Science of the Total Environment 461–462 (2013) 170–179

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Systemic solutions for multi-benefit water and environmental management

Mark Everard [a,*], Robert McInnes [b]

[a] Faculty of Environment and Technology, University of the West of England (UWE), Coldharbour Lane, Frenchay Campus, Bristol BS16 1QY, UK
[b] RM Wetlands & Environment Ltd., 6 Ladman Villas, Littleworth, Faringdon, Oxfordshire SN7 8EQ, UK

HIGHLIGHTS

- Overlooked inputs and outputs in environmental management compromise net outcomes.
- Low-input, optimised ecosystem service output solutions are urgently required.
- Inputs and outputs were assessed for some ecosystem-based management technologies.
- 'Systemic solutions' comprise low-input technologies using natural processes to optimise ecosystem services.
- Legacy regulations, budgets and practices can be implemented more systemically.

ARTICLE INFO

Article history:
Received 7 January 2013
Received in revised form 30 April 2013
Accepted 5 May 2013
Available online 28 May 2013

Editor: Simon Pollard

Keywords:
Ecosystem services
Integrated constructed wetlands
Washlands
Sustainable drainage systems
Treatment wetlands
Systemic solutions

ABSTRACT

The environmental and financial costs of inputs to, and unintended consequences arising from narrow consideration of outputs from, water and environmental management technologies highlight the need for low-input solutions that optimise outcomes across multiple ecosystem services. Case studies examining the inputs and outputs associated with several ecosystem-based water and environmental management technologies reveal a range from those that differ little from conventional electro-mechanical engineering techniques through methods, such as integrated constructed wetlands (ICWs), designed explicitly as low-input systems optimising ecosystem service outcomes. All techniques present opportunities for further optimisation of outputs, and hence for greater cumulative public value. We define 'systemic solutions' as "…low-input technologies using natural processes to optimise benefits across the spectrum of ecosystem services and their beneficiaries". They contribute to sustainable development by averting unintended negative impacts and optimising benefits to all ecosystem service beneficiaries, increasing net economic value. Legacy legislation addressing issues in a fragmented way, associated 'ring-fenced' budgets and established management assumptions represent obstacles to implementing 'systemic solutions'. However, flexible implementation of legacy regulations recognising their primary purpose, rather than slavish adherence to detailed sub-clauses, may achieve greater overall public benefit through optimisation of outcomes across ecosystem services. Systemic solutions are not a panacea if applied merely as 'downstream' fixes, but are part of, and a means to accelerate, broader culture change towards more sustainable practice. This necessarily entails connecting a wider network of interests in the formulation and design of mutually-beneficial systemic solutions, including for example spatial planners, engineers, regulators, managers, farming and other businesses, and researchers working on ways to quantify and optimise delivery of ecosystem services.

1. Introduction

Increasing concerns about the environmental and financial costs of energy and chemical inputs, with associated carbon footprints, waste generation and transportation implications, are focussing attention on the need for low-input, low-maintenance approaches to water and environmental management (EuCheMS, 2008; Voulvoulis, 2012). Addressing the multifarious issues surrounding water scarcity, sanitation and flood risk similarly requires consideration of low-cost, low-energy solutions which minimise the impacts on society and the environment (Shannon et al., 2008). There is indeed a perceived conflict between the objectives of water treatment and the energy requirements to achieve it (Lamb, 1980), at least if the focus remains rooted in traditional 'heavy-engineering' approaches. However, the use of 'green' technologies and the adoption of sustainable approaches are seen as potential solutions to this conflict (Omer, 2008). There is also rising interest at international and national scales in optimising societal value from environmental management solutions in terms of taking an Ecosystem Approach to deliver multiple, simultaneous ecosystem services

---

* Corresponding author.
E-mail address: mark@pundamilia.co.uk (M. Everard).

0048-9697/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scitotenv.2013.05.010

(Millennium Ecosystem Assessment, 2005; UK NEA, 2011). However, this remains as yet far from pervasive in regulatory thinking, practice and incentives (Everard, 2011a).

Traditional 'hard' engineered or electro-mechanical solutions to water management tend to maximise one target output, such as removal of pathogens from waste water or the physical storage of stormwater, through a high level of investment in inputs at the expense of other potential benefits. Consequently, global investments in engineered water infrastructure have been estimated to be in the order of trillions of US dollars (Vörösmarty et al., 2010). By contrast, 'green' techniques which work with or emulate natural processes in order to optimise a broad spectrum of ecosystem services tend to represent low-input, multiple-output solutions. They may thereby provide alternative, more efficient approaches that may also be cost-effective due to their decreased capital and operational costs (Emerton and Bos, 2004). The consideration of ecosystems as infrastructure that works with natural processes has been applied in progressive approaches to flood risk management (Everard et al., 2009), wastewater treatment using both constructed wetland systems (Nuttall et al., 1997; Vymazal, 2011) and natural wetlands (Everard et al., 1995; Fisher and Acreman, 2004), urban floodwater management (Neal et al., 2006; Woods-Ballard et al., 2007) and the settlement of airborne particulate pollutants (Sarajevs, 2011).

However, even where they are based on harnessing ecosystem processes, solutions applied to achieve only narrowly-defined outcomes, such as wastewater treatment or flood risk reduction, fall short of their potential to deliver multiple or cumulative benefits unless planning for multiple outcomes is an inherent part of design (Emerton and Bos, 2004). Irrespective of the kind of administrative and legal tools available, such an approach is unlikely to be accepted by stakeholders unless the wider values of natural capital are explicitly acknowledged as important infrastructure within an existing holistic approach (Mackay et al., 2009). In the case of wetland management, true integration can be interpreted as requiring an understanding of the following three elements: systems ecology in order to appreciate how each component influences other components; biogeochemical and physical systems to evaluate how water interacts with other biophysical elements; and socio-economic and socio-cultural elements in order to link the wetlands to relevant policy networks, social systems and co-operative solutions (Brouwer et al., 2003). Such an approach embraces the concept that the human universe and the economic and social 'cosmos' should never be considered as separate systems independent of nature (Mebratu, 1998). Such a model of interdependence recognises a nested construct where the intersection of abiotic, biotic, social and economic components is the area where millions of four dimensional interactions take place in varying degrees of harmony and conflict. The failure to understand the implications for any of these four components may result in a plethora of feedback systems (Mebratu, 1998).

Therefore, in this paper the term 'systemic solutions' is used to describe low-input techniques that work with natural processes and across economic and social systems deliberately to achieve multiple ecosystem service outcomes, optimised for multiple benefits rather than maximisation of a single benefit. Explicit within our definition of 'systemic solutions' is the consideration of synergies, and innovation to circumvent trade-offs and negative feedbacks wherever possible, for the advantage of all ecosystem service beneficiaries and therefore potential optimisation of net value to society. This is largely consistent with the Ecosystem Approach, affirmed by the Convention on Biological Diversity (www.cbd.int) at its Seventh Conference of Parties in 2004, which provides a strategy for the integrated management of land, water and living resources which promote conservation and sustainable use in an equitable way. However, notwithstanding this commitment, systemic approaches remain poorly reflected in established environmental management and development practices. Whilst significant challenges prevail in the application of the Ecosystem Approach regarding the integration and communication of economic, ecological, hydrological and other processes across spatial and temporal scales (Apitz et al., 2006), there are some examples of best practice, and other practices are progressively evolving to take a more systemic approach.

Constructed wetlands have a long history of using macrophytes and natural processes to remove pollutants from wastewater (Kadlec and Knight, 1996). However, the use of the technology has traditionally adopted a formulaic process engineering approach (Cooper et al., 1996). Widespread in Ireland, integrated constructed wetlands (ICWs) have evolved considerably from this traditional thinking and are an applied example of a 'systemic solution' which embraces an Ecosystem Approach (Harrington et al., 2011). Designed and managed explicitly to address, amongst a range of services, point and diffuse pollution, nutrient cycling and carbon sequestration, whilst delivering the provision of habitat, amenity and landscape aesthetics benefits, ICWs seek coherence in environmental and water management (Harrington and McInnes, 2009; Everard et al., 2012).

Other practices are evolving progressively to take a more systemic approach. For example, Everard and Moggridge (2012) note potential synergies between urban river restoration techniques, 'green infrastructure', sustainable drainage systems (SuDS) and a range of other often separately-applied solutions which may be integrated to optimise service production. Similarly, Morris et al. (2004a,b) have demonstrated that the establishment of washlands on floodplains can manage flood risk and also support the rural economy through the provision of a range of other benefits.

We explore the inputs to and outcomes from a selected range of water and environmental management practices, learning from this what constitutes genuinely systemic solutions, the obstacles to their wider uptake, and potential for their expansion in the context of environmental management and wider societal practices. Transformation to the recognition and realisation of the integrated set of simultaneous benefits potentially delivered by low input, natural systems which provide 'systemic solutions' can only be achieved through the participation of multiple stakeholders and their different perspectives, consistent with Principles 11 and 12 of the Ecosystem Approach (http://www.cbd.int/ecosystem/principles.shtml). Russi et al. (2013) promulgated that such an approach to water management should be viewed as part of an overall transition to a sustainable global economy. In order to ensure that the optimisation of ecosystem services becomes an active component within decision-making requires consideration by a range of actors including: policy makers across intergovernmental to local scales; a variety of business sectors including inter alia agriculture, extractive industries and energy production; non-governmental organisations; regulators; and academia.

2. Charting inputs and outcomes in water and environmental management solutions

2.1. Water and environmental management as an element of systems

Systems comprise complex entities dependent upon the functioning of, and interactions amongst, constituent parts. Systems range from the subatomic to the universal scale, including complex, socio-ecological systems. Systemic thinking has proven helpful in addressing some of the shortcomings of reductionist understanding, policy and regulatory responses, and management solutions (Pullin et al., 2009).

Applying the principles of systems thinking to sustainable water and environmental management solutions requires an understanding of open systems where inputs and outputs are appropriately considered in order to reduce impacts to the environment and its functions, and hence to optimise benefits to society. 'Systemic solutions' then basically comprise low-input, multiple-outcome approaches. Such solutions are thus commensurate with an Ecosystem Approach and, where natural infrastructure is used to manage water, consistent with the wise use of wetlands as emphasised in the text of the Ramsar Convention on Wetlands (Finlayson et al., 2011).