The Service Provision Index (SPI): linking environmental flows, ecosystem services and economic value

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Abstract Environmental flow is the water needed for the proper functioning of ecosystems. Ecosystems, in turn, provide a wide range of valuable services. Providing for environmental flow is not exclusively a matter of sustaining ecosystems, but also a matter of supporting humankind and livelihoods. None of the existing environmental flow assessment methods explicitly link environmental flow to ecosystem services. Consequently, such methods cannot readily deliver inputs to economic valuation studies. Furthermore, existing holistic environmental flow assessment methods are very resource demanding (time, money, data). This is a real constraint to undertaking environmental flows assessments, in particular in developing countries. This paper attempts to bridge the current gap between biophysical scientists, socio-economic scientists and decision-makers in Integrated Water Resources Management (IWRM) by presenting and encouraging the use of a Service Provision Index (SPI). It is a pragmatic, operational and flexible approach that is easy to use while maintaining a holistic and comprehensive assessment of environmental flows.

Key words decision support systems (DSS); environmental flows; economic valuation; ecosystem services; Integrated Water Resources Management (IWRM); multi-disciplinary approach; Service Provision Index (SPI)

INTRODUCTION

Environmental flow is water for ecosystems—the silent water users. Ecosystems, in turn, provide a wide range of valuable services. Providing for environmental flows is, therefore, not exclusively a matter of sustaining ecosystems, but also a matter of supporting humankind/livelihoods (Dyson *et al*., 2003).

Nevertheless, environmental flows are often undervalued and thus frequently omitted from decision-making (Emerton & Bos, 2004; Millennium Ecosystem Assessment, 2005). One reason for the marginalization of environmental flows is the lack of operational methods to demonstrate the inherently multi-disciplinary links between environmental flows, ecosystem services and economic value. While agriculture and other economically powerful sectors have well developed tools for quantifying and justifying their needs, this is not the case with ecosystems.

Several holistic and interactive environmental flows assessment methods have been developed (Tharme, 2003; Acreman & Dunbar, 2004), but none of them explicitly links environmental flows to ecosystem services. Consequently, such methods cannot readily deliver inputs to economic valuation studies. There is a need to develop an environmental flows assessment method that pays due attention to the ecosystem services provided to people.

THE CONCEPT: LINKING MIKE BASIN, SPI AND MS EXCEL

In the context of Integrated Water Resources Management (IWRM), the environmental flow requirement is a negotiated trade-off. In order to facilitate the analysis of trade-offs between various river basin management strategies and water allocation scenarios, environmental flow must be included on equal terms with other water uses. This paper describes the development of a simple and transparent decision support tool for assessing various environmental flow scenarios and arriving at a negotiated environmental flow requirement/allocation, and thereby a negotiated river condition and economic trade-off between water uses.

Figure 1 gives a conceptual overview of the tool. MIKE BASIN is an ArcGIS based river basin simulation model and the Service Provision Index (SPI) is an Environmental Flows assessment approach. MS Excel is used to calculate economic values and explore trade-offs. The resulting tool can serve to support decision-making in IWRM.

THE SERVICE PROVISION INDEX (SPI)

The core of operationalizing the tool is the development of the Service Provision Index (SPI). This novel approach to assessing environmental flows is described in detail in Korsgaard & Schou (2007). In the following, SPI will be briefly presented and the main advantages and disadvantages will be discussed.

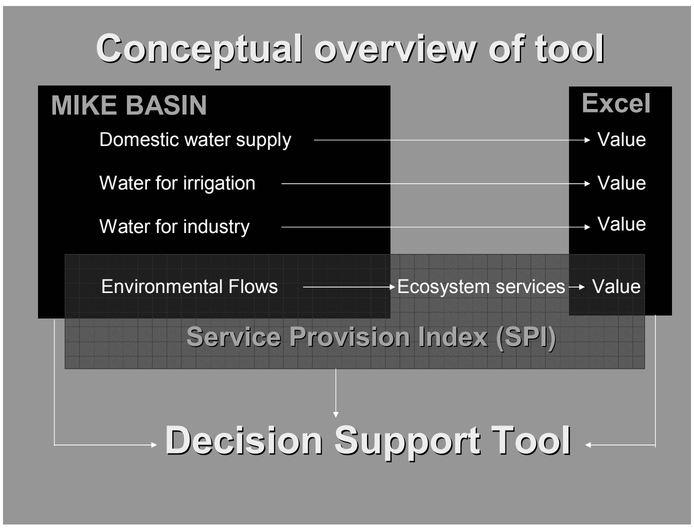

Fig. 1 Conceptual overview of how MIKE BASIN (a river basin simulation model), MS Excel and the Service Provision Index (SPI) are linked to provide a decision-support tool for IWRM.

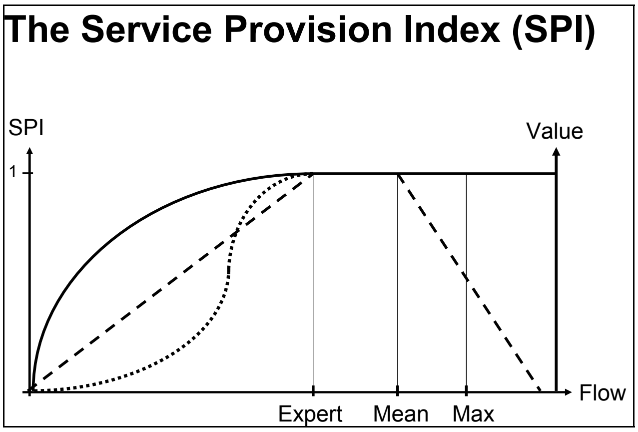

Fig. 2 The Service Provision Index (SPI). SPI shows how suitable a given flow scenario is for providing a given service. The SPI can be linked to value. Note that the second *y*-axis (Value) may or may not be linear. *Expert* refers to a flow lower than mean flow but judged by experts to be sufficient for full service provision (SPI = 1).

For a given flow scenario, the SPI gives a relative estimate of the level of service provision for selected services. Depending on the resources available, the SPI curve may be based on extensive and comprehensive field work (e.g. using the DRIFT framework; King *et al.*, 2003), by using existing species-level information (e.g. PHABSIM; Bovee *et al.*, 1998) or by assuming a certain relationship. In the latter case, the SPI curve may be based on standard linear, logarithmic or logistic relationships (see Fig. 2). SPI may decrease if flows are above a certain limit.

In order to establish the SPI curve, appropriate flow classes must be identified for each selected service. An appropriate flow class is a characteristic of the natural flow regime that is considered vital for provision of a particular service. Thus a flow class may be a seasonal mean flow, a particular flood event or minimum flow during a certain period. The number of important flow classes to include in the assessment depends entirely on the service in question. In the case of limited data and knowledge, mean monthly flows can be used by default.

The level of service provision may be assigned an economic value using one or more existing economic valuation method (Korsgaard & Schou, 2007). The steps needed in order to use SPI for environmental flows assessment are summarized in Table 1.

Advantages of the Service Provision Index (SPI)

The main advantage of the SPI approach is that it explicitly links environmental flows to (socio)-economic values by deliberately focusing on ecosystem services. Furthermore, when establishing the links, a wide variety of information can be used, depending on the resources (time, money, expertise) available for the assessment. This flexible nature is particularly appealing in data-scarce cases and/or in the context of adaptive management.

The SPI approach differs from existing holistic environmental flows assessment methodologies in several ways. Firstly, while existing methodologies focus on

Table 1 Overview of steps required to use the Service Provision Index (SPI) method for assessing environmental flows. * These steps may be omitted, if economic valuation of the service provision is not undertaken.

Phase	Step	Comment
Linking flows to services	Identifying all flow related ecosystem services (existing and potential)	Use checklist provided by Korsgaard *et al* (2005) and/or framework developed by Meijer (2006)
	Selecting the most important flow related ecosystem services	Should be a stakeholder-oriented and participatory process
	Defining most important flow classes for each service	List of recommended/suggested flow components is a crucial research need
	Quantifying links between flow and each service	Use standard curves or suitability curves based on comprehensive assessments
	Calculating the Service Provision Index (SPI) for each service	For a given environmental flows scenario
Linking services to values	Defining the spatial and temporal scale of valuation	Whose benefits should be included?
	*Estimating, for each service, the economic value at a certain SPI	Use existing valuation methods, see Korsgaard & Schou (2007)
	*Calculating the economic value of each service	For a given environmental flows scenario
Evaluating environmental flows scenarios	*Calculating total value of each scenario	If economic valuation is undertaken
	Calculating total SPI of each scenario	If economic valuation is not undertaken, total SPI can act as an indicator of the relative value of environmental flows scenarios

ecosystem components (e.g. fish, invertebrates, plants, water quality, geomorphology), SPI focuses on services—the end product of ecosystem functioning to humans. This is crucial for enabling the subsequent valuation of environmental flows. Secondly, while existing methodologies operate with a fixed number of flow classes (e.g. dry-season low-flows, wet-season low-flows, and eight different flood events), SPI allows a flexible inclusion of the most relevant flow classes. Thirdly, history is not taken into account in existing methodologies. The SPI approach does to some extent allow preceding events to influence the calculation of SPI and corresponding value. Fourthly, existing holistic methodologies are very resource intensive and may take several years with inputs from numerous experts. Depending on the resources available, SPI can be set up from a desk-top study, using standard relationships, or a comprehensive field study. Finally, as SPI is set up in MS Excel it can be easily incorporated into existing river basin simulation models (for example MIKE Basin) and used directly in decision support systems (see Fig. 1). This possibility of mainstreaming environmental flows into river basin management is a great advantage of the SPI approach.

Disadvantages of the Service Provision Index (SPI)

The main shortcoming of the SPI approach is that in data scarce applications the links between flows and services are assumed. As more and more information becomes available, such links can be refined and documented. Ideally, output from existing holistic environmental flows assessment may directly feed into an SPI for some services (e.g. "biodiversity conservation"). However, a major challenge remains regarding the establishment of links between flows and services: identifying the extent to which flow is responsible for service provision. For each service, this should be further explored, and empirical guidelines should be developed.

STAKEHOLDER INVOLVEMENT—GETTING A NEGOTIATED RESPONSE

The approach put forward in this paper focuses on the end-results to people of providing environmental flows and sustaining ecosystem services. It is therefore important to involve the affected people, i.e. the stakeholders. The relevant stakeholders to involve depend entirely on the objectives of the environmental flows assessment and thus on the political issues addressed and prioritized.

In relation to environmental flows assessment it is useful to distinguish between two main groups of stakeholders: (1) the above-mentioned stakeholders that are directly affected by ecosystem services provided by environmental flows; and (2) the stakeholders representing all other water uses in the river basin, e.g. irrigation, industry, etc.

The two groups of stakeholders are involved in different parts of the process. The first group should be involved in the identification and valuation of important ecosystem services. Both stakeholder groups should then be involved in evaluating the trade-offs between various water allocation scenarios and arriving at a negotiated solution. This solution will then determine the amount of water allocated for environmental flows and the resulting ecosystem condition and level of service provision.

Some of the more intangible services, for example carbon sequestration and biodiversity conservation, do not lend themselves easily to stakeholder assessment. Therefore, experts form an important stakeholder group that can speak on behalf of the "silent" or "diffuse" beneficiaries ("expert participation" as opposed to "expert consultation").

A successful participatory approach not only ensures that stakeholder judgement/-knowledge is incorporated into the valuation of ecosystems services. It also enables communication and learning among stakeholder groups (including experts). Furthermore, it establishes processes and builds capacity within the local civil society to participate in Integrated Water Resources Management (IWRM).

CONCLUSIONS

In the context of IWRM, the environmental flows requirement is a negotiated trade-off. The trade-offs involved are inherently case specific. In order to facilitate the analysis of trade-offs between various river basin management strategies and water allocation scenarios, environmental flows must be included on equal terms with other water uses. Economic valuation of ecosystem services, and thus of environmental flows, is controversial and highly debated. However, as long as we are making choices that affect ecosystems, we are implicitly engaging in valuations of ecosystems, whether acknowledged or not. It is of utmost importance that this valuation is made explicit in order to ensure high levels of information and transparency in decision-making. The SPI approach presented in this paper will serve to support such efforts and provides an operational tool for incorporating ecosystems and environmental flows into decision-making in IWRM.

The approach has several advantages compared to existing environmental flows assessment methods. By focusing on services sustained by environmental flows, it places due emphasis on the "end product" of ecosystem functions to humans. This, in turn, renders environmental flows somewhat easier to justify and value. Furthermore, the SPI approach may be tailored to conform to case specific data availability. Thus it may be used as a desk-top method or a comprehensive holistic methodology, depending on the data and information available. In either case, SPI can be easily combined with existing river basin simulation models (e.g. MIKE Basin) and thus provide a flexible, transparent and relatively rapid tool to explore trade-offs and support IWRM.

In conclusion, the Service Provision Index (SPI) approach is a novel contribution to the existing field of environmental flows assessment methodologies

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