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Ecoservices and multifunctional landscapes: Balancing the benefits of integrated ES based water resources, agricultural and forestry production systems

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Abstract.

Ecosystem services (ES) are a powerful tool in assessing the relationships that people have with their surrounding tangible environment and the more distant intangible global benefits. Ecoservices are often studied in parallel or viewed as linear, and this misunderstanding or ignorance of the complex interaction among ecoservices may lead to poor or inappropriate land and water management decisions. Quantitatively understanding and establishing the risk to the complex functional relationships among ES impacted by the introduction of alternate production systems requires a new pathway to better decision making.

Ecoservices are often interrelated in dynamic and complex ways and provide an avenue, if appropriately coupled, to a more balanced land use-land cover (LULC) multifunctional production system. Variable land use intensities and landscape configurations impact differentially on selected ecosystem functions and services. Anthropogenic activities impact this functionality and require an innovative analytical approach to building an integrated multifunctional ES analytical framework (IMESAF); an approach that spans diverse fields of inquiry.

An IMESAF would need to incorporate a variety of ecoservices based best practice production systems that can elucidate balanced land use scenarios to deliver better environmental and productivity outcomes. In addition, this framework requires policy, economic, sustainability, monitoring and evaluation indices to provide guidance on intermediate and long-term effects of an ecoservices based production and planning system. This paper provides a synthesis of ideas for creating the framework and how it may underpin balanced land use and investment choices.

Keywords: Water, land cover, multifunctionality, ecosystems, sustainability, policy, practice

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1. Introduction

Sustainable development, implemented in its many guises for more than 25 years, is based on the convergence of the three pillars - economic development, social equity, and environmental protection coupled with good governance. Progress has been made in developing adoption and assessment frameworks, with the derivation of sustainable development metrics, and improved business and government participation in the sustainability precepts embodied in the Sustainable Development Goals, SDGs (Drexhage and Murphy 2010; UN 2015). However, their widespread adoption remains elusive and implementation continues to be difficult. Even though existing business models and approaches were declared to be unsustainable at the world economic forum in 2010 (Waughray, 2011) and in numerous documents and public statements since; there has been limited notable progress towards changed business practice and governance. Suggested methodologies have yet to find the political entry points required to make real progress.

Hydrological ecoservices are global, multi-scalar and fundamental to human and environmental well-being, underpinning a myriad of interconnected dynamic systems (Haines-Young and Potschin, 2013; Costanza et al 2014; Young et al 2015). Anthropogenic activities and urbanisation have replaced or modified these hydrological ecoservices, and their natural processes of cycling and rejuvenation. Significant portions of the globe are now given over to activities, such as agriculture, forestry, fisheries, energy production and mining that interdict or displace ecoservices provided through natural processes (UN-Water 2013; IPCC Synthesis Report 2014; Bourke et al 2015; Young et al 2015). However, these industry activities and sectors remain crucial for strengthening food and water security globally, therefore the impact of these production systems must be reduced or modified, or communities and the environment will remain vulnerable and potentially at risk.

Alternative options in water and land use are therefore required at local and global scales that are transferable to catchments of any size. The productive focus can then shift towards enhancing source water quality and land-use optimisation through a transformative process that encourages a move from traditional single-use rural landscapes to an ecosystem services (ES) based multi-functional landscape. Creating a framework that encourages innovative and novel pathways to a more holistic and integrated management approach to Land Use-Land Cover (LULC) changes that can deliver the SDGs.

2. An Ecoservices Approach - A suggested methodology for implementing the SDGs.

The European Union (EU) ratified the Biodiversity Action Plan (BAP) in 2006. Since then, its implementation has increased the broader communities understanding of the drivers of biodiversity loss (including climate change) and how biodiversity is linked with other sectoral activities (European Commission 2010a). Implementing the BAP objectives highlighted the basic role and fundamental importance of ecosystem dynamics and has strengthened the need for better managed outcomes to facilitate mitigation and adaption to climate change (European Commission 2010b). Highlighting the need to deliver sustainability across the all agricultural production, urban and industrial sectors. Clearly a necessity if any of the SDG's are to be delivered.

Multi-functionality represents a new challenge for stakeholders operating in these sectors. Both regulators and operators need to manage natural resources or natural capital to achieve the environmental standards of the relevant EU policies (Roebeling et al., 2014), while also maintaining viable and sustainable integrated dynamic ecoservices. This can be measured by the enhancement in the services provided by functional agro-ecosystems, peri-urban, urban and environmental systems (MEA, 2005; Brauman et al., 2007; Polasky et al 2015). Whilst agricultural systems are often the dominant land-use, multi-functional land use considers integrating alternate nature based land management practices, such as pasture, transitions to agro-forestry (Seppelt et al., 2013; Volk, 2013; Wang et al., 2015) and can include nature based options for mining and urbanisation. The spatial mosaic of variable land-use types and intensities are decisive in the provision of water-related ecosystem services and will create synergies with other aspects of landscapes (e.g. soil conservation, habitat protection). The re-allocation of critical water resources without understanding these interdependencies often has unintended and irreversible consequences for ecosystem functions and its services. Understanding these interdependencies is crucial to reducing biodiversity loss and ecosystem functional (ESF) impairment associated with land use intensification (Pilaš et al., 2011; Seppelt et al., 2012; McKnight et al., 2015).

2.1. Water the key ingredient

The concept of water as part of a natural capital asset that is available to all independent nation States is an important one and it forms part of the global services economy (Seppelt et al. 2012). Over the next 25 years an ever increasingly urbanized planet, coupled with climate change and population shifts, will continue to exert significant pressure on the level and complexity of natural capital allocation and trade-offs are required (Figure1). Trade-offs that at the same time must act to minimize ecosystem degradation and deliver sustainable outcomes in multiple sectors and scales (Coles and Hall 2012). Given the cross-sectoral nature of the inter-relationships, scale factors and environmental interdependencies, a revised valuation, commoditisation and governance approach is required (Figure 2). A failure to recognise the need to operationalise an integrative analytical framework will undermine the capacity of our natural capital and industrial complex to provide for future societal demands; with the food, health, energy, and environment the sectors most at risk (IGES, 2015).

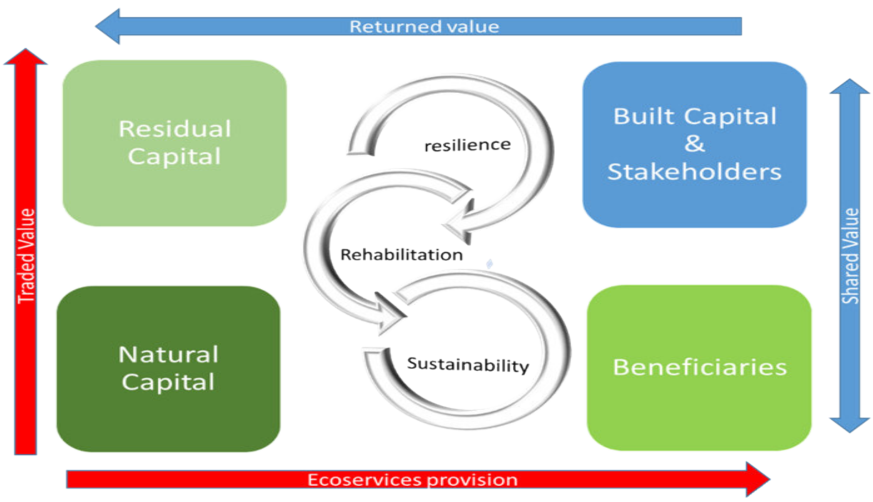

Figure 1. Establishing indices and metrics based on Ecosystem Services (ESS) and Ecosystem Functionality (ESF) performance evaluation, that is linked to resilience, rehabilitation potential and therefore sustainability will provide a strong indicator of LULC changes. Creating a framework in which investment and assessment of economic benefits can be determined enabling the incorporation of a wider range of beneficiaries, stakeholders and socio-ecological elements. A process that can deliver sustainable outcomes over the short, medium and long-term to a wider range of assets and community groups.

However, achieving food, energy and water security is an enormous challenge due to the size and diversity of societal and environmental needs, by the same token, growing insecurities threaten the safe operating space of human society (Rockström, et al 2009). The prevailing paradigm presents technological approaches to agricultural intensification as the most viable solution to increasing food production, despite its severe and negative impacts on the environment (Daily and De Clerck, 2014); even while our resource use is not yet meeting the minimum threshold required to obtain just social conditions for humanity, including meeting global food and income needs (Raworth, 2012).

2.2 Alternative strategies

Until recently ecosystem services (ESS) have largely been treated as if they have no value with ecosystems frequently managed for short-term gain at the expense of broader, longer-term societal benefits (Bourke et al. 2015). Therefore, it makes sense to create a process in which the adoption of an integrated perspective, positions water primacy at its core, with the focus aimed at a more secure and sustainable future. Thus, by linking the biophysical aspects of ecosystems with human benefits through the notion of ES, the basis for determining value and the trade-offs (ecological, socio-cultural, economic and monetary) for the loss of ecosystem functionality (ESF) can be established (see Figure 1 & 2). By establishing ES metrics that are both spatially and temporally explicit, and at scales meaningful for policy formation or best practice interventions, further analysis of action-impact can be undertaken prior to implementation (Figure 2).

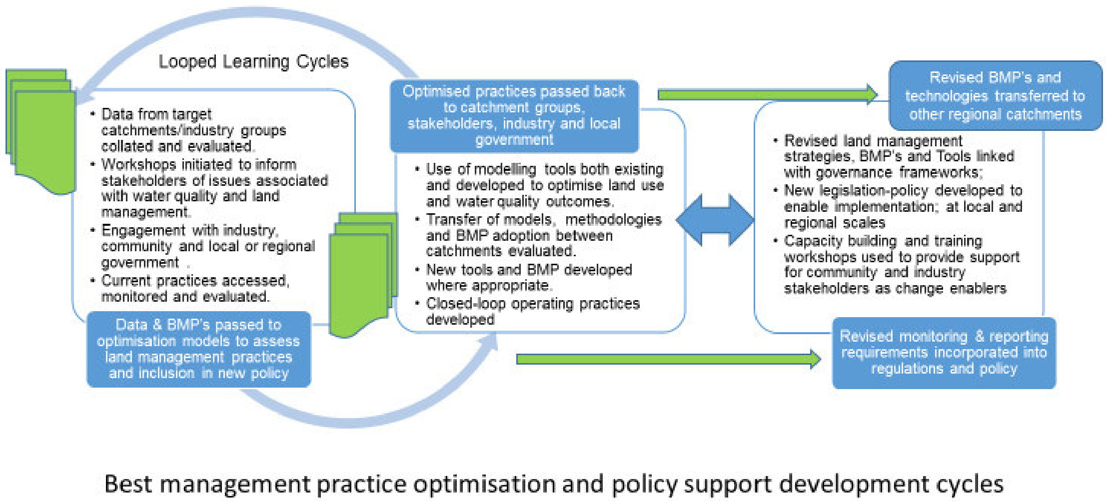

Figure 2. Ecoservices Framework: Potential activity cycle that could be adapted to create the basis for an eco-credit system and guide the evaluation of ESS-BMPs, community and farmer engagement, socioeconomic elements, governance frameworks, supply chain management, soil health and water quality. Where services provided by the biophysical environment are valued and traded to beneficiaries, through policy, governance and market instruments. Equity and benefits in service provision determines the level and value of service degradation in ecosystem performance.

In addition to innovative technologies a new framework that enables assessment of the interconnectedness of environment and ecoservices, industry and economics, and social and national interests is required. The "triple bottom line" approach currently used by governments and industry for examining the effectiveness, efficiency and economics of decisions has proven to be limited in its understanding of this interconnectedness and therefore invites reinvention (Coles and Hall 20102). A space in which production and water supply systems can be managed as multifunctional- multi-criteria accredited systems, rather than focus on a single-use system. One that also provides for increased resource use efficiency, and promoting the integration of ES based LULC, with the key elements included such as improving and maintaining soil health, food productivity, water quality and system functionality (Figure 2).

3. The Framework

Based on the preceding discussion, it is obvious that integrated analytical frameworks are required to determine the impact, resilience, short to long-term beneficiaries and losses, of various human endeavours. Improved ES based Best Management Practices (BMP's) can provide tangible societal benefits in ways which are both directly financially beneficial through improved quality of life and environmentally sustainable, while increasing net productive capacity (MEA, 2005; Shortle and Jordan, 2014; McIntyre et al 2015). Whether this is from subsistence farming or artisan mining, or from large scale mining and agricultural developments, or increased urbanisation, there are significant and often cumulative negative impacts on our global natural capital assets, particularly soil and water that is resulting in a variety and scale of often irreversible loss of services.

Linking the biophysical aspects of ecosystems with human benefits through the notion of ES-ESF, provides the essential basis to assess and value the trade-offs (ecological, socio-cultural, economic and monetary) involved in the loss of ESF, whether this be temporary or permanent. These approaches by necessity are required to be delivered at local, national and global scales, however the mechanisms do not currently exist that allow this to occur, given the fascination for profitability, stakeholder (shareholder) returns, short-term goals (and cycles) in both industry and governments such that a significant shift in thinking, industry practice, governance, and community expectation is self-evident.

3.1. Changed practice and policy levers

In addressing these issues in a practical sense, there is an ongoing need for monitoring of the natural and productive resource base, and the human impacts on natural capital within this extended environment (Maes et al 2015). This requires not only scientific expertise, but also wider cooperative efforts from industry, policy makers, local government and others (Coles 2014). The challenge remains of improving and maintaining soil health, food productivity and water quality globally, whilst improving agro-ecosystem functionality, resource use efficiency, and promoting the integration of ES-ESF based LULC scenarios. This framework requires that catchments and operations associated with agricultural production and water supply systems is assessed on a multifunctional- multi-criteria basis. Rather than focus on single-use systems (i.e. single-use cropping), with the integration of key ESF elements and best management practices as a focus for revised industry approaches to sustainable production (Figure 3). Incorporating multi-functionality represents a significant transformation for stakeholders operating in agricultural landscapes and peri-urban environments. This is also the case for both regulators and operators that will need to encourage landscape management in such a way as to achieve the environmental standards of the relevant government policies, while maintaining viable and sustainable integrated agro-ecosystems (See Attributes in Figure 3).

Re-assessing current practice, coupled with research and technical innovation (Figure 2), that are linked with integrative policy initiatives (Figure 3), provides an avenue for better water and balanced LULC sustainability outcomes. But how could this transformative initiative be implemented? The use of economic incentives or tax concessions has previously been used to induce farmers, companies and countries to implement best management practices for a range of ecosystem services (e.g. PES or REDD)[1] The intent of these schemes is to create both an economic and societal framework to reduce over-exploitation. In the process potentially generate new markets for eco-services or at least to promote the true value and complexity of natural capital assets (globally) that is fundamental to making progress towards sustainable production systems. Therefore, by creating an analytical framework in which both value and impact can be assessed, a basis for integrating industry practice and government policy development can be established. These objectives can be delivered through innovative and novel pathways that deliver holistic and integrated approaches to i) land and water quality monitoring technologies and methodologies; ii) modification and extension of BMP's for agro-

[1] PES - Payment for Ecoservices; REDD - Reducing Emissions from Deforestation and Degradation.

forestry, agro-ecological health and improved productivity; iii) overcoming socio-economic and environmental constraints, and vi) creating policy instruments and governance techniques that are crucial to delivering sustainability within a catchment and global context.

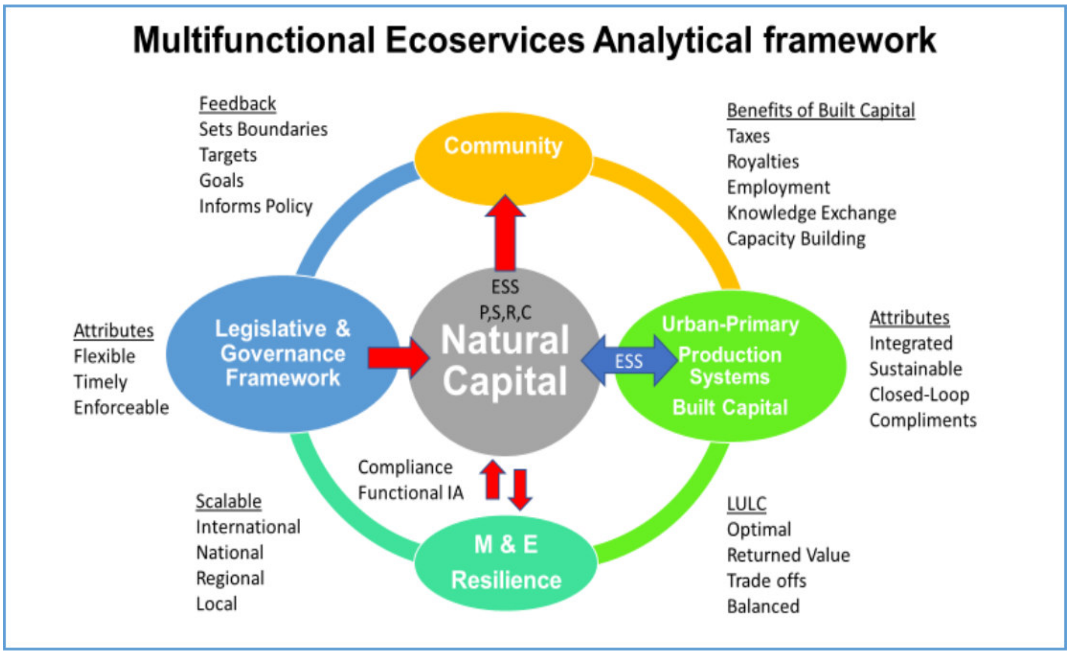

Figure 3. An Integrated Multifunctional Ecoservices Analytical Framework (IMESAF). That uses the quantification of agricultural landscape dynamics and processes. Provides for the evaluation, development and extension of ESS based BMPs that will improve productivity and upstream water quality; Assessment of legislative and governance instruments creating an evidentiary based framework (EBF) that incorporates practice measures, indicators and BMP adoption strategies, and; engage in community and stakeholder consultation to promote knowledge transfer, capacity building and communication.

4. Discussion

Clear evidence now exists that the natural capital, once considered to be 'valueless' or 'free', is of great importance in maintaining supportive and necessary planetary ecosystem functionality (ESF) required for life. An opportunity now exists for government, businesses and primary industries to modify their approach to resource management to facilitate a transformation in sustainable natural capital asset management. A revised strategy can have dual aims of delivering on the SDGs and on the recent climate initiatives (i.e. Paris Agreement), in addition to providing the framework to revitalise industry, agricultural production systems, lead urban renewal and promote greater equity in resource allocation.

Implementation at local and regional scales can build on existing research or reviews (e.g. Holden et al., 2014) and capacity building and knowledge transfer networks (e.g. Environmental Sustainability KTN[2]) or national action plans (e.g. Irish NAP - Agricultural Catchments Programme; UK Critical Zones Program[3]). Through IMESAF supported decisions, water resource management and optimised LULC, the impacts of anthropogenic activities in the landscape can be adjusted, retired or mitigated. These include nature based

[2] www.innovateuk.org/sustainabilityktn
[3] http://www.nerc.ac.uk/research/funded/programmes/czo/

solutions (NBS) for risk management; for example, flood attenuation through changed LULC (e.g. forestry, wetlands); with additional benefits accruing from planting cover and/or companion crops; increased organic matter (as an offset for carbon capture); and improved soil structure and nutrient use that will support increased productivity. Using an ES approach that employs an IMESAF evaluated LULC and integrated multi-functionality, a more efficient and sustainable use of natural resources can be delivered.

But how is this value recognised within government, industry and community? Through using IMESAF, judicial planning and investment governments will enable landholders, industry stakeholders, and the broader community to accrue additional benefits from sustainable ES based production systems. This value (or eco-credit) can be captured by measuring the net impact of an activity as either a net positive or negative outcome attaching an eco-credit to the processes or uses to which the asset is subjected. This can be incorporated into the supply chain whether this is for food production, potable water supply, or industry application, the net change in ES-ESF value is recognised and quantified. As it is highly unlikely, and probably unnecessary, to have detailed values for each service, a simple eco-credit scoring system (++/--) can be formalised in which trends can be captured and used to produce new accreditation tools for the economic characterisation of ES.

By providing documentary evidence through a credit system the change in value can be tracked within the supply chain, the cumulative impact of all elements in the chain can be judged and evaluated based on of sustainability criteria (including bio-ecological, industry practice, temporal benefits and good governance). These criteria, are objective, subjective, cumulative or iterative and will provide continuous chain of evidence for all elements of system management regarding short, medium or long-term operational and environmental objectives (Figure 3). By adopting a monitoring, evaluation and integrative accreditation procedure to managing LULC, natural capital and water resources a balanced sustainable transformative outcome can be delivered. These include those described in Box 1.

Actions undertaken by governments, business and community will be more transparent, the benefits equitably distributed, with poor management practices becoming less economic and relevant. In creating an eco-credit tracking system, payments for services derived from ecoservices (i.e. PES) would be redundant and new funding for enhanced environmental outcomes no longer required, while the value used, recycled or retained is fully recognised at the appropriate temporal and spatial scales. Furthermore an IMESAF derived eco-credit or accreditation system will promote a more integrated rural sector and improve water use through the: a) quantification of agricultural landscape dynamics and processes; b) evaluation, development and extension of ES based BMPs that will improve productivity and water quality; c) assess legislative and governance instruments creating an evidentiary based framework (EBF) that incorporates practice measures, indicators and BMP adoption strategies; and d) engage in community and stakeholder consultation to promote knowledge transfer, capacity building, and communication.

Box 1. Derived benefits from adopting an eco-credit based multifunctional ESS strategy.

- Development of multi-scale and multi-functional industry practices that are monitored and accountable
- Increased uniformity (globally) in resource management, allocation and industry practice;
- Government policies that are linked to sustainable outcomes and objectives (i.e. the SDG's);
- Regulation that is linked to the short, medium and long-term impacts for any activity that affects ESS either directly or indirectly through the supply chain;

- Taxation and regulatory incentives that are employed using similar criteria in (3);
- Levering of Corporate Social Responsibility (CSR) and social media to encourage compliance;
- Identification of resource user beneficiaries and impacted communities or services that can delivers equality based on sustainability criteria;
- Introduction of an accreditation (eco-credit) supply chain system that does not require significant funding for compensation or purchases for changed practices or production systems;
- Development of innovative technologies test sites (e.g. critical zone observatories) that will monitor ESS and ESF provide for assessing and improving long-term sustainability goals (or targets) at local, regional, Nation State and global scales;
- Creation of opportunities for employment in monitoring and assessment at multiple scales, and;
- Increased educational and capacity building opportunities to ensure appropriate best practice development, operational design, compliance, governance and community awareness.

5. Conclusion

Potentially this can be achieved through firstly, the development of the IMESAF decision framework that promotes transparency in sustainable business-industry practice and determining impact in the short, medium and long-term on ESF and thus the services that it rely on it. Secondly, the strategic use of CSR and social capital, in co-operation with governments as an approach to encourage corporations to deliver better environmental and resource outcomes, and provide positive returns to stakeholders and the wider community. Thus, providing a mechanism that extends beyond nation state boundaries where disparities in governance, environmental management, and social equity can be addressed. Thirdly, highlighting the need for education and training to encourage improved governance, and modify industry practices, to enable benefits to be more widely and equitably distributed to those communities that are immediately impacted by corporate and industry activities.

While these mechanisms are not conclusive in themselves, the IMESAF approach can provide a pathway for change, implementation and distribution of broader equitable benefits for the environment and the global community. This can be achieved through an assessment of immediate and future environmental impact, realising and including these costs in the operational bottom line. Through an examination of the demand-supply cycle and determining the resilience and reversibility (i.e. rehabilitation) of the impact on environmental value (over time), beneficial equity, and cost can be adjudicated. By reducing the negative impacts on natural capital assets that generate ecosystem services, and facilitating the overall net positive affect of ESF intervention strategies, it is possible to deliver enhanced sustainable products (i.e. provisioning, regulating, cultural, and habitat maintenance).

On a global level, humanity is at a cross-road, where the opportunity now exists to completely change the way we conduct business, manages the global environment, or seek to empower the less fortunate. The proposed transition in the economy and global operations discussed in this paper is viewed as a necessity to maintain ESF, natural capital health, achieve the SDG' s and a more resilient 'humanised' planet, without which the current prosperity, environmental health and community expectations are unlikely to be maintained or met.

References

Bourke, L., Ranganathan, J. and Winterbottom, R.. 2015. Revaluing Ecosystems: Pathways for Scaling Up the Inclusion of Ecosystem Value in Decision Making. Issues Brief, Apr. Water Resources Institute.

Coles N. A. 2014. “Eco-hydrological Concepts.” In: Handbook of Engineering Hydrology: Vol. 2: Fundamentals and Applications. Eslamain S. (Ed.). Vol 2. Chap. 6. Pp. 97-130. Taylor & Francis-CRC Press. ISBN 978-1-4665-5241-8.

Coles NA and Hall P. 2012. Water, energy and food security: Technology challenges of thinking in a Nexus perspective. IEEE Technology and Society in Asia Oct. 26-28. 2012.

Costanza et.al. 2014. Changes in the global value of ecoservices. Global Environmental Change. Vol. 26. Pg. 152-158.

Daily, G and De Clerck 2014. Foreword. In: Ecosystem Services and Resilience Framework. CGIAR Research Program on Water, Land and Ecosystems (WLE). Colombo, Sri Lanka: International Water Management. 46p. doi: 10.5337/2014.229.

Drexhage, J. and Murphy, D. 2010. Sustainable Development: From Brundtland to Rio 2012. Background paper. United Nations NY.

European Commission, 2010a. The 2010 Assessment of the implementing of EU Biodiversity action plan. IN SEC (2010) 1165. Brussels.

European Commission. 2010b. http://europa.eu/rapid/press-release_IP-10-1303_en.htm Accessed December, 2012.

Haines-Young, R., Potschin, M., 2013. Common international classification of Ecosystem Services (CICES): Consultation on version 4, August–December 2012. Report to the European Environment Agency, rev. January 2013, CEM Research Reports. University of Nottingham, Nottingham.

Holden, J. et al. 2014. Farming and Water 1: Agriculture’s impact on water quality. Report prepared for Global Food Security and UK Water Research and Innovation Partnerships. 2015. 21pg.

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Maes, J. et al 2015. Mapping and Assessment of Ecosystems and their Services: Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010. European Commission Joint Research Centre. Institute for Environment and Sustainability. https://ec.europa.eu/jrc

McIntyre, N., Woodley, A., Danoucaras, N. and Coles, N.A. 2015. Water management capacity building to support rapidly developing mining economies. Water Policy. Published online. doi:10.2166/wp.2015.017. http://www.iwaponline.com/wp/up/wp2015017.htm

McKnight, U.S., Rasmussen, J.J., Kronvang, B., Binning, P.J., Bjerg, P.L. 2015. Sources, occurrence and predicted aquatic impact of legacy and contemporary pesticides in streams. Envir. Poll. 200, 64-76.

Millennium Ecosystem Assessment. (MEA) 2005. Ecosystems and Human Well-being: Synthesis. Washington, DC.: World Resources Institute

Pilaš, I., Feger, K.-H., Vilhar, U., and Wahren, A. 2011. Multidimensionality of Scales and Approaches for Forest–Water Interactions. In Forest Management and the Water Cycle, M. Bredemeier, S. Cohen, DL Godbold, E. Lode, V. Pichler, and P. Schleppi, eds. (Springer Netherlands), pp. 351–380.

Polasky, S., Tallis, H. and Reyers, B. 2015. Setting the bar: Standards for ecosystem services. Nature as Capital. PNAS 100th Anniversary Special Feature. Proceedings of the National Academy of Science. 2015 Vol. 112 (24) pg. 7356-7361; doi:10.1073/pnas.1406490112.

Potschin, M and Haines-Young, R. 2013. Landscapes, sustainability and the place based analysis of ecosystem services. Landscape Ecology (2013) 28(6): 1053-1065. DOI 10.1007/s10980-012-9756-x.

Raworth, K. 2012. A safe and just space for humanity. Can we live within the doughnut? Oxford, UK: Oxfam. www.oxfam.org/files/dp-a-safe-and-justspace-for-humanity-130212-en.pdf. (accessed on April 2, 2015).

Rockström, J., W. Steffen, K. Noone, A. Persson, F.S. Chapin, E.F. Lambin, and T.M. et al. Lenton. 2009. "A safe operating space for humanity." Nature. 461 (7263): 472-475.

Roebeling, P.C., Cunha, M.C., Arroja, L., and vanGrieken, M.E. 2014. Abatement vs. treatment for efficient water quality management in transboundary systems. (Lisbon, Portugal), pp. 21–26.

Seppelt, R., et al., 2012. Form follows function? Proposing a blueprint for ecosystem service assessments based on reviews and case studies. Ecological Indicators Vol. 21 pg. 145–154.

Seppelt, R. Lautenbach, S. and Volk, M. 2013. Identifying trade-offs between ecosystem services, land use, and biodiversity: a plea for combining scenario analysis and optimization on different spatial scales. Current opinion in Environmental Sustainability. Vol. 5:1-6.

Shortle, G. and Jordan, P. 2014. Agricultural Catchments Programme. Phase 1 Report. Teagasc, Crops, Environment and Land-use Programme, Johnstown Castle Environment Research Centre. Pp. 101.

TEEB, 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. ISBN: 978-3-9813410-3-4.

United Nations, 2015. Transforming our world: the 2030 Agenda for Sustainable Development. Sustainable Development knowledge platform. General Assembly resolution. A/RES/70/1 21 October 2015. https://sustainabledevelopment.un.org/post2015/transformingourworld

UN-Water (2013) Water Security and the Global Water Agenda. United Nations University, UN-Water Analytical Brief. 01/2013. http://www.unwater.org/publications/publications-detail/en/c/197890/

Volk, M. 2013. Modelling ecosystem services – Challenges and promising future directions. Sustainability of Water Quality and Ecology. 1-2 (2013) 3-9.

Wang, Y. Xiong, W. Gampe, S. Coles, N.A, Yu, P. Xu, L. and Wang, Y. 2015. A Water Yield Oriented Practical Approach for Multifunctional Forest Management and Its Application in Dryland Regions of China. Jour. American Water Resources Association. 06/2015 -51(3):689-703. DOI:10.1111/1752-1688.12314.

Waughray, D. 2011. Water Security: the water-food-energy-climate nexus: The World Economic Forum water initiative. Island Press Washington DC.

Young G, Siegfried, D. Mishra, A. and Cudennec, C. 2015. Hydrological sciences and water security: An overview. Hydrological Sciences and Water Security: Past, Present and Future (Proceedings of the 11th Kovacs Colloquium, Paris, France, June 2014). IAHS Publ. 366. doi:10.5194/piahs-366-1-2015.

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