Literature review: The case for incorporating an ecosystem services framing as part of a holistic approach to salinity management in the Indus Basin of Pakistan

Michael Mitchell, Catherine Allan and Max Finlayson

1. Introduction

This is a preliminary literature review prepared as part of an ACIAR Small Research and Development Activity (SRA) LWR-2017-028 "Improving Salinity and Agricultural Water Management in the Indus Basin of Pakistan." A more comprehensive literature review will be undertaken if the proposed four-year project emerging from this SRA proceeds.

The purpose of this preliminary review is to scope and assess the literature to develop a case for incorporating an ecosystem services framing as part of the proposed project's holistic approach to salinity management in the Indus Basin of Pakistan. Including ecosystems services in this project is considered to have many advantages, based on experience with holistic frameworks and in particular with the benefits of addressing the wider benefits to humans that come from production landscapes. In preparing this we are aware that the idea has not yet captured the imagination of all of our Pakistan-based collaborators; nor does there seem to be a large amount of experience with ecosystem service frameworks in Pakistan, as shown by a search of the database held by the Ecosystem Services Partnership (https://www.es-partnership.org/).

This is in contrast to the situation in China where ecosystem service frameworks are being developed and supported by the Asian Development Bank and used to drive innovative thinking about the sustainability issues that are being faced (Bennett 2009; Zhang et al. 2010). In particular, payment for ecosystem services and eco-compensation schemes are being developed and applied within the relevant local context and with the realisation that models based on "business as usual" are unlikely to be sustainable nor provide the necessary support required for enhancing human livelihoods. Integral to such efforts are steps to consider the wider benefits that ecosystems, including agroecosystems bring to people.

The CGIAR Research Program on Water, Land and Ecosystems also links the same concepts, as shown through the following text that specifically links ecosystem services with efforts to increase agricultural productivity. (https://wle.cgiar.org/research/themes/integrating-ecosystem-solutions-policy-and-investments) "*The greatest challenge to our food production systems in the coming forty years will be to feed a growing population while addressing critical threats to the environment. Producing more food will only be possible if ecosystems are protected. Functioning, healthy ecosystems provide a wide range of services—including water for irrigation and drinking, nutrients for soils, regulation of pests and diseases and* many more that farmers and industries depend on. If such services are not considered and protected, efforts to increase agricultural productivity will fail."

Molden et al. (2007) in the Comprehensive Assessment of Water Management in Agriculture which drew together hundreds of researchers and practitioners to find

water solutions for the future concluded with a broad set of statements that brought together the need to manage agricultural water within the context of the basin and with good practice also increasingly sensitive to the role of ecosystems. Falkenmark et al. (2007) as part of the same assessment considered the "costs of going too far" and concluded that "*In view of the huge scale of future demands on agriculture to feed humanity and eradicate hunger, and the past undermining of the ecological functions on which agriculture depends, it is essential that we change the way we have been doing business*."

The above examples are a few only of the many that have been encouraging the adoption of a more holistic approach for managing food production in order to reduce poverty and enhance livelihood opportunities for local communities. The ecosystem services concept has been framed within this context and used alongside international initiatives to make better use of natural infrastructure and to adopt nature-based adaptation when addressing the complex problems facing communities that need to contend with increased food and nutrition needs and a degraded natural resource base. The ecosystem service concepts were initially framed as the natural capital that was needed to provide the biophysical foundation for societal development and economic activity (De Groot et al. 2018). This framing is relevant to the Indus Basin given the importance of food production and the problems caused by salinity.

To help develop a case for the case for incorporating an ecosystem services or nature-based framing as part of a holistic approach to salinity management in the Indus Basin, the review authors have determined the following literature as being relevant:

1. Research that uses integrated or holistic approaches, alternatively referred to as ecosystem approaches, and including ecosystem services framing in particular, with reference to improving livelihoods for rural communities in salinity-affected landscapes.
2. Research that uses integrated or holistic approaches, and ecosystem services framing in particular, with reference to sustainable use of natural resources for agriculture in Pakistan and similar agricultural systems in equivalent areas of Asia.

This document begins with a review and critique of holistic or integrated approaches to water and salinity management, and the prospect of an ecosystem services framing to enhance currently used approaches. We then explain our literature search methods before summarising our findings according to the above two areas of research.

2. Current holistic/ integrated approaches to water and salinity management

A holistic approach involves consideration of all aspects of a situation as part of the whole. It is the opposite of an analytic approach, which involves classifying the system to investigate its different component parts. A holistic approach therefore involves integration: integrating perspectives across academic disciplines; and integrating perspectives from researchers, research users (government agencies, non-government organisations and community based organisations) and research

beneficiaries (resource dependent communities and families). A separate review of approaches to water and salinity management in the Indus Basin (Akhter, 2018) suggests that there has been a shift towards adopting what could be understood as a holistic approach, especially through efforts to integrate the perspectives and understandings of salinity affected communities into management responses.

One well documented holistic or integrat*ing*[1] approach for managing water is Integrated Water Resources Management (IWRM). While there are myriad definitions and understandings of IWRM, the 'working' definition used by the Global Water Partnership is often cited: "IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership Technical Advisory Committee, 2000, p. 22).

IWRM gained rapid popularity among water managers and policy makers in the 1990s, as the need to address water issues as "multi-dimensional, multi-sectoral, and multi-regional and filled with multi-interests, multi-agendas, and multi-causes", which could be "resolved only through a proper multi-institutional and multi-stakeholder coordination" (Biswas, 2004, p. 249).

In a world that operates on the principle of reductionism, integrated water resources management offers the impression of being comprehensive and holistic (Biswas, 2008). However, both Biswas 2004 and 2008 are highly sceptical of IWRM in practice.

Recent approaches to IWRM appear to have more positive outcomes, for example in the Mekong Basin (Budryte, Heldt, & Denecke, 2018). These recent approaches appear to be less fragmented and water focused (Budryte et al., 2018), and some move beyond IWRM and similar concepts (de Loë & Patterson, 2017), such as viewing Bangladesh through the lens of a human-delta co-evolutionary system (Roy, Gain, Mallick, & Vogt, 2017).

The prospect of adopting a participatory and systems-based approach to modelling has been applied in a case study related to salinity management in Rechna Doab (Inam et al., 2015; 2017a; 2017b). This long-term project involved the development of an integrated quantitative model achieved by coupling a socio-economic model with one able to simulate outcomes of physical watershed processes (Inam et al., 2017b). The model was framed via input acquired through a participatory qualitative causal loop diagram model of relevant system dynamics (Inam et al., 2015). The modellers were able to develop a set of maps showing changes over time in soil salinity, water availability and farm income distributions according to five scenarios. The scenarios represented selected management interventions designed to address the salinity issues in the area. These were:

1. A continuation of the much praised canal lining policy.

[1] We refer to an integrating approach rather than an integrated approach. Integrating emphasises the process (the act of integrating) whereas integrated can imply a state (the achievement of being integrated). Integration is an ongoing process. There is no end point

2. Ensuring uniform distribution of water across head, middle and tail reaches of the canal.
3. Increasing the percentage of water for downstream users by decreasing the percentage for upstream users.
4. On farm storage of excess irrigation water supply and rainfall for later use (water banking).
5. A revival of the Salinity Control and Reclamation Project (SCARP) techniques that had been abandoned.

Results suggested benefits over the long term from canal lining on all aspects, but this is an approach which requires significant initial government investment for long-term gain. The three scenarios involving different approaches for water redistribution were found to be not feasible, and the results for the SCARP scenario showed that while it could increase water availability and farm incomes, it would result in increased soil salinity over time due to secondary salinisation (Inam et al., 2017b).

Aspects of this modelling approach are useful. In particular, the initial approach of developing system models (Inam et al., 2015) is an approach we would like to adopt as part of our approach. However, a key difference that we would be keen to adopt in the future is to use these models to identify scenarios that stretch stakeholder imagination about intervention options rather than test existing options. Like Rickards et al. (2014), we imagine a process where scenarios can be used to open people's minds to a range of new and previously unimagined possibilities.

3. Potential contribution of an ecosystem services framing to a holistic approach

For all aspects to be considered as part of a holistic understanding of the situation facing communities in saline affected areas, we suggest that an essential component missing is an improved understanding of the supporting role that ecosystems in the surrounding landscape can offer to salinity management.

Ecosystem approaches have been used as an integrating research strategy, especially in the context of promoting sustainable use of natural resources for human benefit in an equitable way (Finlayson et al., 2011). Incorporating the notion of ecosystem services as part of these approaches can help to articulate how the biophysical environment supports human well-being, livelihoods and sustainability (Costanza et al., 2014). It does this by framing the range of services offered by ecosystems: provisioning, regulating, supporting and cultural. While we have not yet applied this framing to the services that ecosystems might play in relation to salinity management, we include an example below taken from the Millennium Ecosystem Assessment (2005) of the range of ecosystem services provided by wetlands (see Table 1).

Table1: Example of ecosystem services framing using examples related to wetlands

Services	Comments and Examples
Provisioning	
Food	production of fish, wild game, fruits and grains
Fresh water	storage and retention of water for domestic, industrial and agricultural use
Fibre and fuel	production of logs, fuelwood, peat, fodder
Biochemical	extraction of medicines and other materials from biota
Genetic materials	genes for resistance to plant pathogens, ornamental species and so on
Regulating	
Climate regulation	source of and sink for greenhouse gases; influence local and regional temperature, precipitation and other climatic processes
Water regulation (hydrological flows)	groundwater recharge/discharge
Water purification and waste treatment	retention, recovery, and removal of excess nutrients and other pollutants
Erosion regulation	retention of soils and sediments
Natural hazard regulation	flood control, storm protection
Pollination	habitat for pollinators
Cultural	
Spiritual and inspirational	source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems
Recreational	opportunities for recreational activities
Aesthetic	many people find beauty or aesthetic value in aspects of wetland ecosystems
Educational	opportunities for formal and informal education and training
Supporting	
Soil formation	sediment retention and accumulation of organic matter
Nutrient cycling	storage, recycling, processing and acquisition of nutrients

Source: Millennium Ecosystem Assessment, 2005, Table 1, p. 2

A project seeking to combine poverty alleviation with wetlands conservation in South Africa, *Working for Wetlands*, determined that such services may be more readily appreciated as “water management functions” (Zabal & Sullivan, 2018, p. 506). Such an alternative phrasing helped secure motivation for engagement and resources from key decision makers and organisational stakeholders who may have been dissuaded by reference to ecosystem services. However, our view is that it is the framing that offers explanatory potential.

By understanding and articulating the range of services that each specific ecosystem might offer, and applying them to aspects related to enhancing livelihoods of those communities living in salinity affected areas, it may be possible to articulate and investigate additional risks and opportunities for these communities. By using this framing, the extent of services provided by different types of ecosystems can also be assessed in a qualitative comparative way (see examples in Millennium Ecosystem Assessment, 2005). An increased appreciation of the services that have been lost

due to wetlands degradation has provided impetus for the world-wide concern to replenish environmental flows (Jägermeyr et al., 2017; Norris, 2011), and underpins the principle behind the World Wide Fund for Nature's position on preventing further deterioration of the Indus Basin due to inadequate environmental flows (WWF Pakistan, nd; also see WWF Pakistan, 2010). These concepts were similarly incorporated into the Comprehensive Assessment of Water Management in Agriculture whereby the multiple values of water used in agriculture were addressed (Molden 2007), as were the costs of going too far (Falkenmark et al. 2007).

4. Literature search methods

Our search methods were rapid and exploratory to provide us with a glimpse of the kinds of research being undertaken. More comprehensive search methods could be adopted later if required.

We therefore only used one journal database, Scopus, and undertook the following searches:

1. A search of salinity AND "ecosystem service" in title, abstract and key words: 190 results, of which 22 were identified as potentially relevant. 15 selected from first 20 results ordered by relevance; another 6 from the next 20, and 1 more selected from the next 40.
2. A search of "ecosystem service" AND Pakistan AND agriculture in title, abstract and key words: 9 results, of which 5 were identified as potentially relevant.
3. A search of "ecosystem service" AND Bangladesh AND agriculture in title, abstract and key words: 15 results, of which 8 were identified as potentially relevant

The process of selecting for relevance was in two stages: first selection by title of the publication only (46 in total, as listed above), then a secondary selection of relevance from a reading of the abstract (24 in total, of which 1 related to Pakistan, and 11 related to Bangladesh or South Asia in general). These were added to publications we had already identified through searches for publications by organisations we had been informed might be working on ecosystem approaches related to water and salinity management (e.g. WWF Pakistan and IUCN), and from our existing literature databases. This included publications in a database from our companion ACIAR project on groundwater management in Pakistan and additional relevant examples we had found relating to the use of ecosystems approaches in China, India, Southeast Asia and elsewhere. A bibliography of publications of potential relevance to the proposed project is attached as an appendix to this report.

As could be expected, many of the publications our search method uncovered were deemed irrelevant as the reference to "ecosystem services" was cursory. However, we were able to identify sufficient examples that made specific use of an ecosystem approach, including some that made specific use of an ecosystem services framing to decide to rely on these examples for the purposes of this review.

5. Use of ecosystem approaches to enhance salinity management

The search method used in this case was too broad, and the bulk of the 190 publications uncovered only made passing reference to salinity and/or ecosystem services. The most useful were broad in scope, helping to position our interest to explore use of an ecosystem services framing as part of this project. They included publications linking ecosystem services to enhance management of irrigation (Crossman et al., 2010), soils (Faber & Van Wensem, 2012), and various types of riverine and coastal areas (Craft et al., 2009; Kelleway et al., 2017; McNally et al., 2016; Schäfer et al., 2012), including four referring to Bangladesh-based studies (Abdullah-Al-Mamun et al., 2017; Hossain et al., 2016; Islam, 2011; and Nicholls et al., 2015). These complemented the literature we were already aware of and relying on to link an ecosystems services framing with sustainable use of water for agriculture (Falkenmark et al., 2007; Finlayson et al., 2011; Gordon et al., 2010; Millennium Ecosystem Assessment, 2005; and Rockström et al., 2004).

The search, however, did uncover a study specifically aimed at improving livelihoods for rural communities in a salinity-affected landscape (Panagea et al., 2016). The example, from Greece, demonstrated particular potential because it referred to the adoption of a participatory research approach for a holistic assessment of three innovative salinity amelioration strategies particular to that context, as endorsed through stakeholder engagement. These strategies were:

1. Greenhouse roof rainwater harvesting.
2. Greenhouse crop rotations to enhance “green manuring.”
3. Application of biological agents to increase crop resistance to salinity.

While the assessment did not use the ecosystems services framing, it enabled a holistic assessment of the proposed strategies, allowing research beneficiaries to easily compare the three strategies in terms of how they balanced production and socio-economic benefits, socio-cultural benefits, ecological benefits and other off-site benefits. This was achieved by listing a range of human well-being and ecosystem impacts from each strategy. Results showed that the first strategy offered benefits across a wider range while the third strategy was the only one to offer comparatively higher production and socio-economic benefits. This helps explain initial resistance to the adoption of the first two strategies as the wider range of benefits are not immediately apparent.

6. Use of ecosystem approaches in research related to Pakistan agriculture

We were already aware of a number of Sindh-based studies that drew on ecologically-based principles to enhance agricultural practices. We had become aware of these studies from literature searches related to environmental impacts of groundwater use undertaken as part of our companion ACIAR research project. These include studies reporting on impacts from changed behaviours by farmers trained using farmer field schools in the use of sustainable farming practices (Khan & Iqbal, 2005) and integrated pest management (Khan et al., 2007). These studies emerged as a result of concern about groundwater contamination.

Another set of studies referred to an “ecosystem approach” in relation to excess water use and waterlogging (Negris et al., 2015; 2016; 2017). The Negris et al. (2015 and 2016) studies included specific reference to an ecosystem approach in the papers’ titles but with minimal elaboration of what such an approach would involve. Instead the authors appeared to be making a case for adopting an ecosystem approach. They explained how excess water use and waterlogging damaged the environment, suggesting that actions to redress these impacts would help improve the livelihoods of those living there. The Negris et al. (2017) paper reports on one remedial action: the university-based trial use of reef beds as a municipal water treatment technique for groundwater recharge. This is the kind of action we would be interested in exploring further as part of a set of innovations to help redress salinity related impacts in the Indus Basin.

A futures-oriented social-ecological systems approach has also been adopted by Ali et al. (2015) and Shelley et al. (2015) for a Ramsar wetland adjacent to a barrage over the Indus River near Multan (the Taunsa Barrage Wildlife sanctuary). Using a participatory approach with stakeholders, Ali et al. (2015) explore ideas that combine wetland rehabilitation and community benefit through ecotourism developments. A companion paper by Shelley et al. (2015) explore the community’s resilience capacity in the face of projected climate change impacts. The view from communities living in the wetland area is that they had shown a high level of capacity to respond to change (Shelley et al., 2015). The major impediments on the communities were institutional constraints preventing them from pursuing ecotourism opportunities (Ali et al. 2015).

7. Use of ecosystem approaches in research related to agriculture in other equivalent parts of Asia: focus on Bangladesh

We were not surprised to find a range of literature from Bangladesh that had adopted ecosystems approaches. Our familiarity with literature on social-ecological systems approaches to research, such as that published by the journal of the Resilience Alliance, *Ecology and Society*, meant we were aware of a number of studies using Bangladesh as case studies, notably Hoque et al. (2017) and Ishtiaque et al. (2017). Our assumption is that the context of the Bangladesh delta under climate change captures the imagination of researchers theoretically disposed to understanding how social and ecological impacts from climate change intertwine to significant detriment, and where transformational solutions are likely to be necessary. It is also a context where the effects of climate change are already immediately apparent, and communities have already had to transformed how they source their livelihoods.

Our search uncovered several papers that specifically referred to ecosystem services as a part of their research approach. Many of these are products of a significant UK-funded long-term research program, the Ecosystem Services for Poverty Alleviation (ESPA) Deltas Project “Assessing Health, Livelihoods, Ecosystem Services and Poverty Alleviation in Populous Deltas, 2012-2016” – see http://www.espadelta.net/. There is a special issue of the *Environmental Sciences: Processes and Impacts* journal devoted to the project (see Nicholls et al., 2015), and the overall process of incorporating ecosystem services as part of a holistic modelling approach to basin development is described by Nicholls et al. (2016). The process included scenario development, with three scenarios ranging less

sustainable, through business as usual to more sustainable. The project invested significantly in developing a wide range of multi-disciplinary data as input for modelling (Adams et al., 2016), and included specific studies exploring on-farm salinity (Clarke et al., 2015), impacts of land use change for ecosystem services (Islam et al., 2015), and implications for future agricultural livelihoods (Lazar et al., 2015) and wellbeing (Hossain et al., 2016).

Others have explored economic valuation methods as a means to explore future implications of ecosystem degradation on livelihoods, particularly those related to mangrove forests (Abdullah-Al-Mamun et al., 2017) and changing agricultural practices (Rasul, 2009). Sohel et al. (2015) have developed the ecosystem services approach further into a new "ecohydrology" based approach to sustainable management of water resources.

The range of studies uncovered in Bangladesh suggest there may indeed be merit in us further exploring the contribution an ecosystem services framing to holistic management of salinity in the Indus Basin. This could further draw on the assessments being undertaken by the Intergovernmental Panel for Biodiversity and Ecosystem Services. The Panel focuses on Nature's Contributions to People and had adopted an assessment approach that is both holistic and draws on multiple knowledge sources. It includes a global assessment on land degradation and restoration that is intended to cover the global status and trends in land degradation, by region and land cover type. The assessment is intended to enhance the knowledge base for policies and approaches for the restoration of degraded land, and is due for release at the end of March 2018.

8. References

Abdullah-Al-Mamun, M. M., Masum, K. M., Raihan Sarker, A. H. M., & Mansor, A. (2017). Ecosystem services assessment using a valuation framework for the Bangladesh Sundarbans: Livelihood contribution and degradation analysis. *Journal of Forestry Research, 28*(1). https://doi.org/10.1007/s11676-016-0275-5

Adams, H., Adger, W. N., Ahmad, S., Ahmed, A., Begum, D., Lázár, A. N., . . . Streatfield, P. K. (2016). Data Descriptor: Spatial and temporal dynamics of multidimensional well-being, livelihoods and ecosystem services in coastal Bangladesh. *Scientific Data, 3*. http://dx.doi.org/10.1038/sdata.2016.94

Akhtar, A. (2018). *Improving salinity and agricultural water management in the Indus Basin, Pakistan: Issues, management and opportunities: A synthesis from a desk-top literature review*. Unpublished report prepared for Charles Sturt University and the Australian Centre for International Agricultural Research.

Ali, Z., Shelly, S. Y., Bibi, F., Nasir, Z. A., Colbeck, I., & Butler, J. R. A. (2015). Prospects for alleviating poverty and protecting the Taunsa barrage wildlife sanctuary, Indus river, Pakistan, through cultural and eco-tourism. *Journal of Animal and Plant Sciences, 25*(3), 341-347.

Bennett, M. T. (2009). *Markets for ecosystem services in China: An exploration of China's "eco-compensation" and other market-based environmental policies*. Washington DC: Forest Trends. http://www.forest-trends.org/publication_details.php?publicationID=2317

Biswas, A. K. (2004). Integrated water resources management: A reassessment - A water forum contribution. *Water International, 29*(2), 248-256. https://doi.org/10.1080/02508060408691775

Biswas, A. K. (2008). Current directions: integrated water resources management – a second look. *Water International, 33*(3), 274-278. https://doi.org/10.1080/02508060802272812

Budryte, P., Heldt, S., & Denecke, M. (2018). Foundations of the participatory approach in the Mekong River basin management. *Science of the Total Environment, 622-623*, 349-361. https://doi.org/10.1016/j.scitotenv.2017.11.345

Clarke, D., Williams, S., Jahiruddin, M., Parks, K., & Salehin, M. (2015). Projections of on-farm salinity in coastal Bangladesh. *Environmental Science: Processes and Impacts, 17*(6), 1127-1136. http://dx.doi.org/10.1039/C4EM00682H

Craft, C., Clough, J., Ehman, J., Jove, S., Park, R., Pennings, S., . . . Machmuller, M. (2009). Forecasting the effects of accelerated sea-level rise on tidal marsh ecosystem services. *Frontiers in Ecology and the Environment, 7*(2), 73-78. https://doi.org/10.1890/070219

Crossman, N. D., Connor, J. D., Bryan, B. A., Summers, D. M., & Ginnivan, J. (2010). Reconfiguring an irrigation landscape to improve provision of ecosystem services. *Ecological Economics, 69*(5), 1031-1042. https://doi.org/10.1016/j.ecolecon.2009.11.020

de Groot, D., Brander, L., & Finlayson, C. M. (2018). Wetland ecosystem services. In C. M. Finlayson, M. Everard, K. Irvine, R. J. McInnes, B. A. Middleton, A. A. van Dam, & N. C. Davidson (Eds.), *The wetland book I: Structure and function, management and methods*. Dordrecht: Springer. http://www.springer.com/gb/book/9789048134939 (in press)

de Loë, R. C., & Patterson, J. J. (2017). Rethinking water governance: Moving beyond water-centric perspectives in a connected and changing world. *Natural Resources Journal, 57*(1), 75-99.

Faber, J. H., & Van Wensem, J. (2012). Elaborations on the use of the ecosystem services concept for application in ecological risk assessment for soils. *Science of the Total Environment, 415*, 3-8. https://doi.org/10.1016/j.scitotenv.2011.05.059

Falkenmark, M., Finlayson, C. M., & Gordon, L. J. (2007). Agriculture, water, and ecosystems: Avoiding the costs of going too far. In D. Molden (Ed.), *Water for food water for life: a comprehensive assessment of water management in agriculture* (pp. 233-277). London: Earthscan.

Finlayson, C. M., Davidson, N., Pritchard, D., Milton, G. R., & MacKay, H. (2011). The Ramsar Convention and ecosystem-based approaches to the wise use and sustainable development of wetlands. *Journal of International Wildlife Law & Policy, 14*(3-4), 176-198.

Global Water Partnership Technical Advisory Committee. (2000). *Integrated Water Resources Management*. Stockholm: Global Water Partnership.

Gordon, L. J., Finlayson, C. M., & Falkenmark, M. (2010). Managing water in agriculture for food production and other ecosystem services. *Agricultural Water Management, 97*(4), 512-519. http://dx.doi.org/10.1016/j.agwat.2009.03.017

Hoque, S. F., Quinn, C. H., & Sallu, S. M. (2017). Resilience, political ecology, and well-being: An interdisciplinary approach to understanding social-ecological change in coastal Bangladesh. *Ecology and Society, 22*(2), 45. http://dx.doi.org/10.5751/ES-09422-220245

Hossain, M. S., Dearing, J. A., Rahman, M. M., & Salehin, M. (2016). Recent changes in ecosystem services and human well-being in the Bangladesh coastal zone. *Regional Environmental Change, 16*(2), 429-443. https://doi.org/10.1007/s10113-014-0748-z

Inam, A., Adamowski, J., Halbe, J., & Prasher, S. (2015). Using causal loop diagrams for the initialization of stakeholder engagement in soil salinity management in agricultural watersheds in developing countries: A case study in the Rechna Doab watershed, Pakistan. *Journal of Environmental Management, 152*(Supplement C), 251-267. https://doi.org/10.1016/j.jenvman.2015.01.052

Inam, A., Adamowski, J., Prasher, S., Halbe, J., Malard, J., & Albano, R. (2017a). Coupling of a distributed stakeholder-built system dynamics socio-economic model with SAHYSMOD for sustainable soil salinity management. Part 1: Model development. *Journal of Hydrology, 551*, 596-618. http://dx.doi.org/10.1016/j.jhydrol.2017.03.039

Inam, A., Adamowski, J., Prasher, S., Halbe, J., Malard, J., & Albano, R. (2017b). Coupling of a distributed stakeholder-built system dynamics socio-economic model with SAHYSMOD for sustainable soil salinity management. Part 2: Model coupling and application. *Journal of Hydrology, 551*, 278-299. http://dx.doi.org/10.1016/j.jhydrol.2017.03.040

Ishtiaque, A., Sangwan, N., & Yu, D. J. (2017). Robust-yet-fragile nature of partly engineered social-ecological systems: A case study of coastal Bangladesh. *Ecology and Society, 22*(3), 5. http://dx.doi.org/10.5751/ES-09186-220305

Islam, G. M. T., Islam, A. K. M. S., Shopan, A. A., Rahman, M. M., Lázár, A. N., & Mukhopadhyay, A. (2015). Implications of agricultural land use change to ecosystem services in the Ganges delta. *Journal of Environmental Management, 161*, 443-452. http://dx.doi.org/10.1016/j.jenvman.2014.11.018

Kelleway, J. J., Cavanaugh, K., Rogers, K., Feller, I. C., Ens, E., Doughty, C., & Saintilan, N. (2017). Review of the ecosystem service implications of mangrove encroachment into salt marshes. *Global Change Biology, 23*(10), 3967-3983. https://doi.org/10.1111/gcb.13727

Khan, M. A., & Iqbal, M. (2005). Sustainable cotton production through skill development among farmers: Evidence from Khairpur District of Sindh, Pakistan. *Pakistan Development Review, 44*(4 PART II), 695-712.

Khan, M. A., Iqbal, M., & Ahmad, I. (2007). Environment-friendly cotton production through implementing integrated pest management approach. *Pakistan Development Review, 46*(4), 1119-1135.

Lazar, A. N., Clarke, D., Adams, H., Akanda, A. R., Szabo, S., Nicholls, R. J., . . . Moslehuddin, A. Z. M. (2015). Agricultural livelihoods in coastal Bangladesh under climate and environmental change - a model framework. *Environmental Science: Processes and Impacts, 17*(6), 1018-1031. http://dx.doi.org/10.1039/C4EM00600C

McNally, C. G., Gold, A. J., Pollnac, R. B., & Kiwango, H. R. (2016). Stakeholder perceptions of ecosystem services of the Wami River and estuary. *Ecology and Society, 21*(3). https://doi.org/10.5751/ES-08611-210334

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Wetlands and water synthesis*. Washington DC: World Resources Institute.

Molden, D., Frenken, K., Barker, R., de Fraiture, C., Mati, B., Svendsen, M., . . . Finlayson, C. M. (2007). Trends in water and agricultural development. In D. Molden (Ed.), *Water for food water for life: a comprehensive assessment of water management in agriculture* (pp. 57-89). London: Earthscan.

Nergis, Y., Sahrif, M., Hussain, A., Butt, J. A., & Tahir, Y. (2017). Reed bed technology and recharging on groundwater: Mitigating the climate effect of coastal areas. *Journal of Earth Science and Climatic Change, 8*(7), 1000406. http://dx.doi.org/10.4172/2157-7617.1000406

Nergis, Y., Sahrif, M., Hussain, A., Naveed, K., & Memon, A. H. (2015). Ecosystem approach and hydrological potential study of coastal area of Thatta Sindh, Pakistan. *International Journal of Economic and Environmental Geology, 6*(2), 52-55.

Nergis, Y., Sahrif, M., Memon, A. H., AlOthmany, D., Zeab, F., Naveed, K., & Hussain, A. (2016). Ecosystem approach and hydrological potential study of coastal area of Port Qasim Industrial Coastal Zone of Karachi Pakistan. *Journal of Civil and Environmental Research, 8*(2), 18-26.

Nicholls, R. J., Hutton, C. W., Lázár, A. N., Allan, A., Adger, W. N., Adams, H., . . . Salehin, M. (2016). Integrated assessment of social and environmental sustainability dynamics in the Ganges-Brahmaputra-Meghna delta, Bangladesh. *Estuarine, Coastal and Shelf Science, 183*, 370-381. http://dx.doi.org/10.1016/j.ecss.2016.08.017

Nicholls, R. J., Whitehead, P., Wolf, J., Rahman, M., & Salehin, M. (2015). The Ganges-Brahmaputra-Meghna delta system: Biophysical models to support analysis of ecosystem services and poverty alleviation. *Environmental Sciences: Processes and Impacts, 17*(6), 1016-1017. https://doi.org/10.1039/c5em90022k

Norris, R. H. (2011). Environmental water: The benefits of ecological goods and services. In D. Connell & R. Q. Grafton (Eds.), *Basin futures: water reform in the Murray-Darling Basin* (pp. 59-80). Canberra: ANU e-press.

Rasul, G. (2009). Ecosystem services and agricultural land-use practices: A case study of the Chittagong Hill Tracts of Bangladesh. *Sustainability: Science, Practice, and Policy, 5*(2), 15-27.

Rickards, L., Wiseman, J., Edwards, T., & Biggs, C. (2014). The problem of fit: scenario planning and climate change adaptation in the public sector. *Environment and Planning C: Government and Policy, 32*(4), 641-662. http://dx.doi.org/10.1068/c12106

Rockström, J., Folke, C., Gordon, L., Hatibu, N., Jewitt, G., Penning de Vries, F., . . . Schulze, R. (2004). A watershed approach to upgrade rainfed agriculture in water scarce regions through Water System Innovations: An integrated research initiative on water for food and rural livelihoods in balance with ecosystem functions. *Physics and Chemistry of the Earth, 29*(15–18), 1109-1118. http://dx.doi.org/10.1016/j.pce.2004.09.016

Roy, K., Gain, A. K., Mallick, B., & Vogt, J. (2017). Social, hydro-ecological and climatic change in the southwest coastal region of Bangladesh. *Regional Environmental Change, 17*(7), 1895-1906. https://doi.org/10.1007/s10113-017-1158-9

Schäfer, R. B., Bundschuh, M., Rouch, D. A., Szöcs, E., von der Ohe, P. C., Pettigrove, V., . . . Kefford, B. J. (2012). Effects of pesticide toxicity, salinity and other environmental variables on selected ecosystem functions in streams and the relevance for ecosystem services. *Science of the Total Environment, 415*, 69-78. https://doi.org/10.1016/j.scitotenv.2011.05.063

Shelly, S. Y., Ali, Z., Bibi, F., Nasir, Z. A., Colbeck, I., & Butler, J. R. A. (2015). Resilience of local communities to climate change around a Ramsar site in Pakistan. *Journal of Animal and Plant Sciences, 25*(3), 324-333.

Sohel, M. S. I., Mukul, S. A., & Chicharo, L. (2015). A new ecohydrological approach for ecosystem service provision and sustainable management of aquatic ecosystems in Bangladesh. *Ecohydrology and Hydrobiology, 15*(1), 1-12. http://dx.doi.org/10.1016/j.ecohyd.2014.10.001

WWF Pakistan. (nd). *WWF - Pakistan's position on environmental flows*. Lahore, Pakistan: WWF Pakistan. Available from: http://wwfpak.org/publication/index.php

WWF Pakistan. (2010). *Recommendations for water policy reforms: A report by WWF - Pakistan*. Lahore, Pakistan: WWF Pakistan. Available from: http://wwfpak.org/publication/index.php

Zabala, A., & Sullivan, C. A. (2018). Multilevel assessment of a large-scale programme for poverty alleviation and wetland conservation: Lessons from South Africa. *Journal of Environmental Planning and Management, 61*(3), 493-514. https://doi.org/10.1080/09640568.2017.1319344

Zhang, Q., Bennett, M. T., Kannan, K., & Jin, L. (2010). *Payments for ecological services and eco-compensation: Practices and innovations in the People's Republic of China*. Mandaluyong City, Philippines: Asian Development Bank. Available from: https://www.adb.org/sites/default/files/publication/27468/payments-ecological-services-prc.pdf