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Ecosystem service assessments in climate adaptation

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Abstract

Ecosystem services is Nature's contribution to human well-being by providing provisioning, regulating, supporting and cultural services. A direct driver affecting availability of ecosystem services is climate change. This is a challenge that needs to be addressed. A possible strategy to cope with these challenges is the use of Ecosystem-based adaptation, defined by Secretariat of the Convention on Biological Diversity as "the use of biodiversity and ecosystem services as a part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change".

In this paper a literature review was conducted to highlight the current use of ecosystem services in relation to coping with climate adaptation. Investigated parameters was I) geographical area and sector; II) aim of article; III) methodological approach; and IV) lessons learned by the authors of the reviewed articles regarding method used and lessons learned by the authors of the reviewed articles regarding implementing EbA. The diversity among methods of ecosystem service assessment used in the reviewed articles indicate that there are many possibilities of assessing ecosystem services and communicating impacts from climate change. A combination of methods was also seen as beneficial to assist decision-makers and planners in climate adaptation decisions. This paper put forward useful knowledge for future ecosystem service assessments, both in preparation and performance of assessments.

Introduction

Ecosystem services, ES, is necessary for mankind's survival. It provides provisioning, regulating, supporting and cultural services, and is considered as the basis of human well-being.

Ecosystem services are affected by both direct drivers as e.g. climate change, land use, external inputs and resource consumption, and indirect drivers as economy, socio-political and demographics. These drivers of change occur within both long and short time frames as well as in different geographical scales from local to global. Climate change is considered to be the major driver of changes for ecosystem services by the end of the 21th century (Millennium Ecosystem Assessment, 2005). Changes in the provisioning of ecosystem services driven by climate change, can be both positive and negative, but dominantly it will mean adverse effects on ecosystem services (Scholes, 2016) (Millennium Ecosystem Assessment, 2005). Not only will the changing climate be a challenge for the delivery of ES, but also the short timeframe of these changes (Mooney, et al., 2009).

Regarding financial support there has, according to IPCC's AR5, there has been more focus on mitigation measures than on adaptation, resulting not only in financial shortages, but also less competence in assessment and implementation regarding adaptation (Noble, et al., 2014). Investing in measures of adaptation has been estimated to provide savings on up to 7 US dollars per one US dollar (UNFCCC, 2010).

Ecosystem-based adaptation, EbA, is defined as "the use of biodiversity and ecosystem services as a part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change" (CBA, 2009), and has been pointed out by IPCC AR5 as an optional strategy to meet the adverse effects of climate change (Noble, et al., 2014).

EbA may be useful as it is possible to apply on many geographical scales from national to household, may be more cost-effective than infrastructure options such as sea walls and dykes, and provide multiple benefits on short and long time scales (CBA, 2009). EbA can also provide benefits for mitigation (Noble, et al., 2014) and has a strong potential to provide no-regret options, with benefits addressing more than climate change related issues, even though uncertainties regarding effects of climate change (Sebesvari, et al., 2017).

This literature review aims to analyse current use of Ecosystem-based Adaptation, methods for assessments used and lessons learned from these, with the purpose to compile information valuable for future ecosystem service assessments and EbA implementation.

Method

Screening criteria for the review was set accordingly to Figure 1 to meet the purpose of the study. As the purpose is to get a contemporary view of the use of assessments on Ecosystem-based Adaptation, the timeframe for the search was set to articles published between 2012 and 2017. However, as the phrase Ecosystem-based Adaptation is rather new in scientific literature (Mercer, et al., 2012) this study included a search in the selected databases of articles published until year 2017, but the articles in the results of the search did not differ from the previous search with the timeframe 2012-2017.

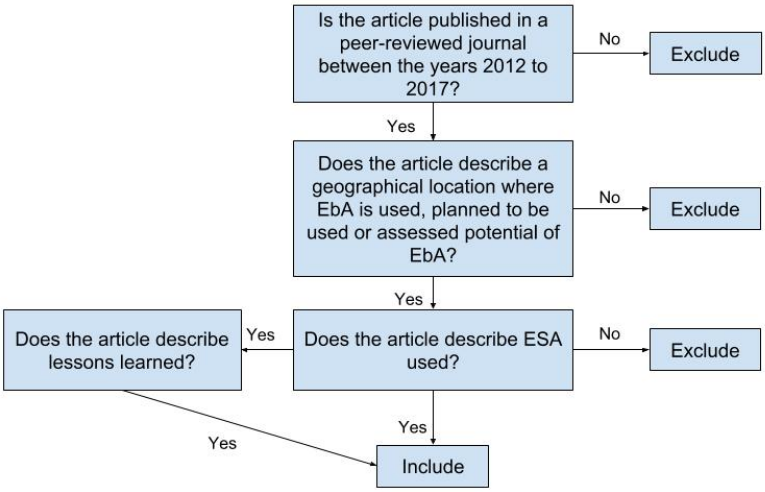

Figure 1. Screening criteria for a systematic review of the articles that were the result of the searches in databases Greenfile and Scopus. (Figure made by author)

The parameters used in the review are geographical locations and sectors, the aim of the reviewed articles, methods used for ecosystem service assessment, ESA, and lessons learned from these.

The parameter *sectors* refers to the type of activity taking place in the area.

Three searches in each of the databases Scopus and Greenfile were carried out. Keywords Ecosystem-based Adaptation and Ecosystem Service Assessment and a few similar phrases. The keywords were used in search strings presented in Appendix A.

As some articles were available in both databases the number of articles are presented separately in the review protocol.

Review protocol

Step	Procedure	Result	
Keyword definition	Keywords defined upon purpose of the study. Selected keyword in bold text, used synonyms in plain text	**Ecosystem-based Adaptation**, EbA, climate adaptation **Ecosystem service assessment**, ESA, Assess*	
Definition screening criteria	Screening criteria based on purpose and research question.	See figure 1	
Data acquisition	Database search using search strings (Appendix A)	Greenfile: 291	Scopus: 313
Data screening	Data screening of title and abstracts using screening criteria, Figure 1	Greenfile: 17	Scopus: 21
Data screening	Data screening of full text using screening criteria, Figure 1	Greenfile: 3	Scopus: 6
Data screening	Total number of approved articles		6
Analysis	Analysis of articles by purpose, method, results, learnings and conclusions		

Results

The results of the review are presented in accordance with the investigated parameters i.e. I) geographical area and sector; II) aim of article; III) methodological approach; and IV) lessons learned by the authors of the reviewed articles regarding method used and lessons learned by the authors of the reviewed articles regarding implementing EbA.

I. Geographical locations and sectors of the reviewed articles

Locations of the investigated sites in the articles were all but one from the southern hemisphere. The selected sectors and geographical locations were municipal areas in South Africa (Bourne, et al., 2016), river catchment areas in Fiji islands (Daigneault, et al., 2016), a watershed for municipal supply in Honduras (Procter, et al., 2017), Action Research for Community Adaptation in Bangladesh sites in coastal Bangladesh (Reid & Alam, 2017), and two urban areas, the city of Durban, South Africa (Roberts, et al., 2012) and the city of Amsterdam, Netherlands (Zardo, et al., 2017).

II. Aims of the reviewed articles

Two of the reviewed articles aimed to demonstrate informative and useful methodologies to decision-makers and planners (Bourne, et al., 2016) (Zardo, et al., 2017). Two other articles aimed to assess infrastructure adaptation alternatives against Ecosystem-based Adaptation alternatives (Daigneault, et al., 2016) (Procter, et al., 2017). The fifth article aimed to assess potential of Ecosystem-based Adaptation (Reid & Alam, 2017). The last one aimed to share insights from implementing Ecosystem-based adaptation (Roberts, et al., 2012).

III. Methods used in the articles for Ecosystem Service Assessment

Methods used for ecosystem service assessments in the reviewed articles were quantitative, semi-quantitative, monetary and qualitative methods.

Two of the reviewed articles described quantitative methods. These used spatial mapping to assess changes within the chosen systems, one by producing maps of biome stability and EbA priority areas (Bourne, et al., 2016), and the other by using bioclimatic envelope models of key ecosystems and species (Roberts, et al., 2012).

One article (Zardo, et al., 2017) described a semi-quantitative method, identifying ecosystem functions of a single ecosystem service, cooling capacity of green urban infrastructure, that was graded in a score 0-100 depending on potential to lower the temperature of an area of a 10*10 km area of the city of Amsterdam, to assess potential to contribute to adaptive capacity.

Two articles described monetary methods, to compare impact of changes between infrastructure options and EbA options. One article (Procter, et al., 2017) used the results of expert judgements in a seven-point Likert scale as a basis for a monetary valuation using Willingness-to-pay and Replacement cost. In the second article (Daigneault, et al., 2016) a socio-economic survey and hydrological models were used to make a Cost-benefit-analysis.

One article (Reid & Alam, 2017) used expert and community judgement in a qualitative method to assess how ES contributes to adaptive capacity, and how changes in ecosystems affect adaptive capacity. This was done to test the hypothesis that EbA contributes to resilience and adaptive capacity using the parameters of ecosystem resilience and maintenance of ES.

IV. Lessons learned by the authors of the reviewed articles regarding Quantitative methods

Regarding input data a lesson learned was that availability to downscaled climate change data is not crucial for producing biome stability maps, but to put it in a local context, to be able to place EbA priority maps. It was also seen that by using industry standard software, publically available data, and a

straightforward methodological approach, usability and replicability were achieved (Bourne, et al., 2016).

By using the method it became visible that to able to use tools such as bioclimatic modelling, local government would benefit from cooperation with research institutes both for increased knowledge and to be able to use the results of such methods (Roberts, et al., 2012).

From the results the methods showed that parameters as *increasing temperatures* could provide useful results, and that uncertainties such as *changes in precipitation* could be addressed with scenario planning, both providing support for decision-makers on suitable adaptation options (Bourne, et al., 2016). In the article describing the use of the two products of *biome stability maps* and *priority areas*, the combination of products can provide a basis for prioritizing areas important to support adaptive capacity. This was seen as an especially useful method in areas where people have a direct dependency of natural resources. (Bourne, et al., 2016)

Identified limitations were that assessed changes in ecosystems do not have to imply vulnerabilities. (Roberts, et al., 2012)

V. Lessons learned by the authors of the reviewed articles regarding Semi-quantitative method

The method used by Zardo et al (2017) were by the authors seen as easy to apply and required limited input data and can provide information to planners on how to use green urban infrastructure for cooling of urban areas.

Limitations of the method were that the use of available literature and expert opinions for computations revealed possible difficulties such as selecting data from similar contexts. Also, to be able to find an equitable compromise between accuracy of the assessment and complexity in computations, only the most influencing factors to cooling capacity was used. The authors pointed out that the method only considers cooling capacity within the green urban infrastructure, not addressing effects outside its boundaries. It was also pointed out that an explicit assessment of beneficiaries was needed to design and assess Ecosystem-based options.

VI. Lessons learned by the authors of the reviewed articles regarding Monetary methods

By using expert judgements in EbA approaches, the authors could see learning opportunities for decision-makers and how to maximize benefits and achieve management goals (Procter, et al., 2017).

Results showed that combining both EbA and infrastructure options, e.g. a water management plan and a new water reservoir, may in some cases complement each other (Procter, et al., 2017), but that EbA options generally are more cost effective. (Daigneault, et al., 2016)

Both articles emphasized the importance to acknowledge values of non-monetised benefits of e.g. soil erosion control, biodiversity and habitat, and also society´s avoided costs in case of dramatic changes. Daigneault et al (2016) estimated that values regarding both cultural and supporting ecosystem services would be higher for the assessed EbA options than for the assessed infrastructure options. They also emphasized the importance of performing a sensitivity analysis, as economic analyses regarding management of natural catastrophes often depend on strong assumptions.

VII. Lessons learned by the authors of the reviewed articles regarding Qualitative methods

The qualitative approach of the study clearly showed that ecosystems and ecosystem services are key factors to adaptive capacity and resilience even without quantification of ecosystem services. The authors noted that the assessment also support EbA as being a relevant approach to climate change, but also that more knowledge is needed to assess costs and benefits of EbA compared to other adaptation options. The authors also noted that the results implies that substantial changes in an ecosystem lead to trade-offs among ecosystem services, among stakeholders (for example the wetlands degradation has

affected fishermen negatively while agricultural workers have benefited) and on temporal and spatial scales. (Reid & Alam, 2017)

VIII. Lessons learned by the authors of the reviewed articles regarding implementing EbA

One of the articles had included lessons learned from using Ecosystem-based Adaptation (Roberts, et al., 2012). Detected possibilities from their experience were that EbA can be cost-effective, provide multiple benefits, and is more adaptable compared to infrastructure options. That by the use of bio-infrastructure as a frame for the work, EbA is centred in discussions on development. That there is a possibility to use already existing tools for management and planning to protect important biodiversity assets.

The authors saw a number of challenges e.g. i) that as EbA is a more modern science than engineering solutions, it is also more challenging to argue for its use, but that pilot projects can facilitate the introduction of new projects ii) that a possible obstacle for EbA is the need for capital and operational funding that is required for protection and management of priority areas by for example land acquisition due to the short periods set for budgets for local governments iii) that the use of EbA shows that the need for data, skills and technology is just as high as for infrastructure options, and iv) that there are trade-offs, as when protecting priority areas, when not everyone will gain from the necessary changes meaning that decision-makers will face difficult decisions.

Discussion and Conclusions

Even though ecosystems do not have the capacity to be a panacea for adverse effects of a changing climate due to the extensive degradation of ecosystems (Roberts, et al., 2012) there are some arguments that speak for EbA and are of interest to many stakeholders. EbA can, beside contribute to adaptive capacity (Reid & Alam, 2017) also be beneficial for mitigation (Noble, et al., 2014). Despite future uncertainties, EbA has a potential to provide no-regret options, with benefits even in the absence of climate change (Sebesvari, et al., 2017).

Few scientific articles could meet the aim of the study. The initial set of articles from the search was 604, but the systematic review resulted in only six articles fitting the screening criteria during the time period of the years between the years 2012-2017. This may be due to the fact that the phrase Ecosystem-based Adaptation is relatively new in scientific literature (Mercer, et al., 2012), why a broader use of keywords might have led to an increased number of articles. However, the articles included, provided sufficient explanatory information on used methods and lessons learned.

Due to the low number of articles, no conclusions are drawn of the investigated parameters *geographical location and sectors* and *aim of the reviewed articles*. Notable, however, is that among the articles in the review, only one was located in the global north.

The articles reviewed showed a diversity in methods used, which indicate the many possibilities of assessing ecosystem services and communicating impacts from climate change.

By assimilating the experience of those who tested the different methods, it is possible to avoid mistakes and pitfalls, as well as make use of the benefits that the methods entail.

The lessons learned by the authors of the reviewed articles points out that a combination of methods for valuation of ecosystem services would be beneficial to assist decision-makers and planners in climate adaptation decisions. As an example, a quantitative valuation, showing changes of ecosystem services provision, could benefit from a qualitative approach describing possible impacts from these changes.

The review showed that local governments would benefit from cooperation with research institutes to improve their skills and knowledge, in order to maximize the use of the results provided by the assessment.

The lessons learned concern both the need for input data, the use of the method, reflections on results, possible trade-offs and experience of implementing EbA.

Conclusively, the articles provide useful knowledge for future ecosystem service assessments, both in preparation and performance of assessments.

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Appendix A

Table 1A: Database Greenfile

Search ID#	Search terms	Search options	Results	Results (title and abstract)	Results (full text)
S1	TX "Ecosystem-based adaptation"	**Limiters** - Scholarly (Peer Reviewed) Journals; Publication Date: 20120101-20171231 **Search modes** - Find all my search terms	34	11	3
S2	TX ("ecosystem-based adaptation" OR EbA OR "climate adaptation") AND TX ("Ecosystem service assessment*" OR ESA OR assessment)	**Limiters - Scholarly (Peer Reviewed) Journals; Publication Date: 20120101-20171231** **Search modes -** Boolean/Phrase	153	2	0
S3	AB ("ecosystem-based adaptation" OR EbA OR "climate adaptation") AND AB ("Ecosystem service assessment*" OR ESA OR assessment)	**Limiters** - Scholarly (Peer Reviewed) Journals; Publication Date: 20120101-20171231 **Search modes** -Boolean/Phrase	58	3	0
Total number of approved articles			3		

Table 2A: Database Scopus

Search ID#	Search terms	Search options	Results	Results (title and abstract)	Results (full text)
S1	ABS ("Ecosystem-based adaptation")	DOCTYPE (ar) AND PUBYEAR > 2011 AND PUBYEAR < 2018 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SRCTYPE , "j"))	54	15	4
S2	(ABS ("ecosystem-based adaptation" OR eba OR "climate adaptation") AND ABS ("Ecosystem service assessment*" OR esa OR assessment)) AND	DOCTYPE (ar) AND PUBYEAR > 2011 AND PUBYEAR < 2018 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))	156	1	0
S3	(TITLE-ABS-KEY ("Ecosystem-based Adaptation") AND TITLE-ABS-KEY ("Ecosystem service assess*" OR esa OR assess*))	DOCTYPE (ar) AND PUBYEAR > 2011 AND PUBYEAR < 2018 AND (LIMIT-TO (SRCTYPE , "j"))	27	5	3
Total number of approved articles			6		