TESSA: a toolkit for rapid assessment of ecosystem services at sites of biodiversity conservation importance

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ABSTRACT

Sites that are important for biodiversity conservation can also provide significant benefits (i.e. ecosystem services) to people. Decision-makers need to know how change to a site, whether development or restoration, would affect the delivery of services and the distribution of any benefits among stakeholders. However, there are relatively few empirical studies that present this information. One reason is the lack of appropriate methods and tools for ecosystem service assessment that do not require substantial resources or specialist technical knowledge, or rely heavily upon existing data. Here we address this gap by describing the Toolkit for Ecosystem Service Site-based Assessment (TESSA). It could guide local non-specialists through a selection of relatively accessible methods for identifying which ecosystem services may be important at a site, and for evaluating the magnitude of benefits that people obtain from them currently, compared with those expected under alternative land-uses. The toolkit recommends use of existing data where appropriate and places emphasis on enabling users to collect new field data at relatively low cost and effort. By using TESSA, the users could also gain valuable information about the alternative land-uses; and data collected in the field could be incorporated into regular monitoring programmes.

Key words: Climate regulation; Cultivated goods; Ecosystem-service tools; Harvested wild goods; Nature-based recreation; Water-related services

1. Introduction

There has been growing international recognition that the contribution that nature makes to human well-being is often not adequately valued or integrated in decision-making, and that ecosystem services are being eroded as a result (MEA, 2005), with considerable cost to society (Kumar, 2010). Increasingly, governments are being asked to initiate a range of policy processes aimed at integrating the environment and development, including environmental mainstreaming (UNDP-UNEP, 2009), achieving the proposed Sustainable Development Goals (UNCSD Secretariat, 2012) and delivering a Green Economy (ten Brink et al., 2012). In addition, countries have committed to assessing their contribution to the Convention on Biological Diversity's Strategic Plan 2011–2020 by tracking progress against the 20 Aichi Biodiversity Targets (Conference of the Parties [COP] 10; CBD, 2010). Target 14 directly relates to maintaining and enhancing ecosystem services.

Ecosystem service provision varies spatially across landscapes, determined by diverse human social, political and ecological interactions. Measuring services at broad scales is mostly reliant on modelling approaches, which are often limited by the coarse resolution of the input data. In order to inform local decision-making, there is a growing need to measure ecosystem services at individual sites at a fine spatial grain, as this is the scale at which many land-use decisions are typically made and need to be informed. Such information is valuable for establishing whether there are utilitarian, as well as intrinsic arguments, in support of conserving particular areas, and for informing decision-makers whether conserving (rather than converting), or restoring, a site has broader benefits for society (Balmford et al., 2002; Turner et al. 2003).

To be useful at the site scale, methods for quantifying services need to produce data relevant to decisions affecting that site, should be practical and affordable (in terms of expertise, equipment and time) and should provide results in an accessible form to actors such as policy-makers, planners and land managers. A range of tools have been developed that bear testament to great progress in measuring ecosystem services. However, some issues remain, especially in respect of site-scale assessments (see Table A for an overview of multi-ecosystem service assessment techniques). They tend to rely upon either technically demanding or expensive fieldwork (Fisher et al., 2011), and/or the use of models or extrapolation from data collected in other locations (Turner et al., 2012; Posthumus et al., 2010) which may not reflect local conditions (Eigenbrod et al. 2010). Most other tools are not appropriate for estimating the net consequences of a particular action (e.g. conversion to a different land use) on ecosystem services (Balmford et al., 2008) even though this is often the question of greatest interest to decision-makers. TESSA provides a net benefits framework through applying a set of appropriate methods for two alternative states of a site. It recommends use of existing data where appropriate and places emphasis on enabling users to collect new field data at relatively low cost and effort. It thus combines the advantages of other approaches into an innovative practical toolkit. If TESSA is routinely performed across site-network, this will provide good data for landscape-scale decision tools such as InVEST (see Table A).

We achieved this by working with many ecosystem service experts to develop a toolkit designed to enable stakeholders with limited capacity, time and resources to gather accessible, robust and locally relevant ecosystem service information for themselves,. TESSA (available at http://www.birdlife.org/datazone/info/estoolkit) currently includes five classes of services (selected based on their importance and measurement tractability): global climate-regulating services, water-related services, harvested wild goods, cultivated goods and nature-based recreation.

2. Toolkit design

TESSA is designed to help users identify which ecosystem services to assess, what data are needed to measure them, which methods or sources might be used in different contexts, and how the results can then be communicated. For ease of use, decision trees lead the user towards specific methods, providing additional guidance on data collection and analysis. However, because sites vary widely, methods are designed as templates only and users need to adapt the methods according to local conditions.

A methodological framework is outlined in Fig.A. Preliminary work involves defining the site of interest based on its biological importance and perceived threats, exploring the local policy and governance context, and identifying stakeholders. The early engagement of stakeholders and decision-makers is a key component of an assessment of this kind, as it can help to provide an accurate understanding of the economic, ecological, social and cultural importance of the site, and help ensure that the results are relevant to individuals who will determine its future. Indeed, engaging stakeholders in identifying and assessing services, and sharing the information, often results in existing tensions between groups being ameliorated (Edwards and Gibeau, 2013), so the process itself can have benefits almost independent of its findings. Regular communication with key officials and stakeholders, including local beneficiaries and/or losers will help to embed the results in local and national policy levels.

Next, a rapid appraisal helps to identify the most important habitats, drivers of land-use change and the services provided by the site. Different stakeholders will recognise and value services differently, so TESSA offers guidance to help users understand and consider all services (Table B). This includes those services that may be important to distant beneficiaries but which are not necessarily recognised by local stakeholders, and vice versa. The rapid appraisal identifies all services that are delivered by a site, but further assessment then focuses on those that are: (1) significant in either biophysical, social or economic terms; (2) sensitive to potential drivers of change; and (3) measurable with limited capacity and resources.

Information gathered about drivers of land-use change can then be used, in combination with knowledge of the local context, to work with stakeholders to identify the most plausible alternative state or states of the site. The plausible alternative state is a description of how the future (typically the next 10-20 years) may plausibly develop (or how a past decision has affected the current state), based on the management question of interest, the best available current information and a coherent and internally consistent set of assumptions about key threats and drivers of change. Its identification often requires consideration of the policy, management and governance context at the site and the most likely threats. Often the plausible alternative state involves the site being converted (e.g. to agriculture) or being intensively exploited (e.g. by logging), but TESSA can also be used for assessing the ecosystem-service consequences of restoring a currently degraded site. To be most useful, the assessment of the alternative state should include all significant services under the current state of the site, as well as any new services delivered under the alternative state, and any one-off changes in stocks (such as timber obtained when a forest is cleared for farming) generated by conversion between states. Measuring these one-off goods and including them in the overall assessment (alongside changes in the annual flows of all other measured services) is essential for understanding the net benefits (or costs) of conservation. Whenever possible, data representative of the alternative state should be collected from a nearby site that that has undergone the plausible change but which is otherwise as similar as possible to the focal site in terms of attributes such as geological and hydro-climatological characteristics, steepness of the terrain, and proximity to beneficiaries of the same social background.

Having identified focal services and the appropriate alternative state of the site, TESSA then leads the user through decision trees to appropriate methods for each service. These include collecting primary data through field surveys, key informant interviews and household questionnaires; using existing databases and studies; and (in one instance) employing numerical models (Table C); the chosen method will depend on the availability of time, resources, expertise and on the extent to which useful data have already been collected. Primary (field) data collection is desirable wherever resources permit, because these provide contemporary, ground-truthed, site-specific data and important local contextual information. For example, a user facing the task of estimating carbon storage in above-ground biomass could use one of two approaches: (1) using credible values from similar sites or reliable sources (e.g. IPCC reports); and (2) conducting simple field surveys to quantify the biomass of living vegetation. In this case, the trade-off is between the extra precision of (2), versus the smaller demand on resources in (1). Estimating total carbon storage in a system (across all carbon pools) may involve using a combination of these methods. In a similar way, estimates of water provisioning services can be generated using data from water companies or from questionnaire surveys. However, estimating how water-related services are likely to change under alternative states is often difficult because of the complex interplay between biophysical and social factors. To address this, the toolkit recommends the use of an accessible web-based tool to generate information on plausible proportional changes in water provision, peak flows and sedimentation so that the data collected from the questionnaire surveys and/or water agency could then be calibrated for the alternative state (Mulligan 2012).

Decision-makers and stakeholders need to know not only the overall change in net service provision but also the impact of such changes across different groups of people. TESSA includes guidance on how to assess the distribution of benefits between stakeholders both according to spatial scale (e.g. local, national and global) and among different socio-economic groups (e.g. richer vs. poorer people in local communities). This can provide useful information on how decisions about land-use at sites can have both positive and negative outcomes for people, depending on who they are.

We believe that the incorporation of a diverse range of data collection techniques increases the flexibility and usefulness of TESSA. However, it is important to recognise that the resulting data are associated with varying levels of uncertainty, with some methods yielding results with lower degrees of confidence. For example, while methods involving new local data collection can yield high accuracy, the use of values from other studies could introduce uncertainty if (1) the method from which the values were derived is unknown or not comparable (e.g. the use of harvesting data for a very different group of users, or data that is significantly out of date); (2) continent-level sources of data were used instead of region- or site-specific sources; or (3) exisiting data used have low precision. We therefore provide generic guidance in TESSA on whether the user can have high, medium or low confidence in estimates for each service, as well as suggestions on how to narrow uncertainties where feasible.

Finally, TESSA suggests approaches for communicating findings. We believe that planning this at the outset of the assessment is an essential part of effectively engaging stakeholders and informing decision-making. Different sites have different physical characteristics and ecosystem services, but there are common principles about the communication of results that can be applied. For example, a greater impact on decision making may be achieved by presenting estimates of the net, rather than the gross, value of conservation or restoration (Turner et al. 2003; see Figure B and C for two fictional but illustrative examples of how we suggest presenting the results). Users should be transparent about uncertainty, caveats and limitations. As well as decision-makers, it is vital to provide feedback to other stakeholders, and especially those who participated in fact-finding or data collection. The format of such presentations will need to be adjusted according to context and provided in local languages and as short summaries, policy briefs or technical reports. In all reports, the level of uncertainty for each of the findings should be made explicit, using the guidance in the toolkit – indicating, for example, which results are more speculative (i.e. for which there is a low level of confidence) and which results are well understood.

3. Limitations and future development

To date TESSA has been tested at more than 10 case-study sites, where we measured services and their sensitivity to plausible land-use changes, in both biophysical and monetary units. These assessments covered different habitat types in different parts of the world. The toolkit is being improved and revised in response to this real-world application and feedback from users, experience that will continue to guide its development. Our experiences so far show that TESSA could guide local non-specialists through a selection of methods for the rapid estimation of services at their sites of interest at relatively low cost and effort. By using this toolkit, these users could also gain valuable information about the counterfactuals (i.e. the alternative states); and data collected in the field could be incorporated into regular monitoring programmes. Here we discuss some of the limitations and challenges identified to date, and future plans to address them.

TESSA does not deal in detail with all ecosystem services. Many services, including cultural services, will be important to people, and this needs to be recognised and effectively communicated. A ‘rapid appraisal’ section helps users to identify all important services (as perceived by the stakeholders), and to provide context about those services that are not easily quantified. We aim to add more services to the more detailed parts of the toolkit in the future.

The current version enables users to derive monetary values – where appropriate – for some services (e.g. greenhouse gas fluxes for global climate regulation, harvested wild goods, cultivated goods and nature-based recreation), but generating monetary values for water-related services has proved much harder. As well as working to address this, we plan to increase the socio-economic sophistication of the toolkit, in particular so that it generates more information on how values of different services relate to the overall wellbeing of different service-users in the communities affected. We also aim to supplement the toolkit with guidance on how to monitor changes in service provision over time, and from such monitoring data determine how indices might be derived.

Providing answers to the many complexities in ecosystem services science is beyond the current scope of TESSA. The toolkit does not as yet address sustainability or resilience, although the long-term delivery of services is obviously an important element of responsible decision-making.

Second, TESSA does not deal with variation in service delivery through time; this requires detailed consideration of relevant time horizons and discount rates as well as the changes in flows of services into the future. Third, the toolkit does not explore non-linearities and tipping points, whereby small change in ecosystems may have disproportionate effects on the provision of the services. These phenomena are still insufficiently understood to be incorporated into the toolkit at present (Cardinale et al. 2012). Lastly, we have not explicitly included climate change projections here because the toolkit mainly deals with threats on a shorter time scale, although we recognise that some users may find it useful to think of their alternative state under climate change projections.

4. Conclusion

TESSA inevitably has limitations, some of which will be addressed in subsequent updates. Its scope is currently limited to a small subset of ecosystem services, but others will be developed, recognising that some important services will always be inherently difficult to measure. As the methods used are intended to be rapid and affordable, estimates of ecosystem service quantities or values sometimes have considerable uncertainties and errors associated with them, and hence this approach (which focuses on making comparisons between the current and alternative states) may not always be suitable where more detailed, robust measurements of particular services are required (such as tracking benefit provision for a Payment for Ecosystem Services scheme).

Nevertheless we think TESSA has the potential to help empower local users and non-specialists to engage in ecosystem service assessments, using methods that are flexible, designed by experts in each service, and which can be adapted according to time and capacity. Application of TESSA to date has been demonstrably low cost: at four pilot sites it has required 13–49 person-days (median 39) of personnel time in the field, plus an additional £1,000–£6,000 (median £4,200) for equipment, local travel and meetings.

TESSA's application has shown the critical role that local people can play in generating locally relevant data on ecosystem services to inform management options at the sites in question. In each of our test sites, trade-offs have been revealed and these have provided insights into the actions required to achieve biodiversity conservation whilst ensuring fair and equitable distribution of costs and benefits to people. We draw encouragement from the recent publication of a report by Bird Conservation Nepal (BCN and DNPWC, 2012) which made several detailed policy and site-based recommendations as a result of using TESSA, and which has been endorsed by the Nepali Department of National Parks and Wildlife Conservation and the Ministry of Forests and Soil Conservation.

Our experiences lead us to believe that TESSA can improve understanding of ecosystem services, and promote consideration of the diverse values of nature more widely in national and local decision-making. Its use can raise awareness and build public and government support for more sustainable, evidence-based policy and management decisions that take into account the crucial role of nature in delivering human wellbeing and sustainable livelihoods.

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Table A. An overview of multi-ecosystem service assessment techniques, mainly compiled from an assessment by Waage and Stewart (2008). Landscape means that the tool provides area-specific information which may be at a local level (e.g. a site). Low data demand means that the tool allows the use of existing databases and high data demand means that the tool enables the users to input their own site-specific data. A tool with high resolution will produce 'fine grain' analysis while that of a low resolution produces a broad, coarse scale assessment. High valuation focus means that the users could assess the value of ecosystem services, while a tool with low valuation focus might not have an emphasis on valuing services. The scoring of TESSA is based on the authors' field experience.

Approach/ Tool*	Description	Feature				Capacity/Resources requirement				
		Scope	Data demand	Resolution	Valuation focus	Computing skill	Specialist technical knowledge	Time	Man-power	Cost
Toolkit for Ecosystem Service at Site-based Assessment[a] (TESSA)	A practical suite of tools for measuring and monitoring ecosystem services at a site scale	Landscape	Low – High	Low – High	Low – High	Intermediate	Low	Low	Low	Low
Assessment and Research Infrastructure for Ecosystem Services[b] (ARIES)	A modelling programme for quantifying environmental services and factors influencing their values, in a geographical area and according to needs and priorities set by its users	Landscape – Global	Low – High	Low – High	Low	Intermediate – High	Low – High	Low	Low	Low

Corporate Ecosystem Services Review[c] (ESR)	A series of questions for developing strategies to manage risks and opportunities arising from the company's dependence on natural resources	Landscape – Global	Low	Low	Low	High	High	Low	Low	High
Integrated Valuation of Ecosystem Services and Tradeoffs[d] (InVEST)	A computer-based programme for assessing how distinct scenarios might lead to different ecosystem service and human-wellbeing related outcomes in a geographical area	Landscape – Global	Low – High	Low – High	High	High	High	Low	Low	High
Multi-scale Integrated Models of Ecosystem Services[e] (MIMES)	A suite of models for assessing how distinct management scenarios might lead to different ecosystem service and human-wellbeing related outcomes	Landscape – Global	Low – High	Low – High	High	High	High	Low	Low	High

Natura 2000[s]	A tool for assessing the total overall socio-economic benefits and value of a site, and for determining more monetary values of individual benefits provided by the site.	Landscape	Low	Low	High	Intermediate	Low	Low	Low	Low

*The list is not exhaustive

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Table B. The ecosystem services considered in the rapid appraisal based on the Common International Classification of Ecosystem Goods and Services developed by the European Environment Agency. Adapted from www.cices.eu.

Classification of ecosystem goods and services		
Section	Division	Group
Provisioning	Nutrition	Terrestrial plants and animals for food
		Freshwater plants and animals for food
		Marine algae and animal for food
	Water supply	Water for human consumption
		Water for agricultural use
		Water for industrial and energy uses
	Materials	Biotic materials
	Energy	Biomass based energy
Regulation and Maintenance	Regulation of bio-physical	Bioremediation
		Dilution and sequestration
	Flow regulation	Air flow regulation
		Water flow regulation
		Mass flow regulation
	Regulation of physico-chemical	Atmospheric regulation
		Water quality regulation
		Pedogenesis and soil quality regulation
	Regulation of biotic environment	Lifecycle maintenance, habitat and gene pool protection
		Invasive alien, pest and disease control
Cultural	Symbolic	Aesthetic, Heritage
		Spiritual
	Intellectual and Experiential	Recreation and community activities
		Information and knowledge

Table C. An overview of the methods covered in TESSA, for each of the five classes of ecosystem services. Data collection may include collecting primary data through field surveys, key informant interviews and household questionnaires; using existing databases and studies; and (in one instance) employing numerical models. TESSA recommends use of existing data where appropriate and places emphasis on enabling users to collect new field data at relatively low cost and effort.

Service	**What is measured?**	**Method**	**Output**
Global climate regulation	Carbon (C) storage	Estimating above-ground live biomass carbon stock	Mg of C ha^{-1}
		Estimating below-ground biomass carbon stock	Mg of C ha^{-1}
		Estimating dead organic matter (litter and dead wood) carbon stock	Mg of C ha^{-1}
		Estimating soil organic carbon stock in mineral and organic soils	Mg of C ha^{-1}
		Estimating loss of biomass carbon stocks due to disturbance	Mg of C ha^{-1}
	Carbon dioxide (CO_2) emissions	Estimating emission of carbon dioxide from organic soils	Mg of CO_2 ha^{-1} $year^{-1}$
	Methane (CH_4) emissions	Estimating methane emissions from wet soil and grazing animals	Mg of CO_2 equivalents ha^{-1} $year^{-1}$
	Nitrous oxide (N_2O) emissions	Estimating nitrous oxide emission	Mg of CO_2 equivalents ha^{-1} $year^{-1}$
Water services	Water quantity used for domestic purposes and irrigation	Estimating water quantity produced	L of H_2O produced $year^{-1}$

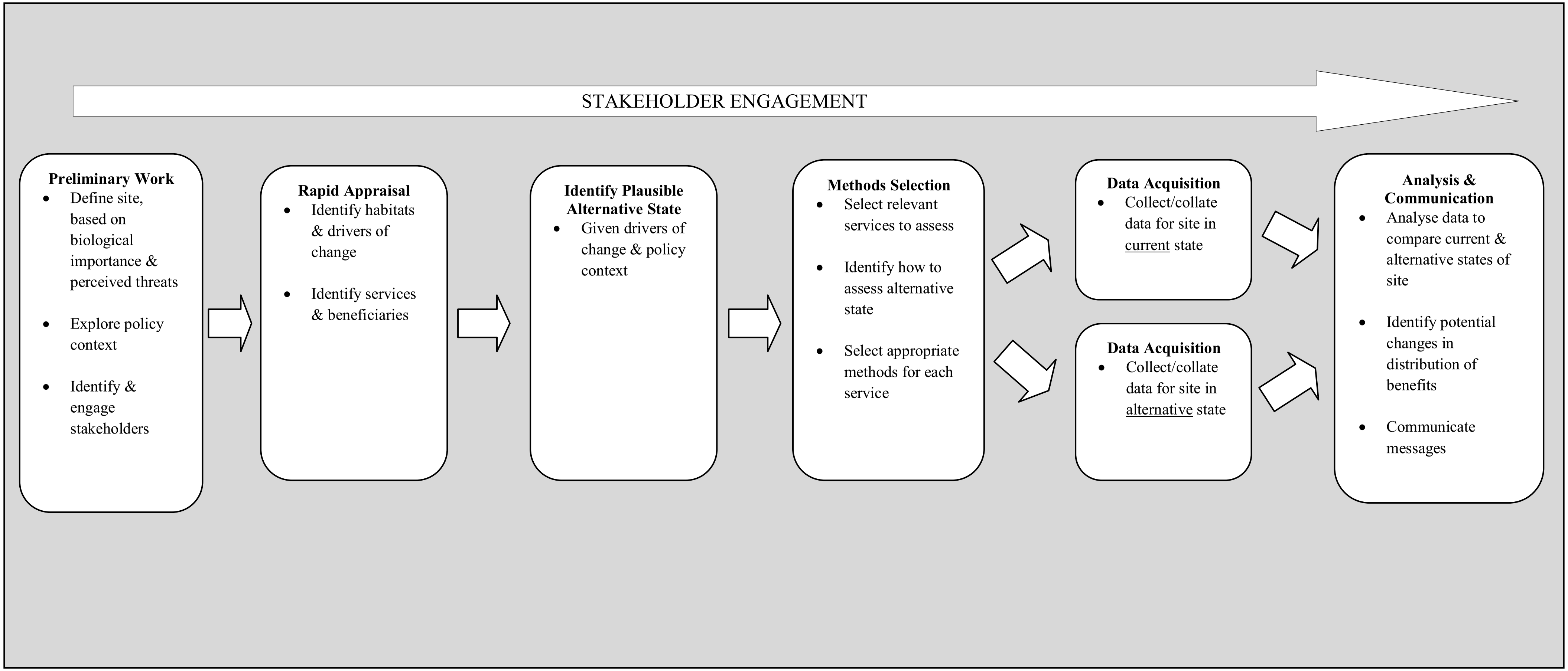
	Flood protection	Estimating flood protection capacity	No. of days not flooded; No. of household not flooded; No. of months with increased/reduced flood risk; Avoided damage cost expressed in \$ $year^{-1}$
	Water quality	Estimating water quality improvement	Mg/L of nutrient removed
Harvested wild goods	Wild products	Estimating the amount and net economic value of the major wild goods harvested	Kg of wild products harvested $year^{-1}$; Benefit expressed in \$ ha^{-1} $year^{-1}$
Cultivated goods	Cultivated products	Estimating the amount and net economic value of the major cultivated goods grown	Kg of cultivated goods grown $year^{-1}$; Benefit expressed in \$ ha^{-1} $year^{-1}$
Nature-based recreation	Number of visits	Estimating the number and total income from nature-based activities	No. of visitors $year^{-1}$; Benefit expressed in \$ $year^{-1}$

Figure A. Methodological framework (as used by TESSA). The steps for identifying habitats at the site and identifying the important ecosystem services delivered by the site are repeated for both the current state of the site and a plausible alternative state.

Figure B. Bar charts show the economic costs (US$) and benefits associated with the ecosystem service flows for each state (restored forest and farmland) so that their net economic values can be compared. Greenhouse gas sequestration is presented with three potential $ values: the black shaded area presents a mid-point value, white dashed line the lower value and black dot-dashed line the upper value.

Figure C. Rose plots 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.

Figure A



STAKEHOLDER ENGAGEMENT
Preliminary Work
Define site, based on biological importance & perceived threats
Explore policy context
Identify & engage stakeholders
Rapid Appraisal
Identify habitats & drivers of change
Identify services & beneficiaries
Identify Plausible Alternative State
Given drivers of change & policy context
Methods Selection
Select relevant services to assess
Identify how to assess alternative state
Select appropriate methods for each service
Data Acquisition
Collect/collate data for site in current state
Data Acquisition
Collect/collate data for site in alternative state
Analysis & Communication
Analyse data to compare current & alternative states of site
Identify potential changes in distribution of benefits
Communicate messages

Figure B

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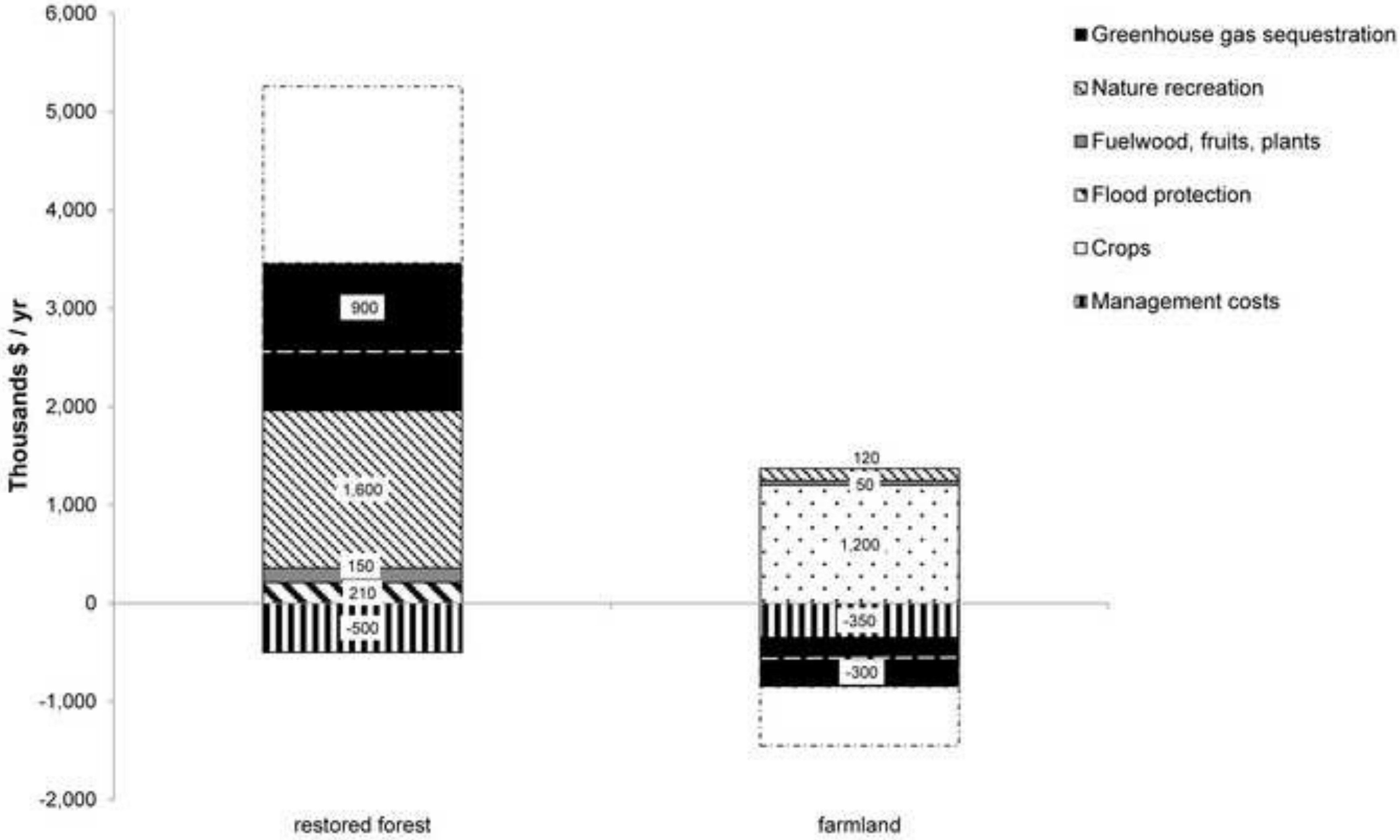

Figure C
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