Journal of Environmental Management 342 (2023) 118298

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Socio-economic or environmental benefits from pondscapes? Deriving stakeholder preferences using analytic hierarchy process and compositional data analysis

Hoang-Tien Vo [a,*], Maria Vrachioli [a], Fabian Frick [a], Johannes Sauer [a], Sandra Brucet Balmana [b], Lluís Benejam Vidal [b], Thomas Mehner [c], Pieter Lemmens [d], Beat Oertli [e], Aurélie Boissezon [e], Meryem Beklioğlu [f], Antoine Dolcerocca [f], Mariana Meerhoff [g]

[a] *Technical University of Munich – Chair of Agricultural Production & Resource Economics, Alte Akademie 14, 85354 Freising, Germany*
[b] *University of Vic, Aquatic Ecology Group c/ de la Laura, 13, 08500 Vic, Catalonia, Spain*
[c] *Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany*
[d] *Katholieke Universiteit Leuven, Oude Markt 13, 3000 Leuven, Belgium*
[e] *University of Applied Sciences and Arts Western Switzerland, HEPIA Genève, Rue de la Prairie 4, CH-1202 Genève, Switzerland*
[f] *Middle East Technical University, Üniversiteler, Dumlupınar Blv. 1/6 D:133, 06800 Çankaya/Ankara, Turkiye*
[g] *University of the Republic Uruguay, Avenida 18 de Julio 1824, 2o piso, Montevideo, Montevideo, Uruguay*

A R T I C L E I N F O

Handling Editor: Jason Michael Evans

Keywords:
Nature-based solutions
Multi-criteria decision analysis
Biodiversity
Nature contribution to people
Ecosystem
Ponds

A B S T R A C T

Ponds occupy a large share of standing water worldwide and play an important role in providing various ecosystem services. There are concerted efforts of the European Union either to create new ponds, or to restore and preserve existing ponds as nature-based solutions to provide benefits to ecosystem and human well-being. As part of the EU PONDERFUL project, selected pondscapes (i.e. landscapes of ponds) in eight different countries – hereafter "demo-sites", are studied to comprehensively understand their characteristics and their efficiency to provide ecosystem services. In addition, the needs and knowledge of stakeholders who own, work, research, or benefit from the pondscapes are also important, because of their capabilities to create, manage and develop the pondscapes. Therefore, we established connection with stakeholders to study their preferences and visions on the pondscapes. Using the analytic hierarchy process, this study shows that in general stakeholders in the European and Turkish demo-sites prefer environmental benefits to economic benefits, while stakeholders in the Uruguayan demo-sites rank the economic benefits higher. More specifically, in the European and Turkish demo-sites, the biodiversity benefits, i.e. life-cycle maintenance, habitat and gene pool protection, receive the highest ranking among all groups. On the other hand, stakeholders at the Uruguayan demo-sites rank provisioning benefits as the most important, because many ponds in Uruguayan demo-sites are being used for agricultural purposes. Understanding those preferences helps policy makers to address the needs of stakeholders more correctly, when considering any action or policy for the pondscapes.

1. Introduction

What if all the ponds are dried? A large scale of biodiversity will be lost, carbon dioxide will be released back to the atmosphere, and other contributions to human will be gone. Various ponds-related conservation efforts have been conducted, but are the provided benefits aligned with stakeholders' wishes, so that the conservation results can sustain in long-term?

1.1. Background

Ponds are classified as small water bodies with sizes from 1 m

* Corresponding author. ,
E-mail addresses: tien.vo@tum.de, tienptnkbk@yahoo.com (H.-T. Vo), maria.vrachioli@tum.de (M. Vrachioli), fabian.frick@tum.de (F. Frick), jo.sauer@tum.de (J. Sauer), sandra.brucet@uvic.cat (S. Brucet Balmana), lluis.benejam@uvic.cat (L. Benejam Vidal), thomas.mehner@igb-berlin.de (T. Mehner), Pieter.lemmens@kuleuven.be (P. Lemmens), beat.oertli@hesge.ch (B. Oertli), aurelie.boissezon@hesge.ch (A. Boissezon), meryem@metu.edu.tr (M. Beklioğlu), adolce@metu.edu.tr (A. Dolcerocca), mmeerhoff@hotmail.com (M. Meerhoff).

https://doi.org/10.1016/j.jenvman.2023.118298
Received 27 February 2023; Received in revised form 25 May 2023; Accepted 28 May 2023
Available online 2 June 2023

squared to about 2–5 ha, might be permanent or seasonal, naturally or artificially created (Richardson et al., 2022). Despite their small size, small water bodies like ponds are dominating the water area worldwide, with the total of around 30–50% of standing water (Biggs et al., 2017). Ponds also provide various ecosystem services (ES), such as hosting a larger number of species compared to lakes or rivers at landscapes level (Hill et al., 2021), storing carbon (Holgerson and Raymond, 2016), mitigating flood risk, recharging ground water bodies, ameliorating pollution, as well as providing opportunities for recreation, tourism, cultural services along related commercial activities (Biggs et al., 2017; IPBES et al., 2018).

1.2. Motivation

Due to these socio-economic and environmental benefits, pondscapes conservations might serve as nature-based solutions (NBS), which are defined by IUCN (2020) as "the actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits". However, there is not a single perfect solution to solve all the problems of climate change. Lee and Lautenbach (2016) stated that socio-economic and environmental benefits do not always have a synergetic relationship. For example, there can be a negative correlation between "life-cycle maintenance, habitat and gene pool protection" and "food provisioning", or between "food provisioning" and "atmospheric composition & climate regulation". Because of this trade-off among different types of benefit, stakeholders' preferences should be taken into account because of their crucial role in the success of implementing NBS on pondscapes. Otherwise, the NBS implementation would provide mismatched benefits to stakeholders' needs, thus leading to the waste of resources or even unsuccessful implementation.

Despite their abundance and importance, pondscapes are largely neglected by European policy makers, together with the stakeholders' preferences (Biggs et al., 2017). Therefore, currently there is not any research about pondscapes as NBS, which integrates stakeholders in evaluating benefits of pondscapes to the local area. To integrate the stakeholders' needs in pondscapes conservation, analytic hierarchy process (AHP) is a suitable method in the context of PONDERFUL project, which involves various types of stakeholders. AHP is simple enough to reach stakeholders at all professional levels, but still capable of understanding stakeholders' preferences thoroughly.

1.3. Progress of using multi-criteria decision analysis (MCDA) and AHP to understand stakeholders in nature conservation

Multi-criteria decision analysis (MCDA) has gained its importance in nature conservation since 1990s by helping to integrate stakeholders' opinions in supporting decision making among conservational alternatives (Adem Esmail and Geneletti, 2018). MCDA methods have various applications in nature conservation, especially in water research, such as flood risk mitigation (Alves et al., 2018; Shivaprasad Sharma S V et al., 2018), water pollution control (Liquete et al., 2016), water supply planning (Scholten et al., 2017), urban water drainage systems evaluation (Loc et al., 2017) or on a larger spatial scale of water management (Campos et al., 2020; Ruangpan et al., 2021). Among MCDA methods, Analytical Hierarchy Process (AHP) is the most commonly used method to evaluate the alternatives to mitigate flood risks (de Brito and Evers, 2016), and the second most popular in nature conservation, only after the simplest form of MCDA, the Simple Additive Weighting (SAW) (Adem Esmail and Geneletti, 2018).

AHP method is a pairwise comparison approach using a pre-defined scale from 1 to 9 to derive the relative importance of one criterion to another. Pairwise comparison is useful when the decision weights or utility functions are not known in advance, as in SAW or in Multi-attribute Utility Theory (Ishizaka and Nemery, 2013). AHP can serve as the main research method to derive weights for ES and to rank environmental alternatives. Figueiroa et al. (2020) used AHP to derive relative criteria importance as well as rank benefit categories for protected areas. AHP's weights can subsequently be fed into further analyses or models, such as constructing maps of the soil's protection function for forest (Bozali, 2020) identifying suitable areas for rainwater harvesting (Haile and Suryabhagavan, 2019), or building indices to evaluate the ecosystem situation (Bryan et al., 2011; Macedo et al., 2018)). Some authors also used an expansion of AHP with fuzzy logic to account for the uncertainty of participants' evaluation in assessing ES. For example, Fang et al. (2021) first used original AHP to derive the weights from 20 experts, and then let them grade the eco-health of the assessed wetland park. However, Saaty & Tran (2007) and Li et al. (2018) warned about the invalidity of fuzzy AHP, that when the original judgements are good, there would be no gain, as in case of Park et al. (2020), the judgements only varied slightly, and not at the high and low-weight groups. When the judgements are poor, fuzzifying can make the results farther away from the actual values.

1.4. Objective

Therefore, to fill in the mentioned knowledge gaps, this study aims to use the original AHP method by Saaty (1977) to explore the stakeholders' perception about the relative importance of socio-economic and environmental benefits of pondscapes NBS, and then integrate those preferences into the conservation decision at the very specific areas of the pondscapes. The detailed introductions of pondscapes, NBS and their stakeholders can be found in Appendix 5. The results of this study can provide important preferences of stakeholders for policy makers, to implement NBS on pondscapes effectively and sustainably with the support from stakeholders. In addition, this study can also further support future research, e.g. benchmarking the pondscapes in terms of providing ES.

The rest of the paper is organized in the following way: in Section 2, we outline the methodology used in this study, while in Section 3 and 4 we provided the obtained results from the analysis. Finally, in Section 5, we provide some discussion of the results and the concluding remarks are presented in Section 6.

2. Methodology

2.1. Identify and define criteria for the AHP hierarchy

In the currently available literature, the criteria of AHP are set without referring to any classification standard or system, thereby leading to ambiguous interpretation of the criteria by participants. For example, Ruangpan et al. (2021) placed socio-economic benefits and human well-being as two different criteria, but according the Common International Classification of Ecosystem Services (CICES), the human health should be at the same level with recreational or educational activities. Also, according to CICES, the habitat structure should be classified at the same level with land-use, and together with other factors to "regulate physical, chemical and biological conditions". Alves et al. (2018) also built up a decision tree without referring to any standard, e.g., putting air quality and water quality at different comparison levels. Campos et al. (2020) put permeabilization, streambank stabilization, local flood vulnerability and impact on downstream floods at the same comparison level, while according to CICES, they are related to different types of extreme events and thus should be placed at different comparison levels. To avoid classifying benefits intuitively, this study builds up the criteria and comparison levels combining the newest CICES version 5.1 and the handbook of European Commission (2021).

The use of Millennium Ecosystem Assessment (MEA) as the reference to identify and classify ES for assessment is quite popular (Bryan et al., 2010; Khomalli et al., 2020; Segura et al., 2015; Srdjevic et al., 2019). The MEA was established in 2005 and works as a reference to classify ES into four big groups: provisioning, regulating, cultural and supporting services. Because the MEA is only a suggestion for classifying ES, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) provides a more human-oriented classification, called Nature's Contribution to People (NCP), which re-classifies ES into 18 NCPs to serve as a guideline for assessment production.

The IPBES assessment framework has been getting attention in research that focuses on stakeholders' perceptions regarding ecosystems and environmental assessment. Inkoom et al. (2018) referred to regulating NCPs as one of the mechanisms to achieve the context-suitable hazards and climate control. Srdjevic et al. (2019) combined both MEA and IPBES frameworks to assess four big groups of ES in urban areas. Nevertheless, the IPBES framework is still a general guideline that needs to be adapted for specific research contexts. Therefore, Haines-Young & M.B. Potschin (2018) established CICES to complement frameworks like MEA or IBPES, by providing a clearly defined and understandable 5-level classification of ES. Despite the clear classification, we are aware of only one study that uses CICES to assess ES using AHP. Antognelli and Vizzari (2016) used sections, divisions and classes of CICES to be the levels for AHP assessment, and simplified the classification for the non-expert stakeholders to understand.

Even though CICES is a good classification of ES, there are still unbalances among sections. Specifically, there are only 17 classes of cultural ES compared to 31 regulation and maintenance ES or 42 provisioning ES. Consequently, the cultural services – mostly related to socio-economic benefits of an ecosystem – are not elaborated as thoroughly as the other two. Therefore, current CICES design could overlook other intangible impacts that ES providers might bring, such as social justice, or participatory planning and governance. A NBS might also create business and job opportunities, but this factor is not recognized as an ES, and thus might be bypassed using only CICES. To improve the assessment framework and apply it in assessing pondscapes as NBS, this study proposes a classification that combines CICES, which has clear structures and definitions of provisioning and regulating services, with the classification provided by the handbook to evaluate NBS by the European Commission (2021), which elaborates the indicators and definitions in socio-economic aspects. The relationship between the MEA, the IPBES assessment framework, CICES and the EU Handbook is illustrated in Fig. 1. The hierarchy used in this research to build the AHP questionnaire is presented in Fig. 2. Appendix 4 provides the stakeholders identification, the questionnaire and detailed explanations of each criterion.

Guarini et al. (2018) argued that AHP is not applicable if there are too many criteria. As a rule of thumb, Saaty and Ozdemir (2003) stated that if the number of criteria in each comparison matrix is less than 7, AHP is still valid. In our proposed hierarchy, there are at most six criteria in a group, thus AHP can be applicable. Furthermore, with an equal number of criteria under each large group, this model can avoid problems caused by an unbalanced design as mentioned by Rodríguez Sousa et al. (2020).

2.2. Data collection

Overall, 242 stakeholders related to the researched pondscapes were identified and collaboration with 123 of them was established. The other 119 stakeholders were neither contacted nor necessary to, due to their

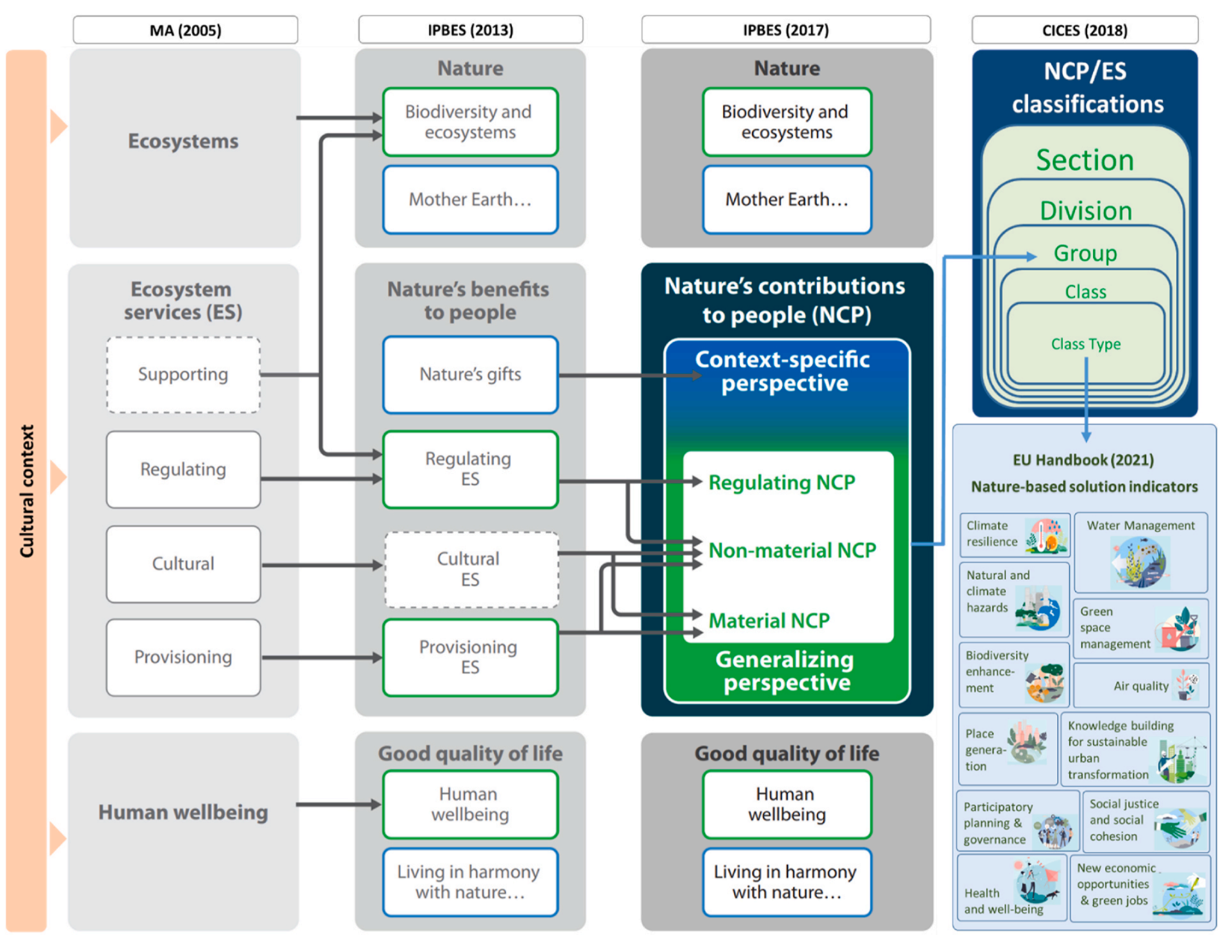


Fig. 1. Relationship between MEA and IPBES assessment framework. MA (2005), IPBES (2013, 2017) adopted from Díaz et al. (2018). Photos of EU Handbook adopted from European Commission (2021).

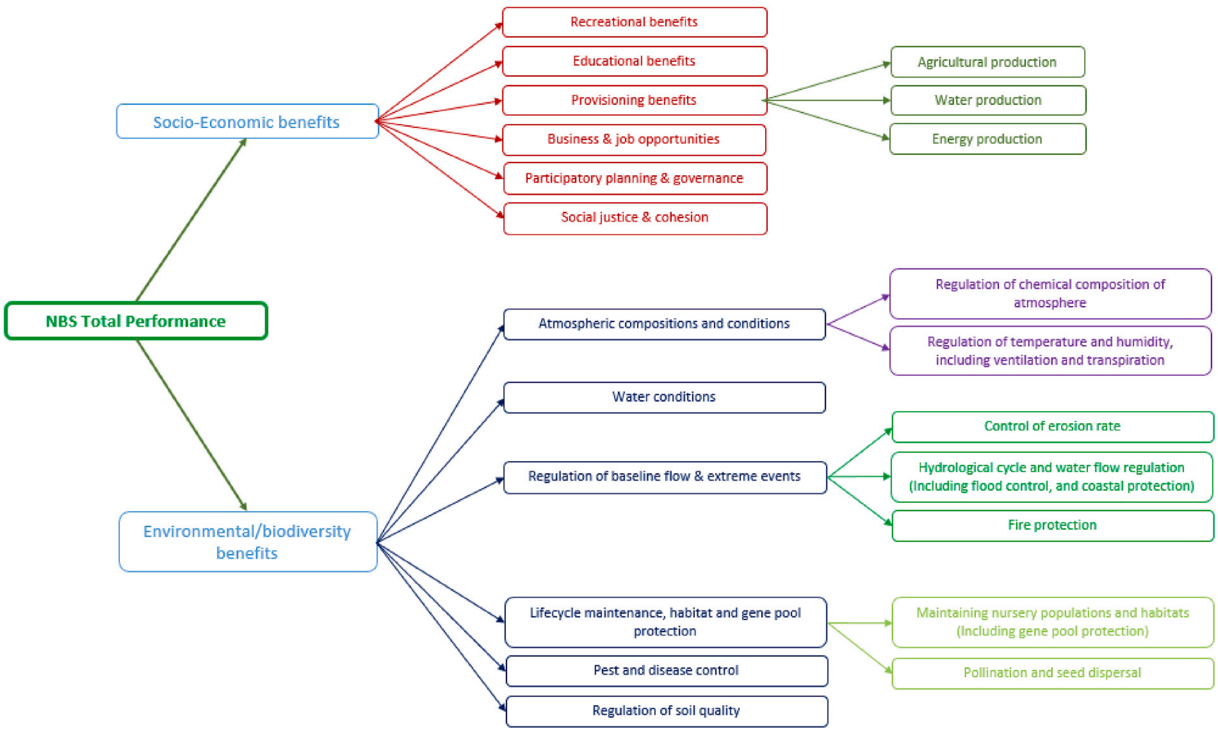


Fig. 2. Classification model/hierarchy of this study.

influence on decisions about the pondscapes. Among the 123 approached stakeholders, 101 stakeholders agreed to take part in the workshops. The detailed introduction of each pondscape and stakeholders' descriptions are presented in Appendix 5.

To collect data, stakeholders' workshops were organized on-site from October 2021 to March 2022 in all eight demo-sites. The objective of the PONDERFUL project is to cover ponds representing three bioclimatic regions, and Uruguayan demo-site serves as a test of the PONDERFUL idea in the contrast of the southern hemisphere. Most of the workshop participants were stakeholders who were actively involved in the management decisions regarding the pondscapes, i.e., whether and, if yes, what type of ponds will be created, and how to manage the ponds. For example, the stakeholders might be, but not limited to, landowners of the ponds, authorities, scientists working with those ponds, or representatives of non-governmental organizations.

The workshops lasted approximately 4–6 h each depending on the local conditions and COVID-19 restrictions of the hosting organizations. The organizers first presented an introduction to the PONDERFUL project (that this study is part of), the definition of NCPs, and interviewed the stakeholders regarding their opinions about the most important NCPs that pondscapes provide, how they perceive the role of pondscapes, and how they want them to develop in the future. Then, the stakeholders took part in a mapping exercise, in which they received a map of the area and tried to plan the future of the pondscapes as they wish, with the support of visualized objects. Finally, when the participants already got the basic knowledge about NBS, NCPs, ES, and had their vision toward what they want for the pondscapes, they filled in the AHP questionnaire. By conducting the questionnaire at the end of the workshops, we ensured that the stakeholders had received the necessary information from the former sessions, so that a high load of information in the questionnaire would not overwhelm the participants.

After collecting the data, we checked the inconsistency to choose the suitable scales, then applied the Harker's algorithm to inconsistent data instead of eliminating them. The preference of each stakeholder was derived by the geometric mean method to avoid the rank reversal problems, and then aggregated. Aggregating group results after deriving the individual weight vector can help avoid the risk that the aggregated results might not reflect the preferences of the group or any opinion of the group member because of the compromising characteristics (Ramanathan and Ganesh, 1994; van den Honert and Lootsma, 1997). More details about this consistency check, chosen scales and Harker's algorithm can be found in Appendix 1.

2.3. Compositional data analysis

To understand the stakeholders' preferences elaborately, it is necessary to consider the heterogeneity among stakeholders across different demo-sites and test the differences statistically for more useful information. Furthermore, when gender equality is encouraged and emphasized in the implementation of pondscapes as NBS, the difference of preference among genders is of essential relevance.

There are several ways to analyze differences across groups of participants in the context of an AHP analysis. Uddin et al. (2019) descriptively compared the four groups of academia, government, NGOs, and local community leaders with respect to their preferred strategies to protect community-managed forest. Marques et al. (2021) conducted similar descriptive comparisons, in terms of differences in criteria, alternatives, and how different criteria contribute to the alternative selection across groups. Rodríguez Sousa et al. (2020) used an index of Relative Global Agreement to estimate the differences of opinions of individual groups with respect to the average of all groups. These approaches are mainly qualitatively and purely descriptive.

Marre et al. (2016) used t-tests to analyze the difference in each criterion's weight between citizens and political decision makers. Due to the nature of the AHP weights data that sum to one, at least one negative correlation must exist between variables, meaning if one increases, others have to decrease. This is the so-called closure effect, which leads to various problems when applying normal analysis on a Euclidean sample space, such as spurious correlation, Simpson's paradox in splitting and merging data, and difficulties in interpreting results (Filzmoser et al., 2018; Pawlowsky-Glahn et al., 2015). Therefore, the approach for such data that sums to a constant, so-called compositional data analysis developed by Aitchison (1986), should be implemented.

Bryan et al. (2010) applied compositional analysis on AHP results, in the context of deriving the perception of stakeholders about the priorities among capital groups and among ecosystem services to manage basins in Australia. That research used a center log-ratio (clr) to convert data from Euclidean space to the simplex, and then carried out the analysis on the clr-coefficients. The use of only clr-coeffcients was criticized in Pawlowsky-Glahn et al. (2015) and Filzmoser et al. (2018) due to its singular covariance matrix and difficulties in interpreting results. Therefore, this study uses isometric log-ratio (ilr) for converting data. Appendix 2 provides a more detailed summary of the Aitchison's geometry and transformations.

The balances to define isometric log-ratios should be chosen in order to interpret the targeted log-ratios easily. Appendix 2 provides a more detailed explanation of balances. The log-ratios of interest are: (i) Economic/Environmental: how stakeholder groups differ in the relative importance between economic benefits and environmental benefits; (ii) One benefits over 11 others: how stakeholder groups differ in the relative importance of one benefit over other eleven; and (iii) All pairs of benefits. These isometric log-ratios are then compared within and across stakeholders grouped by demo-sites, gender, and educational levels. Among groups, the ilr-coordinates will be tested first by Kruskal-Wallis test to see if there is anything different among groups in general. Then if the Kruskal-Wallis test yields a significant result, pairwise Wilcoxon test will be conducted to clarify which group differs to which group specifically.

3. Results from AHP

3.1. Consistency check results

As expected by the nature of the Power Scale and the Root Square scale, the former yields a very high and the latter yields a very low level of inconsistency. Harker and Vargas (1987) checked these two scales and opposed their use for this reason. Therefore, we do not use those two scales. Among other scales, only the logarithmic, inverse linear and asymptotical scale yield a high number of observations, i.e., yield consistent results in approximately 80% or more of the cases, thus we use these three scales to analyze the data at hand. The consistency check results by scale are illustrated in Table 1. Using Harker's algorithm, the inconsistent data from the logarithmic, inverse linear and asymptotical scales are transformed. The data from these three scales are consistent after the transformation, and because each scale has its own advantage, the arithmetic means of the values from these scales were used for further analysis (in total, 101 observations).

3.2. Group's weight

After aggregating the preferences by stakeholder groups for each demo-site, the results are summarized in Table 2 and illustrated in Fig. 3. Only the third level of the hierarchy in the ES categorization, including six socio-economic and six environmental ecosystem services, enters the compositional analysis stage because they sum to unity. The second level is only the two big groups containing 12 ES, so their relative importance can be analyzed via the sum of their components; the most disaggregated level of the hierarchy do not sum to one because not all the ecosystem services at the third level have sub-services.

Table 1
Number of consistent observations by scale.

Scales	Number of valid observations	Percentage of valid observation
Linear	23	22.8%
Logarithmic	80	79.2%
Root Square	93	92.1%
Inverse Linear	86	85.1%
Balanced	74	73.3%
Balanced-n	51	50.5%
Adaptive-balance	19	18.8%
Adaptive	1	1%
Power	1	1%
Geometric	2	2%
Asymptotical	81	80.2%

Table 2
Robustness' check result (a) Differences in ranking by centering and by arithmetic average, (b) Absolute changes of weight from the simulation.

Gender	Less than 0
Male (58)	0.000
Female (39)	0.000

Education	Less than 0	Greater than 0
PhD (20)	0.139	0.869
NonPhD (79)	0.000	1.000

Country	Less than 0	Greater than 0
CH (11)	0.000	1.000
DE (6)	0.078	0.953
TU (8)	0.020	0.988
UK (20)	0.001	0.999
ES (23)	0.000	1.000
BE (11)	0.000	1.000
UY (13)	0.960	0.047
DK (9)	0.002	1.000

Note: The number of stakeholders are in parentheses. Deep/light green: Significant at 5% / 10% significance level.

	Sum of absolute change	% rank reversed by AHP	% rank reversed by continuous 0-1
CH	4.34%	1.3947%	1.4546%
DE	4.68%	1.5215%	1.5745%
TU	3.93%	1.4306%	1.4580%
UK	0.24%	0.0668%	0.0751%
ES	2.60%	0.8498%	0.8788%
BE	4.12%	1.4729%	1.4606%
UY	2.47%	1.1037%	1.1184%
DK	3.82%	1.1683%	1.1618%

3.3. Robustness check

Adem Esmail and Geneletti (2018) showed that the sensitivity of the results can be analyzed by changing weights and scores to see how the rankings of alternatives change accordingly. Changing assessment method or aggregation rule are also options for sensitivity analysis. Researchers might also collect general feedback from stakeholders or additional data sources to validate the robustness of the results qualitatively.

This study already checked the AHP's consistency and used the average of three different scales, so the result is quite robust in terms of using different weight derivation scales. Furthermore, a nature of this research is that the data were collected in the same workshop with other tasks as described above. Therefore, the preference on environmental benefits of stakeholders of European and Turkish demo-sites, and the preference on socio-economic benefits of stakeholders of the Uruguayan demo-site, might be confirmed qualitatively by the other parts of the workshop. More specifically, emphasis on provisioning services from Uruguayan demo-site and on biodiversity of the other demo-sites were also confirmed qualitatively via the story-telling and mapping exercises during the workshops.

To check the robustness quantitatively by changing the aggregation rule, the centering concept of compositional data analysis is adopted to see how the rankings of ES change compared to the arithmetic average aggregation. For the calculation of the compositional center, see Appendix 2. Table 3a shows the change in rankings of ecosystem services.

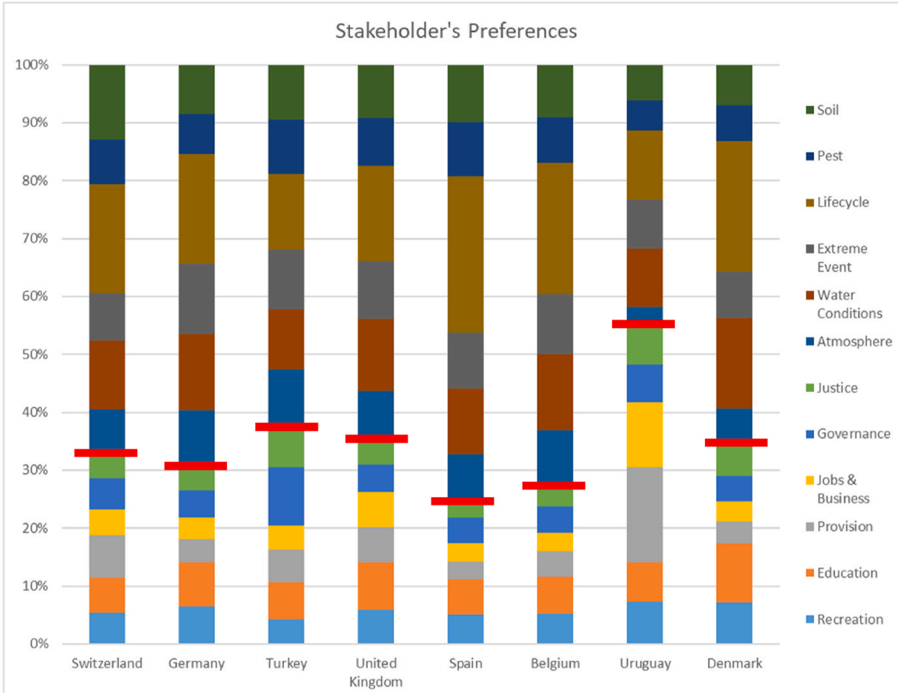


Fig. 3. Stakeholder group aggregation by demo-site.

Overall, the first-ranked ES (provision in Uruguayan demo-site and life-cycle maintenance in the others) do not change in both aggregation rules. Details about ES ranking can be found in Appendix 3. Rankings do not change but only break the equal ranks in the case of Germany, United Kingdom and Uruguay. Only one or two pairs of rankings change by one rank and not among the top three most important ecosystem services in the case of Swiss, Spanish, Belgian and Danish demo-site. Therefore, the ranking results from those pondscapes are quite robust. The only exception is the case of the demo-site in Turkey, where there are ecosystem services that change two ranks, and the changes occur at high ranked (2nd to 7th ranked) services, so it is worth looking into more details about the magnitude of this change. The total absolute changes of weight are expressed in the second column of Table 3b.

Studies using AHP and conducting a sensitivity analysis, such as Mostert et al. (2018) and Marques et al. (2021), changed the weights so they can test how the ranking responds to alternative weights. The 5 percent threshold was adopted, meaning that if a weight has to increase more than 5 percent to change the ranking of the highest-ranked alternative, then the results are considered robust. However, the robustness of interest here is the one of the weights, not of the alternatives. The performance for each ecosystem service of one alternative is simulated in two ways, first by AHP scores, and second by choosing a random value between 0 and 1. The performance in that ecosystem service of the other alternative thus equals to one minus that value, which reflects the normalization of the performance. The simulation runs one million times for each way of scoring. The results of the simulation are as in the third and fourth column of Tables 3b and in which there are no more than 1.6% cases of rank reversal for both AHP scoring and normalized-scoring. Considering the 5% threshold, both of the total absolute change of weight and the simulation proved that the results are quite robust under the change of aggregation rules.

4. Results from compositional data analysis

4.1. Compositional normality test

Before proceeding to the analytical part, a compositional normality test was conducted to explore whether the compositional data distribute normally. Appendix 2 provides more details about the compositional normality test and Appendix 3 presents the test results. The normality tests were carried out using the CoDaPack software.

The normality test shows a significant discrepancy from a normal distribution. Furthermore, the radius test shows that the data set is significantly different from a Chi-square distribution with 11 degrees of freedom. Therefore, the analysis for the differences within and among groups will be non-parametric.

4.2. Differences among ES within stakeholders' groups

Within the demo-sites, the 1-sample Wilcoxon test of the isometric log-ratio yields significant different results for all demo-sites. As depicted in Fig. 3, the red lines are the border between economic (lower) and environmental (upper) benefits. The difference between economic and environmental benefits of German demo-site stakeholders is large, but due to the low number of stakeholders, the result is only significant at 10% level. Only Uruguayan demo-site stakeholders significantly prefer economic benefits to environmental benefits. On the other hand, all other participants in the European and Turkish demo-sites significantly emphasize environmental benefits more than economic ones.

Both male and female stakeholders emphasize the environmental benefits significantly more than economic benefits, and so do non-doctorate stakeholders. For stakeholders with a doctorate degree, no significant result is observed, but the p-value is close to the threshold 0.1 of preferring environmental benefits to economic benefits. The results are illustrated in Table 4.

Conducting a more detailed analysis within each demo-site, the ecosystem services are compared among each other to determine whether the differences between each pair of services are significant. Fig. 4 illustrates the results for each demo-site.

4.3. Difference among stakeholders' groups for each ES

The Kruskal-Wallis test for stakeholders in different demo-sites yields significant results for tested ilr(s), except for the educational, water

Table 3
Stakeholder group-aggregation by demo-sites.

	Recreation	*Education*	Provision			*Jobs & Business*	*Governance*	*Justice*	Atmosphere		Water Condition	Extreme Event			Lifecycle		*Pest*	*Soil*
			Agriculture	*Water*	*Energy*				*Chemical*	*Physical*		*Erosion*	*Flood*	*Fire*	*Nursery*	*Pollination*		
CH	*5.4%*	*6.1%*	*7.4%*			*4.3%*	*5.5%*	*4.2%*	*7.6%*		*12.0%*	*8.1%*			*18.8%*		*7.8%*	*12.9%*
			2.2%	*3.4%*	*1.8%*				*3.7%*	*3.9%*		*2.8%*	*3.0%*	*2.3%*	*13.5%*	*5.3%*		
DE	*6.5%*	*7.6%*	*4.0%*			*3.7%*	*4.7%*	*4.5%*	*9.3%*		*13.2%*	*12.1%*			*19.0%*		*6.9%*	*8.5%*
			1.3%	*1.9%*	*0.8%*				*3.0%*	*6.3%*		*2.7%*	*5.6%*	*3.8%*	*12.5%*	*6.5%*		
TU	*4.3%*	*6.3%*	*5.8%*			*4.1%*	*10.2%*	*7.2%*	*9.5%*		*10.4%*	*10.4%*			*13.0%*		*9.3%*	*9.5%*
			2.0%	*2.1%*	*1.6%*				*4.7%*	*4.8%*		*3.3%*	*4.7%*	*2.4%*	*7.0%*	*5.9%*		
UK	*5.9%*	*8.2%*	*6.1%*			*6.1%*	*4.6%*	*4.4%*	*8.3%*		*12.4%*	*10.0%*			*16.5%*		*8.2%*	*9.2%*
			2.2%	*2.4%*	*1.5%*				*4.1%*	*4.2%*		*2.9%*	*5.0%*	*2.2%*	*10.4%*	*6.1%*		
ES	*5.1%*	*6.0%*	*3.1%*			*3.2%*	*4.5%*	*3.1%*	*7.8%*		*11.2%*	*9.8%*			*27.0%*		*9.3%*	*9.9%*
			1.1%	*1.3%*	*0.6%*				*3.3%*	*4.5%*		*2.6%*	*4.2%*	*3.0%*	*18.8%*	*8.2%*		
BE	*5.2%*	*6.5%*	*4.4%*			*3.1%*	*4.5%*	*3.7%*	*9.4%*		*13.1%*	*10.4%*			*22.6%*		*8.0%*	*9.0%*
			1.4%	*1.9%*	*1.1%*				*3.9%*	*5.5%*		*3.0%*	*5.2%*	*2.3%*	*16.5%*	*6.1%*		
UY	*7.3%*	*6.9%*	*16.4%*			*11.2%*	*6.4%*	*6.7%*	*3.3%*		*10.1%*	*8.3%*			*11.9%*		*5.3%*	*6.2%*
			8.1%	*5.8%*	*2.5%*				*1.2%*	*2.1%*		*1.9%*	*4.1%*	*2.3%*	*7.4%*	*4.5%*		
DK	*7.2%*	*10.1%*	*3.7%*			*3.5%*	*4.4%*	*5.5%*	*6.1%*		*15.7%*	*8.0%*			*22.4%*		*6.2%*	*7.0%*
			1.0%	*1.7%*	*1.0%*				*2.6%*	*3.5%*		*2.4%*	*3.6%*	*1.9%*	*15.7%*	*6.7%*		

Note: Stakeholders' group of demo-sites in CH: Switzerland, DE: Germany, TU: Turkey, UK: United Kingdom, ES: Spain, BE: Belgium, UY: Uruguay, DK: Denmark.

Table 4
P-values of 1-sample Wilcoxon-test of ilr-(economic benefits/environmental benefits) within genders, education and demo-site groups.

	gender	**education level**
economic/environmental	0.566	0.015
recreational	0.096	0.065
education	0.089	0.239
provisioning	0.257	0.023
business/job opportunites	0.607	0.077
governance	0.494	0.741
justice	0.005	0.185
atmospheric regulating	0.654	0.037
water conditions	0.895	0.280
extreme events prevention	0.947	0.143
life-cycle maintenance	0.211	0.577
pests & diseases prevention	0.935	0.001
soil	0.702	0.094

Note: Deep/light green: significant at 5% / 10% significance level.

conditions and extreme events prevention benefits. Significant results are presented in Fig. 6.

Regarding gender and educational levels, there are only two groups, thus the Kruskal-Wallis and Wilcoxon test yields the same result as in Table 5. Except the significantly different opinions in social justice and cohesion, male and female stakeholders' opinions mostly do not differ significantly at 5% level. However, there are many statistically significant differences between stakeholders with doctorate degree and who without. Both genders and education's perspective are illustrated in Fig. 5.

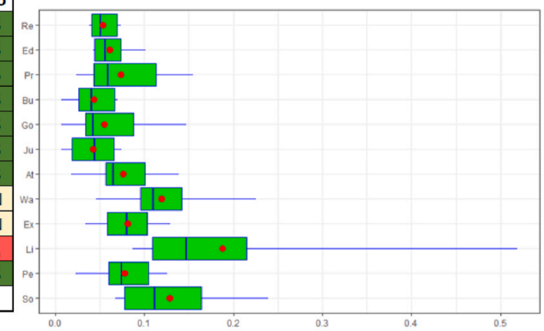
5. Discussion

The stakeholders' preferences closely reflect the purpose and characteristics of the pondscapes and the occupation of stakeholders involved. In the case of the Uruguayan demo-site, all the ponds are used for agricultural purposes (e.g., watering cattle) and located entirely onto private properties. Therefore, stakeholders of these ponds include farmers who own the land and technical public servants or policy makers aware of that purpose, thus provisioning benefits are not surprisingly the highlighted as in Table 2 and Fig. 4. This happened even if some other benefits (such as habitat creation and biodiversity) could also occur under certain local management practices of the studied ponds. These results indicate that such other potential benefits are currently not seek nor promoted under the prevailing paradigm of these pondscapes being solely useful to boost agricultural production. On the contrary, these results suggest that different management paradigms should actively be established, and different management practices should actively be promoted by the relevant public institutions, to increase the conservation and climate mitigation value of these and other similar pondscapes in Uruguay. In contrast, the European and Turkish demo-sites have been dedicated for conservation purposes or connected to various environmental programs, so the environmental services play a more important role in the perception of stakeholders. For example, the *Gete Vallei* pondscapes in Belgium has been implemented various conservational activities since 1970, *Bois de Jussy* of Switzerland since 1960, *Fyn Islands* of Denmark since 1980 or the *Pinkhill Meadow* of United Kingdom since 1990.

Other European studied pondscapes were created or implemented NBS later, and are dedicated mostly to conservation management,

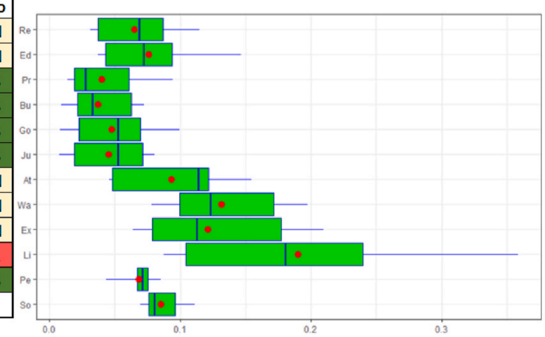
Switzerland

Mean	Median	IQR		Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
5.4%	5.1%	2.9%	Re		N	N	L	N	N	N	S	S	S	S	S
6.1%	5.6%	3.0%	Ed	N		N	L	N	N	N	S	S	S	N	S
7.4%	5.9%	7.0%	Pr	N	N		L	L	L	N	S	N	S	N	S
4.3%	4.1%	4.1%	Bu	S	S	S		N	N	S	S	S	S	S	S
5.5%	4.3%	5.4%	Go	N	N	S	N		N	S	S	S	S	N	S
4.2%	4.5%	4.8%	Ju	N	N	S	N	N		S	S	S	S	S	S
7.6%	6.6%	4.4%	At	N	N	N	L	L	L		S	N	S	N	S
12.0%	11.0%	4.6%	Wa	L	L	L	L	L	L	L		L	N	N	N
8.1%	8.0%	4.5%	Ex	L	L	N	L	L	L	N	S		S	N	N
18.8%	14.7%	10.5%	Li	L	L	L	L	L	L	L	N	L		L	L
7.8%	7.5%	4.5%	Pe	L	N	N	L	N	L	N	N	N	S		S
12.9%	11.1%	8.6%	So	L	L	L	L	L	L	L	N	N	S	L	



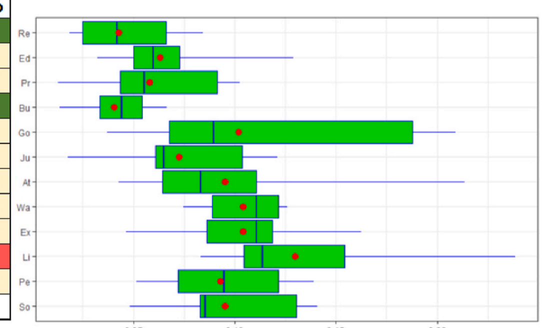
Germany

Mean	Median	IQR		Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
6.5%	6.9%	5.0%	Re		N	L	L	N	N	N	S	S	S	N	N
7.6%	7.3%	5.1%	Ed	N		L	L	N	N	N	S	N	N	N	N
4.0%	2.8%	4.2%	Pr	S	S		N	N	N	N	S	S	S	N	S
3.7%	3.3%	4.1%	Bu	S	S	N		N	N	N	S	S	S	S	S
4.7%	5.3%	4.7%	Go	N	N	N	N		N	N	S	S	S	N	S
4.5%	5.3%	5.2%	Ju	N	N	N	N	N		N	S	S	S	N	S
9.3%	11.4%	7.3%	At	N	N	N	N	N	N		N	N	S	N	N
13.2%	12.3%	7.2%	Wa	L	L	L	L	L	L	N		N	N	L	N
12.1%	11.3%	9.8%	Ex	L	N	L	L	L	L	N	N		N	L	N
19.0%	18.1%	13.5%	Li	L	N	L	L	L	L	L	N	N		L	L
6.9%	7.1%	0.8%	Pe	N	N	N	L	N	N	N	S	S	S		S
8.5%	8.1%	2.0%	So	N	N	L	L	L	L	N	N	N	S	L	



Turkey

Mean	Median	IQR		Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
4.3%	4.2%	4.1%	Re		S	N	N	S	S	S	S	S	S	S	S
6.3%	6.0%	2.3%	Ed	L		N	L	S	N	N	S	N	S	N	N
5.8%	5.5%	4.8%	Pr	N	N		L	S	N	N	S	S	S	S	N
4.1%	4.4%	2.1%	Bu	N	S	S		S	S	S	S	S	S	S	S
10.2%	9.0%	12.0%	Go	L	L	L	L		L	N	N	N	N	N	N
7.2%	6.5%	4.3%	Ju	L	N	N	L	S		N	S	N	S	N	N
9.5%	8.3%	4.7%	At	L	N	N	L	N	N		N	N	N	N	N
10.4%	11.1%	3.3%	Wa	L	L	L	L	N	L	N		N	S	N	N
10.4%	11.1%	3.2%	Ex	L	N	L	L	N	N	N	N		S	N	N
13.0%	11.4%	5.0%	Li	L	L	L	L	N	L	N	L	L		L	L
9.3%	9.5%	4.9%	Pe	L	N	L	L	N	N	N	N	N	S		N
9.5%	8.6%	4.8%	So	L	N	N	L	N	N	N	N	N	S	N	



United Kingdom

Mean	Median	IQR		Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
5.9%	5.5%	3.8%	Re		S	N	N	N	L	N	S	S	S	S	S
8.2%	6.1%	4.7%	Ed	L		L	L	L	L	N	S	N	S	N	N
6.1%	6.4%	5.3%	Pr	N	S		N	N	N	N	S	S	S	S	S
6.1%	5.1%	4.3%	Bu	N	S	N		N	L	N	S	S	S	S	S
4.6%	4.6%	2.6%	Go	N	S	N	N		N	S	S	S	S	S	S
4.4%	4.5%	2.4%	Ju	S	S	N	S	N		S	S	S	S	S	S
8.3%	7.1%	7.1%	At	N	N	N	N	L	L		S	S	S	N	N
12.4%	13.0%	4.5%	Wa	L	L	L	L	L	L	L		L	S	L	L
10.0%	10.4%	6.9%	Ex	L	N	L	L	L	L	L	S		S	N	N
16.5%	14.6%	10.6%	Li	L	L	L	L	L	L	L	L	L		L	L
8.2%	8.9%	3.3%	Pe	L	N	L	L	L	L	N	S	N	S		N
9.2%	10.0%	3.8%	So	L	N	L	L	L	L	N	S	N	S	N	

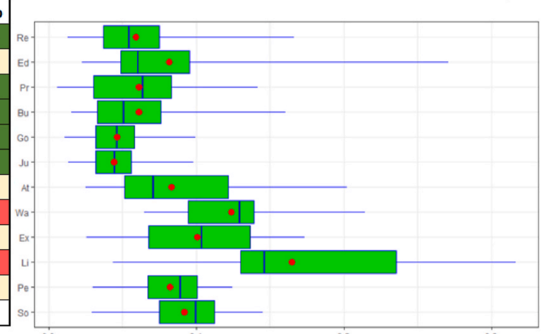
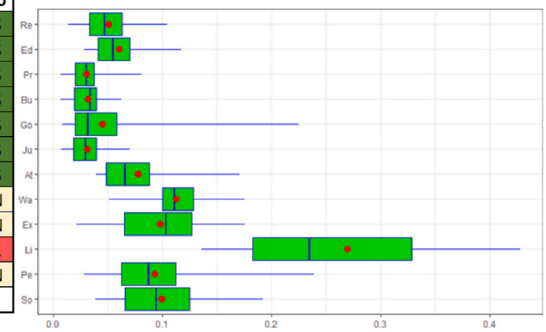


Fig. 4. Differences between pairs of ecosystem services – within demo-site
Note: Re: Recreation. Ed: Education. Pr: Provision. Bu: Business & Job Opportunities. Go: Participatory Governance. Ju: Social Justice & Cohesion. At: Atmospheric Regulation. Wa: Water Conditions. Ex: Extreme Events. Li: Life-cycle maintenance. Pe: Pests & Diseases Prevention. So: Soil Protection.
The boxplot shows the minimum, lower quartile, median, upper quartile, maximum and the red dots in the right panel of the figure show the aggregated results. The matrix shows how the service at the row is compared to the service at the column. "S" is significantly smaller, "L" is significantly larger, and "N" is not significant at 5% significance level. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

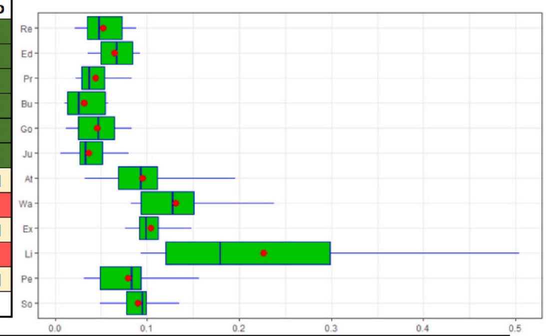
Spain

Mean	Median	IQR		Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
5.1%	4.7%	3.0%	Re		S	L	L	N	L	S	S	S	S	S	S
6.0%	5.5%	2.9%	Ed	L		L	L	L	L	S	S	S	S	S	S
3.1%	3.0%	1.8%	Pr	S	S		N	N	N	S	S	S	S	S	S
3.2%	3.4%	2.1%	Bu	S	S	N		N	N	S	S	S	S	S	S
4.5%	3.2%	3.8%	Go	N	S	N	N		L	S	S	S	S	S	S
3.1%	3.0%	2.1%	Ju	S	S	N	N	S		S	S	S	S	S	S
7.8%	6.6%	3.9%	At	L	L	L	L	L	L		S	S	S	N	S
11.2%	11.1%	2.9%	Wa	L	L	L	L	L	L	L		N	S	L	N
9.8%	10.3%	6.2%	Ex	L	L	L	L	L	L	L	N		S	N	N
27.0%	23.5%	14.6%	Li	L	L	L	L	L	L	L	L	L		L	L
9.3%	8.7%	5.0%	Pe	L	L	L	L	L	L	N	S	N	S		N
9.9%	9.4%	5.9%	So	L	L	L	L	L	L	L	N	N	S	N	



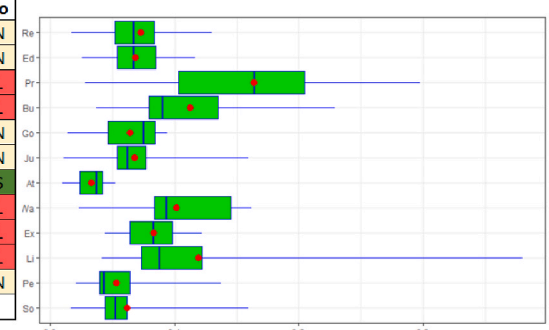
Belgium

Mean	Median	IQR		Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
5.2%	4.8%	3.7%	Re		S	N	L	N	L	S	S	S	S	S	S
6.5%	6.7%	3.5%	Ed	L		L	L	L	L	S	S	S	S	N	S
4.4%	3.7%	2.5%	Pr	N	S		L	N	N	S	S	S	S	S	S
3.1%	2.6%	4.1%	Bu	S	S	S		S	N	S	S	S	S	S	S
4.5%	4.8%	4.0%	Go	N	S	N	L		L	S	S	S	S	S	S
3.7%	3.4%	2.5%	Ju	S	S	N	N	S		S	S	S	S	S	S
9.4%	9.3%	4.3%	At	L	L	L	L	L	L		S	N	S	L	N
13.1%	12.8%	5.8%	Wa	L	L	L	L	L	L	L		N	S	L	L
10.4%	9.9%	2.0%	Ex	L	L	L	L	L	L	N	N		S	L	N
22.6%	18.0%	17.8%	Li	L	L	L	L	L	L	L	L	L		L	L
8.0%	8.4%	4.4%	Pe	L	N	L	L	L	L	S	S	S	S		N
9.0%	9.5%	2.1%	So	L	L	L	L	L	L	N	S	N	S	N	



Uruguay

Mean	Median	IQR		Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
7.3%	6.7%	3.1%	Re		N	S	S	N	N	L	N	N	N	L	N
6.9%	6.7%	3.1%	Ed	N		S	S	N	N	L	N	N	S	L	N
16.4%	16.5%	10.2%	Pr	L	L		L	L	L	L	L	L	L	L	L
11.2%	9.1%	5.6%	Bu	L	L	S		L	L	L	N	N	N	L	L
6.4%	7.5%	3.8%	Go	N	N	S	S		N	L	S	S	N	L	N
6.7%	6.2%	2.3%	Ju	N	N	S	S	N		L	N	S	S	L	N
3.3%	3.7%	1.9%	At	S	S	S	S	S	S		S	S	S	S	S
10.1%	9.3%	6.2%	Wa	N	N	S	N	L	N	L		N	N	L	L
8.3%	8.3%	3.4%	Ex	N	N	S	N	L	L	L	N		N	L	L
11.9%	8.8%	4.9%	Li	N	L	S	N	N	L	L	N	N		L	L
5.3%	4.3%	2.5%	Pe	S	S	S	S	S	S	L	S	S	S		N
6.2%	5.3%	1.8%	So	N	N	S	S	N	N	L	S	S	S	N	



Denmark

Mean	Median	IQR		Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
7.2%	6.6%	1.7%	Re		S	L	L	L	L	N	S	N	S	N	N
10.1%	9.2%	2.4%	Ed	L		L	L	L	L	L	S	N	S	L	N
3.7%	4.0%	3.4%	Pr	S	S		N	N	S	S	S	S	S	S	S
3.5%	3.5%	2.2%	Bu	S	S	N		N	S	S	S	S	S	S	S
4.4%	3.9%	2.7%	Go	S	S	N	N		N	S	S	S	S	S	S
5.5%	4.5%	1.7%	Ju	S	S	L	L	N		N	S	S	S	N	N
6.1%	6.8%	2.5%	At	N	S	L	L	L	N		S	N	S	N	N
15.7%	16.5%	9.4%	Wa	L	L	L	L	L	L	L		L	S	L	L
8.0%	7.2%	4.5%	Ex	N	N	L	L	L	L	N	S		S	N	N
22.4%	18.4%	14.8%	Li	L	L	L	L	L	L	L	L	L		L	L
6.2%	6.4%	1.5%	Pe	N	S	L	L	L	N	N	S	N	S		N
7.0%	7.8%	5.0%	So	N	N	L	L	L	N	N	S	N	S	N	

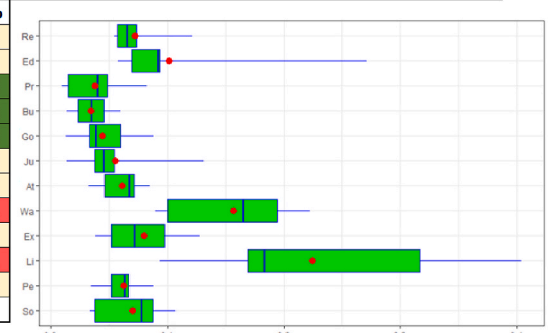


Fig. 4. (*continued*).

especially to promote biodiversity. The pondscapes of this group include *Pikhakendonk* (Belgium) and *Lystrup* (Denmark), which were created to translocate crested newts and provide amphibian-breeding sites. *Tommelen* (Belgium) is a bombcrater pondscape unintentionally created during the second World War, but also dedicated to biodiversity conservation at the moment, especially crested newt. *Rhône de Verbois* (Switzerland) is involved in Ramsar to support amphibian breeding. *Albera* pondscape of Spain aims to mitigate the impact of cattle farms and roads on amphibian, together with *Schöneiche* (Germany) to create more habitat for aquatic animals. Currently, two of the three Turkish studied pondscapes (*Gölbaşı Düzlüğü* and *İmrahor Valley*) contain ongoing projects of restoration. Therefore, it is not surprising that the stakeholders of European and Turkish studied pondscapes value the life-cycle maintenance, habitat and gene pool protection services as the most important position as presented in Table 2 and Fig. 4.

Regarding the analysis among ecosystem services within demo-sites, the results show significant differences between the preferences of ES. We suggest that this statistically "smaller or larger" relationship among

Table 5
P-values of Kruskal-Wallis tests by genders and education levels.

	Difference in ranking											
	Re	Ed	Pr	Bu	Go	Ju	At	Wa	Ex	Li	Pe	So
CH	1	0	0	0	-1	0	0	0	0	0	0	0
DE	0	0	0	0	0	0	0	0	0	0	1	0
TU	0	0	0	0	-2	0	-2	1	-1	0	2	2
UK	0	1	0	1	0	0	0	0	0	0	0	0
ES	0	0	0	-1	0	1	0	0	0	0	0	0
BE	0	0	1	0	-1	0	-1	0	0	0	0	1
UY	0	1	0	0	0	0	0	0	0	0	0	0
DK	0	0	-1	1	0	0	0	0	0	0	0	0

Note: Re: Recreation. Ed: Education. Pr: Provision. Bu: Business & Job Opportunities. Go: Participatory Governance. Ju: Social Justice & Cohesion. At: Atmospheric Regulation. Wa: Water Conditions. Ex: Extreme Events. Li: Life-cycle maintenance. Pe: Pests & Diseases Prevention. So: Soil Protection. The changed rankings are highlighted in yellow.

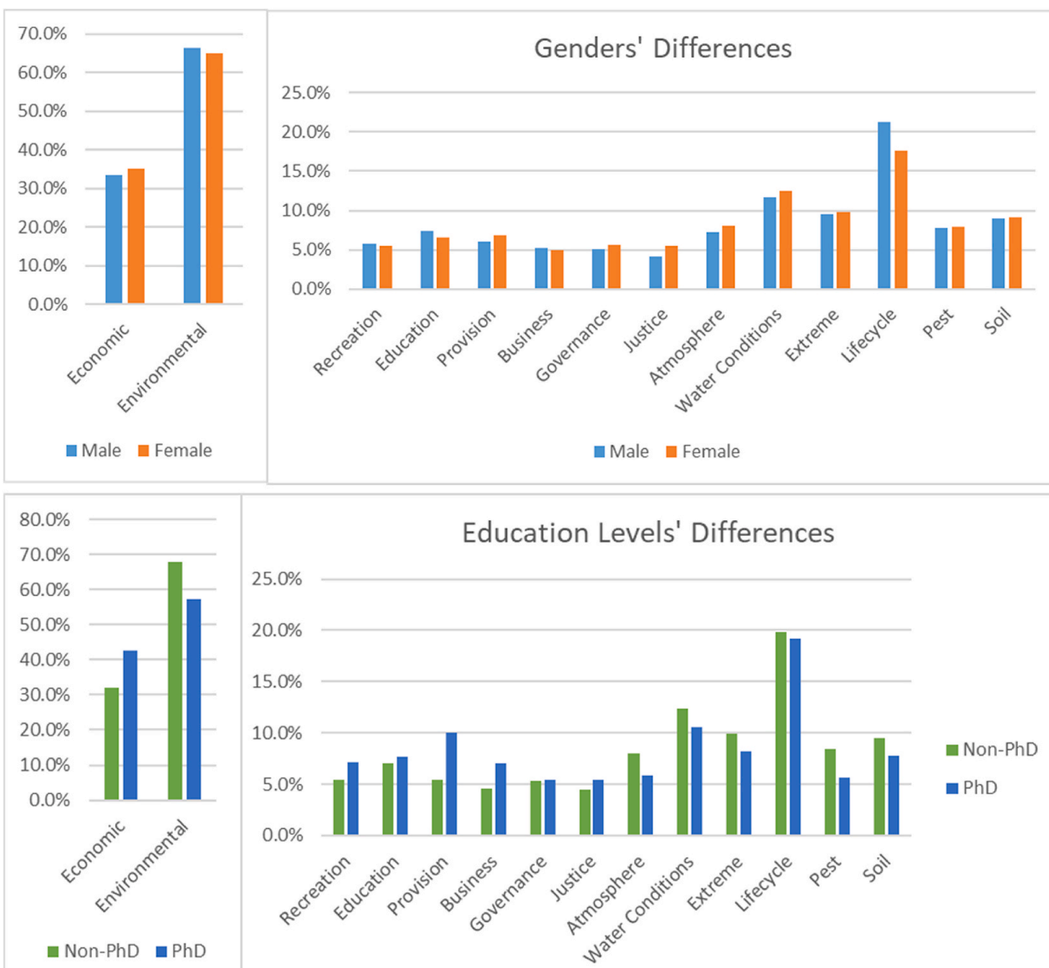


Fig. 5. Differences from gender's and from education's perspective.

ecosystem services should be taken into account when policy makers aim to adopt a restoration action, or in case researchers want to use methods that can accommodate weights for ES such as efficiency analysis tools. For example, in case of the Spanish *Albera* demo-site, evaluating efficiency should take into account that "Life-cycle maintenance" (Li) ecosystem service weight should be higher than any other services. Furthermore, the weight of "Water Quality" (Wa) must be higher than "Recreation" (Re), "Education" (Ed), "Provision" (Pr), "Business and Job Opportunities" (Bu), "Governance" (Go), "Justice" (Ju), "Atmospheric Regulation" (At), "Pest Control" (Pe) but has no restriction with "Extreme Events Prevention" (Ex) and "Soil Protection" (So), and so on for all information of Spain in Fig. 4. A different order might be observed for Uruguayan demo-site as discussed, in which "Pr" – provisioning services are currently higher than any others, while "Bu" weight must be

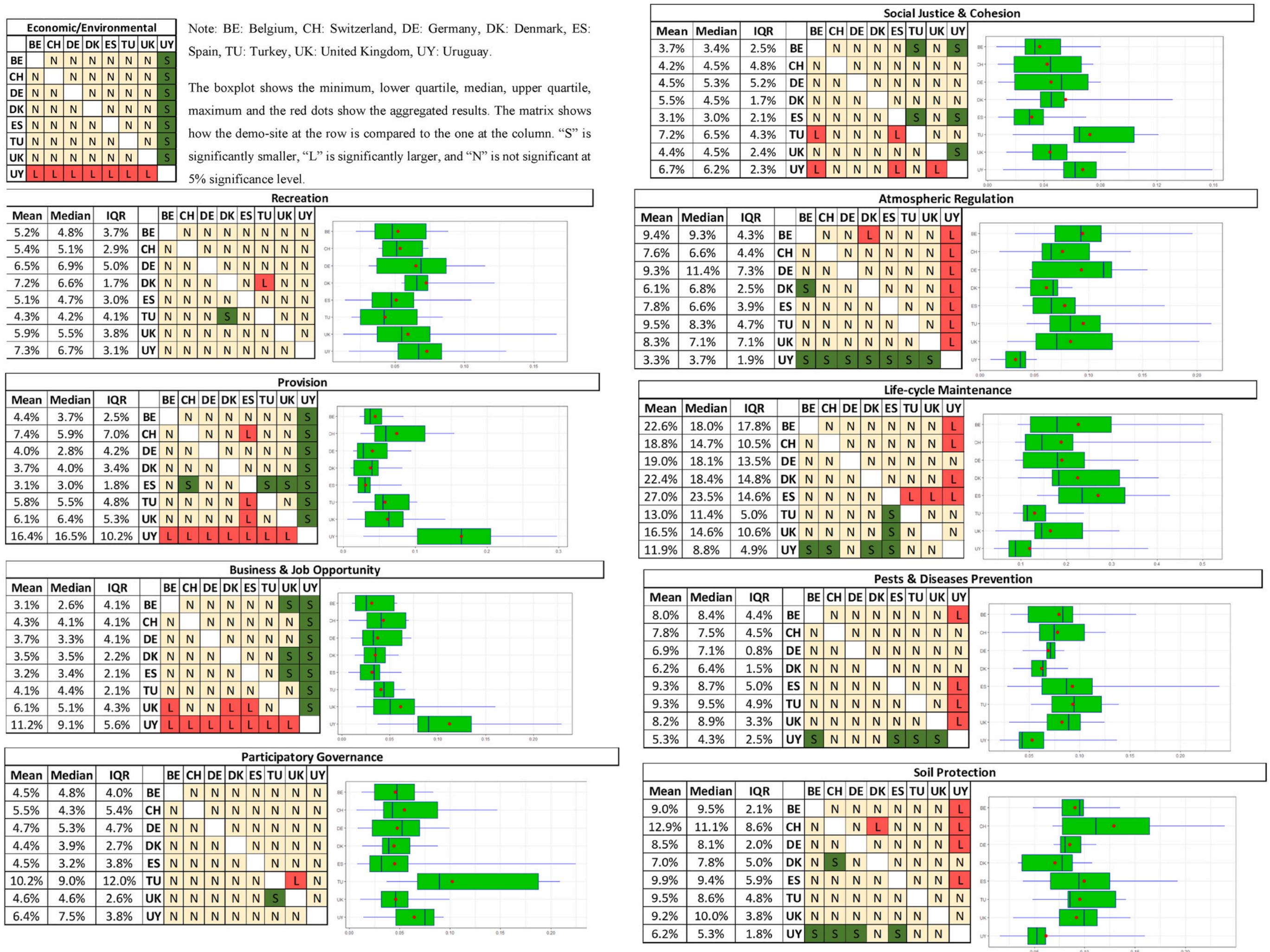


Fig. 6. Cross-demo-site comparison by ecosystem services. Note: BE: Belgium, CH: Switzerland, DE: Germany, DK: Denmark, ES: Spain, TU: Turkey, UK: United Kingdom, UY: Uruguay.
The boxplot shows the minimum, lower quartile, median, upper quartile, maximum and the red dots show the aggregated results. The matrix shows how the demo-site at the row is compared to the one at the column. "S" is significantly smaller, "L" is significantly larger, and "N" is not significant at 5% significance level. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

higher than "Re", "Ed", "Go", "Ju", "At", "Pe" and "So". These results indicate that, to promote a wider array of benefits, farmers and local managers should be advised and supported in an active way by other stakeholders and policy makers, as those services will not occur otherwise under the currently prevailing point of view.

An extension might also present itself following the cross-demo-site analysis in Fig. 6, in which all the pondscapes are pooled together. For example, regarding the provisioning benefits considering a 5% significant level, the Uruguayan demo-site exhibits higher weight than any other demo-site, while the Spanish *Albera* demo-site has a lower weight than its Swiss and British counterparts. The Danish demo-sites also have a lower weight than the Swiss one. Opposite to the provisioning services, the Uruguayan demo-sites has the lowest weight in atmospheric regulation among all the demo-sites covered in this study.

This study could be further improved in a few ways. For example, the composition of the Uruguayan stakeholders' group could be enhanced with more local NGO members, which could potentially explain why provisioning services were not prevailing. On a similar note, the Belgian workshop could be enhanced with the participation of local farmers (especially relevant for Gete Vallei) or representatives from involved municipalities (for example from city of Hasselt for Tommelen). However, for all the demos-site workshops, there were great efforts by the organizers to attract the majority of the local representative stakeholders covering all the aspects of the pondscapes.

Furthermore, there are also theoretical and organizational drawbacks to consider in future research. First, the 6-h workshops required strenuous efforts from both organizers and participants, and thus participants are expectedly not willing to be contacted only to fill out the questionnaire again. Therefore, the choice of scales and Harker's algorithm were applied as alternatives but only on the scales that yield consistency in more than 80% of the observation. Second, several ecosystems services interconnect to each other, thus more complex methodologies which account for the interconnection might be implemented, such as Analytic Network Process or PROMETHEE. However, diversity in participants' backgrounds and resource constraints should be considered thoroughly while choosing method.

6. Conclusion

Research on nature-based solutions and ecosystem services usually overlooks the preferences of stakeholders or only consider them qualitatively, thus implying that all the ecosystem services are equal among all stakeholders without reckoning the context of the NBS or the needs of the local inhabitants. This could also lead to another consequence where even the NBS can provide some ecosystem services that stakeholders do not prefer. This study, using the AHP method, elaborates on the weights that reflect stakeholders' relative importance of ecosystem services provided by the pondscapes as nature-based solution. Further than only exploring the weights, compositional data analysis is implemented to clarify the statistical differences of weights within demo-site and among demo-sites. As far as we know, this study is the first to apply AHP in the context of pondscapes, and combine it with compositional ilr-transformation to analyze the results statistically. The significant differences might serve as conditions/constraints for further analyses, such as benchmarking by data envelopment analysis. For practical purposes, in cases where existing pondscapes need a conservational action, the results can also support policy makers in choosing the most favorable decision to maximize the perceived benefits from the implementation. In contrast, the results may support policy makers in designing appropriate strategies to promote other benefits that may be currently not appreciated nor perceived by the local stakeholders. For instance, emphasizing the potential for education, conservation, and habitat creation besides provisioning benefits in Uruguayan demo-sites area.

Credit author statement

Hoang-Tien Vo: Conceptualization, Methodology, Resources, Data Collection & Curation, Formal analysis, Visualization, Writing - Original Draft, Review & Editing. **Maria Vrachioli, Fabian Frick, Johannes Sauer**: Funding acquisition, Writing - Review & Editing, Supervision. **Sandra Brucet, Lluís Benejam, Thomas Mehner, Pieter Lemmens, Beat Oertli, Aurélie Boissezon, Meryem Beklioğlu, Antoine Dolcerocca, Mariana Meerhoff**: Stakeholder identification, Data collection, Demo-site discussions, Review.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Hoang-Tien Vo reports financial support was provided by European Union.

Data availability

Data will be made available on request.

Acknowledgements

This research has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 869296 – The PONDERFUL Project.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2023.118298.

References

IUCN Global Standard for Nature-Based Solutions: a User-Friendly Framework for the Verification, Design and Scaling up of NbS: first ed.. IUCN, International Union for Conservation of Nature.

Adem Esmail, B., Geneletti, D., 2018. Multi-criteria decision analysis for nature conservation: a review of 20 years of applications. Methods Ecol. Evol. 9, 42–53. https://doi.org/10.1111/2041-210X.12899.

Aitchison, J., 1986. The Statistical Analysis of Compositional Data. Chapman and Hall, London, p. 416.

Alves, A., Gersonius, B., Sanchez, A., Vojinovic, Z., Kapelan, Z., 2018. Multi-criteria approach for selection of green and grey infrastructure to reduce flood risk and increase CO-benefits. Water Resour. Manag. 32, 2505–2522. https://doi.org/10.1007/s11269-018-1943-3.

Antognelli, S., Vizzari, M., 2016. Ecosystem and urban services for landscape liveability: a model for quantification of stakeholders' perceived importance. Land Use Pol. 50, 277–292. https://doi.org/10.1016/j.landusepol.2015.09.023.

Biggs, J., Fumetti, S. von, Kelly-Quinn, M., 2017. The importance of small waterbodies for biodiversity and ecosystem services: implications for policy makers. Hydrobiologia 793, 3–39. https://doi.org/10.1007/s10750-016-3007-0.

Bozali, N., 2020. Assessment of the soil protection function of forest ecosystems using GIS-based Multi-Criteria Decision Analysis: a case study in Adıyaman, Turkey. Global Ecology and Conservation 24, e01271. https://doi.org/10.1016/j.gecco.2020.e01271.

Bryan, B.A., Grandgirard, A., Ward, J.R., 2010. Quantifying and exploring strategic regional priorities for managing natural capital and ecosystem services given multiple stakeholder perspectives. Ecosystems 13, 539–555. https://doi.org/10.1007/s10021-010-9339-0.

Bryan, B.A., Raymond, C.M., Crossman, N.D., King, D., 2011. Comparing spatially explicit ecological and social values for natural areas to identify effective conservation strategies. Conserv. Biol. : the journal of the Society for Conservation Biology 25, 172–181. https://doi.org/10.1111/j.1523-1739.2010.01560.x.

Campos, P.C.d.O., Da Paz, T.S.R., Lenz, L., Qiu, Y., Alves, C.N., Simoni, A.P.R., Amorim, J.C.C., Lima, G.B.A., Rangel, M.P., Paz, I., 2020. Multi-criteria decision method for sustainable watercourse management in urban areas. Sustainability 12, 6493. https://doi.org/10.3390/su12166493.

de Brito, M.M., Evers, M., 2016. Multi-criteria decision-making for flood risk management: a survey of the current state of the art. Nat. Hazards Earth Syst. Sci. 16, 1019–1033. https://doi.org/10.5194/nhess-16-1019-2016.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Hill, R., Chan, K.M.A., Baste, I.A., Brauman, K.A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P.W., van Oudenhoven, A.P.E., van der Plaat, F., Schröter, M., Lavorel, S., Aumeeruddy-Thomas, Y., Bukvareva, E., Davies, K., Demissew, S., Erpul, G., Failler, P., Guerra, C.A., Hewitt, C.L., Keune, H., Lindley, S., Shirayama, Y., 2018. Assessing nature's contributions to people. Science (New York, N.Y.) 359, 270–272. https://doi.org/10.1126/science.aap8826.

European Commission, Directorate-General for Research and Innovation, 2021. Evaluating the Impact of Nature-Based Solutions: A Handbook for Practitioners. Publications Office of the European Union, Luxembourg, 1 online resource.

Fang, X.-S., Liu, S., Chen, W.-Z., Wu, R.-Z., 2021. An Effective Method for Wetland Park Health Assessment: a Case Study of the Guangdong Xinhui National Wetland Park in the Pearl River Delta, China. https://doi.org/10.1007/s13157-021-01418-5. Wetlands 41.

Figueiroa, A.C., Lima, A.S. de, Scherer, M.E.G., Bonetti, J., 2020. How to choose the best category for a protected area? A multicriteria analysis method based on ecosystem services conservation. Environ. Monit. Assess. 192, 416. https://doi.org/10.1007/s10661-020-08333-y.

Filzmoser, P., Hron, K., Templ, M., 2018. Applied Compositional Data Analysis. Springer International Publishing, Cham.

Guarini, M., Battisti, F., Chiovitti, A., 2018. A methodology for the selection of multi-criteria decision analysis methods in real estate and land management processes. Sustainability 10, 507. https://doi.org/10.3390/su10020507.

Haile, G., Suryabhagavan, K.V., 2019. GIS-based approach for identification of potential rainwater harvesting sites in Arsi Zone, Central Ethiopia. Model. Earth Syst. Environ 5, 353–367. https://doi.org/10.1007/s40808-018-0537-7.

Haines-Young, R., Potschin, M.B., 2018. Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure.

Harker, P.T., Vargas, L.G., 1987. The theory of ratio scale estimation: saaty's analytic hierarchy process. Manag. Sci. 33, 1383–1403. https://doi.org/10.1287/mnsc.33.11.1383.

Hill, M.J., Greaves, H.M., Sayer, C.D., Hassall, C., Milin, M., Milner, V.S., Marazzi, L., Hall, R., Harper, L.R., Thornhill, I., Walton, R., Biggs, J., Ewald, N., Law, A., Willby, N., White, J.C., Briers, R.A., Mathers, K.L., Jeffries, M.J., Wood, P.J., 2021. Pond ecology and conservation: research priorities and knowledge gaps. Ecosphere 12. https://doi.org/10.1002/ecs2.3853.

Holgerson, M.A., Raymond, P.A., 2016. Large contribution to inland water CO2 and CH4 emissions from very small ponds. Nat. Geosci. 9, 222–226. https://doi.org/10.1038/ngeo2654.

Inkoom, J.N., Frank, S., Greve, K., Fürst, C., 2018. A framework to assess landscape structural capacity to provide regulating ecosystem services in West Africa. J. Environ. Manag. 209, 393–408. https://doi.org/10.1016/j.jenvman.2017.12.027.

IPBES, 2018. The IPBES regional assessment report on biodiversity and ecosystem services for Europe and Central Asia. In: Rounsevell, M., Fischer, M., Torre-Marin Rando, A., Mader, A. (Eds.), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Bonn, 1 Online Resource.

Ishizaka, A., Nemery, P., 2013. Multi-criteria Decision Analysis: Methods and Software, vol. XII. Wiley, Chichester, p. 296, 2.

Khomalli, Y., Elyaagoubi, S., Maanan, M., Razinkova-Baziukas, A., Rhinane, H., Maanan, M., 2020. Using analytic hierarchy process to map and quantify the ecosystem services in oualidia lagoon, Morocco. Wetlands 40, 2123–2137. https://doi.org/10.1007/s13157-020-01386-2.

Lee, H., Lautenbach, S., 2016. A quantitative review of relationships between ecosystem services. Ecol. Indicat. 66, 340–351. https://doi.org/10.1016/j.ecolind.2016.02.004.

Li, Z., Fan, Z., Shen, S., 2018. Urban green space suitability evaluation based on the AHP-CV combined weight method: a case study of fuping county, China. Sustainability 10, 2656. https://doi.org/10.3390/su10082656.

Liquete, C., Udias, A., Conte, G., Grizzetti, B., Masi, F., 2016. Integrated valuation of a nature-based solution for water pollution control. Highlighting hidden benefits. Ecosyst. Serv. 22, 392–401. https://doi.org/10.1016/j.ecoser.2016.09.011.

Loc, H.H., Duyen, P.M., Ballatore, T.J., Lan, N.H.M., Das Gupta, A., 2017. Applicability of sustainable urban drainage systems: an evaluation by multi-criteria analysis. Environ Syst Decis 37, 332–343. https://doi.org/10.1007/s10669-017-9639-4.

Macedo, D.R., Hughes, R.M., Kaufmann, P.R., Callisto, M., 2018. Development and validation of an environmental fragility index (EFI) for the neotropical savannah biome. Sci. Total Environ. 635, 1267–1279. https://doi.org/10.1016/j.scitotenv.2018.04.216.

Marques, M., Reynolds, K.M., Marto, M., Lakicevic, M., Caldas, C., Murphy, P.J., Borges, J.G., 2021. Multicriteria decision analysis and group decision-making to select stand-level forest management models and support landscape-level collaborative planning. Forests 12, 399. https://doi.org/10.3390/f12040399.

Marre, J.-B., Pascoe, S., Thébaud, O., Jennings, S., Boncoeur, J., Coglan, L., 2016. Information preferences for the evaluation of coastal development impacts on ecosystem services: a multi-criteria assessment in the Australian context. J. Environ. Manag. 173, 141–150. https://doi.org/10.1016/j.jenvman.2016.01.025.

Mostert, E., Gaertner, M., Holmes, P.M., O'Farrell, P.J., Richardson, D.M., 2018. A multi-criterion approach for prioritizing areas in urban ecosystems for active restoration following invasive plant control. Environ. Manag. 62, 1150–1167. https://doi.org/10.1007/s00267-018-1103-9.

Park, Y., Lee, S.-W., Lee, J., 2020. Comparison of fuzzy AHP and AHP in multicriteria inventory classification while planning green infrastructure for resilient stream ecosystems. Sustainability 12, 9035. https://doi.org/10.3390/su12219035.

Pawlowsky-Glahn, V., Egozcue, J., Tolosana-Delgado, R., 2015. Modelling and Analysis of Compositional Data. John Wiley & Sons, p. 256.

Ramanathan, R., Ganesh, L.S., 1994. Group preference aggregation methods employed in AHP: an evaluation and an intrinsic process for deriving members' weightages. Eur. J. Oper. Res. 79, 249–265. https://doi.org/10.1016/0377-2217(94)90356-5.

Richardson, D.C., Holgerson, M.A., Farragher, M.J., Hoffman, K.K., King, K.B.S., Alfonso, M.B., Andersen, M.R., Cheruveil, K.S., Coleman, K.A., Farruggia, M.J., Fernandez, R.L., Hondula, K.L., López Moreira Mazacotte, G.A., Paul, K., Peierls, B. L., Rabaey, J.S., Sadro, S., Sánchez, M.L., Smyth, R.L., Sweetman, J.N., 2022. A functional definition to distinguish ponds from lakes and wetlands. Sci. Rep. 12, 10472 https://doi.org/10.1038/s41598-022-14569-0.

Rodríguez Sousa, A.A., Parra-López, C., Sayadi-Gmada, S., Barandica, J.M., Rescia, A.J., 2020. A multifunctional assessment of integrated and ecological farming in olive agroecosystems in southwestern Spain using the Analytic Hierarchy Process. Ecol. Econ. 173, 106658 https://doi.org/10.1016/j.ecolecon.2020.106658.

Ruangpan, L., Vojinovic, Z., Plavšić, J., Doong, D.-J., Bahlmann, T., Alves, A., Tseng, L.-H., Randelović, A., Todorović, A., Kocic, Z., Beljinac, V., Wu, M.-H., Lo, W.-C., Perez-Lapeña, B., Franca, M.J., 2021. Incorporating stakeholders' preferences into a multi-criteria framework for planning large-scale Nature-Based Solutions. Ambio 50, 1514–1531. https://doi.org/10.1007/s13280-020-01419-4.

Saaty, T.L., 1977. A scaling method for priorities in hierarchical structures. J. Math. Psychol. 15, 234–281. https://doi.org/10.1016/0022-2496(77)90033-5.

Saaty, T.L., Ozdemir, M.S., 2003. Why the magic number seven plus or minus two. Math. Comput. Model. 38, 233–244. https://doi.org/10.1016/S0895-7177(03)90083-5.

Saaty, T.L., Tran, L.T., 2007. On the invalidity of fuzzifying numerical judgments in the Analytic Hierarchy Process. Math. Comput. Model. 46, 962–975. https://doi.org/10.1016/j.mcm.2007.03.022.

Scholten, L., Maurer, M., Lienert, J., 2017. Comparing multi-criteria decision analysis and integrated assessment to support long-term water supply planning. PLoS One 12, e0176663. https://doi.org/10.1371/journal.pone.0176663.

Segura, M., Maroto, C., Belton, V., Ginestar, C., 2015. A new collaborative methodology for assessment and management of ecosystem services. Forests 6, 1696–1720. https://doi.org/10.3390/f6051696.

Shivaprasad Sharma, S.V., Roy, P.S., V, C., G, S.R., 2018. Flood risk assessment using multi-criteria analysis: a case study from Kopili River Basin, Assam, India. Geomatics, Nat. Hazards Risk 9, 79–93. https://doi.org/10.1080/19475705.2017.1408705.

Srdjevic, B., Srdjevic, Z., Lakicevic, M., 2019. Urban greening and provisioning of ecosystem services within hesitant decision making framework. Urban For. Urban Green. 43, 126371 https://doi.org/10.1016/j.ufug.2019.126371.

Uddin, M.N., Hossain, M.M., Chen, Y., Siriwong, W., Boonyanuphap, J., 2019. Stakeholders' perception on indigenous community-based management of village common forests in Chittagong hill tracts, Bangladesh. For. Pol. Econ. 100, 102–112. https://doi.org/10.1016/j.forpol.2018.12.005.

van den Honert, R.C., Lootsma, F.A., 1997. Group preference aggregation in the multiplicative AHP the model of the group decision process and Pareto optimality. Eur. J. Oper. Res. 96, 363–370. https://doi.org/10.1016/0377-2217(95)00345-2.