultimately is released to the atmosphere. Rapid estimation of N_2O emissions could not be easily obtained from field measurements because the methodologies involved are too laborious and may be expensive. Unless data on N_2O emissions at the site exist, this section provides information on how to calculate N_2O emission rates following the tier 1 methods from IPCC (2006).

You will need:

A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

1. Is the site a managed peatland?

Yes: Go to '**Managed peatlands**' below.
No: Go to '**Habitats with managed land**' below.

A. Managed peatlands

Significant amounts of organic nitrogen may be present, in inactive form, in some types of peatland (especially fens). Nitrogen would be converted into nitrates by bacteria when the peatland is drained. The nitrates would then leach into surface where they are reduced to N_2O. Following IPCC (2006), our method here excludes the emissions during the off-site use of horticultural peat. Note that the same data should be used for estimating CO_2 and N_2O emissions from managed peatlands.

2. You need to know the climate domain of the site. See Annex 3A.5 in Chapter 3 of IPCC (2006), for the default climate classification scheme. You may also classify the climate type of your habitat based on your national database or international sources of climate data such as the United Nations Environmental Program. Go to **3.**

3. See Table 7.6 in Chapter 7 of IPCC (2006), to select the appropriate default emission factor, $EF_{peatRich}$ (as expressed in kg N_2O-N ha^{-1} y^{-1}) associated with the climate zone of the site. Go to **4.**

4. Estimate the area of nutrient-rich peat soils managed for peat extraction ($A_{peatRich}$) (as expressed in ha). Go to **5.**

5. Calculate N_2O emission (as expressed in t N_2O y^{-1}) using the following formula: N_2O emission rate = $(A_{peatRich} \times EF_{peatRich}) \times 44/28 \times 10^{-3}$

Worked example for Method A: Managed peatland

The site is a 1500ha fenland site in eastern Europe, of which 500ha is managed for peat extraction.

According to Annex 3A.5 on the IPCC website, the climate domain is cool temperate mosit.

According to Table 7.6 on the IPCC website, the default emission factor is 1.8 kg N_2O-N ha^{-1} y^{-1}.

Therefore, nitrous oxide emission s = (500 x 1.8) x (44/28) x 10^{-3} = **1.41 tonnes per year**.

B. Habitats with managed land

According to IPCC (2006), managed land is an area where 'human interventions and practices have been applied to perform production, ecological or social functions'. This can include tree-dominated, grass-dominated and crop-dominated habitats. N_2O emissions in these habitats consist of direct N_2O emissions and indirect N_2O emissions, often associated with past or present use of organic or synthetic fertiliser.

Guidance for estimating direct N_2O emission
An increase in available N – occurring through human-induced N additions or change of land-use and/or management practices – can enhance nitrification and denitrification rates, which then increases the production of N_2O. IPCC (2006) tier 1 methods do not take into account different land-cover, soil types and climatic conditions.

6. Determine the annual amount of synthetic fertiliser N applied to soils (F_{SN}) as expressed in kg N ha^{-1} y^{-1}. Multiply by the area (in terms of ha) to give the total of synthetic N applied, in kg N y^{-1}. Go **to 7.**

Further guidance for estimating F_{SN}
Annual fertiliser consumption data may be obtained from a survey of farmers or derived from the information collected from:
(1) Official country statistics, often recorded as fertiliser sales or as domestic production and imports.
(2) The International Fertilizer Industry Association (IFIA) (http://www.fertilizer.org/ifa/statistics.asp),on total fertiliser use by type and by crop.
(3) The Food and Agricultural Organisation of the United Nations (FAO, http://faostat.fao.org), on synthetic fertiliser consumption.

However, if this N source is not significant, then ignore it.

7. Determine the annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (F_{ON}) as expressed in kg N ha^{-1} y^{-1}.
Go to **8.**

Further guidance for estimating F_{ON}

To calculate F_{ON}, you will need to:

7.1. Determine the annual amount of animal manure N applied to soils, in terms of kg N ha^{-1} y^{-1}. Multiply by the area to which animal manure is applied at this rate, to give the total amount applied in terms of kg N y^{-1} (F_{AM})

7.2. Determine the annual amount of total sewage N that is applied to soils, in terms of kg N ha^{-1} y^{-1}. Multiply by the area to which sewage residues are applied at this rate, to give the total amount applied in terms of kg N y^{-1} (F_{SEW})

7.3. Determine the annual amount of total compost N applied to soils, in terms of kg N ha^{-1} y^{-1}. Multiply by the area to which compost is applied at this rate, to give the total amount applied in terms of kg N y^{-1} (F_{COMP})

7.4. Sum up F_{AM}, F_{SEW} and F_{COMP} to obtain F_{ON}.

These data may be obtained from a survey of farmers.

8. Determine the annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops and from forage/pasture renewal, returned to soils (F_{CR}), as expressed in kg N y^{-1}. Go to **9.**

Further guidance for estimating F_{CR}

To calculate $F_{CR,}$ you will need to:

8.1. Determine the harvest annual dry matter yield for crop T ($Crop_{(T)}$), as expressed in kg DM ha^{-1}.

8.2. Determine the total annual area harvested of crop T ($Area_{(T)}$), ha y^{-1}.

8.3. Determine the annual area of crop T burnt (Area $burnt_{(T)}$), ha y^{-1}.

8.4. See Table 2.6 in Chapter 2 of IPCC (2006), for the default value of combustion factor, C. Note: the combustion factor is dimensionless. Therefore it has no unit.

8.5. Determine the fraction of total area under crop T that is renewed annually ($Frac_{Renew}$). For countries where pastures are renewed on average every X years, $Frac_{Renew}$ = 1/X. For annual crops $Frac_{Renew}$ = 1.

8.6. Determine the ratio of above-ground residues dry matter ($AG_{DM(T)}$) to $Crop_{(T)}$ ($R_{AG(T)}$) using the following formula:
$R_{AG(T)} = AG_{DM(T)} \times 1000/Crop_{(T)}$ where $AG_{DM(T)}$ can be calculated from the information in Table 11.2 in Chapter 11 of IPCC (2006).

8.7. See Table 11.2 in Chapter 11 of IPCC (2006) for the default value of N content of above-ground residues for crop T ($N_{AG(T)}$), as expressed in kg N (kg d.m.)$^{-1}$.

8.8. Determine the fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction ($Frac_{REMOVE(T)}$), as expressed in kg N (kg crop-N)$^{-1}$. Survey of experts is required to obtain data. If data for $Frac_{REMOVE(T)}$ are not available, assume $Frac_{REMOVE(T)} = 0$.

8.9. Determine the ratio of below-ground residues to harvested yield for crop T ($R_{BG(T)}$), as expressed in kg d.m. (kg d.m.)$^{-1}$ by using the following formula: $R_{BG(T)} = R_{BG\text{-}BIO}$ x $((AG_{DM(T)}$ x $1000 + Crop_{(T)})/Crop_{(T)})$ where:

$R_{BG\text{-}BIO}$ can be obtained in Table 11.2 in Chapter 11 of IPCC (2006).

$N_{BG(T)}$, as expressed in kg N (kg d.m.)$^{-1}$, can be calculated from the information in Table 11.2 in Chapter 11 of IPCC (2006).

8.10 Calculate F_{CR} of crop T (expressed in kg N y^{-1}) using this formula: $F_{CR} = Crop_{(T)}$ x $(Area_{(T)}$ – Area $burnt_{(T)}$ x $C_f)$ x $Frac_{Renew(T)}$ x $[R_{AG(T)}$ x $N_{AG(T)}$ x $(1 – Frac_{Remove(T)}) + R_{BG(T)}$ x $N_{BG(T)}]$

9. Determine the annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of management (F_{SOM}) as expressed in kg N y^{-1}. Go to **10.**

Further guidance for estimating F_{SOM}

9.1. See Climate Method 7 for guidance for estimating soil carbon stock. To estimate the mean annual loss of soil carbon stock in mineral soils ($\Delta C_{Mineral}$) for the area over a period of years (D),

Either:

Use the following formula if you have access to soil carbon stock estimates made over a period of years:

$$\Delta C_{Mineral} = (SOC_0 – SOC_{(0\text{-}T)})/D \text{ where:}$$

SOC_0 = total soil carbon stock in the last year of a time period, tonnes C.

$SOC_{(0\text{-}T)}$ = soil carbon stock at the beginning of the time period, tonnes C.

T = number of years over a single inventory time period, y.

D = 20 (a default value). If T exceeds D, use the value T to obtain an annual rate of change over the inventory time period (0-T years).

Note: Make sure that the figures you collated for this calculation is the TOTAL carbon change per year. If you use SOC values that are expressed as per hectare, multiply by the area being considered.

Or:

If you only have one estimate of soil carbon stock, use literature based estimates of annual loss (such as that given by Bellamy et al 2005, based on the England & Wales National soil Inventory). This has established a relationship between rate of soil carbon loss and soil carbon content. If you use your total soil carbon stock figure from Climate Method 7, the equation below will give you the TOTAL annual change in carbon stock for your site or habitat. If you use a literature based carbon stock figure that is per hectare, you must multiply this by the area of the site or habitat.

$$\Delta C_{Mineral} \text{ (tonne y}^{-1}\text{)} = 0.6 - 0.0187 \times \text{SOC (tonne)}$$

9.2. Calculate F_{SOM} (expressed as kg N y^{-1}) using the following formula:
$F_{SOM} = (\Delta C_{Mineral} \times 1/R) \times 1000$ where

R = C:N ratio of the soil organic matter. Use the default value of 15 for situations involving land-use change from forest land or grassland to cropland. A default value of 10 may be used for situations involving management changes in cropland.

10. See Table 11.1 in Chapter 11 of IPCC (2006) to select the appropriate default emission factor (EF_1) for N_2O emissions from N inputs, as expressed in kg N_2O-N (kg N input)$^{-1}$. Go to **11.**

11. Calculate the annual direct N_2O-N emissions from N inputs to managed soils ($N_2O\text{-}N_{Ninputs}$), as expressed in kg N_2O-N y^{-1} using the following formula:
$N_2O\text{-}N_{Ninputs} = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \times EF_1$
Go to **12.**

12. Determine the annual area of managed/drained organic soils (F_{OS}) as expressed in ha. Go to **13.**

13. See Table 11.1 in Chapter 11 of IPCC (2006) to select the appropriate default emission factor (EF_2) for N_2O emissions from managed/drained organic soils, as expressed in kg N_2O-N ha^{-1} y^{-1}. Go to **14.**

14. Calculate the annual direct N_2O-N emissions from managed organic soils ($N_2O\text{-}N_{OS}$), as expressed in kg N_2O-N y^{-1} using the following formula:
$N_2O\text{-}N_{OS} = F_{OS} \times EF_2$
Go to **15.**

15. Determine annual amount of urine and dung N deposited by cattle, poultry and pigs on pasture, range and paddock ($F_{PRP,CPP}$) as expressed in kg N y^{-1}. Go to **16.**

To calculate $F_{PRP,CPP}$, you will need to:

15.1. Determine the livestock populations for livestock T ($N_{(T)}$).

15.2. Use default values to calculate the annual mean nitrogen excretion rate per head ($Nex_{(T)}$) for each defined livestock species/category T.
$Nex_{(T)} = Nrate_{(T)} \times TAM_{(T)}$ where:

$Nrate_{(T)}$ = default N excretion rate, kg N (1000 kg animal mass)$^{-1}$ day^{-1} (see Table 10.19 in Chapter 10 of IPCC [2006]).

$TAM_{(T)}$ = typical animal mass for livestock category T, kg animal-1. Default TAM values are provided in Tables 10A-4 to 10A-9 in Appendix 10A.2 of IPCC (2006).

15.3. Use default value in Tables 10A-4 to 10A-9 in Appendix 10A.2 of IPCC (2006) for the fraction of total annual nitrogen excretion for each livestock species/category T that is deposited on pasture, range and paddock.($MS_{(T)}$).

15.4. $F_{PRP,CPP} = \sum_T (N_{(T)} \times Nex(T) \times MS_{(T)})$

16. See Table 11.1 in Chapter 11 of IPCC (2006) to select the appropriate default emission factor ($EF_{3,CPP}$) for N_2O emissions from urine and dung N deposited on pasture, range and paddock by cattle, poultry and pigs, as expressed in kg N_2O-N (kg N input)$^{-1}$. Go to **17.**

17. Determine annual amount of urine and dung N deposited by sheep and other animals on pasture, range and paddock ($F_{PRP,SO}$) as expressed in kg N y^{-1}. Go to **18.**

Further guidance for estimating $F_{PRP,SO}$:

To calculate $F_{PRP,SO}$, you will need to:

17.1. Determine the livestock populations for livestock T ($N_{(T)}$).

17.2. Use default values to calculate the annual mean nitrogen excretion rate per head ($Nex_{(T)}$) for each defined livestock species/category T.
$Nex_{(T)} = Nrate_{(T)} \times TAM_{(T)}$ where:

$Nrate_{(T)}$ = default N excretion rate, kg N (1000 kg animal mass)$^{-1}$ day^{-1} (see Table 10.19 in Chapter 10 of IPCC [2006]).

$TAM_{(T)}$ = typical animal mass for livestock category T, kg animal-1. Default TAM values are provided in Tables 10A-4 to 10A-9 in Appendix 10A.2 of IPCC (2006).

17.3. Use default value in Tables 10A-4 to 10A-9 in Appendix 10A.2 of IPCC (2006) for the fraction of total annual nitrogen excretion for each livestock species/category T that is deposited on pasture, range and paddock.($MS_{(T)}$).

17.4. $F_{PRP,SO} = \sum_T (N_{(T)} \times Nex(T) \times MS_{(T)})$

18. See Table 11.1 in Chapter 11 of IPCC (2006) to select the appropriate default emission factor ($EF_{3,SO}$) for N_2O emissions from urine and dung N deposited on pasture, range and paddock by sheep and other animals, as expressed in kg N_2O-N (kg N input)$^{-1}$. Go to **19.**

19. Calculate the annual direct N_2O-N emissions from urine and dung inputs to grazed soils (N_2O-N_{PRP}), as expressed in kg N_2O-N y^{-1} using the following formula: N_2O-N_{PRP} = ($F_{PRP,CPP}$ x $EF_{3,CPP}$) + ($F_{PRP,SO}$ + $EF_{3,SO}$). Go to **20.**

20. Calculate annual direct N_2O-N emission produced from managed soils (as expressed in kg N_2O-N y^{-1}) using the following formula:
Annual direct N_2O-N emission = N_2O-$N_{Ninputs}$ + N_2O-N_{OS} + N_2O-$N_{PRP.}$ Go to **21.**

21. Convert annual direct N_2O-N emission to N_2O emissions by using the following equation: N_2O = N_2O-N x 44/28

Guidance for estimating indirect N_2O emission

Emissions of N_2O can also take place through two indirect pathways: (1) the volatilisation of N as NH_3 and oxides of N (NO_x), and the deposition of these gases and their products (NH_4^+ and NO_3^-) onto soils and surfaces water bodies; and (2) the leaching and runoff from land. All data needed for estimating indirect N_2O emissions are the same as for the estimation of direct emission.

22. Guidance for estimating indirect N_2O emission via volatilisation from managed soils

22.1. Determine the annual amount of synthetic fertiliser N applied to soils (F_{SN}) as expressed in kg N y^{-1}. For guidance, see **6.** above.

22.2. See Table 11.3 in Chapter 11 of IPCC (2006) for the fraction of synthetic fertiliser N that volatilises as NH_3 and NO_x ($Frac_{GASF}$), as expressed as kg N volatilised (kg of N applied)$^{-1}$. The default value of $Frac_{GASF}$ = 0.10.

22.3. Determine the annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils (F_{ON}) as expressed in kg N y^{-1}. For guidance, see **M14.7.** above.

22.4. Determine the annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (F_{PRP}) as expressed in kg N y^{-1}. For guidance, see **14.** and **16.** above.

22.5. See Table 11.3 in Chapter 11 of IPCC (2006) for the fraction of applied organic N fertiliser materials (F_{ON}) and if urine and dung deposited by grazing animals (F_{PRP}) that volatilises as NH_3 and NO_x ($Frac_{GASM}$), as expressed as kg N volatilised (kg of N applied or deposited)$^{-1}$. The default value of $Frac_{GASM}$ = 0.20.

22.6. See Table 11.3 in Chapter 11 of IPCC (2006) for the emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces (EF_4), as expressed in kg N_2O-N(kg NH_3-N + NO_x-N volatilised)$^{-1}$. The default value of EF_4 is 0.01.

22.7. Calculate the annual amount of N_2O-N produced from atmospheric deposition of N volatilised from managed soils ($N_2O_{(ATD)}$-N), as expressed in kg N_2O-N y^{-1}, using the following formula:
$N_2O_{(ATD)}\text{-}N = ((F_{SN} \times Frac_{GASF}) + ((F_{ON} + F_{PRP}) \times Frac_{GASM})) \times EF_4$

22.8. Convert $N_2O_{(ATD)}$-N emissions to N_2O emissions using the following formula:
Indirect N_2O emission via volatilisation = $N_2O_{(ATD)}$-N x 44/28

23. Guidance for estimating indirect N_2O emission via leaching and runoff from managed soils

23.1. Determine the annual amount of synthetic fertiliser N applied to soils in regions where leaching/runoff occurs (F_{SN}) as expressed in kg N y^{-1}. For guidance, see **6.** above.

23.2. Determine the annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils (F_{ON}) in regions where leaching/runoff occurs as expressed in kg N y^{-1}. For guidance, see **7.** above.

23.3. Determine the annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (F_{PRP}) in regions where leaching/runoff occurs as expressed in kg N y^{-1}. For guidance, see **15.** and **16.** above.

23.4. Determine the amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs (F_{CR}) as expressed in kg N y^{-1}. For guidance, see **8.** above.

23.5. Determine the amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land-use or management in regions where leaching/runoff occurs (F_{SOM}) as expressed in kg N y^{-1}. For guidance, see **9.** above.

23.6. See Table 11.3 in Chapter 11 of IPCC (2006) for the fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff ($Frac_{LEACH-(H)}$), as expressed as kg N (kg of N additions)$^{-1}$. The default value of $Frac_{LEACH-(H)}$ = 0.20.

23.7. See Table 11.3 in Chapter 11 of IPCC (2006) for the emission factor for N_2O emissions from N leaching and runoff (EF_5), as expressed in kg N_2O-N(kg N leached and runoff)$^{-1}$. The default value of EF_5 is 0.0075.

23.8. Calculate the annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs ($N_2O_{(L)}$-N), as expressed in kg N_2O-N y^{-1}, using the following formula:

$$N_2O_{(L)}\text{-}N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH-(H)} \times EF_5$$

23.9. Convert $N_2O_{(L)}$-N emissions to N_2O emissions using the following formula:
Indirect N_2O emission via leaching and runoff = $N_2O_{(L)}$-N x 44/28

Worked example for estimating direct N_2O emission

There is a site of 10 ha annual wheat farmland in the UK where only synthetic fertiliser is applied to the soils.

Given that:

The annual amount of synthetic fertiliser N applied to soils (F_{SN}) = 2 kg N ha^{-1} y^{-1}

The annual amount of organic N additions applied to soils (F_{ON}) = 0 kg N ha^{-1} y^{-1}

The harvest annual dry matter yield for wheat ($Crop_{(T)}$) = 100 kg DM ha^{-1}

The total annual area harvested of wheat ($Area_{(T)}$) = 10 ha y^{-1}

The annual area of wheat burnt ($Area\ burnt_{(T)}$) = 10 ha y^{-1}.

The default value of combustion factor, C = 0.9 (Obtained from Table 2.6 in Chapter 2 of IPCC [2006])

The fraction of total area under wheat that is renewed annually ($Frac_{Renew}$) = 1

The above-ground residues dry matter ($AG_{DM(T)}$) = 100 x 1.51 x 0.52 = 78.52 (obtained from Table 11.2 in Chapter 11 of IPCC[2006])

The ratio of above-ground residues dry matter ($AG_{DM(T)}$) to $Crop_{(T)}$ ($R_{AG(T)}$) = 78.52/100 = 0.7852

The default value of N content of above-ground residues for wheat ($N_{AG(T)}$) = 0.006 kg N (kg d.m.)$^{-1}$ (obtained from Table 11.2 in Chapter 11 of IPCC [2006])

The fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction ($Frac_{REMOVE(T)}$) = 0 kg N (kg crop-N)$^{-1}$

$R_{BG\text{-}BIO}$ for wheat = 0.24 (obtained in Table 11.2 in Chapter 11 of IPCC (2006)

The ratio of below-ground residues to harvested yield for crop T ($R_{BG(T)}$) = 0.24 x ((78.52 x 1000 + 100)/100) = 1886.88 kg d.m. (kg d.m.)$^{-1}$ by using the following formula: $R_{BG(T)} = R_{BG\text{-}BIO} \times ((AG_{DM(T)} \times 1000 + Crop_{(T)})/Crop_{(T)})$

$N_{BG(T)}$ for wheat = 0.009 kg N (kg d.m.)$^{-1}$ (Obtained in Table 11.2 in Chapter 11 of IPCC [2006]).

F_{CR} = 100 x (10 – 10 x 0.9) x 1 x [0.7852 x 0.006 x (1 – 0) + 1886.88 x 0.009] = 1698.663 kg N yr^{-1}using this formula: $F_{CR} = Crop_{(T)} \times (Area_{(T)} - Area\ burnt_{(T)} \times C_f) \times Frac_{Renew(T)} \times [R_{AG(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)}) + R_{BG(T)} \times N_{BG(T)}]$

We assumed that the mean annual loss of soil carbon stock in mineral soils ($\Delta C_{Mineral}$) for the area over an inventory period = 20 tonnes C per year.

Therefore, F_{SOM} = (20 x 1/10) x 1000 = 2000 kg N y^{-1}
The default emission factor (EF_1) for N_2O emissions from N inputs = 0.01

The annual direct N_2O-N emissions from N inputs to managed soils (N_2O-$N_{Ninputs}$) = (2 + 0 + 1698.66 + 2000) x 0.01 = 37.01 kg N_2O-N y^{-1} using the following formula: N_2O-$N_{Ninputs}$ = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) x EF_1

The annual direct N_2O-N emissions from managed organic soils (N_2O-N_{OS}) = 0 kg N_2O-N y^{-1}. This is because there was no managed organic soil.

The annual direct N_2O-N emissions from urine and dung inputs to grazed soils (N_2O-N_{PRP}) = 0 kg N_2O-N y^{-1}. This is because there was no livestock.

The annual direct N_2O-N emission produced from managed soils = 37.01 + 0 + 0 = 37.01 kg N_2O-N y^{-1} using the following formula: N_2O-$N_{Ninputs}$ + N_2O-N_{OS} + N_2O-$N_{PRP.}$

Therefore, the annual direct N_2O emissions = 37.01 x (44/28) = 58.15 kg N_2O y^{-1} by using the following equation: N_2O-N x 44/28

Worked example for estimating indirect N_2O emission

There is a site of 10 ha annual wheat farmland in the UK where only synthetic fertiliser is applied to the soils (the same worked example as above).

Given that:
The annual amount of synthetic fertiliser N applied to soils (F_{SN}) = 2 kg N y^{-1}

The fraction of synthetic fertiliser N that volatilises as NH_3 and NO_x ($Frac_{GASF}$) = 0.10 (the default value)

The annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils (F_{ON}) = 0 kg N y^{-1}

The annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (F_{PRP}) = 0 kg N y^{-1}

The default value of $Frac_{GASM}$ = 0.20

The default value of EF_4 is 0.01

The annual amount of N_2O-N produced from atmospheric deposition of N volatilised from managed soils ($N_2O_{(ATD)}$-N) = ((2 x 0.1) + ((0 + 0) x 0.2)) x 0.01 = 0.002 kg N_2O-N y^{-1}, using the following formula: $N_2O_{(ATD)}$-N = ((F_{SN} x $Frac_{GASF}$) + ((F_{ON} + F_{PRP}) x $Frac_{GASM}$)) x EF_4

Therefore, the annual Indirect N_2O emission via volatilisation = 0.002 x 44/28 = 0 kg N_2O y^{-1}

Worked example for estimating indirect N_2O emission via leaching and runoff from managed soils

There is a site of 10 ha annual wheat farmland in the UK where only synthetic fertiliser is applied to the soils (the same worked example as above).

Given that:
The annual amount of synthetic fertiliser N applied to soils in regions where leaching/runoff occurs (F_{SN}) = 2 kg N y^{-1}

The annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils (F_{ON}) in regions where leaching/runoff occurs = 0 kg N y^{-1}

The annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (F_{PRP}) in regions where leaching/runoff occurs = 0 kg N y^{-1}

The amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs (F_{CR}) = 1698.663 kg N y^{-1} (same as the worked example above)

The amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land-use or management in regions where leaching/runoff occurs (F_{SOM}) = 2000 kg N y^{-1}.

The default value of $Frac_{LEACH-(H)}$ = 0.20

The default value of EF_5 is 0.0075

The annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs ($N_2O_{(L)}$-N) = (2 + 0 + 0 + 1698.663 + 2000) x 0.2 x 0.0075 = 5.55 kg N_2O-N y^{-1}, using the following formula: (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) x $Frac_{LEACH-(H)}$ x EF_5

Therefore, the annual indirect N_2O emission via leaching and runoff = 5.55 x 44/28 = 8.72 kg N_2O y^{-1}

Climate Method 13. Estimating carbon sequestration for bogs and mires, using equation

Bryophyte (moss – *Sphagnum* spp.) dominated wetlands (bogs, mires and poor fens) do not have obvious substantial above ground vascular vegetation in the way that other wetlands (rich fens, reed beds, swamps, flooded forests) do. They are, however, still capable of substantial carbon sequestration, by virtue of their peculiar ecology. *Sphagnum* spp. grows slowly, but is very resistant to decay, and builds up substantial deposits which enhance water retention and become anaerobic, further inhibiting decay. In this way, primary production exceeds CO_2 loss through respiration and decay, and peat is built up. *Sphagnum* spp. dominate temperate and boreal bogs in the northern hemisphere, and some regions of the southern hemisphere, but there are other bog forming plants, such as the restiad grasses *Empodisma minus* and *Sporadanthus* spp. in New Zealand, though these often occur in conjunction with *Sphagnum*. The method given below should provide a reasonably robust estimate for the carbon sequestration by *Sphagnum* dominated habitats in the Northern hemisphere, at latitudes of above 45° N, but any estimates for southern hemisphere temperate or austral habitats should be made with caution, since there are few figures for C sequestration available for southern *Sphagnum*- based habitats or restiad or other vascular plant-dominated bogs. Smith (2003) (quoted in Nieveen & Schipper, 2005) gives a range from -1.85 tC ha^{-1} y^{-1} to -2.10 tC ha^{-1} y^{-1} sequestration for a restiad bog ecosystem in New Zealand (38°S). Comparison of these values with those with those given below for boreal or temperate (45° - 65°N) bogs shows them to be considerably higher. The reason for this is not known – it may simply be the decrease in latitude, or the local context for this study, but it is clear that if values are extrapolated for sites at latitudes lower than 45°, or in the southern hemisphere (particularly those dominated by non-bryophytes) these estimates should be treated with a good deal of caution, or obtained using the field sampling methods in **Climate Method 7.A.**

1. Using the latitude of the site, to the nearest degree, estimate the amount of carbon sequestered over a year, using the following equation:

$$C_{seq} = ((\text{Latitude} \times 0.0436) - 2.7302) \times \text{site area (in ha)}$$

The value given will be in t C y^{-1}
A negative value indicates carbon uptake by the site, positive an emission of carbon to the atmosphere.

Worked example for Climate Method 13
The site is a 2000ha bog site in northern Belarus, at latitude 55.2.

Carbon sequestration = ((55 x 0.0436) – 2.7302) x 2000 = -664.4.

Therefore, the site is taking up **664.4 tonnes of carbon per year**.

Climate Method 14. Calculating the overall greenhouse gas flux

By converting the climate influence of all three greenhouse gases (carbon dioxide (CO_2), methane(CH_4) and nitrous oxide (N_2O)) to CO_2 equivalents, the fluxes of these gases can be directly compared and the net greenhouse gas flux of a site can be calculated.

1. Each atom of carbon sequestered represents one molecule of CO_2 removed from the atmosphere. So, take the figure that you calculated for net carbon sequestration (t C y^{-1}) in **Section B1.7** and express this in terms of CO_2 (t CO_2 y^{-1}) by multiplying by 44/12. This is because the molecular weights of C and O are 12 and 16 respectively.

2. To get overall flux of CO_2 (in t CO_2 y^{-1}), add the figure you calculated in **1.** to the estimate of CO_2 emission from soil that you calculated in **Section B1.9**.

3. You now need to convert your carbon dioxide, methane (from **Section B1.10**) and nitrous oxide (from **Section B1.11**) fluxes to carbon dioxide equivalents, so that they can be added together to calculate overall greenhouse gas flux. Carbon dioxide equivalent (CO_2Eq) is a measure used to compare the fluxes of various greenhouse gases based upon their global warming potential (GWP; IPCC third assessment report, Forster et al., 2007).

(1) GWP_{100}* of methane is 25
(2) GWP_{100}*of nitrous oxide is 298
(3) GWP_{100}* of carbon dioxide is 1 (of course!)

*These global warming potential values are not fixed, since CH_4 and N_2O are labile compounds, and degrade with time. Therefore, the potential of a tonne of a gas emitted will reduce with time. For instance, the GWP of CH_4 is 72 over 20 years, but 25 over 100 years (Forster et al., 2007). However, for this toolkit, we use the GWP over a 100 year time horizon.

NB. Sometimes literature values of greenhouse gas fluxes are expressed as kmol ha^{-1} . In this case, you need to convert kmol to g first. To do this, you need the information of the molecular weight (g/mol) of the gas. The molecular weight (g/mol) of the various greenhouse gases are as follows:

Carbon dioxide (CO_2) = 44 g
Methane (CH_4) = 16 g
Nitrous oxide (N_2O) = 44 g

An example of how to sum these greenhouse gas fluxes is shown in the box below.

Worked example for Climate Method 14:

From Anderson-Teixeira & deLucia (2010), we know that the annual nitrous oxide flux for a hectare of tropical forest is 0.082 kmol or 82 mol. To calculate the weight of the emitted nitrous oxide from a hectare of tropical forest, multipy 82 (mol) by 44 (g/mol). This gives 3608 g y^{-1}.
If the total area of a tropical forest block is 1,000 million ha, its total annual emission of nitrous oxide would be 3608 (g) x 10^9 (ha) = 3,608,000 t N_2O. Therefore its carbon dioxide equivalent would be (3,608,000 x 298) = 908,128,000 t CO_2Eq y^{-1}.

From the same published data source, the annual methane flux for a hectare of tropical forest is -0.23 kmol or -230 mol. The negative value means methane uptake by the system. To calculate the weight of methane absorbed by a hectare of tropical forest, multiply 230 (mol) by 16 (g/mol). This gives 14.38 g y^{-1}.

For the same forest block (1,000 million ha), its total annual methane uptake would be 3680 (g) x 10^9 (ha) = 3,680,000 t CH_4. Hence, its carbon dioxide equivalent would be (3,680,000 x 25) = 92,000,000 t CO_2Eq y^{-1}.

The annual carbon dioxide flux for a hectare of tropical forest is -144 kmol or -144000 mol. Again, the negative value means carbon dioxide uptake by the system. To calculate the weight of carbon dioxide absorbed by a hectare of tropical forest, multiply 144000 (mol) by 44 (g/mol). This gives 6336000 g y^{-1}.

The total annual carbon dioxide uptake by the same forest block (1,000 million ha) would be 6336000 (g) x 10^9 (ha) = 6,336,000,000t CO_2. Hence its carbon dioxide equivalent would be (6,336,000,000x 1) = 6,336,000,000t CO_2Eq y^{-1}.

In conclusion, the total amount of greenhouse gases absorbed annually by the forest block = 6,336,000,000 + 92,000,000 – 908,128,000 = 5,519,872,000 t CO_2Eq y^{-1}.

Climate Method 15. Estimating the value of the timber harvested from the site of interest.

For estimating the economic value of the timber harvested from the site of interest, you will need the local merchantable growing stock volume. However, when the information is not available, it is highly recommended to collect local field data on above-ground biomass carbon stock – for the calculation of the growing stock volume – if your resources (i.e., manpower, time etc.) permit. Again, when this is not possible, this section also provides information on where to find the existing estimates on above-ground biomass from IPCC (2006) for tree-dominated habitats.

> You will need:
>
> A copy of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". You can download an electronic copy online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Step 1: Are data on total merchantable growing stock volume (T_{VOL}) of your site, as expressed in m^3, available?

Yes – Utilise existing data on merchantable growing stock volume to calculate the economic value of the timber. Go to Step 3.

No – Go to Step 2.

Step 2: Are resources (i.e., manpower, time, etc.) for local field surveys available?

Yes – Go to Method B1.4 for rapid field measurements for above-ground biomass. Then calculate merchantable growing stock volume from above-ground biomass (see guidance directly below) and go to Step C.

Guidance for calculating growing stock volume from total above-ground biomass carbon stock in your site:

Step A: See Table 4.3 in Chapter 4 of IPCC (2006) for the appropriate default value of carbon fraction of dry matter (CF).

Step B: Calculate above-ground biomass from above-ground biomass carbon stock expressed in tonnes, using the following formula:
Above-ground biomass (tonnes) = Above-ground biomass carbon stock/CF

Step C: See Table 4.5 in Chapter 4 of IPCC (2006) for the appropriate default value of biomass conversion and expansion factor ($BCEF_S$) for expansion of merchantable growing stock volume to above-ground biomass as expressed in tonnes above-ground biomass growth (m^3 growing stock volume)$^{-1}$.

Further guidance:
To choose the right BCEFA, it is necessary to know the current average growing stock of your site. This can be derived from the Global Forest Resources Assessment (FRA) 2005 at http://www.fao.org/forestry/32085/en by clicking "Grow stock in forest and other wooded land" and follow by choosing your country of interest.

Step D: Calculate the merchantable growing stock volume, as expressed in m^3, using the following formula:
Merchantable growing stock volume (m^3) =Above-ground biomass (tonnes)/$BCEF_S$

No – Go to Method B1.2 for estimating above-ground biomass carbon stock using IPCC tier 1 default values. Then calculate growing stock volume from above-ground biomass carbon stock (see guidance directly above) and go to Step A.

Step 3: Are data on timber prices (T_P) available?

Yes – Go to Step 4.

No – There are a few timber classifications ("standard") in which each has its own description of different wood categories. Neighbouring countries may share the same "standard" (e.g. Slovenia and Austria are using the similar classification). The prices of roundwood in certain classes are based on the market demand and their values are unlikely to change drastically over a period of time. The best way to find the estimation of an average price for your particular stand of forest is by asking the large regional buyers of these woods. The price is typically set after the logs are being skidded to the forest road. It is also determined by the tree species and the intention of use.

Step 4: Are data on harvesting cost ($C_{HARVEST}$) available?

Yes – Go to Step 5.

No – The harvesting costs consists of the costs of cutting and skidding the logs. These can be obtained from companies that cut the trees. The costs of cutting and skidding depend mostly on the availability of existing forest roads and skidding routes network. In an area where there is no tradition of harvesting timbers, the harvesting cost should also include the costs of transportation of equipment and the hiring of qualified foresters.

Step 5: Are data on transport cost ($C_{TRANSPORT}$) available?

Yes – Go to Step 6.

No – The transport costs can be obtained from the companies that provide trucks.

Step 6: Total value of timber available in your habitat is (T_{VOL} x T_P x A) - $C_{HARVEST}$ - $C_{TRANSPORT}$ where A is the land area (as expressed in ha) of the site.

Methods: Water

Water Method 1. Obtaining information on flooding, water use and water quality from stakeholder meetings

The rapid appraisal in Section 2 will have provided preliminary information on whether any water-related services are delivered by the site of interest and at what spatial scale these services are received (they may be beneficial to resident local users, downstream users and seasonal users such as pastoralists).

However, it may be beneficial to hold one or more additional meetings with single individuals or groups of people in order to obtain more detailed information and also to find out what are the most likely changes to take place at the site, for example changes to water delivery following a proposed dam upstream. This will then also help in your assessment of the alternative state. The categories of people that you have meetings with could include:

1. *People with technical expertise and /or statutory responsibilities relating to water-related services.*

   These people may not necessarily live locally to the site but they may include representatives of water resource management agencies, water companies, relevant NGOs, regional planners, engineering companies involved in developments that might affect the site or researchers. For example, they may be from a water company and have data on how much water they provide to households or commercial enterprises. They could also be technical experts designing a dam and modelling projected flows downstream. These data would be very useful for determining changes to ecosystem services in the future. If you are running a workshop, it is important to obtain a consensus on the water-related services that people at the workshop think are provided by the site. It is likely that at this workshop the more obvious services that are provided at an institutional level will be discussed. This is a good opportunity to also find out what data are available, over how many years, at what intervals and in what units for each of the identified services. It is also useful to find out how these data can be obtained, permits needed to acquire them, any financial charges applied to data access and what conditions are attached to their use. Examples of quantitative data you might ask for include hydrological data including stage or discharge data or water quality data. Stage data measure the elevation reached by floods while discharge data measure the volume of water passing a given point through time.

2. *People who benefit from water-related services either locally at the site or at a distance from the site (usually downstream).*

   From discussions with these people, it is likely that additional services will be identified as the detail of how the site is used, seasonal variations and informal sector activities emerge. One way of finding out which are the most important water-related services is to ask questions about which water-related services they would be most concerned to lose. They can also tell you in what ways they think services will change with future developments in the area.

Examples are provided below of specific questions that could be asked with regard to individual water-related services. In any location, different questions may be more useful or appropriate.

Specific questions that can be asked to find out if flooding is a problem, whether or not the site is thought to provide protection from flooding and whether or not flooding patterns have changed. You need to find out about the impacts on extent and depth of flooding as a consequence of reduced peak flows. Note that flood protection services often mean that flooding still takes place but is less severe than it would be without the wetland or hillslope habitats in place.

1. Ask if they think that part of the site helps with flood protection by storing water during floods
2. Ask about losses due to floods last season/year: crops/equipment/buildings/contents of buildings/life
3. Ask about losses due to floods within the last 10 years: crops/ equipment/buildings/contents of buildings/life; (Losses in 'past')
4. Look for and ask about evidence of man-made flood protection structures/activities
5. Ask about extent of flooding, e.g. how far did floods come or how deep were they?

Specific questions to ask regarding water use (see also questions on household questionnaire survey in Water Method 4.B)

1. Ask if farm wells have been sunk or irrigation sources created: the number; when they dry out; comparisons between last season and previous seasons in terms of water supplied by them
2. Ask if there are domestic/commercial wells: quantity obtained per unit labour; when they dry out; compare last season with previous seasons

Specific questions to ask regarding water quality improvement services:

The site can only provide this service if it receives inputs of, for example, fertilizers or other polluting chemicals or sediment. To find out if this is the case, you need to ask the following questions:

1. Is there any direct evidence of poor water quality at your site or upstream of your site but not downstream of your site based on data already collected on water quality or anecdotal evidence from local communities?

2. Are fertilizers including nitrogen, ammonia or phosphorus added to farmland whose run-off flows into your wetland site?

3. Do settlements around your wetland discharge sewage into the wetland?

4. Does your wetland site receive contaminated discharge from any industries around the wetland?

4. Does your wetland site receive fertilizer inputs in runoff from upstream sites?

5. Does your wetland site receive inputs of other chemical compounds such as heavy metals from upstream mining sites?

6. Is there any indirect evidence of poor water quality at or upstream of your site but not downstream? These might include water-quality related illnesses, reluctance to use water for drinking or for recreation, fish kills, smelly water.

If the answer is 'yes' to any of these questions, then it is possible that the site does improve water quality, and this should be examined further (see **Water Method 5**).

Cross-checking information

It is important when meeting with any of these stakeholders that you try to cross-check information about water-related services by asking for it in different ways. This should be done both to check that there is agreement between stakeholders on which are the most important services and to check the detail of services described.

A useful social science technique for cross-checking information is to ask paired questions to arrive at the same information.

Examples of paired questions to get information in different ways as a cross-check on accuracy.

Example 1: To find out about seasonal water provision deficits where water is collected from wells.

Q1 In what months do you collect water from these wells?

Q2 For which months of the year are your wells dry?

Example 2: To find out if changes to water quality occur seasonally, perhaps because of a suspected increase in water pollution to a site at a particular time of the year.

Q1 Do people get seasonal illnesses which they think are related to polluted drinking water and if so in which months?

Q2 Are there months in the year that people seek alternative drinking water supplies because they suspect the water is polluted?

Water Method 2. Using Costing Nature to identify the location of beneficiaries and contribution of water from the site

Costing Nature (www.policysupport.org/costingnature) is a conservation prioritization tool which identifies the realised services provided by a site by mapping the *potential* services then calculating the number of users (people and infrastructure such as dams) downstream who could benefit directly from these services (e.g. through an ecosystems contribution to water quantity, maintenance of water quality, flood control, erosion control and the mitigation of geomorphological hazards associated with water such as landslides).(It is important to note that this number of potential users is not necessarily a good estimate of actual users since not all potential services are used by potential users. The rapid appraisal of section A2 will allow you to find out more about the relationship between potential and realised services at local level.)

In Costing Nature, potential and realized services are calculated for any terrestrial area globally on the basis of globally available datasets and process based models. For each of the hydrological services both potential and realised services are calculated on a raster grid basis at 1 square-km or 1-hectare spatial resolution and can be aggregated over relevant spatial units such as protected areas or administrative units. Each service is indexed from 0-1 globally such that the global area with the highest provision of the service in biophysical units is given a value of 1 and that with the lowest is given a value of 0. All others areas fall in between these numbers.

This makes it possible to aggregate and compare different services since all have a common unit. No attempt at economic valuation is made but rather the user is able to weight the different services to reflect the value which they attribute to them. This weighting is used where services are aggregated to generate maps of total potential or realised service provision. Costing Nature version 1 does not permit the calculation of the impacts of land use or climate impacts but version 2, which is currently under development does so.

You will need: A computer with access to the internet and Mozilla Firefox as your browser. The tool is freely available at: http://www.policysupport.org/costingnature

To use Costing Nature follow a similar procedure to that used for WaterWorld (Water Method 3) as both tools are developed using the same web based framework. The following steps are required:

1. Go to Co$ting Nature

2. Follow onscreen instructions to link to the current version of the tool

3. Create a free account so that you can store your results on our servers (detailed instructions for this are given in Water Method 4.C).

4. Define your area of interest by searching for your location in the embedded Google Map. Choose a name for your simulation and use the drop-down list to indicate whether you would like to calculate for a 10 degree square 'tile' around your site (at 1km resolution) or a 1 degree 'tile' around your site (at 1-hectare resolution) and click Step 1: *define area*

Click Step 2: Prepare data. The data that you need to run the simulation will be gathered together and processed ready for the simulation. If your tile has not been run previously then the system will ask to build the datasets and this will take a few more minutes.

6. Click Step 3: Start simulation. This will calculate all of the ecosystem services (potential and realized) for your site and will take a few minutes.

- You can now visualise, analyse and download the maps for each of the services using Step 4, 5 and 6. Downloads are available in a variety of common Geographical Information Systems (GIS) formats and can be further analysed in your own GIS. The ecosystem services maps are those of interest in this part of the toolkit and in particular the following maps:

Ecosystem services maps:

- **Relative realised natural hazard mitigation index.** Relative hazard mitigation services for flood/drought, landslide/erosion, inundation/tsunami/cyclone according to relative risk protected against

- **Relative realised water provisioning services index.** Relative volume of clean (not human impacted) water available to downstream people and dams

The definition of alternative states and the impact of these alternatives on ecosystem service provision are not yet implemented in Costing Nature. These are currently under development and when implemented will act in the same way as described for WaterWorld (Water Method 4.C)

Water Method 3. Assessing flood protection services

Water Method 3.A. Working out if the site offers flood protection services

(not based on stakeholder meetings)

In many circumstances, wetlands provide flood protection services but it may be useful to find out about these through methods other than stakeholder meetings or before going into the field. This set of possible methods is for use at wetland sites. Many wetlands have seasonally variable water levels as a result of variable hydrological inputs from upstream or surrounding areas. If the wetland stores water or floods at any time in the year then it is likely to be preventing flooding from taking place downstream or at least reducing the impacts (extent, depth and duration) of flooding downstream. However in communities that are used to living with floods there are many adaptations made to cope with floods which may include taking advantage of floods for flood-recession agriculture, fishing or moving away from the site seasonally (the services are then measured in the cultivated goods section of this toolkit). It then becomes difficult to decide if flooding is negative or positive. In other communities, such as those in urban areas downstream, flood protection may be a very important service and there may be evidence of flood protection measures such as dykes or other engineered structures in place against the highest flood levels or houses built on stilts. Such evidence is useful in cross-checking whether or not flood protection is a water service that should be measured. In this section you are trying to find out to *what extent the wetland is giving flood protection rather than flood benefit* and the first thing you need to know is if the wetland stores water at any time in the year.

If you have access to hydrological data, e.g. water level (stage) data from the wetland, check them for the following characteristics:

(i) **intra-annual** (or seasonal) fluctuations-this indicates that the wetland holds water for part of the year

(ii) **inter-annual** fluctuations.- this indicates that the amount of water stored each year can vary greatly and that flood protection may only take place in some years.

If you don’t have access to hydrological data, rapid assessment of the potential and actual ability of the site to store water can be made remotely and before visiting the site.

(i) Using maps and previous reports

The flood storage capacity of a wetland is the difference between potential maximum volume of water stored in your wetland and average low water levels. In the wetland illustrated below in Figure 1, low water (on the left) covers a very small area while high water (on the right) covers a much larger area. The flood storage capacity is the difference in the volume of water between these two time periods. At this stage you just need to know that the wetland is capable of reducing flood impacts through this storage function. Many wetlands have been studied so reports or theses with graphs of hydrological data or flood maps may be available.

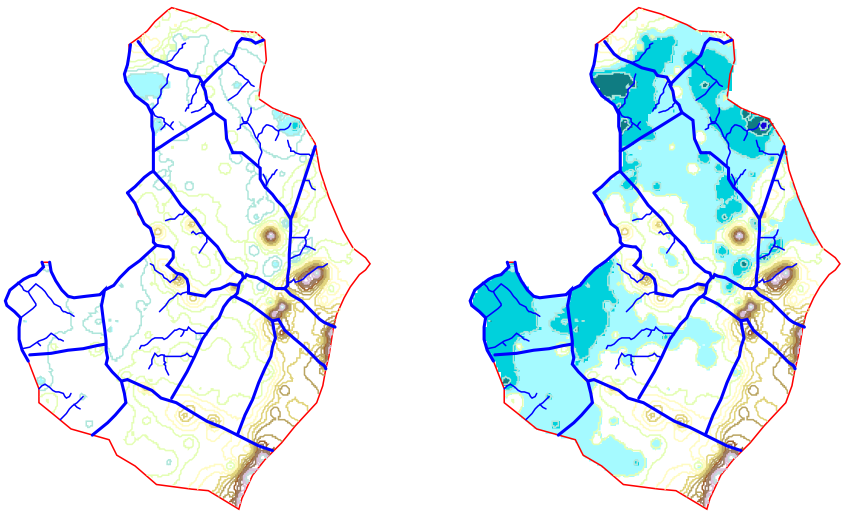


Figure 1. The Pevensey Levels, Sussex, UK. (source: Gasca-Tucker D.L. 2005 ; Baker et al. 2009). Blue areas show extent of water.

(ii) Using remote sensing approaches. For this you will need access to the internet.

(a) Google Earth can provide rapid assessment of the flood storage capacity of a wetland if images are available from wet and dry seasons.

You will need for basic interpretation: A computer with access to the internet Imagery (hard copy or image file) Semi-skilled user to use Google Earth (more technical GIS skills to make area calculations)

Method: Locate site on Google Earth. This could be done using a grid reference or point/boundary file. Identify areas of apparent open water. Look for obvious discontinuities in the vegetation. Figure 2. shows part of the Hadejia-Nguru wetlands in northern Nigeria. The area shaded in green has been added to the image to show a rough outline of the flooding extent during the wet season.

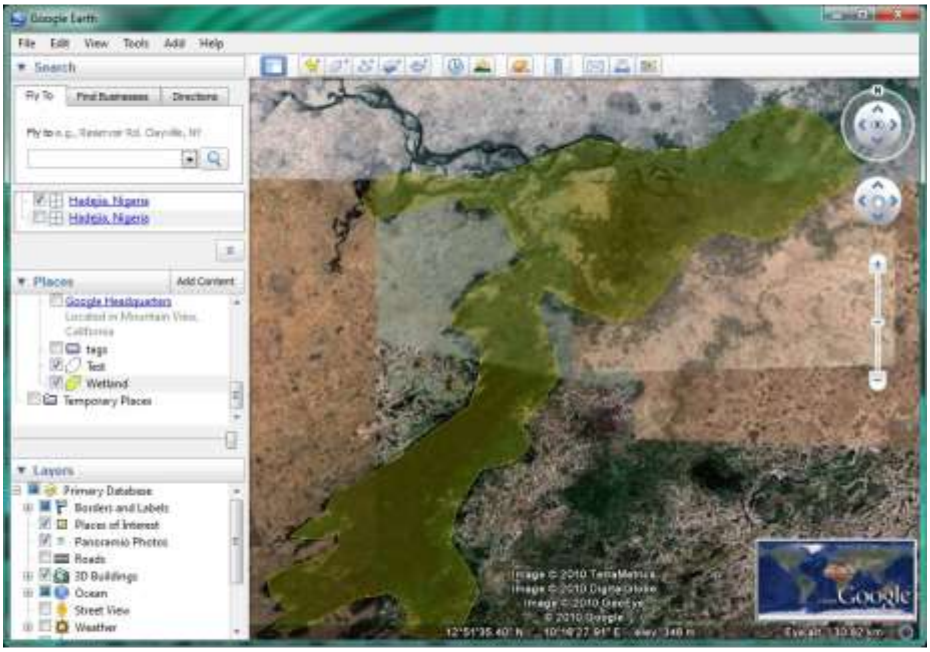


Figure 2. The Hadejia-Nguru wetlands in northern Nigeria.

(b) Satellite images from other sources can also give this information and allow more detailed measurements of flood holding capacity to be made if necessary.

You will need for basic interpretation:

Imagery (hard copy or image file)

Semi-skilled user

Method: Locate site. Identify areas of apparent open water. Look for obvious discontinuities in the vegetation. Define a boundary and estimate area. A satellite image of the Merga Zerga wetland in Morocco is given in Figure 3. It shows in different shades of blue the area occupied by flood waters during the wet season.

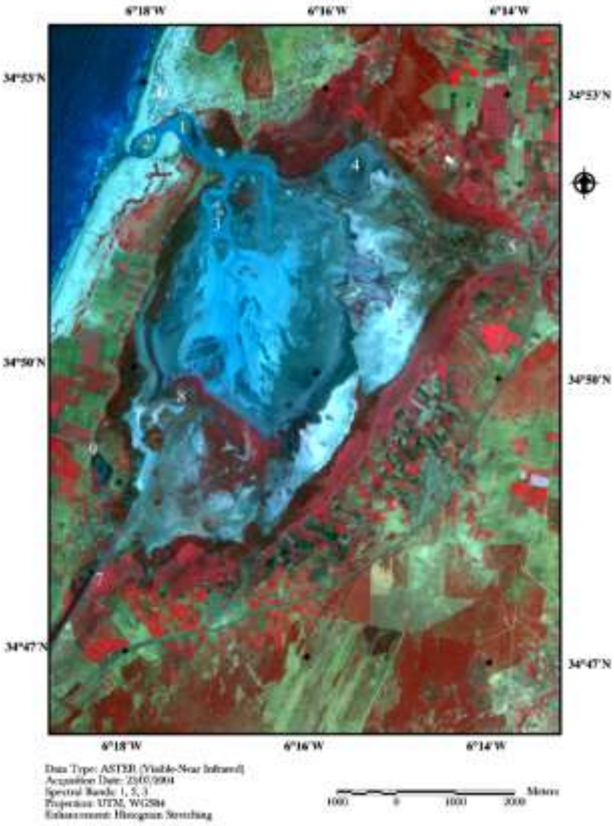


Figure 3. Merga Zerga in Morocco (source: Ahmed et al.(2009))

Figure 4. Debris left after a river flood in northern

(iii) Field observation

If water level data and remote sensing images are not available then during a one-off visit it can be possible to map strandlines – organic and other debris left by a receding flood as shown in Figure 4. This will rapidly tell you if the wetland has high and low water periods. In addition, vegetation patterns can also indicate something about the hydrological dynamism of a site. Those with marked flooding regimes often have a high proportion of pioneer vegetation species e.g. in an active flood plain wetland where high floods cause rapid turnover of sediment and channel movement.

Water Method 3.B. Quantitative approaches to assessing flood prevention

Wetlands often store water for short or long periods. This will have been assessed in **Water Method 3.A**. Where they store flood water, the kind of impact that they have on a hydrograph (a graph showing the amount of water passing a given point through time) is well demonstrated in the graph below.

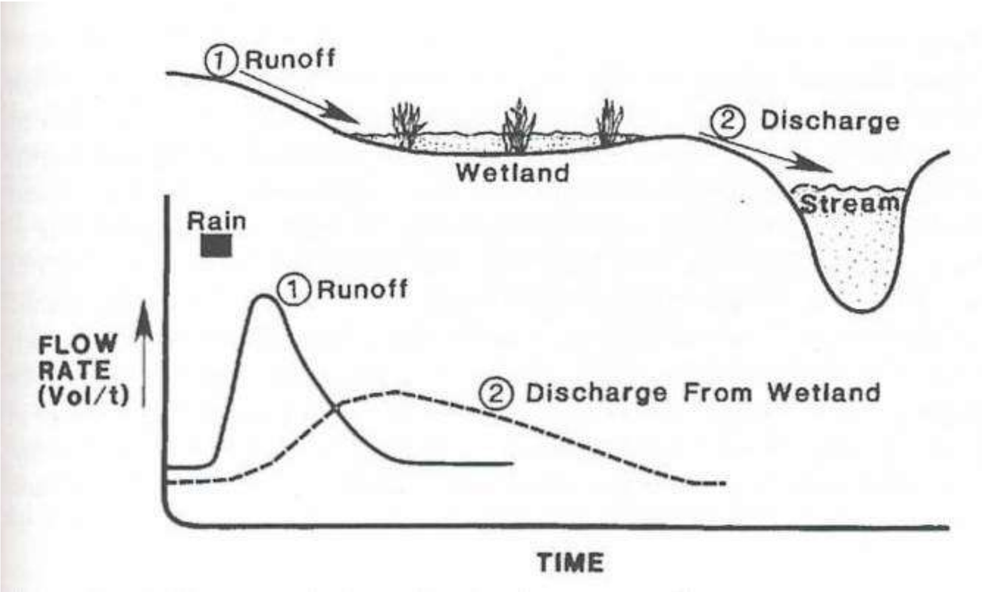


Figure 5. The hydrograph of water entering the wetland at (1) shows a short but high peak flow period whereas at point (2), this peak flow is now lower and lasts for longer. The difference in height between the peak of (1) and the peak of (2) is the result of water being stored in the wetland. Hydrologists often define this height difference as the flood attenuation. Note that the total amount of water passing each point is similar but redistributed through time.

In order to calculate if the wetland has protected anyone from flooding it is necessary to first assess the impact of water detention on peak flows and thus on the extent of flooding and secondly to find out how these changes to extent of flooding impacted on people (e.g. through flooding of their properties or of other structures or resources that have value). In order to make these calculations there are two main approaches including:

1. Direct measurement of the influence of the wetland's water storage on downstream flooding.
2. Indirect measurement of the influence of the wetland's water storage on downstream flooding
3. Economic valuation techniques.

1. Direct measurement of the influence of the wetland's water storage on downstream flooding

For this method it is necessary to have hydrological data from both inflows and outflows from wetlands located in points similar to points (1) and (2) in Figure 1 above. Many rivers and some wetlands around the world have long hydrological records, maintained by government water resource agencies though the records are often disrupted. The most useful hydrological data are given as 'stage' levels, a term that refers to the height of the river level. In many cases, the hydrological data have been converted to discharge data (often given the symbol Q) which uses the stage data and a relationship established between stage and discharge (often but not always given as cubic metres per second (cumecs or m^3sec^{-1}). Stage records are most useful for studying flood heights. These records, if available, can tell you how often floods have occurred and whether or not flood frequency, arrival time, duration and severity have changed over time. They thus allow two calculations useful for assessing flood protection services:

a. For any given flood (see hypothetical example in Figure 6), you can study the difference between the height and duration of the flood peak entering the wetland and the height and duration of the flood peak leaving the wetland. To do this it is necessary for the stage values at both locations to be expressed as an elevation above a common point or datum. If people live immediately downstream, at an elevation that lies between the elevations of the higher upstream flood peak and the lower downstream flood peak, then they will have been protected from flooding by the wetland. If they live further downstream, then an adjustment for that distance has to be made in order to calculate how many people have been protected from flooding downstream since further flood peak attenuation can take place with distance downstream (see case study below). If people live at elevations below the outflow peak, then the wetland will not have fully protected them from flooding (figure 6 below) but the depth to which their property has been flooded will be less than if the wetland was not present and therefore the cost of flood damages may be less (See **Water Method 3.B.3** below for economic valuation techniques). In the example in Figure 6, the flood protection services can be given as number of households or people protected. Once you have these numbers it is possible to use information on the values of the property or resources protected, as discussed in **Water Method 3.B.3** below, to convert the data to monetary values.

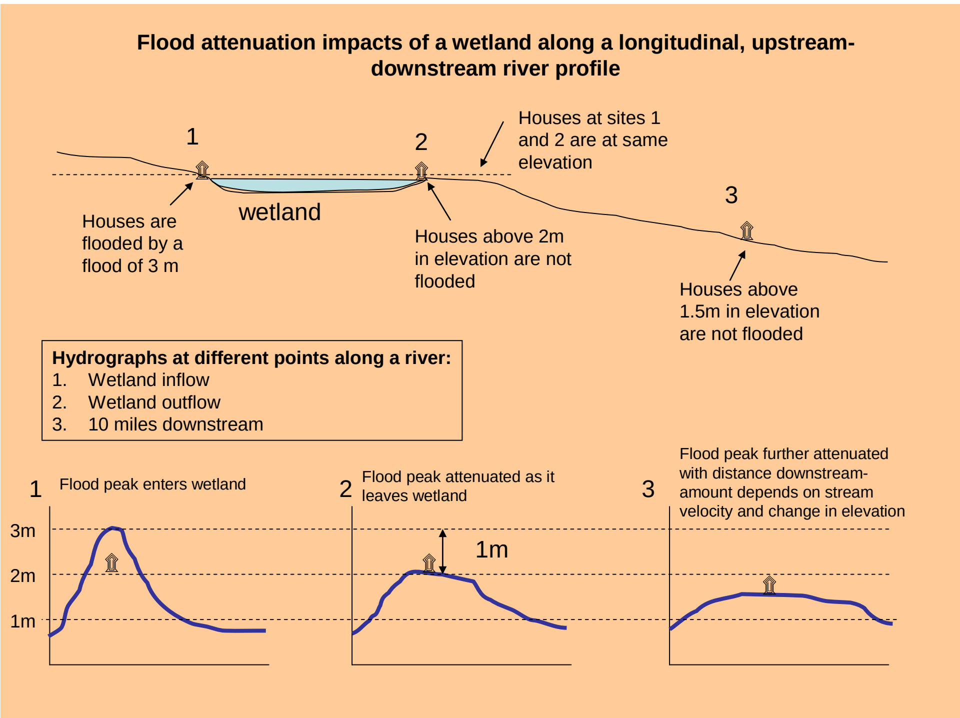


Figure 6

b. By studying hydrological data over a period of years, it is possible to calculate flood risk in terms of flood return frequencies and the number of years in which flood protection has taken place for the duration of the hydrological record. ('Flood return frequency ' describes the frequency of occurrence of floods of particular sizes. Thus a 1 in 10 year flood is the size of flood, based on the available hydrological record that occurs statistically once every 10 years.) To do this you again need to have the flood records from both upstream and downstream of the wetland. For example, if your flood records exist for 20 years then you might be able to calculate that at the upstream site flooding occurred in 16 out of 20 years but at the downstream site it only occurred in 4 of those 20 years. It would be reasonable to say that the wetland has prevented flooding downstream for 12 of the 16 years (or 3 in every 4 years) at the downstream site.

In many countries there will be a water management agency that will already have produced maps to show the extent of flooding during floods of different height and return frequencies. Where you have hydrological records upstream and downstream of the site, these maps can be used in conjunction with the hydrological records to show the height reached by individual flood events at downstream sites and so work out which houses or infrastructures have been protected. Where such maps do not exist then it is possible to make a rough calculation of the height reached by different flood events if there are accurate topographic data and if the hydrological records of water level are corrected to a common datum. In addition, the hydrological record can then be used to calculate the number of times that floods have reached particular heights. This method is explained in the case study below:

Case study: In Figure 7 below there is a hydrograph from the Tana River in Kenya (location shown in Figure 8). This shows a series of flood events during the rain season in 1971 passing a point called Garissa and the same set of flood peaks passing a point several hundred kilometres downstream at Garsen. The flood attenuation is considerable and can be attributed to the temporary storage of water on the Tana River floodplain between these two points.

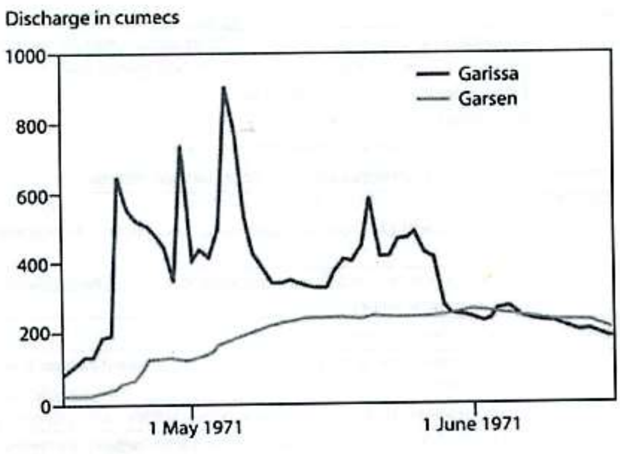


Figure 7. Flood peak attenuation by the floodplain wetlands between Garissa and Garsen (an example from 1971 from Tana and Athi River Development Authority, 1986)

Figure 8. Location of the Tana River in Kenya (map from Hamerlynck et al 2011)

Work on calculating the height reached by different floods and the frequency with which floods reached these locations during the period for which a hydrological record was available at Garissa (available for the period 1934-1982 at the time of study) at two locations downstream of Garissa was carried out by Hughes (1985, 1990). The method used hydrological data from two gauges temporarily erected along the Tana River (at Nanighi and Bura-Pumwani) near which the height of particular locations in the floodplain relative to flood height was required and for which frequency of flooding was also needed. Figure 9 shows the locations of the three river stage gauges.

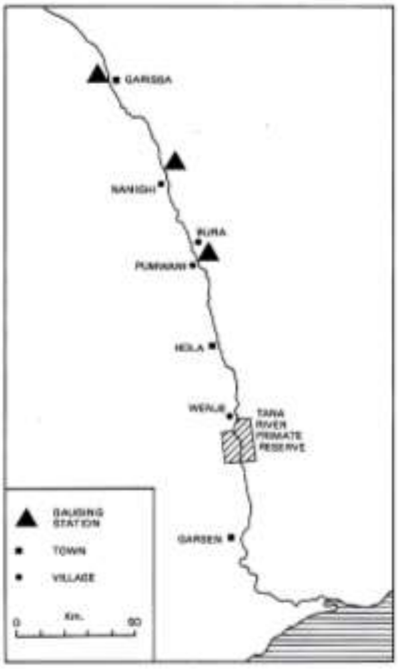


Figure 9 Locations of river gauges at Garissa, Nanighi and Bura-Pumwani

Distance Garissa to Nanighi = 65 km.
Distance Nanighi to Bura-Pumwani = 21km.
(distances measured along centre of river channel)

Elevational differences between zeros on gauges:
Garissa to Nanighi = 27.52m
Nanighi to Bura-Pumwani = 27.12m

(from Hughes 1985)

The steps in the method are as follows (use Figure 10 to help you understand these steps):

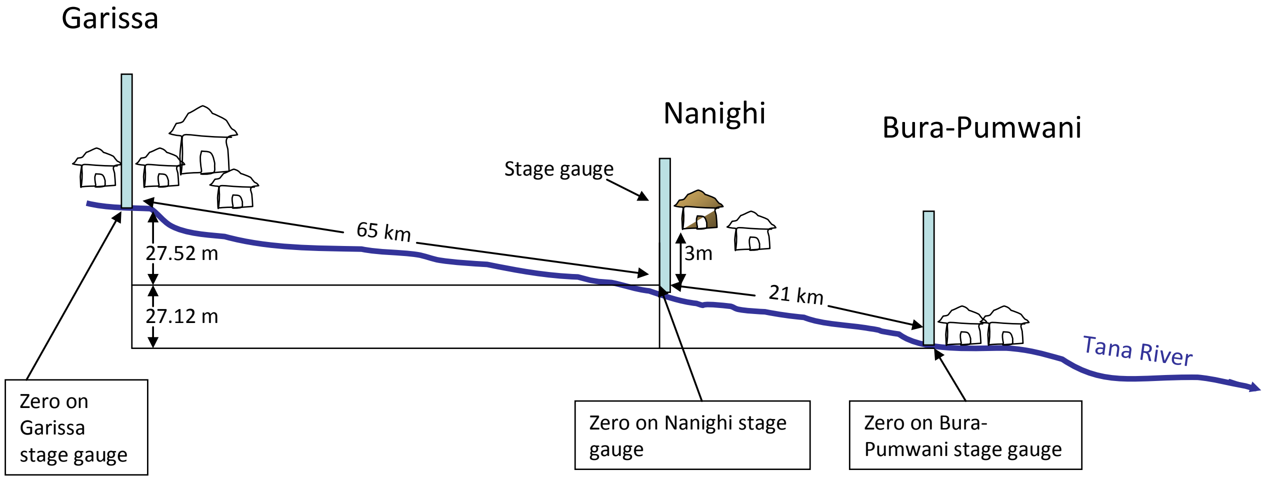


Figure 10. Relative locations and elevations of river stage gauges at three sites on the Tana River, Kenya.

(i) For houses near the Garissa stage gauge, for which there is a long hydrological record, you can rapidly calculate in any single year how many houses were reached by floods of different elevations by surveying the elevation of the floor of each house and comparing them with the elevations on the stage gauge. For example a house at 2.5 m elevation above the zero on the Garissa stage gauge will not be reached by a flood reaching 2m on the stage gauge. The number of times that each house has been reached by floods during the available hydrological record can also be calculated for the period since 1934 when the hydrological records began at Garissa. Note , however, that stage data at Garissa is given in metres above sea-level so you will need to convert the stage value back to metres above zero on the stage gauge or to convert the elevation of the house to metres above sea level.

(ii) For houses at sites downstream of the Garissa gauge (in this example we use the house coloured brown in Nanighi) a more complex procedure is needed to find out flooding frequency since there is only a very short hydrological record in these locations and the following steps can be taken:

a. Survey the elevation of the brown house in Nanighi to find out how high its location is relative to the zero on the temporary Nanighi stage gauge. The house in this example is 3 metres above the zero on the stage gauge at Nanighi.

b. Survey the elevation of the zero of the Nanighi Stage gauge in order to find out how much lower it is than the zero at the Garissa stage gauge. This can be done by relating the zeros on both stage gauges to the national Ordnance Datum (OD-metres above sea level) or to another common baseline such as a temporarily established local survey point to which you have to survey both gauges. In this example the zero on the Nanighi stage gauge is 27.52 m lower than the zero on the Garissa stage gauge.

Because each flood peak gradually attenuates between two points along the river it is also necessary to find out the rate at which flood peaks move down the river before you can relate the hydrological data from Garissa to the elevation data from Nanighi. Thus the following additional steps are necessary:

c. Graph a series of flood peaks at both gauges to measure two things: how long it takes for a particular flood peak to travel between the two gauges and the difference in height between the bottom of the peak and the top of the same peak at both gauges.

d. In this example, flood peaks took about 24 hours to travel between Garissa and Nanighi. This means that a flow registered at 8.00am on day 1 at Garissa, arrives at about 8.00am on day 2 at Nanighi. (There will be variations in flow velocities at different flood heights with, generally, higher floods travelling faster than lower floods but this is difficult to factor in without carrying out complex hydrological modelling).

e. Use the fact that the elevation of a flood on the Nanighi gauge is equivalent to the elevation of a flood on the Garissa gauge measured 24 hours earlier to calculate how many times the house at Nanighi has received flood water since the hydrological record at Garissa began in 1934. In this example, the elevation of the brown house at Nanighi is 3 m above the zero on the stage gauge at Nanighi. Roughly, 3 m on the Nanighi stage gauge is equivalent to 110 m.a.s.l. on the Garissa gauge. Thus all flows at Garissa higher than 110 m.a.s.l. flood the brown house at Nanighi. Since 1934 when the records began at Garissa this has happened approximately once every 10 years.

f. The difference in height between the high and low parts of the same flood peak arriving at both gauges will look something like the difference in height between the two graphs in Figure 5. This height difference will tell you how much the flooding of the floodplain wetlands over the 65 km section of river between the two gauges helps to attenuate the flood peak. In the Tana River example the attenuation ranges between about 1.5 - 2 m in elevation. This allows you to calculate how many houses would have been flooded at Nanighi if the floodplain wetlands did not exist compared with the numbers that have been flooded. Number of houses (or other property or goods of value) not flooded is a useful way of representing the flood prevention service of the intervening floodplain area.

If you do not have stage data (elevation or height data) from inflows or outflows from your wetland or at other sites where they would be useful, you can install equipment to make these measurements.

Installation of a stage gauge

Requirements: A graduated plastic strip, marked in centimetre intervals, attached to a wooden post. Alternatively, the stage gauge can be affixed to suitable structures already installed within the wetland / river. Bridge pillars for example are often ideal for this purpose but require the installation at of the gauge at low water. An estimate of the likely range of water levels is necessary to ensure the stage gauge is tall enough to record all water levels encountered at the site. A literate, local observer is needed, who can read the gauge board manually, daily.

Several of these gauge boards can be installed to get records from inflows, outflows and the wetland itself. It is important to know the relative heights of the zero on the gauge board in order to compare water levels collected from different sites. A secure reference point needs to be installed for this in a location that is likely to give the full range of water levels – this will depend on site characteristics (i.e. topography) and will tend to be in a low lying area. If floods will endanger the observer then consider an automated water level recorder installed within a stilling well but cost is considerably more and requires a computer to download the data logger.

2. Indirect measurement of the influence of the wetland's water storage on downstream flooding

(i) Using discharge data

If you only have discharge data it is not possible to state exactly where floods reach in terms of which locations are flooded and which are not. Broad statements of flood prevention rather than detailed calculations of flood prevention can however still be made:

1. If discharge data are available for stream/rivers entering and leaving the wetland it is possible to calculate the total volume of water flowing into the wetland and to compare this with the volume leaving the wetland. If the former is significantly above the latter, the wetland is likely to be storing water and reducing flood discharges downstream via evaporation and seepage. Similarly, a comparison of the magnitude of flood peaks in the inflow compared to the outflow will provide an indication of the ability of the wetland to reduce downstream flood peaks.

2. Number of years of flood prevention or reduction over time can be calculated using flood recurrence graphs calculated using discharge values such as those shown in **Water Method 3.D** Figure 14.

(ii) Using structured questions with local people who live in flood-prone zones.

Where quantitative data do not exist, it is possible to collect biophysical data on flood probabilities and flood extent using information gathered by talking to local people. You need to compare what people living upstream from the wetland say (who don't enjoy the protective services of the wetland) and those downstream. If people upstream report a higher flood frequency than those downstream, the wetland probably provides some protection against flooding.

This approach relies on gathering information from people who live in flood-affected areas to tell you what elevations have been reached by floods and what has been damaged. In particular it is important to find out how often floods reach a particular location as you can begin to build a flood frequency curve using these data. For example you can interview people at set distances away from a river's edge and ask them if they have been flooded. A crude flood map can be constructed in this way.

After this step, you still have to assess what the properties are that would be damaged in case of a flood, and the numbers or values of those assets.

Examples of questions that can be asked:

- Do you think that your area (village/cropland) is prone to flooding?
- Have you ever experienced a flood?
- If yes, when did you experience floods over the last 20 years? (Note: It is necessary to give a period here to get to a probability, but the relevant range depends on the case study.)
    - 1: Year Month

    - 2: Year Month
    - Etc…

- For each of these events (if possible…),
    - Do you remember which area was flooded? Can you describe how far the water reached? Can you indicate which area was not flooded?
    - Do you remember how high the water came? (may be useful to indicate height along your body, e.g., up to knees, up to hips, up to neck, higher than head…)

(Note: With this information, you may need to do additional measurements as described in **Water Method 3.B.1** above to assess the elevation etc. of the area that was flooded based on information provided by the respondent. It is also worthwhile to cross-check this information, for instance, with other respondents as well as with rainfall records for the same area and period.)

- Have you experienced any change in flood events over the last period (e.g. 10 years)?
    - If yes, what do you believe to be the main cause of these changes (e.g. change in upstream land use, change in climate, don't know, etc).
    - If yes, what are the main problems you encountered when there was a flood?
        - House, health, safety, other property, income, livestock, crops, work/income, evacuation, etc…

3. Economic valuation techniques (for detailed explanations of these see Turner et al. (2008); available online at http://www.aquamoney.org/sites/download/D23_Technical_Guidelines_AQUAMONEY.pdf)

One approach suitable for use at a site scale includes:

Damage costs avoided (direct costs). These can include direct costs of flooding on, for example, built structures or agriculture. Depending on the site and country being studied, publications are available for valuing costs of damage to buildings. These often use a relationship between flood depth and level of damage (Figure 11).

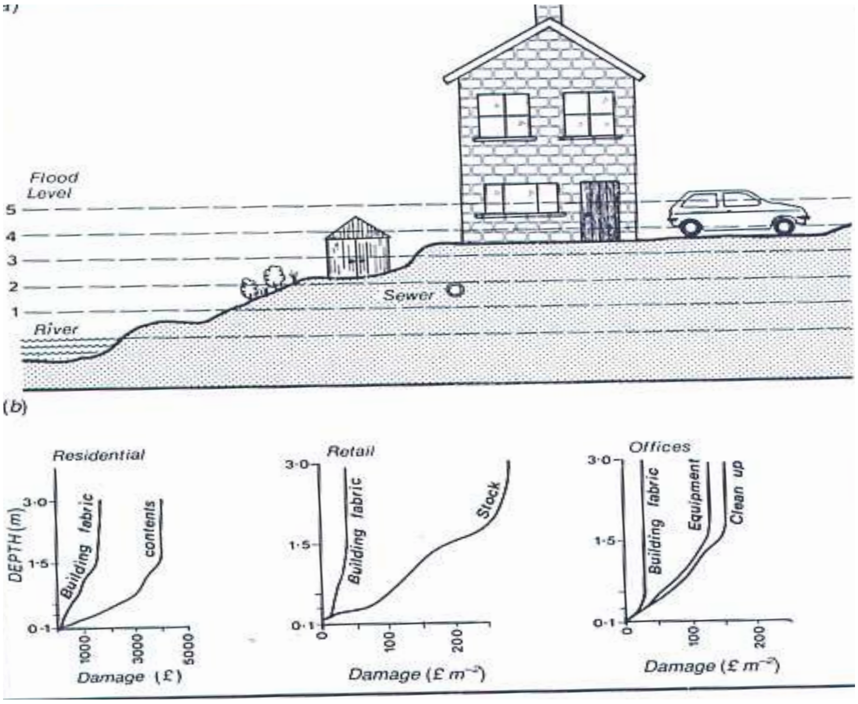


Figure 11. This figure shows for the UK, (a) the relationship between river level and property damage of different types (b) quantified depth/damage curves for various premises (after White, 1964) in Newsom (1994).

Case study: At a nature reserve in the UK, there is a designated flood storage area which will receive flood waters when floods greater than the 1 in 20 year flood occur on a nearby river. It has been calculated that storage of flood water at the site will prevent flooding of 50 ha of nearby agricultural land and a number of domestic dwellings and commercial buildings. The total avoided damage cost of this flood storage is calculated at £266,500 at 2011 prices and includes avoided flooding of domestic and commercial properties as well as farmland. **Because the flood storage facility is only expected to be used once every 20 years, this value needs to be divided by 20.** Thus the value of flood prevention at the reserve can be estimated at £13,325 per annum.

Other valuation techniques also exist but are only usable in some locations and are not covered in detail in this version of the toolkit. For example:

Defensive expenditures: what people have already spent in the past to avoid further flood damages. For instance, people may have relocated to another site and incurred costs, or they may have relocated their cattle to another area, or have taken other measures (e.g. expenses on elevating houses, electricity wires, buying inflatable boats to stay afloat, etc.) to avoid damages in case of a flood. Such expenses give a lower bound estimate of the costs of floods (people usually do not spend as much, as they underestimate the flood probability and overestimate their ability to cope with the flood).

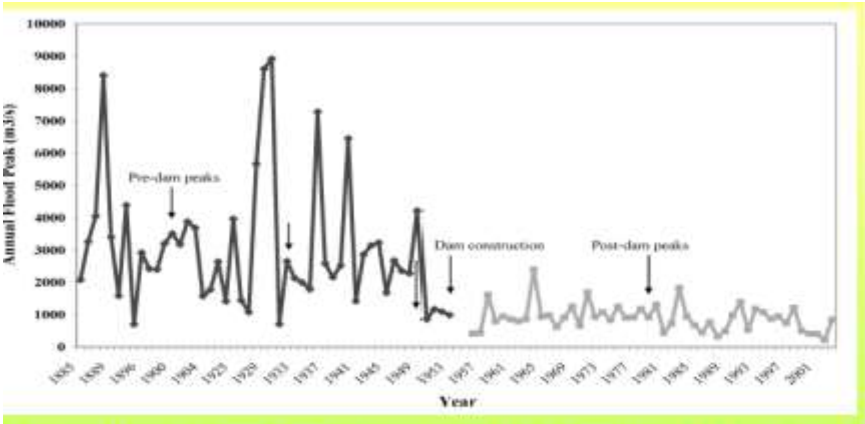
Current expenditures on flood protection measures: what has already been spent to reduce the impact of floods. For instance, have people built dykes to avoid flood impacts? Such cost estimates give a starting point for estimating the costs of additional dykes that would need to be built in absence of the wetland.

Replacement costs : The amount would you have to spend to create an artificial wetland elsewhere in the catchment that would provide the same flood protection level. Man-made nature areas may not be able to provide the same protection level; if the man-made structure provides a higher protection level than the natural habitat, the replacement costs should either be used as an upper-bound estimate or downscaled (how you would do that is arbitrary). If the man-made construction gives a lower protection level, the associated costs give a lower bound estimate of the value of the flood protection services provided by the wetland.

Water Method 3.C. Examples of alternative state contexts for assessing flood prevention

Using **Water Method 1** it is possible to obtain information about the most likely alternative state for the site by asking about the main concerns and predicted future changes based on observed activities/trends affecting the site or known future developments. It is then possible in some cases to find data, either from another place or from previous records or from modelling, to give some idea of how hydrographs are likely to change in the future. With these hydrographs it may be possible to re-calculate flood protection services as shown in **Water Method 3.B**.

Example 1: Construction of a dam makes significant changes to a river's hydrograph (Figure 12). It often reduces flood risk and therefore the flood protection service of the wetland. Set against that there are also frequently losses to flood recession agriculture and these can be measured through the cultivated goods part of the toolkit. By studying flood return periods before and after a dam has been constructed or by studying predicted, modelled changes to flood return periods ahead of a dam being constructed it is possible to estimate the number of times that a place will be flooded downstream using the methods described in **Water Method 3.B**.



Reduced flows following dam construction on the Savannah River, US in 1954
(from Richter and Thomas, 2007)

Figure 12. This hydrograph shows how a dam reduces peak flows and therefore flood return frequencies (the frequency with which a flood of a particular size occurs during the period for which a record exists).

Example 2: In the Tana River of Kenya (see case study in **Water Method 3.B**) changes in flood frequencies were plotted for two different time periods (Figure 13 below).

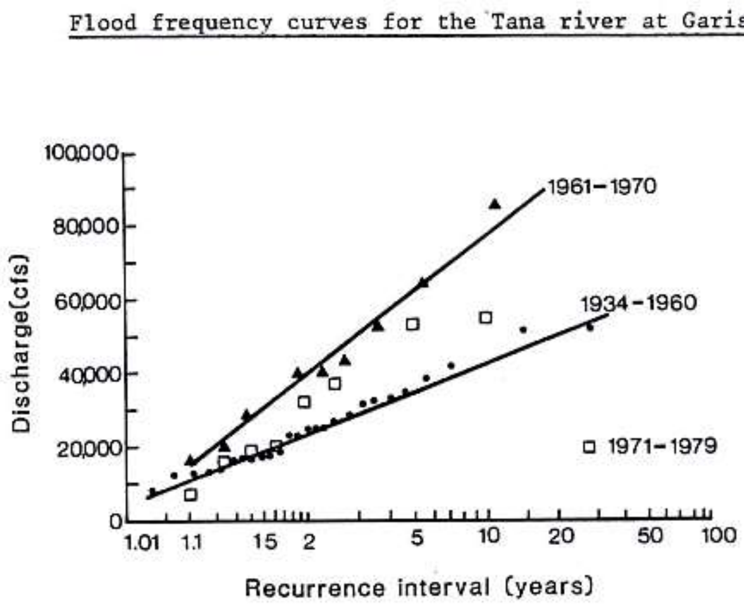


Figure 13. Flood recurrence graphs for the Tana River at Garissa, Kenya (adapted from Dunne and Leopold, 1978). This graph shows that, through different decades, flood return periods for different sized floods can be quite different. This can result from both natural changes to rainfall patterns or from human intervention such as dam construction or river water abstraction for irrigation.

It might also be possible to use the WaterWorld Policy Support System to model changes in flood protection services (see **Water Method 4.C** for how to start using this modelling tool). This will allow you to model changes in water-related services for a range of scenarios but is best used on larger sites. It should also be noted that this model uses many GIS facilities and requires reasonable computer skills.

Water Method 4. Assessing water supply services

Water Method 4.A. Sources of water supply data and calculating water use

1. National/regional water agency

If the water drawn by the beneficiaries is piped, then the best source of data for the monthly water withdrawal by the total population is the national/regional water agency where (1) the **monthly total water production from the site of interest** and (2) the **monthly total surface water production from the entire catchment upstream** are directly measured and recorded. This monthly water withdrawal data could be the sum of estimated monthly water use from domestic, agricultural and industrial sectors. Note that if only the annual average daily water supply is available from your water agency, it is worthwhile checking if they do have the estimates (i.e. average water withdrawal per day) for the dry and wet seasons. The sources could report in units of litre (L) or cubic metre (m^3). To convert cubic metres of water to litres, simply multiply by a conversion factor of 1000.

See below for a case study in Nepal – an example of the data you could get from a regional water agency for the monthly total water production from Shivapuri-Nagarjun National Park (SNNP), and the monthly total surface water production from the entire catchment for Kathmandu.

Case study:

Sub-catchments and water production		June / July 2008	July / Aug 2008	Aug / Sept 2008	Sept / Oct 2008	Oct / Nov 2008	Nov / Dec 2008	Dec 2009 / Jan 2009	Jan / Feb 2009	Feb / Mar 2009	Mar / April 2009	April / May 2009	May / June 2009	Monthly average
SNNP sub-catchments	1) Shivapuri and Bishnumati	24	24	24	26	21	12	9	7	6.5	6	5	5	14.13
	2) Bishnumati													0.00
	i) Alley	1.7	1.7	1.7	1.7	1.7	1.2	1.1	1	1	1	1	1	1.32
	ii) Boude	0	1.3	1.3	1.3	1.3	1	0.8	0.8	0.7	0.7	0.7	0.7	0.88
	iii) Bhandare	1.8	1.8	1.8	1.8	1.8	1.2	1.1	1	0.8	0.8	0.8	0.8	1.29
	iv) Panchamane	1	1	1	1.1	1.1	1	1	1	0.8	0.8	0.8	0.8	0.95
	v) Chhahare	1	1	1	1	1	1	0.8	1	0.8	0.8	0.8	0.8	0.92
	3) Sundarijal (Bagmati, Sylmati and Nagmati)	34	40	42	43	43	43	38	30	26	25	24	23	34.25
Total water production of all SNNP sub-catchments		63.5	70.8	72.8	75.9	70.9	60.4	51.8	41.8	36.6	35.1	33.1	32.1	53.73
Total surface water production of Kathmandu valley		104.3	113.2	116.4	120.3	115.5	104.4	90.2	74.87	67.44	65.64	62.94	61.34	91.38
% share of SNNP water on total surface water production		60.9	62.5	62.5	63.1	61.4	57.9	57.4	55.8	54.3	53.5	52.6	52.3	58.8
Source: (KUKL, 2010)														

Figure 8. Water production status of Shivapuri-Nagarjun National Park catchments (million litres per day). (Data provided by: KUCL Water Company)

2. Household questionnaire surveys.

If the water source is not piped, we suggest you conduct a simple questionnaire survey of the water users.

Household surveys should be carried out for a representative sample of users. Refer to **Water Method 4.B** for a template questionnaire (which will need to be adapted to the local context). For example, if the beneficiaries include both urban dwellers and rural farmers, you would need to survey two sets of randomly chosen households: one of the urban users and another of the rural users. To use the information from the questionnaire, you must know the total population served by the site, and also the proportion of the population for each of the two groups: urban users and agricultural users. Therefore all water withdrawals will be the sum of the water used by both categories. If the industrial sector is involved in the water withdrawals, then another set of random sample should be aimed at the factory owners. In this case, you must know the total number of factories served by the site.

3. Existing databases and studies

Some useful sources of data for the water withdrawals are:

- AQUASTAT (http://www.fao.org/nr/water/aquastat/main/index.stm) - FAO's global information database which is the most complete compilation of water resources statistics to date, according to the World Resources Institute (WRI). This provides national estimates such as annual water withdrawals per capita annual withdrawals and sectoral withdrawals for agriculture, industry and domestic uses. To use this data for the calculation of the total water withdrawals of the beneficiaries, you must know the total population of the people served by the site.

- Earthtrends (http://earthtrends.wri.org/) - free environmental information online portal maintained by WRI. This database harbours a section focusing on "water resources and freshwater ecosystems" where you can find a selection of data tables. For example, "Food and Water" gives national estimates of the annual volume of water used for irrigation in agricultural sector per hectare of arable cropland. For this data to be meaningful, you must also know the total area of irrigation land supported by the site. You may be able to find such information at AQUASTAT's sub-national irrigation database (http://www.fao.org/nr/water/aquastat/main/index.stm)

Note that there is a major caveat to the use of this approach. When using FAO's database or other similar broad data sources, you have to consider if the national averages represent the reality of your field estimates. For example, Earthtrends' database reports that the proportion of water withdrawals in Nepal for agriculture, industry and domestic uses are 96 %, 1 % and 3 %, respectively. Clearly this is not the case for the sectoral withdrawals of water from Shivapuri National Park which serves mainly the population of the capital city, Kathmandu. Also, when using the national estimates of water use for irrigation, you must consider how the different types of crops affects water uses. For example, water used for irrigating water demanding crops will likely be more than water withdrawal for less demanding crops.

Water Method 4.B. Household survey of water provision

The purpose of this questionnaire is to better understand dependence upon water based ecosystem services deriving from the site and how these services could be affected in the alternative state. Collected information will be treated as confidential and used for academic research. The data would be used to supplement those obtained from the workshops or small group meetings (using Water Method 1). To recapitulate, Water Method 1 should enable us to know – before the household interviews – if the water used by the household comes from the site of interest; when the dry and wet seasons in the area are, whether the household use the water company; and if they do, where does water company get the water from to supply the household.

This covers all three services in discrete sections. Depending on the results from the workshop, not all sections may need to be asked. Each section seeks to address the alternative state.

Using this survey you will obtain information on:

- Source, use and importance of freshwater
- Freshwater quantity and seasonal use
- Payment for water
- Perceptions of land-use change and resulting impacts on watershed ecosystem services

Note: It is important to avoid double counting, as water used for agriculture will be counted as a crop elsewhere in the toolkit. Some questions regarding crops grown may give information about water changes. For example when there is a change in water supply, wet crops like rice are exchanged for crops like wheat that can cope with drier conditions, though value may not change. Information on what crops are grown can be obtained in the survey on cultivated goods.

[See next page for the questionnaire]

1. Personal information	
Occupation:	Age:
Gender:	Number of people in household: adults ____ children_______

2. Source, use and importance of freshwater	
2.1) Where does your water come from? Note: Answer will tell us if water used by the Household (HH) comes from site of interest	*[Respondent to list all the sources. Interviewer to assign to the categories below]* *From springs, well, borehole* *From a piped supply or tap* *From rainwater* *From river, stream, dam, lake, pond* *Others (please specify)*
Determine here, using the information supplied in 2.1 whether the source of water used at the HH is from the site	☐ water is supplied by the site ☐ water is not supplied by the site* *Do not continue with the questionnaire if this is the case

2.2) Which of the above sources do you use for each of your uses?	***Main uses (tick all that apply)***	***Sources (In wet season)***	***Sources (In dry season)***
Note: If there are several sources for each use, record the details i.e. seasonality	*Irrigation of crops / vegetable*		
	Water for livestock		
	Drinking (domestic use)		
	Cooking & washing (domestic use)		
	Sanitation (domestic use)		
	Other uses (please specify)		

2.3) For each of the water sources mentioned above, how does the provision of water meet your demand on a month by month basis?	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Use the following keys: + more water than is												

needed – not enough water O about right			
2.4) If your usual source of water runs dry or becomes unavailable what are the alternative sources of supply? (State ‘none’ if this is the case) Note: Refer to question 2.2 for regular sources of supply in wet and dry season	***Main uses (tick all that apply)***	***Alternative sources (In wet season)***	***Alternative sources (In dry season)***
	Irrigation of crops / vegetable		
	Water for livestock		
	Drinking (domestic use)		
	Cooking & washing (domestic use)		
	Sanitation (domestic use)		
	Other uses (please specify)		
2.5) What is your most important water supply source and what is it used for? Note: Main reason is crucial. E.g. a source can be important because there is no alternative supply)	*[Refer to list above and ask respondent to name one and its main reason]*		
3. Freshwater quantity and seasonal use			
3.1) Do you know how much water you use per month/day for each of the uses mentioned above?	YES / NO *If no go to 3.2* *If yes go to 3.4*		
3.2) How many buckets or containers do you use per day (wet season)? **What size are these?**			

3.3) If you have no water supply in your home, how much time do you spend collecting water each time?	
3.4) How much water do you use (litres or other stated unit) for each of the uses listed above?	Total quantity *(ask first)* Breakdown for each use *(if known - %, proportion, fraction…..)*
3.5) Does your household use less water in dry seasons? If yes, how much less?	o Yes, we use.... *[get an actual amount or proportion or percentage]* o No
4. Payment for water	
4.1) Do you pay for your water?	YES / NO *If no, move to section 5.*
4.2) How much do you pay? Note: You can potentially use this in two ways - to put an economic value on water use, to work out what quantity of water is used	For drinking water supply (per month)........................ For HEP energy (per month).. For other use (please specify).....................................
4.3) Do you pay a fixed price per unit used or per year or other? **What is it?**	*[If unknown by HH, ask water company – if there is one supplying this HH)*
5. Land use change and resulting impacts on watershed ecosystem services	
5.1) Have you ever had problems of too little water since living in this area? i.e. drought	*[describe when – year, month, duration – cause and effect]*

In your opinion, what was the cause? **What was the impact of this?**	
5.2) Have you ever had problems of too much water since living in this area? i.e. flooding **In your opinion, what was the cause?** **What was the impact of this?**	*[describe when – year, month, duration – cause and effect]*
5.3) If the amount of water in the rivers supplied by *the site of interest* was to increase at the end of the monsoon, how would this affect you? **Indicate if there are any increased expenses or time spent. If possible, how much.**	
5.4) Have you ever had problems with the water quality affecting your drinking water supply since living here? **In your opinion, what was the cause?** **What was the impact of this? Indicate if there are any increased expenses or time spent. If possible, how much.**	Odour / Taste / Illness *Others (please specify)..* *[describe when – year, month, duration – cause and effect]*

5.5) Have you noticed any change in the colour or amount of sediment in the water during the time you have lived here? **In your opinion, what was the cause?** **What was the impact of this? Indicate if there are any increased expenses or time spent. If possible, how much.**	*[Increased, no change or decreased]* *[describe when – year, month, duration – cause and effect]*
5.6) If the amount of sediment in the rivers supplied *by* *the site of interest* was to increase, how would this affect you?	
5.7) Have you noticed any change in the water availability in the time you have lived here? **In your opinion, what was the cause?** **What was the impact of this? Indicate if there are any increased expenses or time spent. If possible, how much.**	*In wet season: Increased, no change or decreased* *In dry season: Increased, no change or decreased*

Name of Interviewer:.................................. Date:......................
Location:...

Water Method 4.C. Estimating the water quantity of the site of interest using the WATERWORLD Policy Support System (PSS)

Hydrological processes taking place in a catchment located on sloping land are difficult to quantify at the site scale within a short time-scale, since long periods are required to capture climatic averages. Furthermore, it is difficult to estimate or measure the impact that these hydrological processes may have on water-related services in downstream areas, since they mix with impacts from all neighbouring upstream areas. This is especially true when the site forms a small part of the whole catchment contributing to any downstream services. Thus we suggest the application of data-based modelling tools that can capture the entire catchment response for this purpose. One such tool which is both sophisticated but also easily applied is the WATERWORLD Policy Support System. This tool is a web-based spatial modelling system which provides all the data and models required to assess the impacts on water-based ecosystem services of a variety of scenarios for land-use and climate change, for any site globally.

You will need: A computer with access to internet. The tool is freely available at: http://www.policysupport.org/waterworld

Note that the accuracy of the baseline data derived from the WaterWorld Policy Support System (PSS) is dependent on the input data provided by the PSS. The data obtained from this model is rather crude for site scale studies due to the scale at which the baseline data is supplied (much of it at 1 square km resolution), and thus assumptions must be made that these data are valid if you wish to apply at the site scale. However, it gives a good indication of the potential impact of changing the land-use of the site.

Although all the necessary data for use are provided, if the user has better local data and the capacity to convert it into standard GIS (Geographical Information Systems) formats, it can be uploaded and used in preference to the datasets supplied with the system in order to improve the detail of results. All model results are downloadable in standard GIS and spreadsheet formats for comparison with local data or further analysis, if needed or can be visualised online in familiar mapping environments (Google Earth and Google Maps). The services currently incorporated include water quantity on a monthly basis using long term climatic means, water quality according to upstream influences and purification services as well as soil erosion, sediment transportation and deposition.

Steps:

1. Start Mozilla Firefox.

Note: WATERWORLD PSS is compatible with all version of Firefox. Accessing the PSS via other web browsers (especially Internet Explorer) may create display problems.

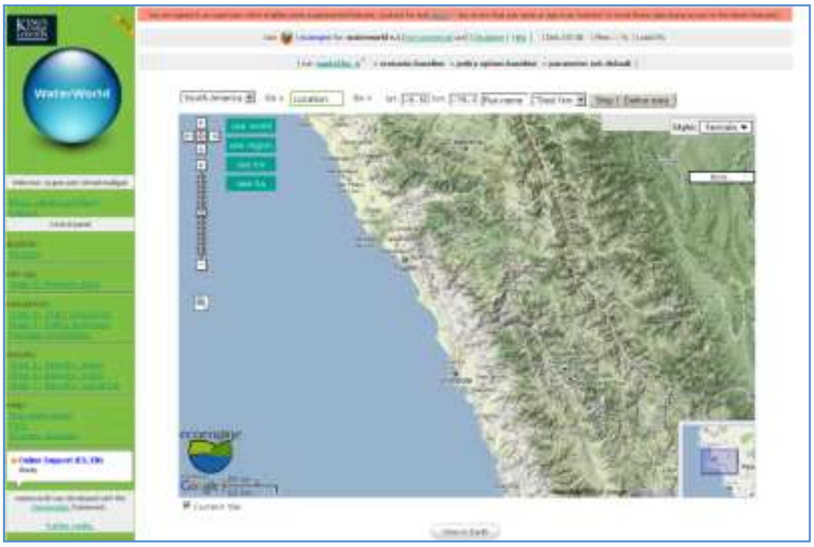
2. Go to http://www.policysupport.org/waterworld. This is freely available.

<u>Note:</u> Always allow pop ups from this website and enable javascript. Use Alt + Tab to navigate between the different screens and F5 to refresh.

3. For the first-time user, register by clicking "Create account" link on the left navigation bar.

<u>Note:</u> Complete the details and the system will send you an email to the email address you provided. You must click the link in the email to complete registration and log in.

4. Log in using the login name and password that you chose and click "Login" to get into the programme. Once logged in, we will see a map.



<u>Note:</u> Login name is case-sensitive. The default setting for log in is "Scientist" interface. The Policy Analyst interface is simpler and does not give access to all results. The default language is English. For a more detailed user guide, go to http://goo.gl/Gi7ai

5. Define area following these instructions:

a. Select the region of the site of interest.
b. Enter the name of your location in the search box
c. Click "Go>".
d. Position the site to the centre of the map where the crosshair is

e. Enter a name for the run where indicated by run name, choose tiled 1Ha from the dropdown list (to use the 1 hectare spatial resolution version), click “Step 1: Define area”

f. Make sure that the “run” (located at the top of the map) changes to the name f the run you just created. If not click the green refresh icon above the map.

6. Prepare all required data about the site following these instructions:

Click “Step 2: Prepare data” in the original screen and a new window will pop up (see below)

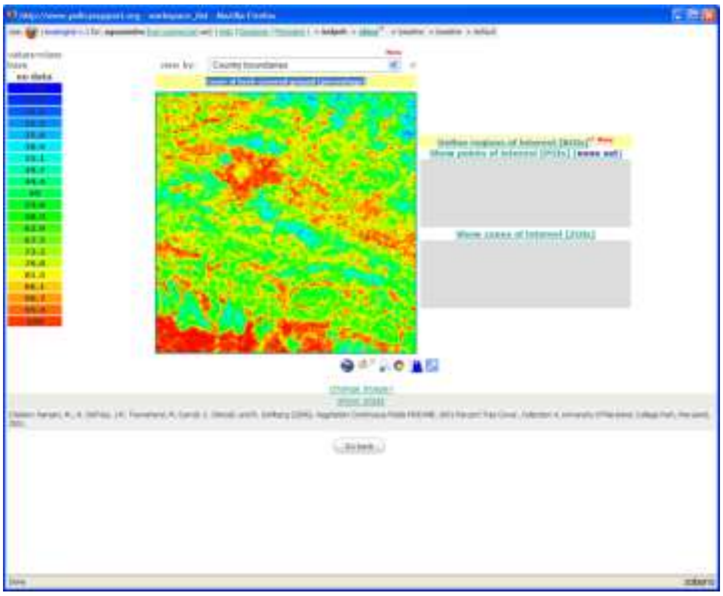
If the data are already available then Click “Copy data to your work space” and the window will change to the one that indicates “Data ready” (see below). If not then click build ‘missing maps’ and when that step is complete (be patient) follow the onscreen instructions to prepare data and copy to your workspace

Note: The data is now copied to your workspace on WaterWorld's servers

Click “show workspace data+” to show the list of available maps

Note: If the data is available to be re-distributed, the link “download” and geobrowse will be active.

Click “geobrowse” to view some of the maps. For example, below is the map of the “Cover of herb-covered ground (percentage)”.



Note: It is important to conduct ground-truthing for the maps of the most important datasets including the following and replace with better maps if these are available:

- Cover of bare ground (percentage)
- Cover of herb-covered ground (percentage)
- Cover of tree-covered ground (percentage)

This is to check if the areas of degradation on the ground match with the land-use cover data the model used.

7. Run the PSS for the site following the instructions below:

Click “Step 3: Start simulation” under “simulation” in the left hand green navigation bar of the original screen and a new window will pop up

Note: There are 48 time-steps – 4 time-steps per month (i.e. 2 night readings and 2 day readings for each month). This means that there are 48 readings throughout the year which represents mean climatic conditions for 1950-2000 and land cover for the year 2000.

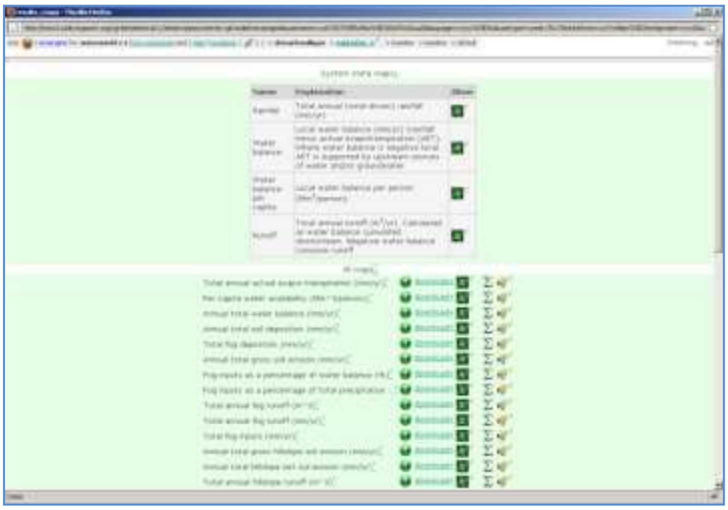
Click “Start” and the window will change to the one that asks if you want to delete the results for any previous baseline run in this area (see below)

Click “Yes” to start the simulation. The window will refresh every 10 seconds. You can also click “refresh” to check the progress

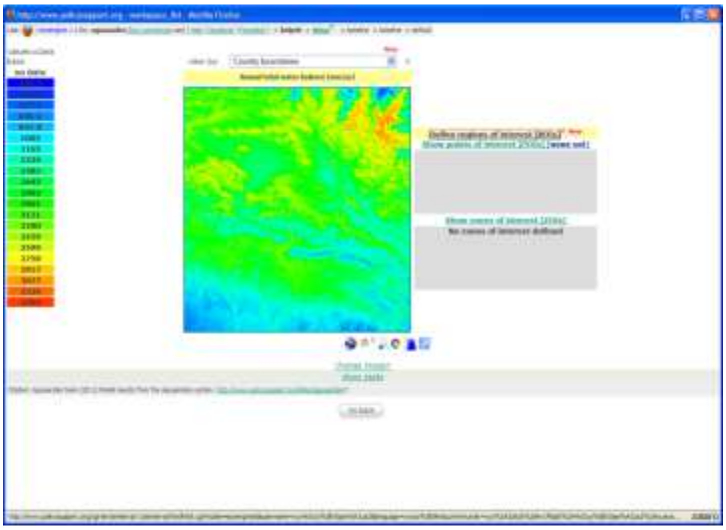
Note: If you are the first person to run it tThe model will take some time to run the simulation (approximately 6 hours) for the 1 degree tile around your area. If the tile has been run before it will take only a few minutes. It is OK to close the window and close the computer and return the next day for the results since the model runs on a server not on your computer.

8. Retrieving the results of the baseline simulation – maps

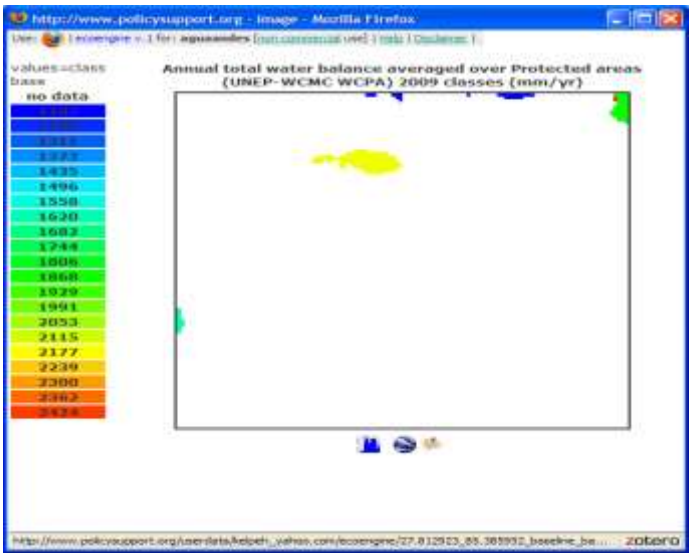
Click “Step 5: Results: maps” under “results” in the left hand green navigation bar of the original screen and a new window will pop up (see below)



Click “geobrowse” to view each of the result maps. For example, below is the map of the “Annual total water balance (mm/yr)”. Maps for all 48 timesteps appear at the bottom of the page and clicking these provides the option to calculate monthly maps.

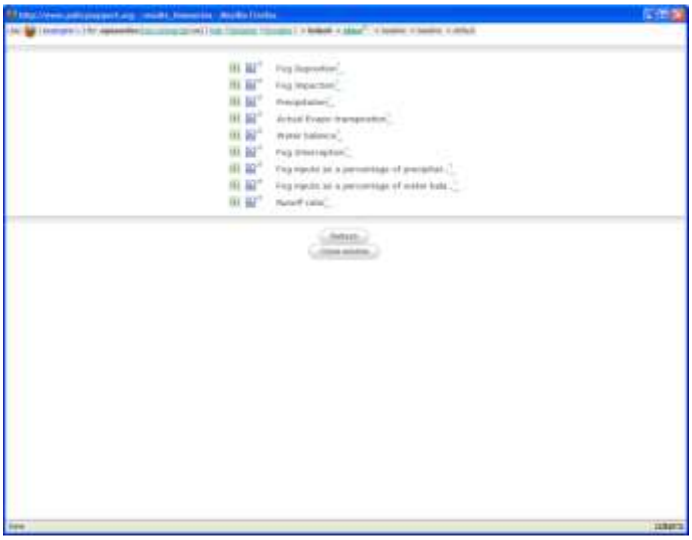


Click "viewby" to list a set of maps that can be used to summarise the results. Choose “IBAs 2011 (Birdlife International)” from the “view by:” field (located above the map) and you will get the map of “Annual total water balance averaged over IBAs classes (mm/yr)”



9. Retrieving the results of baseline simulation – statistics

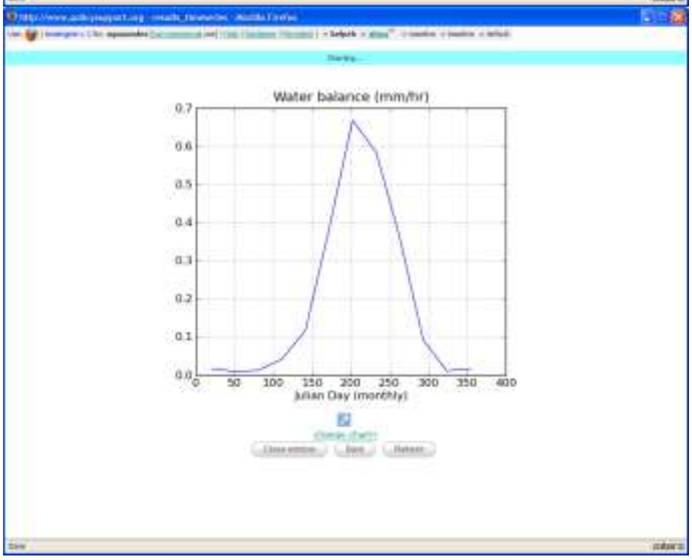
Click "Step 5: Results: stats" under "results" in the left hand green navigation bar of the original WaterWorld screen and a new window will pop up (see below). These are the same outputs summarised over time rather than space. You can download the time-series data by clicking the green Excel icon in the new window



Click the purple graphic icon to view the graph for each variable. Below are the examples of the graphical results of some variables which you may want to focus on:

Actual Evapo-transpiration

Fog Interception



Water balance

10. Retrieving the results of baseline simulation – narrative

Click “Step 5: Results: narrative” under “results” in the left hand green navigation bar of the original screen and a new window will pop up (see below).

Click “For this baseline run+” and then click “Show all” for the narrative results (see below). The narrative provides a verbal description of the baseline information.

Estimating the water quantity of the alternative state using the WATERWORLD Policy Support System (PSS)

The WATERWORLD Policy Support System also could estimate the water quantity for the alternative state of your site and the difference in hydrological fluxes between the current and alternative state (i.e. impact of the change of state). Currently, "land use change" is one of the scenario tools available (others include land management and climate change). These enable the application of land use change scenarios to the baseline so that the consequences of the alternative state for your site can be assessed. Land cover is represented in WaterWorld as the combination of three vegetation functional types. In each pixel the fraction of trees, herb and bare cover are combined to represent different land cover types, so an area >80% trees for example will be a natural or plantation forest. An area dominated by herbaceous vegetation may be a cropland and a bare area could be desert or urban for example. Most landscapes will be combinations of tree, herb and bare covers.

The pre-requisite of using this method is that you have already assessed the water quantity for the current state of your site (i.e. run the baseline simulation) as above.

Section A

Steps:

1. In order to run the scenarios of change, you must have completed Step 1 to 10 in Method 21 (i.e. run the baseline simulation of the PSS for your site) since all scenarios are calculated relative to a baseline.

2. If you want to use a baseline that is not the current simulation as identified at the top of each page you will need to change the current simulation to the one that you wish to use for the alternative. To do this, go to "Manage Simulations" in the original screen and choose "1 degree tile" and "Present your runs as a list". Then click "Submit choice".

3. Click "Choose this baseline" to set your chosen area.

Note: The map in the main screen may not change but the banner which indicates which simulation you are using should change – therefore it is this (for an example see above) which correctly shows which data is interacting with the model system. If it does not change, click the refresh button next to it.

Note: The model must have been completely run before a land use scenario is presented. If the baseline simulation is incomplete the system will not allow you to run an alternative.

4. Click "Step 4: Policy exercises" in the original screen

5. Choose "Land Use Change: assess impacts of land use change". Then click "Submit choice" to run an alternative simulation.

Note: This is the intervention tool menu. If the data has not been prepared and copied over and the simulation not run, the system will not take you further until Steps1 to 3 have been completed.

5. Choose "define your own rule" under "CREATE LAND COVER TYPE"

Note: This is one of the approaches to constructing a land use change scenario. This option is the most useful because it enables you to use specific values for the percentage of tree, herb, and bare covers in each pixel and thus represent specific land cover types rather than the default forest and pasture in the simpler tools at the top of the page.

6. Provide a name for your scenario simulation. It is useful to give a name that reflects its purpose. Then enter the specific values for the percentage of tree, herb, and bare covers of the alternative state of your site. Specific changes can be made to particular locations (i.e. your site/protected area/IBA etc. You would need to enter the identification number; for the method to find this number, see Section B) Then click "Check and submit".

Note: Tree cover includes tree-dominated habitats and shrublands; herb cover includes grasslands and croplands; and bare cover means built-up areas and areas of exposed soils.

7. A progress bar will appear indicating that the model system is copying the baseline maps and applying the defined land use rules. When completed, the following information appears:

Note: At this point you have the option of comparing the input land cover maps of the baseline as previously run and the scenario that you have just constructed. It is useful to do this to check that you did what you intended to do with the land cover.

8. Click "Run scenario" and you will see this:

9. When the simulation is complete you can use the Results: maps, Results: stats and Results: narrative options on the main WaterWorld page as you did with the baseline in order to examine the hydrological impacts of the land use change. As before results can be downloaded as maps or as excel spreadsheets.

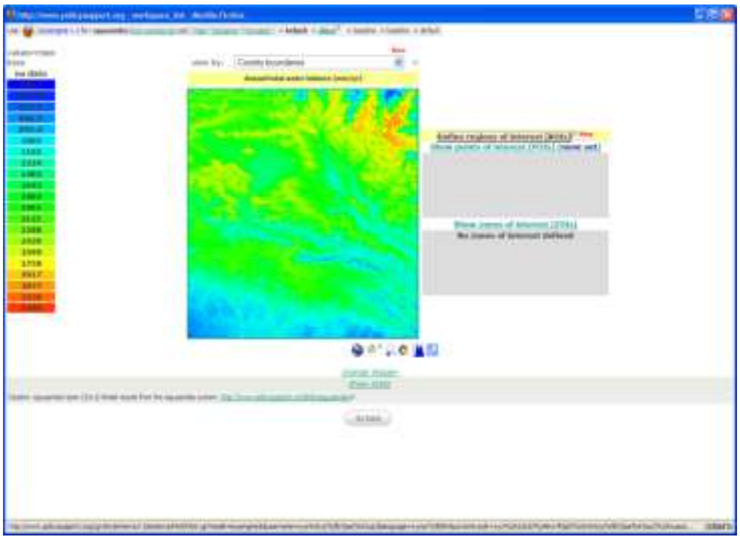
SECTION B

This section guides you through the process of finding the identification number of your site. You need this information to run the scenario simulation in which you make changes to your site (see Section A).

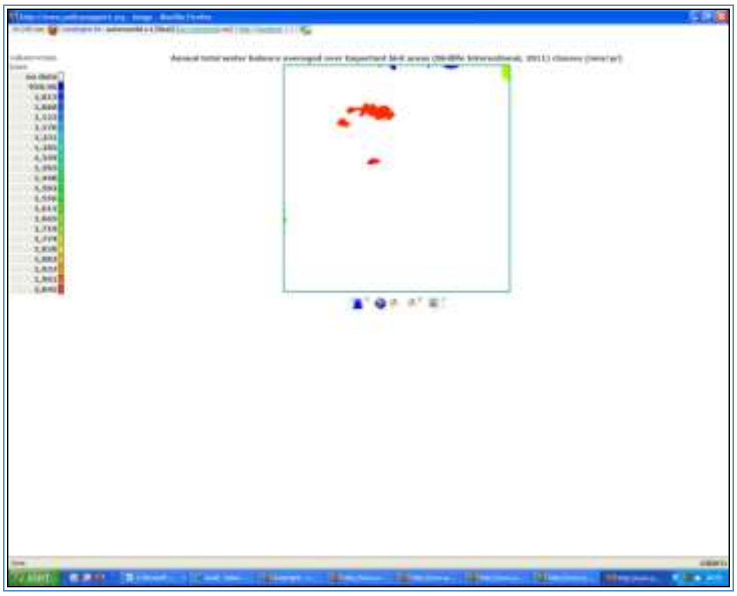
Steps

1. Go back to the original screen and click "Step 5: results: maps". And then click any of the green squares to view a map

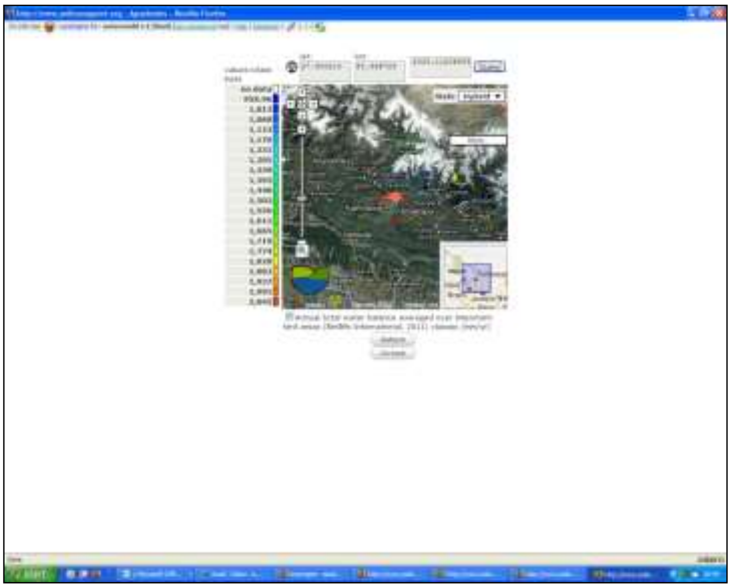
2. Click "viewby" to list a set of maps that show your site. For example, if your site is an Important Bird Area, choose "IBAs 2011 (BirdLife International)" from the "viewby" field directly above the map.



3. Click the third icon below the map for "view in Google maps"



4. Make sure that the crosshair on the map overlies the area of your site, and click "Query" for the identification number of your site.



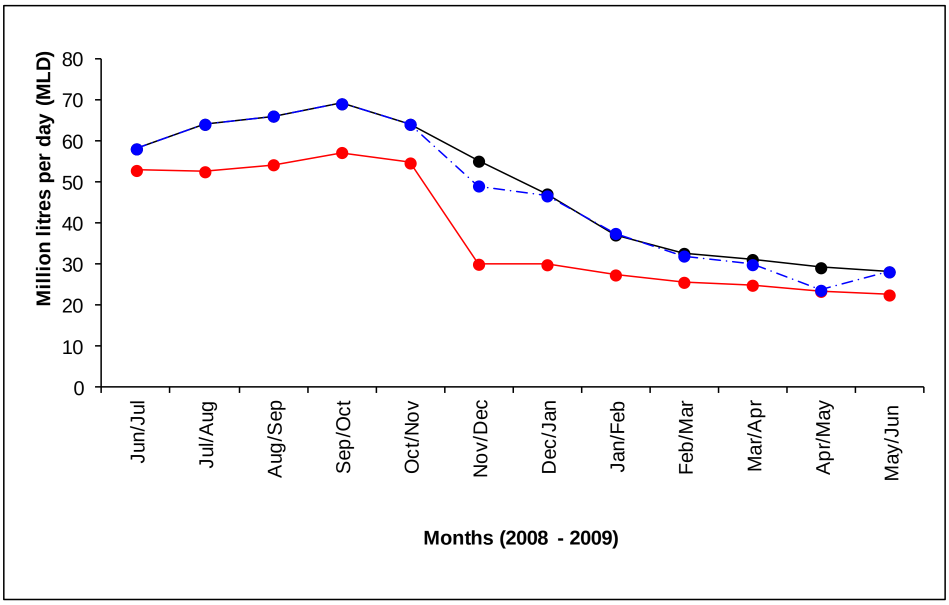
Worked example for Water Method 4.A and C:

Water produced from a national park serves a total population of 3.2 million people in a valley. The need for long-term field surveys for gathering hydrological data puts a limit on the application of rapid service assessment tools to quantify the water balance produced from all the catchments within the park. As an alternate to intensive field studies, data were collated from the regional water agency. The water parameters available from this agency include the monthly total water production from all catchments within the park and monthly total water production in the valley which consisted of both surface water and ground water, for a period between June 2008 and June 2009. The data obtained also included the average monthly current water use of the population in the valley in both dry and wet seasons for the same period. These empirical data can be used to determine the proportion of total water production sourced from the park, and also the proportion of total current water used that was sourced from the park.

Source: Regional water agency												
	Jun/Jul	Jul/Aug	Aug/Sep	Sep/Oct	Oct/Nov	Nov/Dec	Dec/Jan	Jan/Feb	Feb/Mar	Mar/Apr	Apr/May	May/Jun
Seasons	Wet	Wet	Wet	Wet	Wet	Dry	Dry	Dry	Dry	Dry	Dry	Dry
Total water production (surface + groundwater)	130.22	144.56	144.36	143.03	138.89	126.77	108.77	93.47	87.89	86.24	85.84	86.2
Total water production from the national park	58	64	66	69	64	55	47	37	32.5	31	29	28
Proportion of water production from the national park	0.45	0.44	0.46	0.48	0.46	0.43	0.43	0.40	0.37	0.36	0.34	0.32
Amount of current water used	118.4	118.4	118.4	118.4	118.4	68.8	68.8	68.8	68.8	68.8	68.8	68.8
Amount of current water used from thenational park	52.7	52.4	54.1	57.1	54.6	29.8	29.7	27.2	25.4	24.7	23.2	22.3
Based on the counterfactual scenario using WaterWorld Policy Support System												
Proportional change in water balance for the alternative state	1	1	1	1	1	0.89	0.99	1.01	0.98	0.96	0.81	1
Total water production from the national park under the altrna	58	64	66	69	64	48.95	46.53	37.37	31.85	29.76	23.49	28

For quantifying the hydrological services provided by the alternative state, WaterWorld Policy Support System was employed. To assess the impacts of land use change, a baseline scenario (i.e. the current state) was run and the plausible alternative state was applied as a policy scenario which was then compared against the baseline in order to demonstrate and understand the monthly change in water balance and flow. In addition, using the same tool, the baseline and scenario for soil erosion in the park were run as a proxy for water quality.

A counterfactual scenario (i.e., alternative state) using WaterWorld Policy Support System was run based on changing the baseline tree, herb and bare covers to 37%, 41% and 22%, respectively. On average, the monthly water production of the alternative state during the dry season decreased 6% as compared to the current state (baseline scenario). However, the average monthly water balance during the wet season was unchanged.



Legend:

Current water production – black

Counterfactual scenario – dotted blue

Current water use - red

Water produced from the Park averaged 53.73 million litres per day, making up an average of 58.9% of the total water production for the valley which serves a population of 3.2 million people. Initial analysis suggests that land cover change within the Park will not impact greatly on the provision of water from the catchment. However, in some months there is a significant reduction in supply which combined with other factors (such as population increase) may result in shortages at certain times of year.

Water Method 4.D. Assessing water supply in the alternative state for wetlands, using hydrological data

Once you have found out (using Method B2.1) what the most likely future causes of change to water provision for your wetland site might be, you can try to assess the most likely alternative state based on the information available. For example, this might be from an engineering company that is designing a dam to store irrigation water or designing an irrigation scheme water supply system.

As well as construction of upstream dams, there are many causes of change to water provision by a wetland site, including land use change in the wetland catchment, increased development of bore holes in the aquifer supplying the wetland, increased pollution levels (see **Water Method 5**) (possibly through reduced dilution due to reduced water quantity), increased irrigation water off-take upstream. However, in many cases, no data are available to use for predicting changes to water quantity in the wetland. If your site has already been affected by changes that have reduced water provision services then it is possible to use hydrographs from years before the damaging activity to initiate restoration or remedial activities.

Example 1

Figure 14 below shows the typical changes that occur when dams are built and then managed for either irrigation water supply or hydropower. Such graphs are usually available from modelling exercises ahead of the engineering project or can be drawn after such an intervention based on real data. This example is typical of rivers flowing eastwards from the Rocky Mountains in Canada. It shows how spring snow-melt floods are altered by the way that a dam is managed, either for production of hydro-electric power or for provision of irrigation water. Such graphs can be used to assess changes in water supply for different uses under different scenarios of dam management.

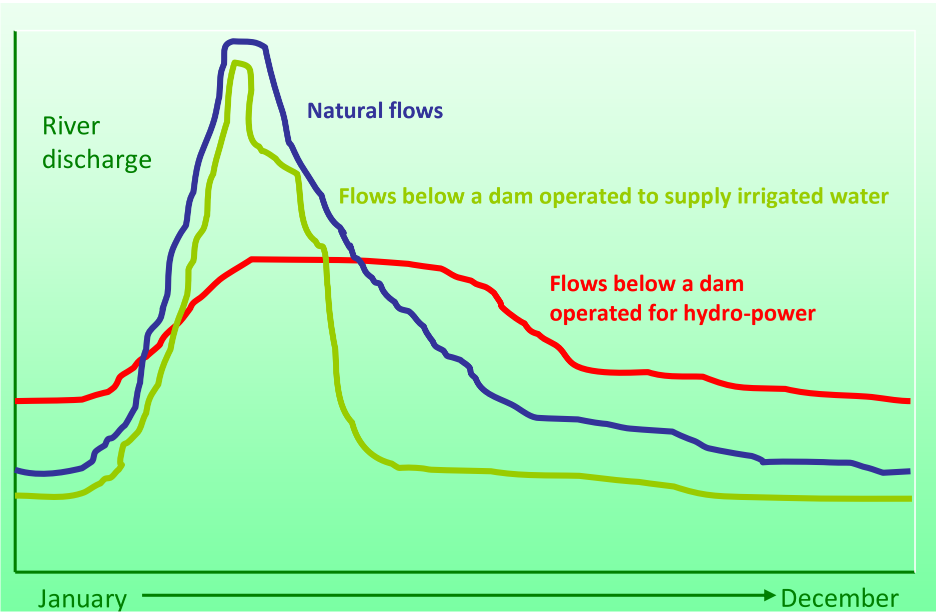


Figure 14: From Rood and Mahoney (1990)

Example 2

Figure 15 below shows how you might calculate the number of months (or days) that water provision might be affected in a chosen location where water is removed from a river for irrigation through a purpose built irrigation canal.

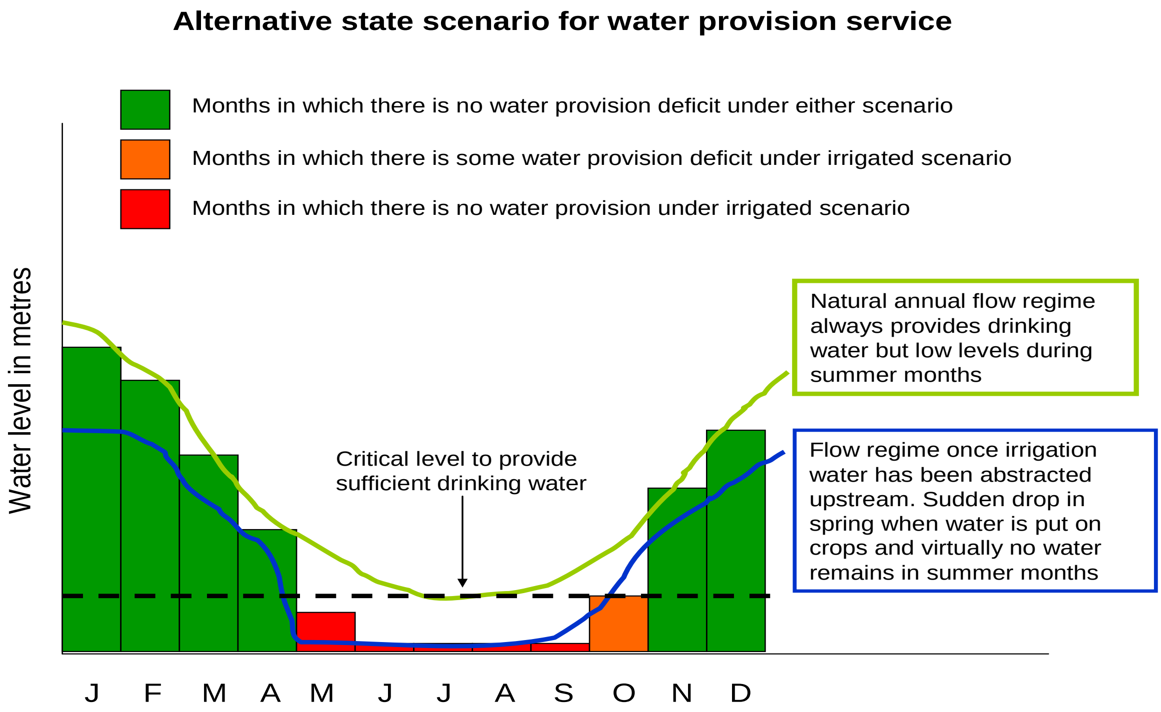


Figure 15: Water provision deficit can be given in terms of number of people affected and number of days or months. In this case there are 5 months with insufficient water under the projected irrigation scenario. The cost of supplying alternative drinking water for people affected for these 5 months will give the change in water provision service provided by the wetland.

Water Method 5. Assessing water quality improvement services

Water Method 5.A. Measuring the contribution of a wetland site to water quality improvement

We discuss both direct measurement methods and economic valuation methods in this section.

1. Direct measurement methods.
Poor water quality in a wetland may be due to poor quality inflows of water from upstream or to pollution taking place either at point-source locations (e.g. sewage inputs) around the wetland or by diffuse pollution (e.g. fertilizer arriving in the wetland at many places through runoff). However, to find out if the wetland is improving water quality, it is necessary to take measures of water samples, upstream and downstream of obvious points of pollution or upstream and downstream of the whole wetland.

The first questions to ask are:

1. Are there any water quality data (e.g. nitrates or phosphates) already available?

2 What sites do these come from and how frequently and for how long have they been collected?

3 Does the wetland have obvious inflows and outflows?

Q3 is important because the only way of finding out if the wetland has an impact on improving water quality is to compare the water quality in the inflows to the wetland, with the water quality in the wetland outflow(s). If there is a difference, then it is possible to attribute the change to some biogeochemical activities taking place in the wetland. Water quality can change rapidly through time. For example, when photosynthesis is active in aquatic plants, different values will be measured in some water quality parameters compared with when photosynthesis does not take place. Extreme events can also arrive and disappear rapidly. For example, when heavy rainfall events follow fertilizer application to agricultural fields, runoff into wetlands can be full of fertiliser for a very short period. Thus, spot checks on water quality are rarely useful and it is important to design a monitoring programme that can take water quality measurements at frequent intervals (fortnightly is recommended) and through all the seasons.

Once you have decided that it is worth measuring water quality, you need to decide what water quality measures to make. There are a number of parameters which can be used to measure water quality in a wetland. These include faecal coliform bacteria, dissolved oxygen, biological oxygen demand, temperature, nitrates, phosphate pH, and turbidity. It is not necessary to measure all these parameters. To identify which parameters are relevant, it is essential first to identify the potential sources of contaminants at the site. For example, if the site has a fishing village with poor sanitation, then the faecal coliform bacteria could be a useful indicator of sewage or faecal contamination.

<u>Understanding the water quality parameters</u>

Faecal coliform bacteria – An indicator of sewage or faecal contamination. The occurrence of these organisms may indicate the presence of other disease-carrying intestinal pathogens in the same waterbody.

Dissolved oxygen – A measure of the amount of oxygen dissolved in water. The ability of water to hold oxygen in solution is inversely proportional to the level of bacteria found in the water. For example, the higher the level of bacteria, the less dissolved oxygen the water can hold.

Biological oxygen demand (BOD) – A measure of how much oxygen is used by microorganisms in the aerobic oxidation, or by the breakdown of organic matter in the water. Human activities could greatly add to the available organic matter in the water-body. In general, the higher the BOD, the lower the water quality.

Nitrate – Water contaminated by human sewage, animal wastes and fertilisers from agriculture via runoffs, untreated discharge and effluents can increase the nitrate concentration in the water-body. This can result in an increase algal growth which in turn smothers the habitats and decreases dissolved oxygen levels due to increased bacterial activities.

pH – A measure of the concentration of hydrogen ions in the water, with the scale ranging from 0 to 14 (0 is very acidic and 14 is very alkaline). Freshwater usually has a pH range between 6.5 and 8.2. A slight change in pH due to industrial waste or agricultural runoff can have detrimental effects because the pH of the water affects the solubility and availability of nutrients.

Phosphate – Sources of excessive phosphates are similar to those of nitrates. In general, excess phosphate will cause algal blooms and their decomposition could lead to the depletion of oxygen.

Temperature – Most often measured in degrees Celsius, temperature directly influences the amount of dissolved oxygen that is available to aquatic life. Waste discharged into the waterbody could affect temperature if it is substantially warmer or cooler than the background water temperature (e.g. water from power stations).

Turbidity – A measure of the clarity of the water. High turbidity means a high amount of suspended solid particles in the water, which can be described as cloudiness or muddiness.

Water test kits

There are simple water test kits that can be purchased cheaply which measure quantitatively the various parameters. These kits vary with different manufacturers and below are two examples:

Green low cost water monitoring kit (http://www.lamotte.com/pages/edu/5886.html) which is designed for testing water for coliform bacteria, dissolved oxygen, biological oxygen demand (BOD), nitrate, pH, phosphate, temperature, and turbidity. The kit is supplied with all necessary apparatus and non-hazardous reagents to test ten water samples and three samples for coliform bacteria with complete manual, colour charts and safety information.

Watersafe All-In-One Water Test Kit (http://www.h2okits.com/site/1286521/product/WS-425B) which is designed for testing water for common contaminant indicators such as bacteria, lead, pesticides, nitrates, nitrites, chlorine, pH and hardness. The kit provides easy methods and non-toxic test ingredients for obtaining analytical data on the spot.

The data can be collected by trained volunteers who are familiar with the simple procedures and protocols provided by the kit. As the kits are designed for schools and citizen monitoring groups, their detailed instructions are easy to follow.

Choosing water sample sites

Where you collect samples will depend on the kind of wetland you have and the kind of water quality problem you have. If you want to measure the overall impact of the wetland on water quality by comparing upstream water quality with downstream water quality then it is probably sufficient to choose sample collection points on inflows to and outflows from the wetland and not to bother collecting water samples from within the wetland. If you are testing the impact of a wetland on an obvious source of pollution, then you could collect samples upstream and downstream of that source. Use the same locations each time you collect samples.

Collecting water samples

Collect samples a little distance from the bank, not immediately next to the bank. Collect two samples each time and use the average values of the two samples. Note that it is important to collect the water sample correctly by following this procedure:

- Sterilise the water sample container (approximately 1L) and cap by boiling them for a few minutes.
- Wear protective gloves and rinse the bottle with the sample water.
- Fill the container completely with the water sample and cap the container while it is still submerged to prevent the loss of dissolved gases.

It is important to test all the chosen parameters on the same day and as soon as possible (within one hour of collection) of the water sample. However, the dissolved oxygen and BOD parameters should be measured at the site immediately after collecting the water sample. The values of the parameters would be the average of estimates obtained from the two sets of water samples.

Care has to be taken that the number of tests/kits bought is sufficient for the design of the monitoring programme. For example, if a one-year monitoring programme requires two nitrate tests each month and two samples are measured each time, then you will need enough materials for 48 nitrate tests from the kit over the monitoring period.

Case study: Taken from**:** http://rangelandwatersheds.ucdavis.edu/main/projects/wetlands.htm

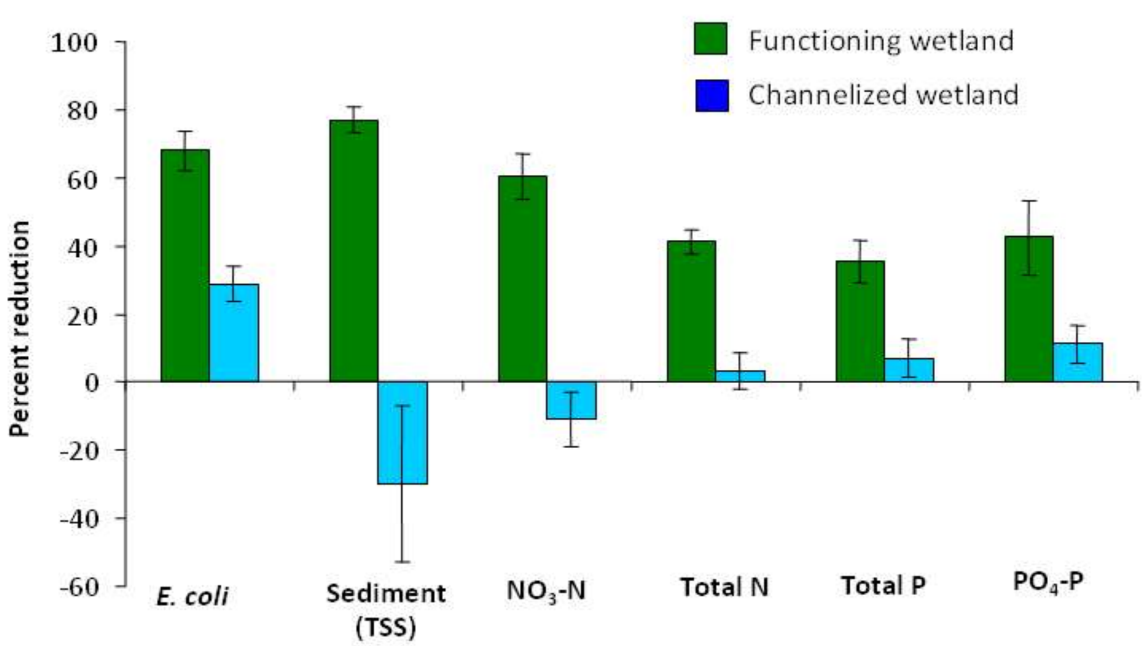
The effect of wetlands on a series of water quality measures was measured at an experimental site in California by researchers from the University of California Davis, USA. The wetlands were approximately 0.5 acres in size, and received tailwater from about 12 acres of pasture that had received fertlizer applications. Tailwater runoff rates entering the wetlands ranged from about 0.30 to 1.40 cubic feet per second (cfs). One wetland had been channelized so that water flowed through it via a narrow channel (channelized wetland) whereas in the other wetland, water filtered through the whole wetland area (functioning wetland).

Functioning Wetland

Channelized Wetland

In the two diagrams above water flowed across the whole of the wetland on the left (Functioning wetland) but was channelled through the wetland on the right without passing through the wetland soils and vegetation. Samples were taken at the inflow and outflow of each of these experimental wetlands

Reduction of Pollutants due to Wetland



Functioning wetland reduced pollutants in pasture runoff

It can be seen in the graph above that for all factors measured the % reduction between the inflow and the outflow was considerably higher for the functioning wetland than for the channelized wetland. Factors measured included: suspended sediments (TSS), nitrate (NO3-N), *Escherichia coli* (a bacteria), total nitrogen (N), total phosphorus (P), and soluble reactive P (PO4-P).

Reference

Knox, A.K, R.A. Dahlgren, K.W. Tate, and E.R. Atwill. 2008. Efficacy of Flow-Through Wetlands to Retain Nutrient, Sediment, and Microbial Pollutants. J. Environmental Quality 37, 1837-1846.

2. Economic valuation methods (from Turner et al., 2008)

i) **Defensive expenditure, replacement cost or avoided cost** can be ways of measuring the value of water quality improvement by a wetland. For example, if users of water have to build a water purification plant to avoid consumption of poor quality water, the cost of that plant represents a (lower bound estimate of the) willingness to pay for this service. Other examples of private investments include water filters for drinking water (domestic use), or buying bottled water instead of drinking tap water. In some cases, people may consider moving away from an area if water quality levels reach unacceptably low levels and this move will incur costs.

These cost-based approaches reflect costs of alternatives that could provide similar water quality services. However, it is unlikely that these artificial structures will provide the same level of water quality for the same volume of water. The service provision level of these man-made structures may be higher or lower, and therefore the costs could be considered as approximations of the upper or lower bound estimates of the benefits of water quality improvements delivered by wetlands.

You can also look at the expenses on substitutes. For instance, if people decide to use less fertilizer and thereby reduce nitrate and phosphate pollution, and therefore their agricultural outputs decrease, that loss in crop production reflects people's willingness to pay for better water quality.

In some cases/areas, higher levels of water pollution may cause health problems, e.g. when people consume water directly from the river or bath in rivers/streams. Here, expenses related to diseases caused by bad water quality could be used as approximations of benefits of water purification services of wetlands. For example, algae blooms in open water cause a certain number of hospital admissions each year. Diarrhoea can be caused by water pollution and people, especially children, are vulnerable to (and dying from) diarrhoea. Again, it is important to assess what the change in health problems would be if a wetland was no longer there – and this change should be valued.

For more detailed investigation of these methods go to:
http://www.aquamoney.org/sites/download/D23_Technical_Guidelines_AQUAMONEY.pdf

Water Method 5.B. Estimating water quality improvement using the WaterWorld PSS

Soil and sediment erosion, transportation and deposition

WaterWorld models soil erosion, transportation and deposition as well as the water balance. In order to simulate the impacts of forest protection or land use change on soil erosion and sedimentation in and downstream of your area of interest, simply follow the instructions for running a WaterWorld baseline and alternative and go through the output maps, statistics and narrative (see method B2.4c). A variety of output maps are written which separate hillslope from channel erosion and gross erosion from net erosion (net erosion is erosion minus sedimentation and reflects the soil flux out of a cell, gross erosion is the total erosion in a cell).

Of particular interest would be the sediment transport output at dams, water treatment plants or other key water sources, since if this increases in an alternative state then water quality for consumers will be reduced. Where gross and net soil erosion increase after in the alternative state this could also be a problem in terms of reducing the productivity of the soil on the converted land.

The human footprint on water quality

Not all of the impacts of an alternative state are captured by analysis of sediment dynamics since the conversion of natural or protected ecosystems to human land uses will also lead to changes in the inputs of point and non-point source contaminants leading to an increase in the human footprint on water at the site and downstream (Beunemann et al, 2011). A high human footprint would generally result in higher levels of organic and inorganic contaminants. Where the human footprint is lower (e.g. where flow generated from rainfall falling on human land uses is diluted by rainfall falling on protected or natural areas) then water treatments costs should be lower.

Both the **Costing Nature** and **WaterWorld** tools calculate the Human Footprint on Water. In WaterWorld it is provided as a separate output as the “percentage of flow that may be polluted” and can be visualised both in the baseline simulation and the alternative. In the baseline simulation the variable reflects the likely quality of water resulting from upstream human activities and can be used to assess disbenefits or negative externalities of human activity upstream on the water quality receive by those downstream. The human footprint is not greatly affected by land *cover* scenarios such as the example shown in method B2.4c, except through changes in the distribution of runoff, but is affected by land *use* scenarios. Land cover scenarios change only the cover, whereas land use scenarios change both the cover and the type of use, where uses are defined as urban, cropland, pasture, road, mining, oil and gas, protected. To invoke a land use scenario at your site follow the steps in method B2.4c to change land cover and choose a new land use type from the dropdown menu. This will not only convert the land cover maps according to your requirements but also change the maps that characterise land use which will thus affect the human footprint at the site and downstream.

Costing Nature embeds the human footprint analysis in the potential and realised water-related services indices, since these reflect only clean water (the proportion of water with no human footprint). Land cover scenarios are not yet available in Costing Nature since they are being developed. When available they will function in the same way as in WaterWorld.

Water Method 5.C. Assessing water quality improvement in the alternative state

To estimate changes in water quality likely to occur in the best estimate of the alternative state it is vital to have good data on the most likely alternative state. The easiest alternative states to deal with are:

- Changes to known point sources of pollution
- Reduced water quantity and thus reduced pollution dilution

In both these alternative states, it is possible to use the same water quality measurements and sample designs as described in Water Method 5.A.

Methods: Harvested Wild Goods

Wild Goods Method 1. Stakeholder meeting for quantifying the benefits obtained from harvested wild goods

A stakeholder meeting is a first step to gather information about the **volume**, **value** and **sustainability** of wild goods used at the site. Its main purpose is to obtain reliable information at a **general** level that can then be used to target efforts to gather more detailed information through consultation of government records, market information, questionnaire surveys, etc. It should also be used to gather general information which can help guide data collection – information on the socio-economic groups involved in harvesting, the seasonality of harvest, and the social value of production for example.

For general guidance on organising and running a workshop (including issues such as who to invite, meeting timing, language, participation and inclusion etc.) refer to Guidance 2.

The site that is being considered and its boundaries should be made clear at the start of the workshop so that participants answer the questions in relation to their harvest from that site only, and not their overall harvest of a particular product which may be sourced from locations other than the site of interest. This could be made clear by showing a map and should be emphasised throughout the workshop. Also, use the map to find out whether different users have access to different parts of the site (for example a community forest, or community fishing area). This information will be important for the questionnaire survey, for deciding the reference area for questions, selection of the sample to be interviewed, and the approach used to extrapolate from the sample to the whole site.

The following questions provide a framework which should be adapted to individual contexts.

It is important to consider that not all harvesting of wild goods will be small scale or by local communities. Some wild products may be harvested commercially, and by companies that are national or even international – for example timber, some types of nut, certain gums and fibres.

Identification of the most important harvested wild goods

The first step is to identify the most important harvested wild goods for the livelihoods of the people in the village. You should aim to identify up to 5 most important goods. 'Most important' includes not just those products that are economically most valuable, but also those that have value in terms of the part they play in local culture, their use in times of famine etc. One way of asking this question is 'Which goods would you be most concerned about losing?'A method for this is suggested in the box below.

Methodology for identifying the most important wild goods.

The following method should allow everyone to have a say – including those that are illiterate and potentially marginalised social groups such as women, ethnic minorities or the poor.

- Sub-divide respondents into groups comprised of individuals with different socio-economic characteristics. E.g. women, landless people, ethnic minorities, the elderly etc. You will probably need local advice to do this effectively and sensitively.
- Ask participants **in each group individually** to name products they obtain from the site. List them all, and use photographs or draw pictures or symbols, which everyone understands, to represent them.
- Give everyone at the meeting a certain number of counters (e.g. 4 each) – you could use seeds or pebbles.
- Within each group ask each participant to place their counters against the 4 products that are most important to them (whether economically, socially, or for subsistence) or those they would be most concerned about losing. If possible do this **individually** and **anonymously**, to avoid marginalised people from feeling socially pressured to follow the example of others.
- Add up the totals to identify the most important products at community level (and make note of differences between the different sub-groups).
- Discuss the findings with the groups and reach a consensus. However, be open to the possibility that different groups might prioritise different products.

The social value of harvested wild goods

The methods in this manual focus on determining the economic value of wild goods obtained from the site. However, many wild goods play very important social functions, and their value may accrue to certain sectors of the population, or at certain critical times of the year. Examples include:

- Products that are mainly harvested by the poorest people in the community, by the landless, or by ethnic minorities or other potentially marginalised groups.
- Products that are harvested, processed or in other ways provide employment and income to women (and for whom there may be few alternatives available).
- Products that are harvested only seasonally or under certain climatic/economic conditions, but which are nevertheless critical to the community at this time – e.g. foods harvested at time of famine, crop failure, flooding or when there is a family labour shortage.
- Products which have great religious or cultural significance, and which might therefore help define a community's identity.
- Resources that might be especially important to seasonal migrants (and others who might not participate in meetings or surveys).

It may be important to get a sense of the value of these products, even if their monetary value is not quantified. The stakeholder workshop is probably the best place to do this, and a narrative describing the significance of the product(s) to the community may be the best way of communicating it to decision/policy-makers.

All of the following questions are to be used for **each** of the most important harvested wild goods identified through the previous activity (recommended 3-5 goods).

For questions marked with the symbol ⭘ it is important to try to get full, clear answers.

You may not need to ask all of these questions as some responses to earlier questions could answer later ones and depending on the context, some of the questions may be irrelevant. The researcher's discretion should be used here to ask only what is absolutely necessary.

Description of the harvesters

1. Approximately how many people harvest the product from the site? ⭘
2. What percentage of the harvest is by: ⭘
   - local rural people
   - non-local rural people
   - urban people
   - people in other countries
3. Do the people who harvest the product come from any particular socio-economic group, and if so what is it (e.g. specific ethnic groups, women, landless people, people with inherited rights to harvest the product)? ⭘
4. Are any harvesters particularly dependent on this product for their livelihood? ⭘
5. Are harvesters organised in any way – for example is there a harvesters' organisation or cooperative? Give details.

Description of the harvested wild good

6. What is the product mainly used for?
7. What units are used locally to quantify the product (e.g. bundles, tins, head-load, basket) ⭘
8. What is the conversion between this unit and the relevant metric unit? (e.g. 1 bundle = 50 kilograms) ⭘
9. Does the availability of the product vary during the year (is production seasonal)? Explain ⭘

10. Where within the site is it harvested?

11. Are there costs associated with harvesting the product (e.g. buying nets, saws, guns, baskets or other equipment)? Are these one-off costs or regular/annual costs?

Users and marketing

12. Out of 100 units of the product, how many units are typically used for subsistence (i.e. by the harvester and his/her household) and how many are sold?

13. If it is sold, who uses it?

14. Is the product processed by the harvesters before it is sold, or do they sell the raw product? Give details.

15. If the product is processed, are there any costs associated with processing? Explain and describe.

16. Where is the product usually sold – locally, in a nearby market town, in the nearest city?

17. How many points of sale are there for the product that has been collected from the site?

18. Do harvesters tend to take the product to market themselves or is there a 'middle-man' who comes to villages to purchase the product? Give details.

19. What is the current market price per unit of the product:

    - Where the harvesters live:
    - In the nearest market:
    - In the nearest city:

20. Does the price vary very much (seasonal variation) during the year? Explain and describe.

Non-marketed goods

21. If the product is not sold in any market, and you were not able to harvest it, what effect would this have on your livelihood?

22. If you could no longer harvest the product and had to replace it, what product would you need to buy and what would it cost for an equivalent amount?

Labour

23. Does a legal minimum wage exist? If so, what is it?

24. What is the typical daily wage rate in the area (for the kind of work needed to harvest this product)? Do rates fluctuate seasonally? Describe.

25. Is there much unemployment in the area? What are the probabilities of an individual getting a day of paid work if they wanted it? ⭘

26. Is there much seasonality in the demand for labour and levels of unemployment? Describe. ⭘

These questions are designed to help determine what value should be given to family labour used for harvesting wild goods (Method 5.2 – questionnaire survey). As a general rule:

- If levels of unemployment are high throughout the year, value any family labour at zero
- If there are periods of high seasonal demand for labour (but high unemployment at other times of year) find out family labour inputs during those peak periods, and value it at the 'market rate'
- If there is a high demand for labour throughout the year, value annual inputs of family labour at relevant market rates

Sustainability

27. Answers to the following questions may help to infer the level of sustainability of the harvested wild goods. If a user group exists then records kept by the members of the user groups relating to past and present harvesting levels of the good can be used to provide a more accurate account and substantiate information collected at the stakeholder meeting.

28. How has availability of the harvested wild good at the site changed in the past 20 years (or other chosen period)? (Declined a lot; declined a little; about the same; increased slightly; increased a lot) ⭘

29. Has the time spent harvesting changed in the past 20 years? (Declined a lot; declined a little; about the same; increased slightly; increased a lot)

30. If the availability of the harvested wild good has changed (or time spent harvesting has changed), what do you think are the reasons?

Rules for the product

31. Are there formal or informal rules on accessing, processing, or selling the product which affect how much is harvested? Give details.

32. Are there restrictions on harvesting this product in regard to the quantity of this good that can be harvested?

33. If there are restrictions as specified above, how is the total quantity to be harvested or used during a year decided?

34. How are any rules monitored and enforced?

Goods harvested during state change

Either in the same or a separate meeting, maybe involving a smaller number of well-informed individuals, discuss whether the process of state change of the site to the likely alternative state would lead to a one-off harvest of any products (e.g. timber from a forest, charcoal from a woodland, peat from a wetland):

35. If the site was converted to another land-use (the plausible alternative state) are there any products that would be obtained through that state change process? ⭘

36. What are those products? ⭘

37. What is their estimated quantity and likely value? ⭘

38. What costs would be involved in harvesting these resources (machinery, labour) and for any capital costs, how long would the capital items last? ⭘

39. Who would be most likely to carry out this harvesting, and where would they come from (local people, non-local rural, urban, people in other countries)? ⭘

Illegal harvesting

In many countries, and despite laws protecting species or limiting the time and place for harvesting, some wild products will be harvested illegally. A number of methodological and ethical issues may then arise, especially where harvesters have reason to fear authorities. These are described below. Ultimately it will be up to you to decide whether it is safe, ethical and necessary to gather information on illegal use in the context of the site which you are studying.

Issues and risks

- Figures for illegal harvests are always likely to be unreliable, especially within short-term studies, because respondents are unlikely to be honest about their activity. Past experience by researchers shows that any accurate information on the illegal harvest of products relies on the building up of trust between communities and the researchers gathering the information. Depending on who is asking for the information and its purpose, communities may refuse to provide any information at all, especially if they can see that it would risk getting them into trouble.

- Including the illegal value might upset officials since it could be taken as an indication that they are not doing their job effectively. Some may even be benefitting personally and may not want the scale of illegal activity brought to attention.

- Illegal harvests might be more likely to be unsustainable than legal ones, so (without some measure of sustainability of the harvest) assigning them their current value into the future would overestimate the long-term value of the service

- In some countries, knowledge of illegal activity may make you legally required to report it. Failure to do so would be to commit an illegal offence yourself.

- Publication of data on illegal activity may result in retribution by the authorities raising important ethical issues about whether this data should even be published at all.

Approaches

- In situations where it would clearly be dangerous or ethically or politically difficult to gather information on illegal harvests from the users, it should not be attempted. In such cases consider including a qualitative description of illegal harvest, based on discussions with local NGOs for example, which describes in broad terms the volume, value and social importance of such illegal harvests, as well as likely sustainability.
- If law enforcement is weak and the products are traded openly, data could be collected via individual or household questionnaires. In such cases the assessor should still work to reduce the perceived risk of cooperation, by making it clear that any information is anonymous and will be treated confidentially and that no identifying details will be taken.
- The quality of the information collected on sensitive subjects may be improved by avoiding direct questions about an informant's involvement in illegal activity. For example the assessor can ask about 'a person in this village' rather than 'you'. Alternatively, if time and resources allow, consider using Randomised Response Techniques (which enable respondents to give truthful answers without implicating themselves) to get accurate information (St John et al. 2010)
- If data on illegal activity can be collected or is available, it could be pooled with information on legal sources (i.e. do not give a disaggregated breakdown). This would avoid underestimating values and any risks of retribution.
- Observe relevant ethical guidelines. Many research institutions have guidelines about conducting social research in relation to informed consent, confidentiality and protecting the interests of participants (for guidelines on ethics, refer to Appendix 6). There may also be ethical issues to consider concerning the reporting of illegal activities that damage the environment or threatened species. It is important that you are sensitive to the possible consequences of your work, and of reporting (or not reporting) the results.

Wild Goods Method 2. Individual questionnaire to estimate quantity and value of harvested wild goods

Through a workshop you should have identified the 3-5 most important products, and obtained background information including their seasonality, their use and marketing and the location of the principal harvesters of the resource (local, rural non-local, urban, in other countries). The purpose of this questionnaire survey is to determine the **quantity** and **value** of these products.

Where should you do your survey?

- You will need to design a sampling frame for the questionnaire (i.e. decide who to interview) based on the information you have on the location of the harvesters. It may be necessary to interview different people in different areas.
- If the workshop suggests that over 20% of harvesters are non-local you should consider sampling those communities/individuals in addition to local communities. If harvesting by non-local people is happening at the time of the survey, try to interview them at the harvest site. Otherwise you will need to go to the non-local communities and interview people there.
- If harvesting by local communities is highly variable, or restricted to certain communities or identifiable groups within communities, consider surveying each of these sub-groups separately (stratification).

Who should you survey?

As far as possible use a randomised design for sampling respondents (e.g. every third household on a street or every fifth name on a list of village residents or names/numbers picked out randomly from a list/container containing all those in the population being sampled).

How many people should I interview?

During the survey you may find that some respondents do not use the wild resources you are interested in. If that is the case move on to the next respondent but do include this 'negative' result in your analysis. Continue sampling, and recording any negative results, until you have interviewed at least 30 people who harvest the product. You should aim to survey a sufficiently large sample to reduce errors caused by variation, so if responses you receive show a high degree of variability you will need to interview more people.

When should I do the survey?

For seasonally harvested products try to collect data during or immediately after the harvesting season rather than rely on people's memories. Consider when in the day is the best time to do the interviews – find out the time that is least inconvenient for people, or when most people will be at home if you are meeting people in their houses.

For **each** product, and for **each** respondent, complete the table below (so if you are investigating three products go through the questions in the table three times with each respondent – dealing with each product in turn).

Assessing feed for Livestock

If feed for livestock was identified as among the most important harvested wild goods, then it will be important to establish whether this is mainly for sale or subsistence. See notes on this below under the section 'Important considerations when conducting the individual questionnaire'.

It is also important to ensure that a clear distinction is made between cultivated feed, and wild harvested feed. This method should be used for wild harvested feed. For cultivated feed refer to Section IV.

> **Wild feed** (Section III) includes all feed fed *in situ* or gathered from uncultivated land (whether for sale or to feed the respondent's own livestock) including from uncultivated communal lands, forests, wetlands, grasslands etc.:
>
> **Cultivated feed** (Section IV) includes all feed that is produced from cultivated land, whether for sale or the respondent's own use, and whether provided *in situ* or harvested, including specially cultivated feed crops (e.g. hay, oats), pasture, crop residues and feed provided from the margins of cultivated land.

Social differentiation

If it is important for your analysis that you understand how benefits are distributed across different social groups, you will need to include some questions in your questionnaire which allow you to identify which social group the respondent belongs to. **Guidance 1** provides details on how to differentiate social groups. The questionnaire template (below) will need to be adapted to gather information accordingly (e.g. on gender; ethnicity; wealth status; age; marital status; education etc.)

Questionnaire template

Be prepared to revise the table and the information that is collected depending on what you have learnt about the product at the workshop and from other organisations etc. – **this is a template for guidance only**. It may be possible to determine some of the answers based on information given during the workshop (for example estimated costs of tools and materials).

However, for questions marked with the symbol ⭘ it is important to try to get full, clear answers.

Understanding the site boundaries

The site that is being considered and its boundaries should be made clear to the respondent at the start of each interview so that respondents answer the questions in relation to their harvest from that site only, and not their overall harvest of a particular product which may be sourced from locations other than the site of interest. This could be made clear by showing a map and should be emphasised throughout the interview - make sure the respondents know the area you are referring to, and only answer with reference to it.

[See next page for the questionnaire]

Wild Harvested Goods – Individual/Household Questionnaire

Name of product			
Name/number of respondent			
If appropriate include one or more questions which allow you to differentiate respondents according to the key factors affecting receipt of benefits. You may want to ask this at the end of the questionnaire once they feel more comfortable about the content of the questionnaire. *E.g.* Household size / Education / Ethnicity / Age / Marital status / Wealth status			
Date			
Location/name of village			
Are the questions being answered per individual, household or business? (circle the one which is applicable)	**Individual** **Household** **Business**		
Name of product (*if more than 3 products use additional forms)*	**1.**	**2.**	**3.**
Quantity and value of product			
a. Total quantity collected **from the site** in last 12 months* ○			
b. Unit ○			
c. Percentage for own use			
d. Percentage sold/ bartered			
e. Average price obtained per unit** ○			
Family labour			
f. Annual time taken by respondent and family members (unpaid) to harvest and process the product (person days)* ○			
Hired labour			
g. Annual input of hired labour for harvesting and processing (person days)* ○			
h. Typical daily wage rate paid for hired labour			
Equipment costs* **			
i. What capital items (tools, materials, equipment) do you need for harvesting and processing this product? ○			
j. How long do you expect each of these tools etc. to last? ○			
k. How much did each item cost to buy? ○			
Transport and marketing costs			
l. What are the annual costs of transport and marketing this product?* ○			
* If respondents find it difficult to recall accurately the harvest for the past 12 months, then break these questions down. For example, Ask for the harvest on a monthly basis (and then add these figures up yourself, to get an annual total). Do the same for each of these questions (price, inputs of labour, costs of equipment and other inputs etc.).			
** If the individual respondent does not sell the product they gather, but others do, then apply the mean price recorded from other respondents.			

*** If any tools or equipment have a lifetime of more than one year, divide the initial purchase cost by their expected lifetime and add typical repair/maintenance costs. If tools are not specifically used/purchased for this product but are for general use, apply a sensible percentage of their cost/maintenance

Feed for respondent's own livestock

If wild harvested feed for harvesters' own livestock was identified as one of the most important harvested wild goods then ask each respondent the following questions.

The value of the service that the land provides to livestock is determined from the value of the feed it provides them. Here we are focused only on wild harvested food (not cultivated feed).			
In the last 12 months, did you feed any livestock with wild harvested feed obtained from the site? ○	**Yes**		**No**
If yes, what and how many animals do you own (sheep, goats, cows, chickens etc.)? ○	**1.**	**2.**	**3.**
For each animal type, approximately **what percentage** of their feed did you obtain from wild harvest at the site? ○	%	%	%
What is the **estimated value** of that feed? (i.e. how much would it cost you to replace that feed if you had to buy it from someone else, or if you had to replace it with another kind of animal feed?) ○			

Important considerations when conducting the individual questionnaire

Accuracy of reporting and respondent recall

Accuracy of recall is always an issue with interview surveys. You can minimise errors by (1) spending time building trust with landholders and ensuring that they understand the purpose of the interviews (they are more likely to be cooperative if there is some tangible benefit to them, e.g. if the interviews can be conducted under the umbrella of an existing local development project); (2) using interviewers who are fluent in local languages, familiar with local cultivation methods, and known to landholders (e.g. local agricultural extension officers); (3) breaking down the period of reference – so instead of asking about the amount harvested in the last year, ask about harvest on a monthly basis, and then add the monthly totals; (4) triangulating responses where possible, for example by using different recall periods or comparing data collected using different methods; (5) training interviewers to spot and challenge suspect responses.

Local units

The biggest pitfall here is the use of local units for area and for quantities of product. **Do not assume that units such as "acres", "tonnes" and "kilos" bear any relationship to internationally recognised definitions**. Ground-truthing, by measuring defined areas in the field, and weighing quantities of product, is essential. weighing quantities of product,

Markets

If market prices fluctuate widely, it might be preferable to use a mean price based on recent historical prices (taking inflation into account).

Licence fees and taxes

Licence fees and taxes are not a production cost, but a mechanism for redistributing benefits. Therefore they should **not** be included as a cost in calculating the net value of ecosystem service benefits.

Livestock

Feed from sites (grass, leaves) may be used to feed livestock. Animals may either be taken to the site, or animal feed may be harvested and transported to the animals. Livestock often require diverse inputs before their value is realised (e.g. labour to herd or take to water, veterinary care), their benefit may sometimes be especially difficult to value (e.g. draught animals, social security, investment, status) and major benefits are often pulsed (e.g. income upon slaughter or sale, only after several years). The main service that sites provide is feed – this is the earliest point in the chain at which the ecosystem service (which ultimately delivers livestock benefits) can be measured.

- If harvesting **and sale** of wild harvested feed is identified as important, then treat it as any other harvested wild good, and collect data on harvesting, processing and income from sale using the first part of the questionnaire form.

- If feeding of the respondent's own livestock (i.e. **subsistence use**) was identified as one of the most important uses of the site you should calculate the value of that use by asking each questionnaire respondent the questions in the second part of the form.

- If **both** harvesting for sale, and harvesting for subsistence are important, then ask the questions in both parts of the form.

Methods: Cultivated Goods

Cultivated Goods Method 1. Meeting producers and/or other informed individuals to characterize the most important cultivated goods

This method is designed to collect general information on cultivation in the area of interest, under its current and alternative state. Note that in most cases, it should be possible to answer these questions by meeting with informed individuals such as agricultural extension officers, government officials or farmers' union or farmers' cooperative representatives. That is by far the most efficient approach and should be the first course of action. It is suggested to meet with 3-5 people as a minimum and more if the situation suggests this is necessary. Alternatively a small community meeting of farmers could be arranged following the advice of informed experts on who is cultivating goods in the area. See **Guidance 2** for general information on running a workshop. For questions marked with the symbol ⭘ it is important to try to get full, clear answers.

The site that is being considered and its boundaries should be made clear at the start of the workshop so that participants answer the questions in relation to cultivation at that site only, and not their overall farming activity, which may be include fields in locations other than the site of interest. This could be made clear by showing a map and should be emphasised throughout the workshop.

Identification of the most important cultivated goods

1. What are the most important cultivated goods for the livelihoods of the people in the area? Aim to identify up to 5 most important goods. ⭘
2. Roughly what percentage of the cultivated area is used for producing each of these goods? If two or more crops are grown in the same place at the same time assign that area proportionally among them (e.g. if 20% of the cultivated area is used to grow rice followed by wheat each year, both crops score 10%). If two crops are grown in succession (e.g. if 30% of the area is used to grow a wet season rice crop followed by a dry season crop of maize) then record both crops (30% rice, 30% wheat) – the total cultivated area will then add up to 130% of the farm area, and an not of explanation should be included in the write up.⭘
3. Approximately how many households in the area are involved in cultivating these main goods? ⭘

All of the following questions are to be used for **each** of the most important cultivated goods.

Description of the cultivators

4. Approximately how many households or businesses in the area cultivate this product? ⭘
5. What percentage of the cultivation is by: ⭘
    - local rural people?
    - non-local rural people?
    - urban people?

- people in other countries?

6. Do the people who cultivate the product come from any particular socio-economic group, and if so what is it (e.g. specific ethnic groups, women, landless people, people with inherited rights to harvest the product)? ⭘
7. Are any of these people particularly dependent on this product for their livelihood? ⭘
8. Are cultivators organised in any way – for example is there a producers/farmers organisation or cooperative? Give details, and contact information where available.

Description of the cultivated good

9. How long does the crop take to grow (from planting to harvest)?
10. If the lifecycle is shorter than one year, are multiple cultivated goods grown on the same land?
11. If the lifecycle is longer than one year, are there defined periods with their own costs, yields and profits (e.g. land preparation, planting, establishment, maturity)?
12. What is the length of any fallow periods between crops or stocking with livestock?
13. What units are used locally to quantify the product (e.g. bundles, tins, head-load, basket) ⭘
14. What is the conversion between this unit and the relevant metric unit? (e.g. 1 bundle = 50 kilograms) ⭘

In cases where two or three important crops are grown on the same land, you will need information on the annual costs and yields of all of them. For crops with a lifecycle longer than one year, you will need to collect enough information to calculate the mean costs, yields and profits through the entire lifecycle, including any fallow periods. For example, if land is left fallow for five years out of every ten years, the mean annual yield is 50% of that produced from cultivated land during a year of cropping; likewise if a crop takes three years before it can be harvested, mean annual yield is 33% of that collected during the harvest year.

15. For livestock, roughly how much would it cost to buy all the food that an average animal needs for a year? It is important to imagine there is no “free” food - from pasture, food scraps , etc. ⭘

Users and marketing

16. Out of 100 units of the product, how many units are used for subsistence (i.e. by the farmer and his/her household) and how many are sold? ⭘
17. If it is sold, what percentage of the users are:
    - local rural people?
    - non-local rural people?
    - urban people?

- foreigners?

18. Is the product processed by the farmer before it is sold, or do they sell the raw product? Give details. ⭘
19. If the product is processed, are there any costs associated with processing? Explain and describe. ⭘
20. Where is the product usually sold – locally, in a nearby market town, in the nearest city? ⭘
21. Do farmers tend to take the product to market themselves or is there a 'middle-man' who comes to villages to purchase the product? Give details. ⭘
22. If the product is sold through traders how many points of sale are there for the product that has been collected from the site? ⭘
23. What is the current market price for a local unit of the product: ⭘
    - where the cultivators live?
    - in the nearest market?
    - in the nearest city?
24. Does the price vary very much during the year? Explain and describe. ⭘
25. If the product is not sold in any market, and you were not able to cultivate it, what effect would this have on your livelihood?
26. If you could no longer cultivate the product and had to replace it, what product would you need to buy and what would it cost for an equivalent amount? ⭘

Sustainable use

27. Looking over the past five years, have the yields of this product (per unit area), the inputs needed to produce it, or the price paid for it noticeably changed? Give details ⭘

This question is designed to identify cases where cultivation is unsustainable even over the short-term, and to shed light on important drivers of change (such as changing markets or demand). It may not detect longer-term unsustainability, which is a conservative shortcoming in that it will cause us to overestimate the long-term value of cultivation.

Labour costs

28. Does a legal minimum wage exist? If so, what is it?
29. What is the typical daily wage rate for agricultural labour in the area? Do rates fluctuate seasonally? Describe. ⭘
30. Is there much unemployment in the area? What are the probabilities of an individual getting a day of paid work if they wanted it? ⭘

31. Is there much seasonality in the demand for labour and levels of unemployment? Describe. ⭘

These questions are designed to help determine what value should be given to family labour used on the farm (Culitvated Goods Method 2 – questionnaire survey). As a general rule:

- If levels of unemployment are high throughout the year, value any family labour at zero
- If there are periods of high seasonal demand for labour (but high unemployment at other times of year) find out family labour inputs during those peak periods, and value it at the 'market rate'
- If there is a high demand for labour throughout the year, value annual inputs of family labour at relevant market rates

Cultivated Goods Method 2. Individual questionnaires with cultivators

It may be necessary to conduct individual questionnaires with cultivators. Through a workshop you should have identified the 5 most important cultivated goods and obtained essential background information on their seasonality, their use and marketing, and how many and what sort of households are involved in their cultivation. The purpose of this questionnaire survey of individual cultivators is to determine the **quantity** and **value** of this cultivation by interviewing a representative subset of households or businesses. The total quantity and value of cultivation across the entire area can then be estimated by multiplying mean values from these individual questionnaires by the total number of households or businesses in the area (obtained from the workshop).

Where should you do your survey?

- You will need to design a sampling frame for the questionnaire (i.e. decide who to interview) based on the information you have on the location of cultivators. It may be necessary to interview different people in different areas.
- If the workshop suggests that over 20% of cultivators are non-local you should consider sampling those communities/individuals in addition to local communities
- If harvesting by local communities is highly variable, or restricted to certain communities or identifiable groups within communities, consider surveying each of these sub-groups separately (i.e. stratifying your sample).

Who should you survey?

As far as possible use a randomised design for sampling respondents (e.g. every fifth household on a street or every fifth name on a complete list of farms in the area).

How many people should you interview?

During the survey you may find that some respondents do not cultivate the goods you are interested in. If that is the case move on to the next respondent but do include this 'negative' result in your analysis. Continue sampling, and recording any negative results, until you have interviewed at least 30 people who cultivate at least one of the products of interest. You should aim to survey a sufficiently large sample to reduce errors caused by variation, so if responses you receive show a high degree of variability you will need to interview more people.

When should you do the survey?

For seasonally harvested goods try to collect data during or immediately after the harvesting season rather than rely on people's memories. Consider when in the day is the best time to do the interviews – find out the time that is least inconvenient for people, or when most people will be at home if you are meeting people in their houses.

For questions marked with the symbol ⭘ it is important to try to get full, clear answers. Be prepared to revise the table and the information that is collected depending on what you have learnt about the product at the workshop and from other organisations, and in the light of your pilot data collection – this is a template for guidance only.

Social differentiation

If it is important for your analysis that you understand how benefits are distributed across different social groups, you will need to include some questions in your questionnaire which allow you to identify which social group the respondent belongs to. **Guidance 1** provides details on how to differentiate social groups. The questionnaire template (below) will need to be adapted to gather information accordingly (e.g. on gender; ethnicity; wealth status; age; marital status; education etc.)

Questionnaire template

Be prepared to revise the table and the information that is collected depending on what you have learnt about the product at the workshop and from other organisations etc. – **this is a template for guidance only**. It may be possible to determine some of the answers based on information given during the workshop (for example estimated costs of tools and materials).

However, for questions marked with the symbol ⭘ it is important to try to get full, clear answers.

Understanding the site boundaries

The site that is being considered and its boundaries should be made clear to the respondent at the start of each interview so that respondents answer the questions in relation to their harvest from that site only, and not their overall harvest of a particular product which may be sourced from locations other than the site of interest. This could be made clear by showing a map and should be emphasised throughout the interview - make sure the respondents know the area you are referring to, and only answer with reference to it.

[See next page for the questionnaire]

1. General information			
Name/number of respondent			
If appropriate include one or more questions which allow you to differentiate respondents according to the key factors affecting receipt of benefits. You may want to ask this at the end of the questionnaire once they feel more comfortable about the content of the questionnaire. *E.g.* Household size / Education / Ethnicity / Age / Marital status / Wealth status			
Date			
Location/name of village			
GPS location of house	N	E	
Are the questions being answered per individual or household?	**Individual**	**Household**	**Business**

2. Crops					
It is important here that you only focus on **up to five** cultivated goods identified as most important in the stakeholder workshop. If any livestock are among the top five cultivated goods then complete section 3.					
What is your **<u>total</u>** size of the land you farm in the area (use local units of area if appropriate):					
How many **fields** do you have?					
Which of the top five cultivated goods do you grow? ○ Please answer the column of questions for each one in turn, giving answers for the past year and all the land you farm in the area*.					
Unit of measurement for that crop ○					
Last year, how much of that crop did you produce? ○					
Last year, what was the average price obtained per unit**?○	1.	2.	3.	4.	5.
Percentage for own use					
Percentage sold/ bartered	**%**	**%**	**%**	**%**	**%**
Did you, or family members, spend (unpaid) time cultivating/ harvesting/ processing this crop? (Yes/No)					
If yes, how many person-days did you or your family spend cultivating/ harvesting/ processing this crop last year*?○					
Did you hire people to cultivate/harvest/process this crop? (Yes/No)					
If yes, how many person-days did hired people					

spend cultivating/ harvesting/ processing this crop last year*? ⭘					
What is the average daily wage rate you paid these hired people (outside of any reciprocal arrangements)?					
Cost of other inputs for this crop (seed, fertiliser, pesticide, water, fuel for machinery)*? ⭘					
What capital items (tools, materials or equipment) do you need for cultivating/ harvesting/ processing this crop? (e.g. tools, machinery)? ⭘					
How long do you expect each of these tools / machines to last (years)***? ⭘					
How much did each tool / machine cost to buy? ⭘					
Last year, what was spent on transporting and marketing this crop*?⭘					
If the crop is a perennial crop (e.g. fruit trees, vines, nut bushes, perennial herbs) ask the following:					
How much did it cost to establish the crop (e.g. plants, stakes, labour etc.)? ⭘					
For how many years will the crop remain productive? ⭘					

3. Livestock****			
It is important to find out the value of livestock as a contribution to cultivated goods. The value of the service that the land provides to livestock is determined from the value of all the feed it provides them.			
Do you have any livestock?	**Yes**		**No**
If yes, what? ⭘	**1.**	**2.**	**3.**
How many of each type did you have on average last year*? ⭘			
What percentage of the total food that these animals needed last year* came from the area*****? Think about all the food they ate (including pasture, fodder crops, hay, food waste, etc.)⭘			
What is the value of that feed? (i.e. how much would it cost you to replace that feed with purchased alternatives?) ⭘			

4. Footnotes
* If respondents find it difficult to accurately recall cultivation details for the past 12 months or for all the land they farm in the area, then break these questions down. For example, ask about the harvest on a monthly basis, and ask how many months the harvest lasts (and then add these figures up yourself, to get an annual total). If necessary you could do the same for each field the cultivator uses, and then add the answers up to get a total for their entire farm.
****** If the individual respondent does not sell what they cultivate but others do, then apply the mean price recorded from other respondents.
*** If any tools or equipment have a lifetime of more than one year, divide the initial purchase cost by their expected lifetime and add typical repair/maintenance costs. If tools are not specifically used/purchased for producing this particular good but are for general use, apply a sensible percentage to their purchase and maintenance cost.
**** Only complete this section for livestock identified as among the top 5 most important cultivated goods. Complete a separate column for each form of livestock which is among this top 5.
********* Here you are asking the respondent about <u>all</u> the animal feed they obtain from the current area or the alternative state that you are studying, i.e. not just from their farm. This may include cultivated feed crops, crop residues, pasture, browse cut from hedgerows and field margins etc.

Considerations when conducting cultivator questionnaires

<u>Site of interest</u>
The site that is being considered and its boundaries should be made clear when you start to interview each respondent so that participants answer the questions in relation to cultivation at that site only, and not their overall farming activity, which may be include fields in locations other than the site of interest. This could be made clear by showing a map and should be emphasised throughout the interview.

<u>Costs of farm inputs</u>
Getting cost data on other inputs can also be difficult. For example, the value of equipment used across all of a farmer's crops should be averaged across the site for all holdings, while the cost of seeds should be averaged only across the area over which they were planted. Capital costs will need to be averaged over some relevant lifetime, e.g. 30 years for a tractor, 2-5 years for hand tools, etc. Estimating total costs becomes especially complex when dealing with large capital costs and with crops with >1 year lifecycle. However, this toolkit is designed to present fairly basic and useable methods and has not considered this issue in detail.

<u>Accuracy of reporting and respondent recall</u>
Accuracy of recall is always an issue with interview surveys. You can minimise errors by (1) spending time building trust with landholders and ensuring that they understand the purpose of the interviews (they are more likely to be cooperative if there is some tangible benefit to them, e.g. if the interviews can be conducted under the umbrella of an existing local development project); (2) using interviewers who are

fluent in local languages, familiar with local cultivation methods, and known to landholders (e.g. local agricultural extension officers); (3) breaking down the period (or area) of reference – so instead of asking about the amount harvested in the last year (or the whole farm), ask about harvest on a monthly (or field) basis, and then add the monthly (field) totals; (4) triangulating responses where possible, for example by using different recall periods or comparing data collected using different methods; (5) training interviewers to spot and challenge suspect responses.

Local units

The biggest pitfall here is the use of local units for area and for quantities of product. **Do not assume that units such as "acres", "tonnes" and "kilos" bear any relationship to internationally recognised definitions**. Ground-truthing, by measuring defined areas in the field, and weighing quantities of product, is essential.

Markets

If market prices fluctuate widely, it might be preferable to use an averaged price based on recent historical prices (taking inflation into account).

Licence fees, taxes and subsidies

Licence fees and taxes are not a production cost, but a mechanism for redistributing benefits. Therefore they should not be included as a cost in calculating the net value of ecosystem service benefits. Likewise subsidies to cultivation (e.g. single farm payments to European Union farmers) are not a benefit from the ecosystem so should be excluded in estimating the net value which the ecosystem provides.

Feed for livestock

If feed for livestock was identified as among the most important cultivated goods, then it will be important to establish whether this is mainly for sale or subsistence. See notes on this below under the section 'Important considerations when conducting the individual questionnaire'.

It is also important to ensure that a clear distinction is made between cultivated feed, and wild feed. This method should be used for cultivated feed. For wild feed refer to Section III.

- **Cultivated feed** (this section) includes all feed that is produced from cultivated land, whether for sale or the respondent's own use, and whether provided in situ or harvested, including specially cultivated feed crops (e.g. hay, oats), pasture, crop residues and feed provided from the margins of cultivated land.
- **Wild feed** (section III) includes all feed fed in situ or gathered from uncultivated land (whether for sale or to feed the respondent's own livestock) including from uncultivated communal lands, forests, wetlands, grasslands etc.:

Methods: Nature-based recreation

Recreation Method 1. Census for estimating number of site visits

As a rough guide we suggest ignoring any visitation that results in <100 visits per year or, <$1,000 gross annual revenue. Three problems need to be addressed in estimating the annual number of visits to a site. The first is estimating visit numbers across the entire site. The ideal situation is where there is a focal point through which all visitors pass (such as an entrance); if there are two sites through which everyone passes collecting data at both would enable numbers to be cross-checked. In the absence of such focal points where everyone passes, it may be necessary to count people at two or more places where a large portion of visitors can be counted (e.g. where major paths intersect, or near facilities such as a picnic area, toilets, restaurant, information centre). In this case care should be taken to avoid double counting (e.g. by taking additional notes on vehicle registrations, or the composition of groups of pedestrian visitors, and comparing notes afterwards). If not every visitor goes to at least one of these locations it will also be necessary to estimate the fraction of visitors that do and adjust the census figure accordingly.

The second problem is in estimating visit numbers across an entire year, which is important because visit rates usually vary with weather, timing of holidays, etc. Ideally the census can be conducted for an entire year (e.g. by staff working at an entrance gate, as a minor addition to their duties). However, this is often impossible to achieve. One alternative is to count all visits on each of a reasonably large and representative sample of days through a year (such as Monday in week 1, Tuesday in week 2, etc); this would spread effort across peak and off-peak seasons, weekends and weekdays, etc. Failing that, another solution is to count all visits to the site on whichever dates are feasible, and to use data from other similar sites (ideally nearby) which do collect both annual and daily visit numbers to estimate the proportion of their yearly visits that took place on the census days; combining these two pieces of information can then yield an estimate of the annual visit total for the site of interest.

Worked example:

If over a 10-day census there were an estimated 1000 visits to the site and over exactly the same 10 days three similar sites nearby received a mean (across sites) of 0.025 of their annual visits, the estimated annual total at the site of interest would be 1000/0.025 = 40 000 visits.

The key assumption in this final method is that the proportion of the year's total visits that is received on the census days is the same across sites (hence the importance of having sites that are roughly similar in terms of factors that are likely to affect the timing of visits, such as weather, accessibility, etc.). Remember also that visits vary from year to year. Historical records can be useful as a cross-check.

The third problem is that if significant numbers of people (say >5% of visitors) are likely to be visiting the site for reasons other than nature-based tourism or recreation they should be discounted from the total. Whether this is an issue can probably be ascertained in advance (e.g. by talking to site staff or local stakeholders). If it is likely to be a problem and nature-related visitors cannot be distinguished from others visually it may be necessary to approach a small sample of visitors (say, 50 in total), asking them whether their main reason for being at the site is to experience nature, and using the results to adjust the estimated visit total. An example question could be: Please indicate what percentage of your reason for visiting this site is for viewing/appreciating nature and/or wildlife?

Worked example:

If the mean response to this answer is, 25%, you would then multiply your visit total by 0.25 to obtain an estimate of the number of nature-based “visit-equivalents”.

Last, you might also want to estimate what would happen to your total figures if the site were under the alternative state, in which case you could ask the same sample of visitors a question like:

Imagine if the state of site had changed **[specify how, given your estimate of the alternative state].** Would you come here?

Recreation Method 2. Questions for estimating tourism and recreation economic value of sites

The following questions will help you estimate the economic value that of the visits to the site. Because it is important to estimate what percentage of the total spend of the visit can be attributed to the nature at the site (e.g. forest, birds, charismatic species) this is deduced based on the response to a question about the likelihood that a visitor would still come if the state of site was changed; these are designed to enable you to value tourism in the alternative state. You must explain the characteristics of the alternative state clearly (perhaps even show a photograph of a nearby site that reflects the alternative state visually) for example:

"The alternative state would have 50% less forest cover with mostly exotic species such as Eucalyptus and Pine trees. There would be small-scale agriculture in the lower altitude areas and there would be no visitor facilities such as café, toilets, picnic sites".

Social differentiation

If it is important for your analysis that you understand how benefits are distributed across different social groups, you will need to include some questions in your questionnaire which allow you to identify which social group the respondent belongs to. **Guidance 1** provides details on how to differentiate social groups. The questionnaire template (below) will need to be adapted to gather information accordingly (e.g. on gender; ethnicity; wealth status; age; marital status; education etc.)

Questionnaire template

Be prepared to revise the table and the information that is collected depending on what you have learnt about the product at the workshop and from other organisations etc. – **this is a template for guidance only**. It may be possible to determine some of the answers based on information given during the workshop (for example estimated costs of tools and materials).

However, for questions marked with the symbol ⭘ it is important to try to get full, clear answers.

Understanding the site boundaries

The site that is being considered and its boundaries should be made clear to the respondent at the start of each interview so that respondents answer the questions in relation to their harvest from that site only, and not their overall harvest of a particular product which may be sourced from locations other than the site of interest. This could be made clear by showing a map and should be emphasised throughout the interview - make sure the respondents know the area you are referring to, and only answer with reference to it.

[See next page for the questionnaire]

Please use these questions for guidance only. Depending on the site you will need to change the specifics. For questions marked with the symbol ⭘ it is important to try to get full, clear answers.

Site name					
Respondent number					
Date					
Location interviewed (e.g. entrance gate)					
If appropriate include one or more questions which allow you to differentiate respondents according to the key factors affecting receipt of benefits. You may want to ask this at the end of the questionnaire once they feel more comfortable about the content of the questionnaire. *E.g.* Income / Education / Ethnicity / Age / Marital status					
What kind of visitor?	**International tourist**			**National visitor**	
Sex	**Male**			**Female**	
Age	**<18**	**18-29**	**30-49**	**50-69**	**70+**
How far away do you live? [Either a place or a distance in miles or km]					
	Foreign country (please indicate which country)				
International tourists only					
a. **How many days will you spend away from home whilst on this trip?** ⭘					
b. **How many people are you travelling with – in your group?** ⭘					
c. **In total, how much money do you expect to spend on the whole of your trip - locally (within 10 km of the site), elsewhere in the country, and in other countries? Include your travel costs getting here** ⭘	**(per person or per group – state which)** **Local spend** **National spend** **International**				
d. **How many days will you spend at this site during your trip?** ⭘					
e. **Of these activities, please rank them in order of**	**Viewing/appreciating forest, nature or**				

importance for your reason for visiting this site ◉ (1 = highest importance)	wildlife _____ Cultural, spiritual (visiting religious or spiritual sites, museums, etc.) _____ Exercise or sports_____ Time with family or friends _____ Other (please specify)_____ (e.g. picnic, education…)	
f. Imagine if the site was… [specify how, given your estimate of the alternative state]. Would you still come here for these activities?	Yes	No
National visitors only		
g. How many times have you visited this site in the last year? ◉ __________		
h. How many people are you travelling with – in your group? ◉		
i. In total, how much money do you expect to spend on the whole of a trip – locally (within 10 km of the site), and elsewhere in the country? Include things like entrance fees, food, accommodation, transport and fuel ◉	(per person or per group – state which) Local spend National spend	
j. Of these activities, please rank them in order of importance for your reason for visiting this site ◉ (1 = highest importance)	Viewing/appreciating forest, nature or wildlife _____% Cultural, spiritual (visiting religious or spiritual sites, museums, etc.) _____% Exercise or sports_____% Time with family or friends _____% Other (please specify)_____% (e.g. picnic, education…)	
k. Imagine if the site was… [specify how, given your estimate of the alternative state], would you	Yes	No

come here for these activities?		
Reliability of respondent/other notes		

Worked example 1 for Recreation Method 2:

A wetland near Cambridge has a total visit of 40,000 adults per year (derived using Recreation Method 1). Majority of the visitors are local residents in Cambridge living within 10 km from the site.

Number of visitors interviewed: 100 (precision level of 10% based on the mean total spend of a sub-sample)

Mean total spend (include transport costs, car parking fees, entrance fees, expenditures in the gift shops and cafes etc.): £10 per person

The total annual income derived from tourism and recreation for this wetland would therefore be: 40000 x 10 = £400,000 per year.

30% of visitors reported that they would still visit in the alternative state (meaning that 70% would not return).

The total annual income derived from nature-based tourism and recreation for this wetland would therefore be: 40000 x 10 x 0.7 = £280,000 per year.

Worked example 2 for Recreation Method 2:

A small reserve with rich endemic avifauna in a Caribbean island is an attraction for international tourists for nature-based activities such as birdwatching and trekking. A typical tourist spends a full day at the reserve.

Annual total visits of the island: 10,000 tourists per year (derived using Recreation Method 1 by interviewing key informant from the tourism board)

Number of tourists interviewed at the airport departure lounge = 85 (precision level of 20%)

Proportion of interviewed tourists visited the reserve: 20%

Therefore the annual total visit of the reserve is estimated to be: 10000 x 0.2 = 2000 tourists per year

Median total spend of a tourist per day (include transport costs, accommodation, car rental, meals etc.): $150 per person per day

The percentage of people who would still visit the alternative state (i.e. extinction of endemic animal species) is: 10%

The total annual value from tourism and recreation for this reserve would therefore be: 2000 x 150 = $300,000 per year

The total annual value from nature-based tourism and recreation for this reserve would therefore be: 300000 x 0.9 = $270,000 per year

Section 7. References, Glossary and Appendices

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Glossary

Agroforestry – Mixed systems of crops and trees providing wood, non-wood forest products, food, fuel, fodder and shelter.

Alternative state (counterfactual) – A plausible and often simplified description of how the future may develop, based on the best available current information and a coherent and internally consistent set of assumptions about key driving forces (e.g., availability of appropriate technology, market prices) and relationships. Alternative states are neither predictions nor projections and sometimes may be based on a "narrative storyline".

Beneficiaries - a person or group that receives benefits, profits, or advantages.

Benefit – *See Ecosystem service*.

Biodiversity (a contraction of biological diversity) – The variability among living organisms, including those that inhabit terrestrial, marine, and other aquatic ecosystems, and the ecological interactions of which they are a part. Biodiversity includes diversity within species, between species, and between ecosystems.

Biological diversity – *See Biodiversity*.

Biomass – The mass of tissues in living organisms in a population, ecosystem, or spatial unit.

Carbon sequestration – The process of increasing the carbon content of a reservoir other than the atmosphere.

Cultural services – The nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values.

Decision-maker – A person whose decisions, and the actions that follow from them, can influence a condition, process, or issue under consideration.

Deforestation – Conversion of forest to non-forest.

Degradation of an ecosystem service – For provisioning services, decreased production of the service through changes in area over which the services is provided, or decreased production per unit area. For regulating and supporting services, a reduction in the benefits obtained from the service, either through a change in the service or through human pressures on the service exceeding its limits. For cultural services, a change in the ecosystem features that decreases the cultural benefits provided by the ecosystem.

Degradation of ecosystem – A persistent reduction in the capacity to provide ecosystem services.

Discounting – Reducing the value of future goods to a representative present value based on economic theory

Double-counting – Erroneously including the same ecosystem service more than once in an economic analysis

Ecosystem – A dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit

Ecosystem service – the aspects of ecosystems utilized (actively and passively) to produce human well-being" (Fisher *et al.* 2009). These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth. The concept "ecosystem goods and services" is synonymous with ecosystem services.

Ecosystem stability (or ecosystem robustness) **–** A description of the dynamic properties of an ecosystem. An ecosystem is considered stable or robust if it returns to its original state after a perturbation, exhibits low temporal variability, or does not change dramatically in the face of a perturbation.

Equitable – Fairness of rights, distribution and access. Depending on the context this can refer to resources, services or power.

Forest – Systems in which trees are the predominant life forms. Forest statistics used in this assessment are based on areas that are dominated by trees (perennial woody plants taller than five meters at maturity), where the tree crown cover exceeds 10%, and where the area is more than 0.5 hectares. "Open forests" have a canopy cover between 10% and 40%, and "closed forests" a canopy cover of more than 40%. "Fragmented forests" refer to mosaics of forest patches and non-forest land.

Greenhouse gases (GHG) – Any gas that absorbs infrared radiation in the atmosphere.

Gross value – The total value without deductions; as the amount of sales, salary, profit, etc., before taking deductions for expenses, taxes, or other costs (opposed to net).

Human well-being – *See Well-being*.

Hydroperiod – This term is used to describe the timing, duration and depth of flooding and can range from a twice daily tide to a seasonal flood lasting days or months.

Indigenous knowledge (or local knowledge) – The knowledge that is unique to a given culture or society.

Intrinsic value – The value of something in and for itself, irrespective of its utility for people.

Land-cover – The physical coverage of land, usually expressed in terms of vegetation cover or lack of it. Related to, but not synonymous with, land-use.

Land-use – The human use of a piece of land for a certain purpose (such as irrigated agriculture or recreation). Influenced by, but not synonymous with, land-cover.

Landscape – An area of land that contains a mosaic of ecosystems, including human-dominated ecosystems. The term cultural landscape is often used when referring to landscapes containing significant human populations or in which there has been significant human influence on the land.

Local knowledge – See Indigenous knowledge.

Methane (CH_4) – A hydrocarbon that is a greenhouse gas with a global warming potential most recently estimated at 25 times that of carbon dioxide.

Mitigation – An anthropogenic intervention to reduce negative or unsustainable uses of ecosystems or to enhance sustainable practices.

Monitoring – to observe, record, or detect (an operation or condition) over time to identify trends

Nitrous oxide (N_2O) – A powerful greenhouse gas with a global warming potential of 298 times that of carbon dioxide.

Non-linearity – A relationship or process in which a small change in the value of a driver (i.e., an independent variable) produces a disproportionate change in the outcome (i.e., the dependent variable). Relationships where there is a sudden discontinuity or change in rate are sometimes referred to as abrupt and often form the basis of thresholds. In loose terms, they may lead to unexpected outcomes or "surprises".

Opportunity cost – The benefits forgone by undertaking one activity instead of another.

Policy-maker – A person with power to influence or determine policies and practices at an international, national, regional or local level.

Provisioning services – The products obtained from ecosystems, including, for example, genetic resources, food and fibre and fresh water.

Regulating services – The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.

Scale – The measurable dimensions of phenomena or observations. Expressed in physical units, such as meters, years, population size, or quantities moved or exchanged. In observations, scale determines the relative fineness and coarseness of different details and hence any patterns that these data may form.

Service – See *Ecosystem services*.

Site - an operative or potential management unit such as a protected area, community forest, farm co-operative, Important Bird Area, Key Biodiversity Area, Alliance for Zero Extinction site etc, typically ranging in size from 100 to 2,000,000 ha (1-20,000 km^2). A 'site' should not be thought of as broad as the country-scale. It must make sense in relation to the management and institutional context of the area being considered.

Stakeholder – A person, group or organisation that has a stake (interest) in the outcome of a particular activity.

Supporting services – Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include production of biomass, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling and provision of habitat.

Sustainable – capable of being maintained at a steady level without exhausting natural resources so that an ecosystem may yield continuous benefits to present populations and future generations without causing ecological damage.

Sustainability – A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs.

Threshold – A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, then fall sharply after a critical threshold of degradation is reached. Human behaviour, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers. (Compare *Non-linearity*.)

Tipping point - the point at which a system is displaced from a state of stable equilibrium into a different state. In such cases, a small (anthropogenic) change in nature may have disproportionate effects on the provision of the benefit (Balmford et al. 2008).

Trend – A pattern of change over time, over and above short-term fluctuations.

Valuation – The process of expressing a value for a particular service in a certain context (e.g., of decision-making) usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (e.g., sociology, ecology). See also *Value*.

Value – The contribution of an action or objective to user-specific goals, objectives, or conditions. Compare *Valuation*.

Watershed (also catchment basin) **–** The land area that drains into a particular watercourse or body of water. Sometimes used to describe the dividing line of high ground between two catchment basins.

Well-being – A context- and situation-dependent state comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind and spiritual experience.

Wetlands – Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters. May incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands.

Appendix 1. Habitat classification

The tree-dominated and grass-dominated habitat classification is based on the International Geosphere-Biosphere Project (IGBP) land-cover classification system (http://www.fao.org/forestry/4031-1-0.pdf); the wetlands classification is adapted from the International Union for Conservation of Nature (IUCN) wetlands atlas (Dugan, 1993); and the crop-dominated habitat and developed area classification is adapted from the National Land-cover Data (NLCD) land-cover class definitions (http://land-cover.usgs.gov/classes.php).

Tree-dominated habitats

Evergreen Needleleaf Forests – Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Almost all trees remain green all year. Canopy is never without green foliage.

Evergreen Broadleaf Forests – Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Almost all trees remain green all year. Canopy is never without green foliage.

Deciduous Needleleaf Forests – Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Consist of seasonal needleleaf tree communities with an annual cycle of leaf-on and leaf-off periods.

Deciduous Broadleaf Forests – Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Consist of seasonal broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.

Mixed Forests – Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Consist of tree communities with interspersed mixtures or mosaics of the other four forest cover types. None of the forest types exceeds 60% of landscape.

Closed Shrublands – Lands with woody vegetation less than 2 meters tall and with shrub canopy cover is >60%. The shrub foliage can be either evergreen or deciduous.

Open Shrublands – Lands with woody vegetation less than 2 meters tall and with shrub canopy cover is between 10-60%. The shrub foliage can be either evergreen or deciduous.

Woody Savannas – Lands with herbaceous and other understory systems, and with forest canopy cover between 30-60%. The forest cover height exceeds 2 meters.

Grass-dominated habitats

Savannas – Lands with herbaceous and other understory systems, and with forest canopy cover between 10-30%. The forest cover height exceeds 2 meters.

Grasslands – Lands with herbaceous types of cover. Tree and shrub cover is less than 10%.

Wetlands*

Estuaries/Salt marshes/Tidal flats – Areas that receive twice daily tides.

Coastal brackish/saline lagoons (including dune slacks) – Areas that are recharged twice daily through tidal
cycles.

Floodplains/Deltas (coastal and inland) – Areas that receive large seasonal hydrological pulses – e.g. annual flood event – and therefore have very different spatial extent between seasons. These lands may also subject to seasonal floods.

Forested wetlands – These are floodplain forests, swamp forests and could include mangroves. Some may be
on peat substrates, others on mineral substrates. These lands may also subject to seasonal floods.

Freshwater marshes – Areas that are not forested, usually groundwater-fed but can receive flood events. They
could range from large complexes like the Everglades to small marshes such as prairie potholes.

Peatlands – Areas where partially decayed vegetation matter accumulates to form organic-rich soils (peats);
may be groundwater fed (e.g. fens and some peat-dominated marshes) or rainwater fed (e.g. blanket bogs, raised bogs).

Freshwater lakes – Permanent water bodies that are hugely variable in origins, location, depth, function and level of eutrophication.

Crop-dominated habitats

Orchards/Vineyards (woody crops) – Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals. Areas dominated by non-natural woody vegetation; non-natural woody vegetative canopy accounts for 25-100 percent of the cover.

Planted/Cultivated (non-woody crops)/Others – Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover. This includes pasture/hay - areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops; row crops - areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton; small grains - areas used for the production of graminoid crops such as wheat, barley, oats, and rice; fallow - areas used for the production of crops that do not exhibit visable vegetation as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage; and urban/recreational grasses - vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Developed areas

Low Intensity Residential – Includes areas with a mixture of constructed materials and vegetation.

Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

High Intensity Residential – Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80 to100 percent of the cover.

Commercial/Industrial/Transportation – Includes infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

*Wetlands classification is largely based on the IUCN simplified version. The categories take into account the hydrological function/origin, habitat type and physical location. This, in turn, leads to an overlap in classification categories. This is a perennial problem for all wetland classification schemes and is, in fact, intractable. For example, an area may be a floodplain, containing both forested wetland areas and freshwater marsh areas, and also includes patches of accumulating peat.

IUCN Habitat Classification Scheme for BirdLife Partners

1 Forest
- 1.1 Boreal Forest
- 1.2 Subarctic Forest
- 1.3 Subantarctic Forest
- 1.4 Temperate Forest
- 1.5 Subtropical/Tropical Dry Forest
- 1.6 Subtropical/Tropical Moist Lowland Forest
- 1.7 Subtropical/Tropical Mangrove Forest Vegetation Above High Tide Level
- 1.8 Subtropical/Tropical Swamp Forest
- 1.9 Subtropical/Tropical Moist Montane Forest

2 Savanna
- 2.1 Dry Savanna
- 2.2 Moist Savana

3 Shrubland
- 3.1 Subarctic Shrubland
- 3.2 Subantarctic Shrubland
- 3.3 Boreal Shrubland
- 3.4 Temperate Shrubland
- 3.5 Subtropical/Tropical Dry Shrubland
- 3.6 Subtropical/Tropical Moist Shrubland
- 3.7 Subtropical/Tropical High Altitude Shrubland
- 3.8 Mediterranean-type Shrubby Vegetation

4 Grassland
- 4.1 Tundra
- 4.2 Subarctic Grassland
- 4.3 Subantarctic Grassland
- 4.4 Temperate Grassland
- 4.5 Subtropical/Tropical Dry Lowland Grassland
- 4.6 Subtropical/Tropical Seasonally Wet/Flooded Lowland Grassland
- 4.7 Subtropical/Tropical High Altitude Grassland

5 Wetlands (inland)
- 5.1 Permanent Rivers, Streams, Creeks [includes waterfalls]
- 5.2 Seasonal/Intermittent/Irregular Rivers, Streams, Creeks
- 5.3 Shrub Dominated Wetlands
- 5.4 Bogs, Marshes, Swamps, Fens, Peatlands [generally over 8 ha]
- 5.5 Permanent Freshwater Lakes [over 8 ha]
- 5.6 Seasonal/Intermittent Freshwater Lakes [over 8 ha]
- 5.7 Permanent Freshwater Marshes/Pools [under 8 ha]
- 5.8 Seasonal/Intermittent Freshwater Marshes/Pools [under 8 ha]
- 5.9 Freshwater Springs and Oases
- 5.10 Tundra Wetlands [includes pools and temporary waters from snowmelt]
- 5.11 Alpine Wetlands [includes temporary waters from snowmelt]
- 5.12 Geothermal Wetlands
- 5.13 Permanent Inland Deltas
- 5.14 Permanent Saline, Brackish or Alkaline Lakes

- 5.15 Seasonal/Intermittent Saline, Brackish or Alkaline Lakes and Flats
- 5.16 Permanent Saline, Brackish or Alkaline Marshes/Pools
- 5.17 Seasonal/Intermittent Saline, Brackish or Alkaline Marshes/Pools
- 5.18 Karst and Other Subterranean Inland Aquatic Systems

6 Rocky Areas [e.g. inland cliffs, mountain peaks]

7 Caves and Subterranean Habitats (non-aquatic)
- 7.1 Caves
- 7.2 Other Subterranean Habitats

8 Desert
- 8.1 Hot
- 8.2 Temperate
- 8.3 Cold

9 Marine Neritic (Submergent Nearshore Continental Shelf or Oceanic Island)
- 9.1 Pelagic
- 9.2 Subtidal Rock and Rocky Reefs
- 9.3 Subtidal Loose Rock/Pebble/Gravel
- 9.4 Subtidal Sandy
- 9.5 Subtidal Sandy-Mud
- 9.6 Subtidal Muddy
- 9.7 Macroalgal/Kelp
- 9.8 Coral Reef
  - 9.8.1 Outer Reef Channel
  - 9.8.2 Back Slope
  - 9.8.3 Foreslope (Outer Reef Slope)
  - 9.8.4 Lagoon
  - 9.8.5 Inter-Reef Soft Substrate
  - 9.8.6 Inter-Reef Rubble Substrate
- 9.9 Seagrass (Submerged)
- 9.10 Estuaries

10 Marine Oceanic
- 10.1 Epipelagic (0–200 m)
- 10.2 Mesopelagic (200–1,000 m)
- 10.3 Bathypelagic (1,000–4,000 m)
- 10.4 Abyssopelagic (4,000–6,000 m)

11 Marine Deep Ocean Floor (Benthic and Demersal)
- 11.1 Continental Slope/Bathyl Zone (200–4,000 m)
  - 11.1.1 Hard Substrate
  - 11.1.2 Soft Substrate
- 11.2 Abyssal Plain (4,000–6,000 m)
- 11.3 Abyssal Mountain/Hills (4,000–6,000 m)
- 11.4 Hadal/Deep Sea Trench (>6,000 m)
- 11.5 Seamount
- 11.6 Deep Sea Vents (Rifts/Seeps)

12 Marine Intertidal
- 12.1 Rocky Shoreline

12.2 Sandy Shoreline and/or Beaches, Sand Bars, Spits, etc.
12.3 Shingle and/or Pebble Shoreline and/or Beaches
12.4 Mud Shoreline and Intertidal Mud Flats
12.5 Salt Marshes (Emergent Grasses)
12.6 Tidepools
12.7 Mangrove Submerged Roots

13 Marine Coastal/Supratidal

13.1 Sea Cliffs and Rocky Offshore Islands
13.2 Coastal Caves/Karst
13.3 Coastal Sand Dunes
13.4 Coastal Brackish/Saline Lagoons/Marine Lakes
13.5 Coastal Freshwater Lakes

14 Artificial - Terrestrial

14.1 Arable Land
14.2 Pastureland
14.3 Plantations
14.4 Rural Gardens
14.5 Urban Areas
14.6 Subtropical/Tropical Heavily Degraded Former Forest

15 Artificial - Aquatic

15.1 Water Storage Areas [over 8 ha]
15.2 Ponds [below 8 ha]
15.3 Aquaculture Ponds
15.4 Salt Exploitation Sites
15.5 Excavations (open)
15.6 Wastewater Treatment Areas
15.7 Irrigated Land [includes irrigation channels]
15.8 Seasonally Flooded Agricultural Land
15.9 Canals and Drainage Channels, Ditches
15.10 Karst and Other Subterranean Hydrological Systems [human-made]
15.11 Marine Anthropogenic Structures
15.12 Mariculture Cages
15.13 Mari/Brackish-culture Ponds

16 Introduced Vegetation

17 Other

18 Unknown

Appendix 2. Estimated values of biomass and mineral soil organic matter of various habitat types.

The estimates of above-ground live biomass (AGB), below-ground biomass (BGB), dead wood (DEAD), litter or peat (LITTER) and soil organic matter in mineral soil (SOM) values (expressed in terms of Mg dry matter ha^{-1}) are compiled from Anderson-Teixeira and deLucia (2010). * See below the table for the definitions of habitat types used in this table.

Habitats*	AGB	BGB	DEAD	LITTER	SOM
Native					
Tropical peat forest	444	107	?	1389	297
Northern peatland	101	18	3	946	369
Marsh and swamp	150	19	?	25	350
Tropical forest	250	55	20	10	297
Temperate forest	534	139	103	51	275
Boreal forest	128	28	6	59	160
Tropical savanna	21	39	0	14	228
Temperate scrub/woodland	48	48	0	6	153
Temperate grassland	2.3	14	0	6	202
Tundra	11.7	12	0	120	245
Desert	7	8	0	0.2	107
Aggrading					
Tropical forest	0	2	0	1	-
Temperate forest	0	2	0	1	-
Boreal forest	0	2	0	1	-
Tropical non-forest	0	2	0	1	-
Temperate non-forest	0	2	0	1	-
Managed					
Tropical pasture	3.6	15.2	0	0	228
Temperate pasture	2.3	14	0	6	202
Tropical cropland	10	2	0	1	-
Temperate cropland	10	2	0	1	-
Wetland rice	10	2	0	6	107

The estimates are mean values. Refer to Anderson-Teixeira and deLucia (2010) for the number of sites contributing to the estimate, and references from which the values were obtained.

Definitions of habitat types

Compiled from Anderson-Teixeira and deLucia (2010). Note that this is a different, and less exhaustive list to that in Appendix 1 – however, this list is for the very specific purpose of use in Appendix 2 and 4, while the list in Appendix 1 serves the wider needs of the toolkit.

Native habitats	Description
Tropical peat forest	Tropical wetland forest with significant peat accumulation. No recent disturbance or drainage.
Northern peatland	Northern wetlands with significant peat accumulation. Includes bogs, fens, and forested peatlands. No recent disturbance or drainage.
Marsh and swamp	Wetland without significant peat accumulation in any climate. Includes flooded grasslands and savannas, freshwater marsh, and freshwater swamps. No recent disturbance or drainage.
Tropical forest	Unmanaged tropical (humid or semi-arid) forest with no recent disturbance, aged at least 23 years.
Temperate forest	Unmanaged temperate (humid or semi-arid) forest with no recent disturbance, aged at least 72 years.
Boreal forest	Unmanaged temperate (humid or semi-arid) forest with no recent disturbance, aged at least 75 years.
Tropical savanna	Unmanaged tropical savannas, ranging from grassland savannas to savanna woodland. As frequent fires occur naturally, recently burned sites were not excluded.
Temperate scrub/woodland	Temperate non-desert and non-forest ecosystems with woody vegetation. Includes closed shrubland, sclerophyllous shrub, savanna, chaparral, and woodland. As frequent fires occur naturally, recently burned sites were not excluded.
Temperate grassland	Unmanaged temperate grasslands. As frequent fires occur naturally, recently burned sites were not excluded.
Tundra	Undisturbed tundra (no trees).

Desert	Undisturbed deserts, including desert grasslands and shrublands.

Aggrading habitats	Description
Tropical forest	Unmanaged tropical (humid or semi-arid) forest with major disturbance in the last 23 years.
Temperate forest	Unmanaged temperate (humid or semi-arid) forest with major disturbance in the last 72 years.
Boreal forest	Unmanaged temperate (humid or semi-arid) forest with major disturbance in the last 75 years.
Tropical non-forest	Former agricultural land in tropical regions that is not succeeding to forest, or where succession to forest is significantly delayed. This includes both abandoned land in non-forest regions and degraded land in forest regions.
Temperate non-forest	Former agricultural land in temperate regions of age ≤10 years that is succeeding to grassland or shrubland/woodland.

Managed habitats	Description
Tropical pasture	Tropical pasture (grassland) with moderate, sustainable grazing intensity.
Temperate pasture	Temperate pasture (temperate grassland biomes) with moderate, sustainable grazing intensity.
Tropical cropland	Annually tilled tropical cropland that has been under cultivation long enough for soil carbon to have reached equilibrium.
Temperate cropland	Annually tilled temperate cropland that has been under cultivation long enough for soil carbon to have reached equilibrium.
Wetland rice	Wetland rice that has been under cultivation long enough for soil carbon to have reached equilibrium.

Appendix 3. Equations for estimating above-ground live biomass for different tree species and habitats

Temperate ecosystem equations (where D is diameter at breast height)

General classification	Species group	Equation	Source	Data originating from	Max. D (cm)
Hardwood	General	Biomass = 0.5 + ((25000 x $D^{2.5}$)/ ($D^{2.5}$ + 246872))	Schroeder *et al.* (1997)	Eastern USA	85.1
Hardwood	Aspen/alder/ cottonwood/ willow	Biomass = exp(-2.9132 + 0.9232 x lnD)	Jenkins *et al.* (2003)	USA	70.0
Hardwood	Soft maple/birch	Biomass = exp(-1.9123 + 2.3651 x lnD)	Jenkins *et al.* (2003)	USA	66.0
Hardwood	Mixed hardwood	Biomass = exp(-2.4800 + 2.4835 x lnD)	Jenkins *et al.* (2003)	USA	56.0
Hardwood	Maple/oak/hickory / beech	Biomass = exp(-2.0127 + 2.4342 x lnD)	Jenkins *et al.* (2003)	USA	73.0
Hardwood	Beech	Biomass = exp(-3.0366 + 2.5395 x lnD)	Joosten *et al.* (2004)	Germany	~70.0
Softwood	Pine	Biomass = 0.887 + ((10486 x $D^{2.84}$)/($D^{2.84}$ + 376907))	Brown and Schroeder (1999)	Eastern USA	56.1

Softwood	Fir/spruce	Biomass = 0.357 + ((34185 x $D^{2.47}$)/($D^{2.47}$ + 425676))	Brown and Schroeder (1999)	Eastern USA	71.6
Softwood	Cedar/larch	Biomass = exp(-2.0336 + 2.2592 x lnD)	Jenkins *et al.* (2003)	USA	250.0
Softwood	Douglas-fir	Biomass = exp(-2.2304 + 2.4435 x lnD)	Jenkins *et al.* (2003)	USA	210.0
Softwood	True fir/hemlock	Biomass = exp(-2.5384 + 2.4814 x lnD)	Jenkins *et al.* (2003)	USA	230.0
Softwood	Pine	Biomass = exp(-2.5356 + 2.4349 x lnD)	Jenkins *et al.* (2003)	Western USA	180.0
Softwood	Spruce	Biomass = exp(-2.0773 + 2.3323 x lnD)	Jenkins *et al.* (2003)	Western USA	250.0
Softwood	Scots Pine	Biomass = 0.152 x $D^{2.234}$	Xiao and Ceulemans (2004)	The Netherlands	9.87
Woodland	Juniper/oak/mesquite	Biomass = exp(-0.7152 + 1.7029 x lnD)	Jenkins *et al.* (2003)	USA	78.0

Tropical ecosystem equations (where D is diameter at breast height, and BA is basal area)

General classification	Species group	Equation	Source	Data originating from	Max. D (cm)
Dry (<900 mm rainfall)	General	Biomass = $10^{(-0.535 + \log BA)}$	Brown (1997)	Mexico	30.0
Dry (900-1500 mm rainfall)	General	Biomass = $0.2035 \times D^{2.3196}$	Brown (unpublished)		63.0
Moist (1500-4000 mm rainfall)	General	Biomass = $\exp(-2.289 + 2.649 \times \ln D – 0.021 \times \ln D^2)$	Brown (1997)		148.0
Wet (> 4000 mm rainfall)	General	Biomass = $21.297 -6.953 \times D + 0.740 \times D^2$	Brown (1997)		112.0
Cecropia	*Cecropia* species	Biomass = $12.764 + 0.2588 \times D^{2.0515}$	Winrock	Boliva	40.0

Agroforestry equations in tropics (where D is diameter at breast height, and BA is basal area)

General classification	Species group	Equation	Source	Data originating from	Max. D (cm)
Agroforestry shade trees	All	$\text{Log}_{10}\text{Biomass} = -0.834 + 2.223(\log_{10} D)$	Segura *et al.* (2006)	Nicaragua	44.0

Shade grown coffee	Coffea arabica	Biomass = exp(-2.719 + 1.991(lnD) x $\log_{10}$D	Segura *et al.* (2006)	Nicaragua	8.0
Pruned coffee	Coffea arabica	Biomass = 0.281 x $D^{2.06}$	van Noordwijk *et al.* (2002)	Java, Indonesia	10.0
Banana	*Musa* X *paradisiaca*	Biomass = 0.030 x $D^{2.13}$	van Noordwijk *et al.* (2002)	Java, Indonesia	28.0
Peach palm	*Bactris gasipaes*	Biomass = 0.97 + 0.078 x BA – 0.00094 x BA^2 + 0.0000065 x BA^3	Schroth *et al.* (2002)	Amazonia	2.0 – 12.0
Rubber trees	*Hevea brasiliensis*	Biomass = -3.84 + 0.528 x BA + 0.001 x BA^2	Schroth *et al.* (2002)	Amazonia	6.0 – 20.0
Orange trees	*Citrus sinensis*	Biomass = -6.64 + 0.279 x BA + 0.000514 x BA^2	Schroth *et al.* (2002)	Amazonia	8.0 – 17.0
Brazil nut trees	*Bertholletia excelsa*	Biomass = -18.1 + 0.663 x BA - 0.000384 x BA^2	Schroth *et al.* (2002)	Amazonia	8.0 – 26.0
Homegarden	All	Biomass = exp(-2.134 + 2.530 x ln D)	Brown (1997)		

Appendix 4. Estimated values of greenhouse gas flux of various habitats

The estimates of carbon dioxide flux (kmol CO_2 ha^{-1} y^{-1}), methane flux (kmol CH_4 ha^{-1} y^{-1}) and nitrous oxide flux (kmol N_2O ha^{-1} y^{-1}) of various habitat types are compiled from Anderson-Teixeira and deLucia (2010). *See below the table for the definitions of habitat types.

Habitats*	Carbon dioxide flux	Methane flux	Nitrous Oxide flux
Native			
Tropical peat forest	-443	9.9	0.017
Northern peatland	-22	9.9	0.009
Marsh and swamp	-50	16.4	0.065
Tropical forest	-144	-0.23	0.082
Temperate forest	-155	-0.23	0.026
Boreal forest	-38	-0.23	0.026
Tropical savanna	-83	-0.19	0.029
Temperate	-141	-0.19	0.013
Temperate grassland	-34	-0.15	0.012
Tundra	-26	-0.19	0.012
Desert	-11	-0.19	0.005
Aggrading			
Tropical forest	-467	-0.23	0.031
Temperate forest	-302	-0.23	0.026
Boreal forest	-159	-0.23	0.026
Tropical non-forest	-128	-0.19	0.012
Temperate non-forest	-131	-0.19	0.029
Managed			
Tropical pasture	-35	-0.15	0.067
Temperate pasture	5	-0.15	0.134
Tropical cropland	0	-0.13	0.152
Temperate cropland	0	-0.13	0.151
Wetland rice	0	23	0.097

Sign convention: negative indicates non-greenhouse gas uptake by habitats. The estimates are mean values for carbon dioxide flux and nitrous oxide flux, and median values for methane flux. Refer to Anderson-Teixeira and deLucia (2010) for the number of sites contributing to the estimate, and references from which the values were obtained.

Definitions of habitat types

Compiled from Anderson-Teixeira and deLucia (2010). Note that this is a different, and less exhaustive list to that in Appendix 1 – however, this list is for the very specific purpose of use in Appendix 2 and 4, while the list in Appendix 1 serves the wider needs of the toolkit.

Native habitats	Description
Tropical peat forest	Tropical wetland forest with significant peat accumulation. No recent disturbance or drainage.
Northern peatland	Northern wetlands with significant peat accumulation. Includes bogs, fens, and

	forested peatlands. No recent disturbance or drainage.
Marsh and swamp	Wetland without significant peat accumulation in any climate. Includes flooded grasslands and savannas, freshwater marsh, and freshwater swamps. No recent disturbance or drainage.
Tropical forest	Unmanaged tropical (humid or semi-arid) forest with no recent disturbance, aged at least 23 years.
Temperate forest	Unmanaged temperate (humid or semi-arid) forest with no recent disturbance, aged at least 72 years.
Boreal forest	Unmanaged temperate (humid or semi-arid) forest with no recent disturbance, aged at least 75 years.
Tropical savanna	Unmanaged tropical savannas, ranging from grassland savannas to savanna woodland. As frequent fires occur naturally, recently burned sites were not excluded.
Temperate scrub/woodland	Temperate non-desert and non-forest ecosystems with woody vegetation. Includes closed shrubland, sclerophyllous shrub, savanna, chaparral, and woodland. As frequent fires occur naturally, recently burned sites were not excluded.
Temperate grassland	Unmanaged temperate grasslands. As frequent fires occur naturally, recently burned sites were not excluded.
Tundra	Undisturbed tundra (no trees).
Desert	Undisturbed deserts, including desert grasslands and shrublands.

Aggrading habitats	Description
Tropical forest	Unmanaged tropical (humid or semi-arid) forest with major disturbance in the last 23 years.
Temperate forest	Unmanaged temperate (humid or semi-arid) forest with major disturbance in the last 72 years.
Boreal forest	Unmanaged temperate (humid or semi-arid) forest with major disturbance in the last 75 years.
Tropical non-forest	Former agricultural land in tropical regions that is not succeeding to forest, or where succession to forest is significantly delayed. This includes both abandoned land in non-forest regions and degraded land in forest regions.

Temperate non-forest	Former agricultural land in temperate regions of age ≤10 years that is succeeding to grassland or shrubland/woodland.

Managed habitats	Description
Tropical pasture	Tropical pasture (grassland) with moderate, sustainable grazing intensity.
Temperate pasture	Temperate pasture (temperate grassland biomes) with moderate, sustainable grazing intensity.
Tropical cropland	Annually tilled tropical cropland that has been under cultivation long enough for soil carbon to have reached equilibrium.
Temperate cropland	Annually tilled temperate cropland that has been under cultivation long enough for soil carbon to have reached equilibrium.
Wetland rice	Wetland rice that has been under cultivation long enough for soil carbon to have reached equilibrium.

Appendix 5. Ethical Protocols

This guidance is based on the Code of Conduct for researchers contributing articles to Oryx, as published in Oryx 35(2), 99-100.

Conservation research should conform to the highest possible ethical and legal standards. The Code detailed below covers important aspects of both research and the preparation of articles for publication.

1. All research must have the necessary approvals and permits from appropriate institutions and statutory authorities in both the host country and the researchers' country of origin (if different).

2. Any intellectual property rights on data and results obtained from the research must be managed within the legal requirements of the host country and be shared fairly among the participants, especially those from the host country. Such arrangements should be formalized prior to initiating the research through prior informed consent by the host country and institutes. Research should not infringe local rights in intellectual property. If research is carried out in a host country that has few legal requirements for such work, researchers should follow the standards of their country of origin.

3. Capacity building is an important component of conservation activity, as well as the importance of full involvement by all stakeholders in research activity. Therefore we recommend that:

- any social, anthropological or ethnobiological research should follow the highest standards of research ethics;
- researchers should confirm that their research conforms to the standards set out by a reputable source, such as the guidelines developed by the British Sociological Association, which are based on the ethical codes produced by the American Sociological Association, the Association of Social Anthropologists of the Commonwealth, and the Social Research Association.

4. Any research undertaken in a foreign country should, wherever possible, be based on active collaboration with appropriately qualified and experienced individuals from the host country. One objective of the research should be, where necessary, to enhance the capacity of scientific and technical staff in the host country.

- Copies of any reports and publications resulting from the research shall routinely be provided to all relevant institutions in the country where the research is being undertaken
- Wherever appropriate, researchers from the host country should be included as co-authors of all relevant publications.
- Where appropriate, the results of research should be reported back to relevant local and national organizations.
- Where research involves fieldwork in areas occupied by people, or affects species or ecosystems within which people have de facto or de jure tenure rights or cultural connections, it should be carried out in a way that respects local beliefs, economic and cultural interests, and rights.

- Where relevant, research should involve the participation of local partners, and should have regard for the enhancement of local capacity to understand and manage ecosystems and populations.

5. Field researchers should adopt the highest precautionary standards to avoid the accidental introduction and distribution of invasive and pathogenic organisms.

6. For more details see: Social Research Association: Ethical Guidelines, 2003. http://www.the-sra.org.uk/documents/pdfs/ethics03.pdf

Section 8. Annexes

Annex 1. Workplan

Having conducted the Rapid Appraisal at the site, it is important to plan your work for the full assessment. Each site is unique and so you will need to use your own knowledge to determine which of the services and which of the methods provided in this toolkit will be suitable at the site. By following steps 4 – 8 in Section 2, complete this planning matrix to help plan the work. It is advisable to collect all the information required with the minimum effort in order to keep the work practical, manageable and cost-effective.

<table>
<tr><td>A1.1 Specify the policy change or management issue being addressed</td><td></td><td colspan="7">A1.5 Select appropriate survey methods (refer to Methods)</td></tr>
<tr><td colspan="2"></td><td>Secondary data</td><td>Stakeholder workshop</td><td>Household questionnaire</td><td>Focus group interviews</td><td>Key informant interviews</td><td>Field work</td><td>Modelling tool</td></tr>
<tr><td>A1.2 Describe the alternative state</td><td>A1.3 Note the location(s) for taking measurements of the alternative state</td><td>Climate M1, 2, 5, 6, 8-14, Water M3, Recreation M1</td><td>Water M1, 6-7, Wild Goods M1</td><td>Water M4, Wild Goods M2, Cultivated Goods M2</td><td>Wild Goods M1, Cultivated Goods M1</td><td>Cultivated Goods M2, Recreation M1</td><td>Climate M3, 4, 7, Water M6, 7, Recreation M2</td><td>Water M2, 5</td></tr>
<tr><td colspan="2">A1.4 Ecosystem services to measure</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td colspan="2">4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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Activity Timeline	1	2	3	4	5	6	7	8	9	10	11	12	

Annex 2. Complexities not yet incorporated into the toolkit

The following are difficult issues which the toolkit has not dealt with yet. Nevertheless, it is important to give explicit consideration to these issues in the future in-depth assessments.

Non-linearities

The relationship between biodiversity and ecosystem services and between services is complex and rarely linear. These non-linearities are represented by a relationship or process in which a small change in the value of a driver (i.e., an independent variable) produces a disproportionate change in the outcome (i.e., the dependent variable). Relationships where there is a sudden discontinuity or change in rate are sometimes referred to as abrupt and often form the basis of thresholds. In loose terms, they may lead to unexpected outcomes or “surprises.”

Tipping points

i.e. the point at which a system is displaced from a state of stable equilibrium into a different state. In such cases, a small change in nature may have disproportionate effects on the provision of the benefit (Balmford et al. 2008). For example, there may be a threshold at which sufficient habitat destruction may result in the population crash of pollinating insects or collapse of key pollinating species (Larsen et al. 2005).

Resilience

Ecosystem resilience, i.e. an ecosystem’s ability to maintain its basic functions and controls under disturbances, is an important consideration. Resilience relates to the vulnerability of an ecosystem i.e. whether it can accommodate changes without losing key functionality. Studies have shown that decreasing the functional diversity of a system may have a negative impact on the ability of the ecosystem to survive disturbances (Schulze and Mooney 1993; Folke et al. 1996). This is particularly relevant in relation to climate change, and changing weather patterns.

Discounting

Discounting applies to the economic value of ecosystem services that are obtained over time (e.g. sustainable off-take of harvested wild goods). Calculating the economic value of benefits over time requires consideration of the potential value of services to future generations. In economics this is dealt with by discounting future values to an equivalent present value based on the fact that we value the future less than today.

This requires a much more complex consideration of the time horizon influencing the alternative state and the change in flows of ecosystem services into the future - a level of economics that is beyond what this toolkit aims to achieve. Since we are focusing on the change in delivery of services between two states and not projecting this strictly into the future, we consider that discounting does not need to be considered unless the user wishes to do so and has the capability to do so.

Future development of the toolkit

The toolkit is currently a hard-copy document. During the second stage of this project we intend to make it web-based and more interactive, and add proforma datasheets for ease of use and understanding.