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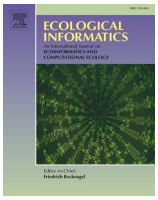

Comparative analysis between AHP and ANP in prioritization of ecosystem services - A case study in a rice field area raised in the Guadalquivir marshes (Spain)

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ABSTRACT

Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) are helpful multi-criteria methods used by the decision-makers to prioritize the ecosystem services provided to humankind by a natural area. Despite being the most common in this field, as it is the easiest and quickest method, AHP simplifies reality by distributing criteria as a hierarchy. As many ecosystem services are firmly connected, this simplification can alter the results owing to the inherent subjectivity of the decision-makers' judgments when completing the required pairwise comparisons. In contrast, ANP considers the relationships among criteria, drawing a complex network that can help in reducing subjectivity and uncertainty. This study aims to compare how both the methods deal with these possible biases. This study prioritizes the ecosystem services provided by a farming area in an internationally recognized wetland with various interconnected services. The case study was conducted in a rice field area raised in the Guadalquivir marshes located within the Doñana Biosphere Reserve in Spain. After applying both methodologies, the results conclude that AHP considerably overestimates the most abstract services. Generally, decision-makers overvalue cultural services as they are socially more visible than others, and in AHP, they are not compared directly with other elements. Additionally, when a problem impacts the production and many people are affected, AHP also magnifies its importance because it is in the limelight. Therefore, ANP is an efficient method when a study requires higher accuracy and coexists with intangible assets despite the benefits and drawbacks of each multi-criteria method.

1. Introduction

Natural assets are territories or physical spaces that sustain a particular ecosystem and offer different environmental goods and services to society (Moratilla, 2010). Ecosystem services (ESS) are the outputs that benefit humankind, directly or indirectly enhancing social welfare (MEA, 2005, Moratilla, 2010, Mace et al., 2012, Aznar Bellver and Estruch Guitart, 2020). Although they are provided, at this base, by an ecosystem, several studies also recognize human contributions delivered in different environmental contexts (Palomo et al., 2016). Some ES are easily observable, as they are involved in the economy (such as food supply or raw material). Nonetheless, society hardly perceives others despite contributing to these areas' social and economic value (including cultural services) (Aznar Bellver and Estruch Guitart, 2020). This has caused inefficient use and progressive deterioration of natural resources (Farber et al., 2002; Outlook, 2010).

The prioritization of ESS and their economic valuation allow governments to improve their management. They can utilize the research to improve the usage of public funds by distributing them among different assets through preservation and restoration plans (Aznar Bellver and Estruch Guitart, 2020). In the Common Agricultural Policy 2014–2020, the European Parliament recognized that the demand failed to reward farmers to protect the environment and other public goods, claiming monetary incentives for farmers to optimize ESS delivery. Many institutions prioritize ESS as an essential decision-making tool for future policies considering the area's social, cultural, environmental, and economic value (Hamel and Bryant, 2017). It allows for a more rational design of public interventions to correct social or environment-related market failures.

Analytic Hierarchy Process (AHP) (Saaty, 1990) is one of the most common multi-criteria decision-making (MCDM) methods for prioritizing or ranking certain criteria (Fountzoula and Aravossis, 2022).

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However, AHP simplifies reality by not considering the relationships among elements. Contrary to this hierarchical goal criteria method, Analytic Network Process (ANP) (Saaty, 1986, 2004) draws a network capable of incorporating feedback and interdependent relationships within and between clusters (Reig et al., 2010). However, "it makes the consistent pairwise comparison more difficult and time-consuming" (Asadabadi et al., 2019).

The function of ANP is to determine and consider the relationship of a network structure with a high degree of interdependence (Janeš et al., 2018). "Most complex real-world decision-making problems have numerous interdependent elements that can be captured and processed utilizing the feedback and interaction capabilities of an ANP model" (Saaty and Ozdemir, 2021; Tjader et al., 2014). Thus, this method is more appropriate for the economic valuation of natural areas. Some authors have underlined the importance of power relationships in ESS interactions and their influence on the process flow (Bennett et al., 2009; Villa et al., 2014). As an example of synergies in farming areas, the decisions about which crop to grow or which chemicals to use in the fields (such as pesticides or fertilizers) influence not only the food production itself but also the landscape, biodiversity, soil erosion, water quality, and other services (Bennett et al., 2021; Palomo et al., 2016).

Recent critiques have shown "some challenges associated with using the ESS framework to understand human-environment relationships", highlighting values' social and intersubjective nature (Raymond et al., 2014). In both multi-criteria methods (AHP and ANP), decision makers complete pairwise comparisons by delivering individual judgments based on their technical knowledge. Nevertheless, they can sometimes experience particular inflections through personal experiences or even emotions, when dealing with abstract concepts (Cooper et al., 2016). For instance, the valuation of cultural services must assess social and emotional assets based on human experience. Some authors also express an involuntary tendency "to under-report behaviors considered inappropriate and to over-report behaviors socially viewed as appropriate" (Donaldson and Grant-Vallone, 2002:247). In addition, some studies have inferred that "people who have similar choices are often less likely to be concerned about other factors that might influence their choice than people who must decide from among closely related alternatives" (Ozdemir and Saaty, 2006:359).

Therefore, decision-makers and researchers need a robust technique, given some ESS uncertainty and inherent subjectivity (Raymond et al., 2014). For instance, the valuation of cultural services needs to indirectly assess personal and emotional assets based on human experience and feelings. In AHP, pairwise comparisons are made only within each group of ES, so the compared alternatives or criteria are much similar. On the contrary, an ES confronts all the criteria in ANP, effectively addressing the existing relationships. A similar study carried out in Albufera Natural Park in Valencia (Spain) reported that ANP overrated cultural services (Jorge-García and Estruch-Guitart, 2020). However, that analysis did not focus on the ES individually but on the four groups. Consequently, it is expected that ANP is a more appropriate tool when decision-makers need a high degree of accuracy in prioritizing or valuing intangible assets.

Nowadays, many similar studies use AHP owing to its clearness and time-saving benefits, despite not being the most accurate method, as it does not consider the interdependence among criteria. However, it is necessary to determine if the differences between the results obtained by both methods are sufficiently relevant and whether the increasing effort of using ANP compensates them. Accordingly, this study aims to rank or prioritize ecosystem services (ESS) provided by a natural space using both AHP and ANP methods to compare the results and determine how they deal with uncertainty and biases. Such studies allow public administration to map areas for future economic, social, and environmental policy. The study area is the rice field area in the Guadalquivir marshes within the Doñana Biosphere Reserve in Spain, where there is prominent interdependence among all the ESS.

2. Literature review

2.1. Multi-criteria methods

Multiple Criteria Decision Making (MCDM) methods are divided in two groups: Multiple Objective Decision Making (MODM) and Multiple Attribute Decision Making (MADM) (He et al., 2016). MODM methods are primarily used to solve decision problems of the continuous type with a set of infinite solutions or criteria. On the contrary, MADM methods are used to solve discrete problems, with the finite number of alternatives or criteria (Córdoba Bueno, 2004). Table 1 shows the commonly used MADM methods.

However, various techniques extend or adapt these methods to specific studies or applications and to fuzzy, hybrid, and integrated approaches (De Brito and Evers, 2016). Some experts suggest that future applications of AHP should include an integrated application of this method with other techniques (Vaidya and Kumar, 2006). For instance, a case study reported by Ransikarbum et al. (2021) demonstrates how a framework of integrative multi-criteria decision analysis can be used, despite the fact that AHP does not consider the existing interdependence among criteria. Additionally, this integrated framework is used with fuzzy AHP (fuzzy-AHP) and other methods such as the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). "This fuzzy logic helps decision-makers account for data uncertainty" (Ransikarbum and Khamhong, 2021).

According to Ishizaka and Nemery (2013), pairwise comparison methods are instrumental when defining utility functions is not possible. Fountzoula and Aravossis (2022) conducted a literature review on the use of MCDM methods. They have analyzed that, during the period 2010–2020, "multi-criteria decision-making methods were commonly used in public sector decision-making and AHP was the most frequent one when counting both simple and integrated methods". Khan and Ali (2020) also concluded that by analyzing a literature review of the studies incorporating either AHP or ANP, "the highest number of publications have used AHP applications in every category". Nevertheless, "ANP can improve communication and resolve conflicts, help diffuse responsibility, and assist decision-makers in understanding other members' viewpoints" (Janeš et al., 2018 based on Saaty, 1996). ANP allows decision-makers to solve real-world issues due to the consideration of complex and interrelated relationships between decision elements and "the ability to apply quantitative and qualitative attributes simultaneously" (Kheybari et al., 2020; Toth et al., 2021). Table 2 summarizes the advantages and disadvantages of ANP in comparison with AHP.

Based on recent studies, Nimawat and Gidwani (2021) prioritized the barriers to Industry 4.0 in India, concluding that "the outcome received employing the ANP varies to some extent as with that of the

Table 1
Widely used MADM methods (De Brito and Evers, 2016; Hajkowicz and Collins, 2007).

Groups	Methods
Multi-attribute utility and value functions	Multi-attribute utility theory (MAUT) and Multi-attribute value theory (MAVT)
Pairwise comparisons	Analytic Hierarchy Process (AHP), Analytic Network Process (ANP) and Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH)
Outranking approaches	Elimination et choix traduisant la realité (ELECTRE), Elimination et choix traduisant la realité (PROMETHEE) and Organization, rangement et synthese de donnes relationnelles (ORESTE)
Distance to ideal point methods	Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), Compromise Programming (CP) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)
Other methods	Data Envelopment Analysis (DEA), Multi-Objective Programming (MOP)

Table 2
Advantages and disadvantages of ANP (Zhu et al., 2010).

Advantages	Disadvantages
It improves the management understanding and the transparency of the procedure.	It involves greater complexity than AHP, so decision-makers must better understand the method.
Qualitative and quantitative criteria and their relationships can be introduced into the problem. Decision-makers usually use it as a consensus tool.	The number of questions is proportional to the number of relationships, which gets heavier. The feeling of repetition increases potential subjectivity.
When the elements present strong relationships, this method is more precise and objective as it avoids double-counting. It allows the inclusion of the interdependence between all the elements, which reduces subjectivity.	Its complexity can increase the statistical inconsistency as more quantity and broader-range matrices are used. It is more challenging to maintain the consistency below the limits, driving the expert to repeat the pairwise comparison and distort the results.

AHP". However, the ranking orders did not differ. Janeš et al. (2018) also found some differences between the two methods in prioritizing the BSC's strategic goals. Their study concluded that "the priorities which resulted from the application of the ANP method are more acceptable because of the capability that enables it to be more complementary with the Benefits of Balanced Scorecard".

Regarding environmental issues, De Brito et al. (2018) concluded that both methods have the proper performance in flood hazard assessment, but "ANP is preferable due to consideration of the dependence between all the criteria". Dano et al. (2019) also concluded that ANP could accurately model the interdependence among factors affecting flood phenomena in their study area. Similarly, another study on flood hazard zoning by Daneshparvar et al. (2022) showed that "there were differences in weight and criteria priority depending on the method". The main factor coincides with both methods, but its weight differs from 7.21% in AHP to 19.13% in ANP. Further, Baviera-Puig et al. (2014) concluded that "companies can better adapt their strategy for Corporate Social Responsibility (CSR) to the expectations of different stakeholders using ANP". Nevertheless, a limitation of this methodology is the use of long and complex questionnaires compared to AHP.

Considering recent studies on ESS in similar areas to the Guadalquivir marshes, AHP is used in some cases, such as those by Cruz Abad (2021) in the Albufera Natural Park, Martín et al. (2017) in the Hoces del Cabriel Natural Park, or Gómez Aguayo (2017) on La Safor's coast. However, others prefer to use ANP considering the interdependence among ESS, such as Colomar Andrés (2018) in the L'Horta Nord natural area or Gómez-Aguayo and Estruch Guitart (2021) in a natural area of Xàbia. Valls Civera (2020) studied the economic value of the ESS provided by Turia Natural Park using both methods. The comparison revealed that the differences were not sufficiently significant for the study area's total economic value (TEV). However, when ESS was individually ranked in the Albufera Natural Park, the cultural services were overrated when AHP was used, even though the TEV did not vary (Jorge-García and Estruch-Guitart, 2020).

2.2. Ecosystem services (ESS) and their valuation

Ecosystem services (ESS) are aspects of the ecosystems used directly or indirectly to induce human well-being (MEA (Millennium Ecosystem Assessment), 2005). Natural areas are relevant for biodiversity, but "they also provide a wide range of ESS such as water provision, climate regulation, or recreational opportunities" (Jenkins and Schaap, 2018; Olschewski et al., 2018). Regarding the study area, "wetlands, including rivers, lakes, marshes, rice fields, and coastal areas, provide many services that contribute to human well-being and poverty alleviation" (MEA (Millennium Ecosystem Assessment), 2005). However, intensified and continuously expanding human activities have seriously impacted the world (Small et al., 2017). Thus, societies have taken advantage of ESS, which is unsustainably damaging by up to 60% (Xu et al., 2017).

Several international initiatives have considered the importance of ESS, which has helped to promote research on sustainable development. Some of them are the Economics of Ecosystems and Biodiversity (TEEB), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), the Ecosystem Services Partnership (ESP), and the United Nations Sustainable Development Goals (UN SDGs). When it comes to research, there has been a relative increase in the number of highly cited articles in which the ESS concept has gained increasing attention, especially since the mid-2000s (Zhang et al., 2019:12). The valuation and prioritization of ESS can contribute to resolving potential conflicts among beneficiaries, establish trade-offs, and sustainable management of ecosystems (Costanza et al., 2011; Farber et al., 2002). In any case, the ESS and its impact on human welfare and sustainability must be studied using an integrated approach (Bennett et al., 2015; Liu et al., 2015). The political, social, and ecological challenges in managing and monitoring natural areas require the social values of ESS to be accurately reflected (Daily and Matson, 2008).

Experts currently use many verified ESS classifications while evaluating a natural space. In this study, the Millennium Ecosystem Assessment (MEA) list (MEA (Millennium Ecosystem Assessment), 2005) was chosen because of its international recognition since the United Nations (UN) created it as an agreement among scientists from >95 countries worldwide. It is widely used by transnational organizations and public administrations (Camacho and Ruiz, 2012). According to the MEA, ecosystems deliver four types of services: supporting (those necessary for the production of other services), provisioning (products and other material benefits), regulating (benefits obtained from the regulation of ecosystem processes), and cultural (intangible benefits). Currently, most research focuses on easily measurable ESS, provisioning, or ESS quantified using modelling (Geijzendorffer et al., 2017; Raymond et al., 2014). Despite their importance in global sustainability policies, cultural services are vastly less depicted (Geijzendorffer et al., 2017).

Farming areas play a relevant role in provisioning public goods, owing to their effects on biodiversity, landscape, culture, and natural resources. Consequently, agriculture provides goods and services to society beyond pure food production. This notion is known as multifunctionality. "Crop production systems provide a material basis for human survival and economic development, which depend on natural and human inputs" (Zhang et al., 2016:622). Despite being considered a source of provisioning ESS, these economic activities are also provided to and by all other groups (Shah et al., 2019; Zhang et al., 2007).

3. Methodology

The methodology used in this study was divided in various phases as presented in the flowchart shown in Fig. 1.

All these phases or steps are explained in detail below:

1. Choice of experts participating in the process. Their technical or scientific knowledge determined their selection. They also represent the main sectors, interests, and perspectives involved in the area. The nine chosen experts or decision makers (DM) are

   - DM1: Freelance agrarian technician.
   - DM2: A local politician who runs the agricultural and environmental area.
   - DM3: Technician working for a cooperative (ARROZÚA).
   - DM4: Technician of a Community of irrigation.
   - DM5: Technician working for a red swamp crayfish industry.

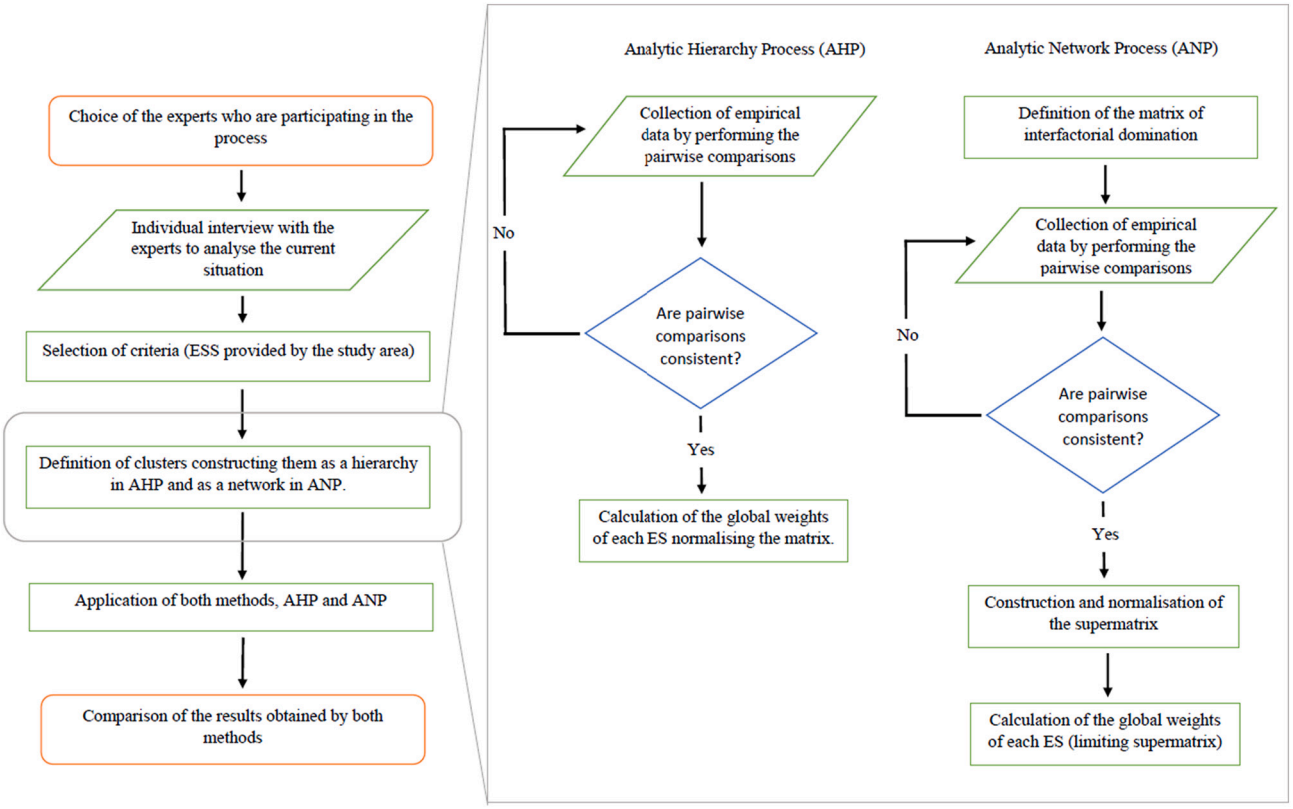

Fig. 1. Flowchart representing the methodology followed in this study.

- o DM6: Technician working for the Federation of rice growers of Seville.
- o DM7: Ecological NGO member (SEO-Bird Life)
- o DM8: Agrarian Union member (UPA)
- o DM9: Professor at the University of Seville.

2. Individual interviews with experts to analyze the current situation. This phase aimed to comprehend the positive and negative circumstances faced by farmers at that moment. This knowledge about the problems, helps to interpret how both methods deal with social perceptions. Decision makers have individually analyzed the relevant ESS provided by the study area and their current state, including both the positives and the negatives. All interviews were conducted in July 2021, two months before harvest.
3. Selection of criteria: ESS provided by the area. This study did not consider the complete list of MEAs, as some do not exist in the Guadalquivir marshes, and others are not sufficiently relevant. The selection of ESS considered the decision-maker's knowledge through interviews conducted in the previous step. All of them agreed with the last selection criteria. Table 3 shows the complete list of ESS provided by a wetland according to MEA (Millennium Ecosystem Assessment) (2005). In addition, the removed or aggregated ESSs are marked.

Non-existence is one of the reasons why some ESS have been removed (such as medicinal resources or moderation of extreme events). Additionally, as more elements are assumed while using multi-criteria techniques, preserving the consistency ratio below the limits, and distorting the results is more challenging. Therefore, some ES have been removed because they are not sufficiently relevant (such as raw material). In contrast, biological control of pests and diseases and the pollination effect can operate together. This simplifies the process and renders it more functional and understandable. The chosen criteria are listed in Table 4.

Table 3
General list of ESS provided by a wetland (MEA (Millennium Ecosystem Assessment), 2005) and its adaptation to the study area.

Groups	ESS provided by wetlands (MEA, 2005)	Adaptation to the study area
Supporting services	Habitat for species	
	Maintenance of genetic diversity (biodiversity)	
	Soil formation and nutrient cycling	Removed
Provisioning services	Food	
	Freshwater / Water supply	
	Medicinal resources	Removed
	Raw material	Removed
Regulation services	Local climate and air quality	
	Waste-water treatment	
	Erosion prevention and maintenance of soil fertility	
	Biological control of pests and diseases	
	Pollination effect	Aggregated
	Moderation of extreme events	Removed
	Carbon sequestration and storage	Removed
	Regulation of water flow	Removed
Cultural services	Recreation and mental and physical health	Aggregated
	Tourism	
	Aesthetic appreciation and inspiration for culture and arts	
	Spiritual experience and sense of place	
	Knowledge, science and education	

4. Definition of Clusters. In the AHP, the criteria (ESS) are placed in a hierarchy. In ANP, they form a network in which the existent interactions among all elements, denoted by unity entries in the matrix of interfactorial domination (Table 5), are deemed to exist.

Table 4
Criteria (C) considered in this work.

Groups	Ecosystem services (ESS)
Supporting services	C1: Habitat for species
	C2: Maintenance of genetic diversity (biodiversity)
Provisioning services	C3: Food
	C4: Freshwater / Water supply
Regulation services	C5: Local climate and air quality
	C6: Waste-water treatment
	C7: Erosion prevention and maintenance of soil fertility
	C8: Biological control and pollination
Cultural services	C9: Tourism, recreation and mental and physical health
	C10: Aesthetic appreciation and inspiration for culture and arts
	C11: Spiritual experience and sense of place
	C12: Knowledge, science and education

5. Application of AHP and ANP. Pair comparisons made by selected decision makers or specialists are the basis of these two methods. They completed them verbally using Saaty's comparison scale, as shown in Table 6.

Complete fieldwork was simultaneously conducted (July 2021) to avoid misinterpretation while comparing the results. As for the comparison matrices, if the number of criteria exceeds three, an inconsistency arises (Piengang et al., 2019; Tavana et al., 2017), as humans cannot maintain consistent pairwise judgments when the number of components increases (Miller, 1956). Accordingly, each matrix was associated with a consistency ratio (*CR*). Inconsistencies were accepted to be below 10% for matrices of rank $n > 4$, 5% for $n = 3$, and 8% for $n = 4$. Experts must repeat the pairwise comparison matrix when it surpasses the established CR.

The priority vectors are the normalized eigenvectors of the pairwise comparison matrices, and, in this investigation, they offer the weight of each ES among the total economic value. It permits ranking of all the ESS in order of priority or prominence. In this phase, each method, AHP and ANP, has different steps to obtain the results:

- In the AHP, experts must complete five pairwise comparisons. First, one per group obtains the priority vector of each ES over the value of the group to which it belongs (ω_{c1}, ω_{c2}... ω_{c12}). Second, a fifth matrix among the four groups (ω_p, ω_r, ω_s, ω_c) obtains the priority vector of each group (supporting, provisioning, regulating, and cultural services) over the total value of the area. The final weight of each ES is the result of multiplying its priority vector (ω_1, ω_2... ω_{12}) by the weight of its corresponding group (ω_p, ω_r, ω_s, ω_c).
- In ANP, the priority vectors that have been delivered from pairwise comparison matrices are entered as a part of a column of the supermatrix, substituting the unity entries of the matrix of interfactorial domination. Each segment represents the influence of a cluster on the left of the matrix on a cluster at the top of the matrix (Reig et al., 2010). Second, it is necessary to develop them using the corresponding cluster priorities. This means that there are four groups (ωp, ωr, ωs, ωc). It then corresponds to normalizing each column as the matrix is unweighted. Finally, the limiting supermatrix is obtained by increasing the previous one to a significant amount of power to stabilize the values. This mathematical operation captures the transmission of influence along with all the ESS. After this step, every column had the same number. Consequently, these results are the priority or weight of each ES in the area.

6. Comparison (per expert and average) of the results obtained using both methods. This is performed using a coefficient *K* developed as a quotient of the ANP results (w) divided by the AHP results (w').

$$K = \frac{w}{w'}$$

Its interpretation follows the following mathematical intervals:
If $K < 0{,}95$, AHP > ANP (the results obtained by AHP were higher).
If $0{,}95 \leq K \leq 1{,}05$, AHP = ANP (The differences were insignificant).
If $K > 1{,}05$; ANP > AHP (the results obtained by ANP were higher).

4. Study area: The Guadalquivir marshes in Doñana

Doñana was designed as a biosphere reserve in 1980 and its area was extended in 2012. It is one of the most important protected wetlands globally as it hosts a massive variety of species (over 300 vertebrates). Furthermore, more than six million birds pass through this area annually

Table 6
Saaty's comparison scale (Saaty, 1986, 1990, 2004).

Intensity of the importance of one ES over another	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6 and 8	Comparison between the above values

Table 5
Matrix of interfactorial domination in ANP.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	0	1	1	1	1	1	1	1	1	1	1	1
C2	1	0	1	1	1	1	1	1	1	1	1	1
C3	1	1	0	1	1	1	1	1	1	1	1	1
C4	1	1	1	0	1	1	1	1	1	1	0	0
C5	1	1	1	0	0	0	1	1	1	1	0	1
C6	1	1	1	0	1	0	1	1	1	1	0	1
C7	1	1	1	1	1	1	0	1	1	1	0	1
C8	1	1	1	0	1	1	1	0	1	1	0	1
C9	1	1	0	0	0	0	0	0	0	0	1	0
C10	0	0	0	0	0	0	0	0	1	0	1	1
C11	0	0	0	0	0	0	0	0	1	0	0	0
C12	1	1	1	0	1	1	1	1	0	1	1	0
					1	There is a relationship between the two ESS						
					0	There is not any relationship between the two ESS						

Ecosystem services: C1 (Habitat for species), C2 (Maintenance of genetic diversity), C3 (Food), C4 (Water supply), C5 (Local climate and air quality), C6 (Waste-water treatment), C7 (Erosion prevention and maintenance of soil fertility), C8 (Biological control and pollination), C9 (Tourism, recreation and mental and physical health), C10 (Aesthetic appreciation and inspiration for culture and arts), C11 (Spiritual experience and sense of place) and C12 (Knowledge, science and education).

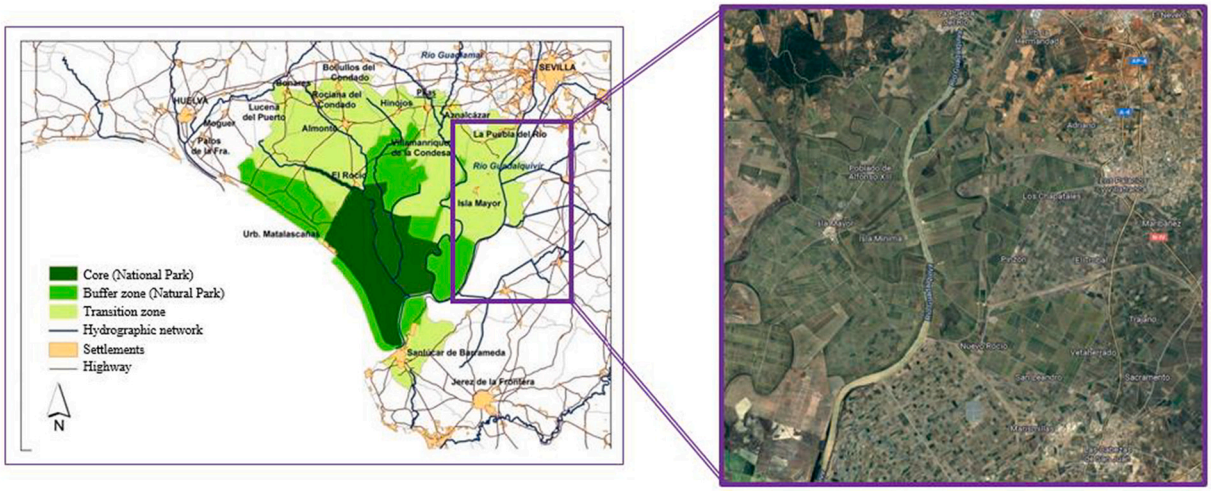

Fig. 2. Boundaries of the Doñana Biosphere Reserve (UNESCO, 2020) and orthophoto of the rice fields.

on migratory flyways because of the strategic location between Europe and Africa (UNESCO, 2020). It is located in the Gulf of Cádiz, belonging to three Spanish provinces: Seville, Cadiz, and Huelva, all in Andalusia's region (distribution shown in Fig. 2). Total area (269,158 ha) is divided in three parts as the core made up of Doñana National Park (54,680 ha), the buffer zone, which mainly represents the Natural Park (59,333 ha), and the transition zone where the surface is dedicated to agriculture, livestock, fishing, and other primary economic activities (155,145 ha). UNESCO has also conceived of the entire site as a World Heritage Site and is part of the Wetlands of International Importance (RAMSAR) and the Natura 2000 network.

Rice fields in the province of Seville (36,000 ha in 2016) occupy a part of the transition zone. A total of 1500 ha belongs to the natural park. They are located in the marshes of the Guadalquivir River. Currently, this is the largest rice-producing area in Spain, with 350,000 ton production in 2016, representing 42.6% of the national and 10% of the European production, according to official statistics (Castillo-Manzano et al., 2021). Currently, integrated production accounts for 60% of the total fields. According to the Ministry of Agriculture, Fisheries, and Food of Spain (Ministry of Agriculture, Fisheries and Food (MAPA), 2020), the contribution to the labor market is estimated to be >5000 jobs and 100 million euros paid in salaries.

The water supply links the National Park and the rice field area, as this crop grows on flooded shallow land. As a result, birds use the area as their habitat to feed, as long as the natural marshes are dry during summer and when there are no crops in winter. Furthermore, the fishing of the red swamp crayfish (*Procambarus clarkii*) is a new industry associated with rice cultivation that has recently arisen in the area. Although scientists consider this species invasive, the manufactured crayfish production in the Guadalquivir marshes rose to 4000 t in 2015, which is 10% of the world production (Ministry of Agriculture, Fisheries and Food (MAPA), 2020).

5. Results

5.1. Mapping of the situation in the Guadalquivir marshes

Considering the results obtained from the interviews of the nine decision-makers, these are the most relevant concerns people are facing in the rice fields of the Guadalquivir marshes during the study period (July 2021).

Water shortage, affecting the C4 directly: Freshwater / Water Supply. There is an increasing accumulation of salty water in the Guadalquivir River, the water source of the irrigation system, due to drought and dredging of the riverbed upstream. This situation also hinders farming resulting in reduced rice production. These two problems, both related to the water supply, are the most disturbing problems. They persisted during the following seasons because of severe droughts affecting all marshes. All interviewed experts highlighted this problem.

Water salinization, affecting the C4 directly: Freshwater / Water Supply and C6: Waste-water treatment. There is an increasing accumulation of salty water in the Guadalquivir River, the source of the irrigation system, due to drought and dredging of the riverbed upstream. This also hinders farming resulting in reduced rice production. These two problems, both related to the water supply, are the most disturbing problems in the area. They seem to persist during the following seasons because of the severe droughts affecting all marshes. All interviewed experts highlighted this problem.

Red swamp crayfish industry, affecting the C3 directly: Food. This industry has both supportive and opposing sectors, as it is a growing source of occupation. The species is not local and yields some problems on the banks of the fields. On the other hand, flamingos from Doñana National Park are also causing some trouble during winter because they occupy rice fields when farmers flood their fields and the crayfish further attracts birds. This problem has been highlighted only by the experts directly related to farming (DM1, DM4, DM6, and DM8) because it affects their production and DM8 (conservationist) because the red swamp crayfish is an invading species.

Biodiversity and sustainable farming practices affect all the supporting and regulating ESS. There has been a significant expansion in the number of fields embracing integrated and organic farming, partly due to the EU agri-environmental aid agenda. Despite this effort, conservationists (DM8) mark single crops as a weakness because of the lack of biodiversity. This coincides with the situation in Spain's other rice field areas, such as the Albufera Natural Park in València (Jorge-García and Estruch-Guitart, 2020).

5.2. Prioritization of the ESS and comparison of AHP and ANP

Based on the results obtained by each method, Table 7 illustrates the weights of each group per expert, and average.

Looking at the four groups, the differences among the nine decision-makers are high in both methods; therefore, there is no remarkable reduction in heterogeneity when ANP is used. Specifically, the standard deviation decreases in the cultural services and increases in the other three groups, similar to the average value. Moreover, the order of importance of the four groups did not change to 100% for the decision-makers. Thus, the method used does not change the ranking order when the analysis focuses on groups.

Regarding provisioning services, this group occupied half of the total

Table 7
AHP and ANP results per group.

Group of ESS	WEIGHT (%) OF EACH GROUP OF ES OVER THE WHOLE VALUE BY USING AHP (PER EXPERT AND AVERAGE)										Standard deviation
	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Average	
Supporting	14.95	8.10	5.32	16.86	16.67	20.85	9.15	10.13	15.12	13.02	5.05
Provisioning	49.30	55.56	54.85	36.79	50.00	48.74	57.41	52.90	50.83	50.71	6.03
Regulation	28.22	11.47	29.66	36.79	16.67	20.85	5.23	13.41	26.53	20.98	10.14
Cultural	7.52	24.88	10.18	9.56	16.67	9.56	28.21	23.55	7.52	15.29	8.23

Group of ESS	WEIGHT (%) OF EACH GROUP OF ES OVER THE WHOLE VALUE BY USING ANP (PER EXPERT AND AVERAGE)										Standard deviation
	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Average	
Supporting	15.28	8.91	5.22	17.18	17.83	21.41	10.29	10.93	15.40	13.61	5.10
Provisioning	50.37	61.14	53.83	37.49	53.50	50.05	64.54	57.10	51.78	53.31	7.70
Regulation	28.84	12.61	34.08	37.48	19.23	21.41	5.88	14.47	27.03	22.34	10.42
Cultural	5.52	17.34	6.87	7.85	9.44	7.13	19.30	17.49	5.79	10.75	5.61

Experts: DM1 (Freelance agrarian technician), DM2 (Local politician with agricultural competency), DM3 (Technician working for a cooperative), DM4 (Technician of a Community of irrigation), DM5 (Technician working for a red swamp crayfish industry), DM6 (Technician working for the Federation of rice growers of Seville), DM7 (Environmentalist and member of the NGO, SEO-Bird Life), DM8 (Agrarian Union member in UPA) and DM9 (Professor at the University of Seville).

value according to both methods (50.71% in AHP and 53.31% in ANP), a typical situation in a farming area. This also reveals that another 47–50% of the area's TEV is incorporated by other services that the market is not rewarding. The provisioning service results are relatively homogeneous (a standard deviation of 6.03 in AHP and 7.70 in ANP). Moreover, six out of nine (66%) decision-makers assigned a value between 45% and 55% to provisioning services in both methods. In addition, 100% of the participants ranked this group as the most relevant. DM7 (conservationist) gave the highest value to provisioning services, with 57.41% in AHP and 64.54% in ANP.

Furthermore, cultural services had the most considerable differences between the obtained results. When AHP was used, its value was 15.29%, whereas that of ANP was 10.75%. This tendency occurs with 100% of decision-makers. It is also noticeable that DM7 (conservationist) is the expert who has given the highest value to cultural services as it has happened with provisioning services. After the analysis per group, Table 8 shows the results obtained per ES using both the methods.

Table 8
AHP and ANP results per ES in detail.

ESS		WEIGHT (%) OF EACH ES OVER THE WHOLE VALUE BY USING AHP (PER EXPERT AND AVERAGE)										Standard deviation
		DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Average	
Supporting	C1	7.48	6.75	1.33	8.43	8.33	10.42	6.86	7.60	12.60	7.76	3.05
	C2	7.48	1.35	3.99	8.43	8.33	10.42	2.29	2.53	2.52	5.26	3.39
Provisioning	C3	12.32	6.94	9.14	4.60	6.25	24.37	7.18	26.45	12.71	12.22	7.96
	C4	36.97	48.61	45.71	32.19	43.75	24.37	50.23	26.45	38.12	38.49	9.40
Regulation	C5	2.70	1.23	2.32	11.04	1.89	6.44	0.43	3.74	3.97	3.75	3.25
	C6	10.38	6.48	5.93	11.04	7.08	5.02	0.48	0.86	13.08	6.70	4.32
	C7	10.38	1.12	15.49	11.04	3.71	6.44	2.86	1.75	7.49	6.70	4.87
	C8	4.76	2.63	5.93	3.68	3.99	2.95	1.46	7.06	2.00	3.83	1.84
Cultural	C9	0.58	5.66	0.69	1.06	1.09	0.90	1.83	1.19	1.86	1.65	1.57
	C10	1.58	1.79	2.30	2.86	2.18	1.68	15.95	7.65	3.63	4.40	4.72
	C11	2.94	15.33	5.22	4.76	6.17	4.61	8.28	7.65	0.71	6.19	4.13
	C12	2.43	2.09	1.96	0.88	7.23	2.36	2.15	7.06	1.32	3.05	2.37

ESS		WEIGHT (%) OF EACH ES OVER THE WHOLE VALUE BY USING ANP (PER EXPERT AND AVERAGE)										Standard deviation
		DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Average	
Supporting	C1	9.32	6.15	3.79	8.38	9.85	9.80	8.09	5.42	9.07	7.76	2.15
	C2	5.95	2.76	1.43	8.80	7.99	11.61	2.19	5.52	6.33	5.84	3.34
Provisioning	C3	24.98	37.30	26.48	19.90	11.55	24.72	35.87	31.56	28.84	26.80	7.96
	C4	25.39	23.83	27.35	17.59	41.95	25.33	28.66	25.54	22.94	26.51	6.58
Regulation	C5	2.09	1.06	3.12	3.06	1.09	4.42	0.24	3.49	1.96	2.28	1.35
	C6	9.61	3.86	14.41	15.16	4.87	3.45	0.68	2.65	8.77	7.05	5.21
	C7	12.62	6.22	14.32	12.74	10.73	9.57	4.02	6.61	13.63	10.05	3.68
	C8	4.51	1.48	2.23	6.52	2.54	3.96	0.93	1.72	2.67	2.95	1.76
Cultural	C9	0.19	0.97	0.09	0.41	0.94	0.34	0.72	0.54	0.63	0.54	0.31
	C10	0.40	4.01	0.18	0.68	1.17	0.61	4.54	3.34	0.39	1.70	1.74
	C11	0.00	0.06	0.00	0.01	0.04	0.01	0.03	0.02	0.01	0.02	0.02
	C12	4.93	12.30	6.61	6.75	7.29	6.17	14.00	13.60	4.76	8.49	3.73

Ecosystem services: C1 (Habitat for species), C2 (Maintenance of genetic diversity), C3 (Food), C4 (Water Supply), C5 (Local climate and air quality), C6 (Waste-water treatment), C7 (Erosion prevention and maintenance of soil fertility), C8 (Biological control and pollination), C9 (Tourism, recreation and mental and physical health), C10 (Aesthetic appreciation and inspiration for culture and arts), C11 (Spiritual experience and sense of place) and C12 (Knowledge, science and education).
Experts: DM1 (Freelance agrarian technician), DM2 (Local politician with agricultural competency), DM3 (Technician working for a cooperative), DM4 (Technician of a Community of irrigation), DM5 (Technician working for a red swamp crayfish industry), DM6 (Technician working for the Federation of rice growers of Seville), DM7 (Environmentalist and member of the NGO, SEO-Bird Life), DM8 (Agrarian Union member in UPA) and DM9 (Professor at the University of Seville).

Decision-makers have ranked C4 'Water supply' as the most critical service in the area (38.49% on average) when AHP is used. This result is similar for the 100% experts, although DM6 and DM8 shared their importance with C3 'Food'. On the other hand, this situation completely changes when ANP is used as C3 'Food' has been the most relevant ES (26.80% on average), followed by C4 'Water supply' (26.51% on average). In this method, homogeneity among decision makers disappear. In four of nine cases (44%), the ranking order between C3 and C4 changed when ANP was used.

However, the value of cultural services considerably decrease when ANP is used, a tendency followed by 100% of decision-makers. However, C12 'Knowledge, science, and education is the exception since its value is 3.05% in AHP and 8.49% in ANP. About the other two groups, it is noticeable that ANP slightly decreases the standard deviation of the supporting and regulation services, especially to C7 'Erosion prevention and maintenance of soil fertility'.

Furthermore, Table 9 shows the coefficient K (ANP/AHP) per expert and the average in which the differences between the two methods can be better analyzed.

Cultural services were consistently higher when AHP was used (K = 0,7 on average). This tendency is repeated in 100% of the decision makers' results. However, there is a peculiarity with C12 'Knowledge, science, and education' since its weight reduced while using AHP (K = 2,78 on average). This tendency is also observed in 100% of the decision-makers. The most significant case in this group is spiritual experience and sense of place, as it has a 6% importance in AHP and about 0% in ANP (K = 0).

Regarding the provisioning services, there is no relevant difference between the two methods as a group (K = 1.05 on average). However, while considering them individually, it is noticeable that AHP tends to

Table 9
Coefficient K (ANP / AHP).

ESS		K = ANP / AHP									
		DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Average
Supporting	C1	1.25	0.91	2.85	0.99	1.18	0.94	1.18	0.71	0.72	1.00
	C2	0.80	2.04	0.36	1.04	0.96	1.11	0.96	2.18	2.51	1.11
Provisioning	C3	2.03	5.37	2.90	4.33	1.85	1.01	5.00	1.19	2.27	2.19
	C4	0.69	0.49	0.60	0.55	0.96	1.04	0.57	0.97	0.60	0.69
Regulation	C5	0.78	0.86	1.35	0.28	0.58	0.69	0.57	0.93	0.49	0.61
	C6	0.93	0.60	2.43	1.37	0.69	0.69	1.43	3.08	0.67	1.05
	C7	1.22	5.54	0.92	1.15	2.89	1.49	1.40	3.77	1.82	1.50
	C8	0.95	0.56	0.38	1.77	0.64	1.34	0.64	0.24	1.34	0.77
Cultural	C9	0.33	0.17	0.13	0.39	0.86	0.38	0.39	0.45	0.34	0.32
	C10	0.25	2.24	0.08	0.24	0.54	0.37	0.28	0.44	0.11	0.39
	C11	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00
	C12	2.03	5.89	3.36	7.67	1.01	2.61	6.51	1.93	3.59	2.78

Group of ESS	K = ANP / AHP									
	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Average
Supporting	1.02	1.10	0.98	1.02	1.07	1.03	1.12	1.08	1.02	1.05
Provisioning	1.02	1.10	0.98	1.02	1.07	1.03	1.12	1.08	1.02	1.05
Regulation	1.02	1.10	1.15	1.02	1.15	1.03	1.12	1.08	1.02	1.06
Cultural	0.73	0.70	0.68	0.82	0.57	0.75	0.68	0.74	0.77	0.70

K < 0,95; AHP > ANP
0,95 ≤ K ≤ 1,05; AHP = ANP
K > 1,05; ANP > AHP

Ecosystem services: C1 (Habitat for species), C2 (Maintenance of genetic diversity), C3 (Food), C4 (Water Supply), C5 (Local climate and air quality), C6 (Waste-water treatment), C7 (Erosion prevention and maintenance of soil fertility), C8 (Biological control and pollination), C9 (Tourism, recreation and mental and physical health), C10 (Aesthetic appreciation and inspiration for culture and arts), C11 (Spiritual experience and sense of place) and C12 (Knowledge, science and education).

Experts: DM1 (Freelance agrarian technician), DM2 (Local politician with agricultural competency), DM3 (Technician working for a cooperative), DM4 (Technician of a Community of irrigation), DM5 (Technician working for a red swamp crayfish industry), DM6 (Technician working for the Federation of rice growers of Seville), DM7 (Environmentalist and member of the NGO, SEO-Bird Life), DM8 (Agrarian Union member in UPA) and DM9 (Professor at the University of Seville).

overrate C4 'Freshwater supply' (K = 0,69 on average) and, as a result, misjudge C3 'Food' (K = 2,19 on average). This tendency was repeated in eight out of nine decision makers (88%).

Eventually, the pattern is not as straightforward in the other two groups as the concept studies are the most technical (K supporting services = 1.05 on average; K = regulation services = 1.06 on average). Therefore, the differences in supporting services are sufficiently small or insignificant. When the ESS are compared individually, there are slight differences among the decision-makers. However, there is no specific tendency except for C7 'Erosion prevention and maintenance of soil fertility' (K = 1,50 on average). In this case, eight out of nine decision-makers (88%) increased the value of C7 in the ANP.

6. Discussion

The results show that AHP overestimates cultural services, a pattern repeated for 100% of decision-makers. It is necessary to point out that AHP only compares one service with another in the same group. Consequently, regarding cultural services, they face two abstract concepts that are socially visible in AHP. Accordingly, they tended to compare them equally or choose one over the other moderately. This effect does not occur in ANP, because experts have compared these ESS with supporting, provisioning, and regulating services.

Additionally, considering the interdependence among all network elements improve the accuracy of the results, as in studies by Janeš et al. (2018) and De Brito et al. (2018). Concurrently, these results agree with those of previous research conducted in the Albufera Natural Park in Valencia (Jorge-García and Estruch-Guitart, 2020), a field rice area within a Mediterranean wetland with similar characteristics. In that study, this pattern was also repeated for the 100% of decision-makers who participated. Therefore, on average, ANP reduced 31.40% of the value of the cultural services in the Guadalquivir marshes (Seville) and 87.36% in the Albufera Natural Park (Valencia). These results support a previous explanation.

Down to the last detail of cultural services, 'Identity' is an intricate and conceptual idea that intensely clicks feelings. Therefore, this is the ES for which the ANP value decreases the most. Following the previous explanation, decision-makers compare this ES to other cultural services in AHP, the least valued. On the contrary, this service is compared with the most valuable ESS such as 'Food' and 'Freshwater supply' in ANP. This drastically diminishes this matter.

Additionally, when experts use AHP, they incorporate some extra value to the cultural services from the other groups because this method cannot relate all the criteria in the pairwise comparisons. In contrast, ANP almost entirely considers each value in its place, reducing subjectivity. As in the other studies analyzed in the literature review, there is an evident variation based on the method used by decision-makers.

However, there has been an exception with 'Knowledge, science, and education' since ANP has increased its value despite being a cultural service. As the matrix of interfactorial domination (Table 5) shows, this is a cultural service with more connections; therefore, ANP raises its estimation. This finding was unexpected because the ESS was not individually valued in the case study carried out in the Albufera Natural Park (Jorge-García and Estruch-Guitart, 2020). Consequently, not all cultural services are overrated by AHP, but the most abstract and subjective. However, it is necessary to examine this finding in other areas to better understand the reason.

However, regarding provisioning services, the differences between both methods are wholly linked to the problems previously highlighted by the nine decision-makers. 'Water supply' is the essential service when AHP is used, but its importance considerably decreases in ANP. This behavior relates perfectly to the water shortage and increased salty water as mentioned by the farmers as the rice fields' major concerns. Hence, the current situation affects the results considerably for both methods, although ANP reduces the effect. In AHP, experts indirectly showed their concern about lowering the cultivated surface and irrigation constraints. Regardless, the network outlined with all relationships in ANP fulfils the goal of reducing subjectivity. In contrast to the studies carried out by Nimawat and Gidwani (2021) and Daneshparvar et al. (2022), where the main factor coincided in both methods despite the different weights, the water shortage problem has provoked a change in the ranking order by 44% of decision makers. Moreover, this will also generate a difference in the area's total economic value, as the financial service 'Food' considerably differs from one method to the other, unlike the case study in the Albufera Natural Park (Jorge-García and Estruch-Guitart, 2020).

7. Conclusions

Decision makers only compare each ecosystem service within the same group in the AHP. Cultural services are, as a group, the most subjective ESS because their concepts include intangible aspects related to feelings that are visible to society. With the simplification of reality, the AHP may overestimate them. On the contrary, ANP decreases this consequence as the questions answered by decision-makers are more thorough and interconnected to regulating, provisioning, and supporting services. Additionally, in AHP, only one cultural service is compared with the others within the same group. This finding coincides with the conclusions of the Albufera Natural Park rice fields in València (Spain).

However, when cultural services are individually analyzed, the same pattern continues in this area. The more abstract ES is the one whose value decreases more in ANP. It is also noticeable that there has been an exception with the service 'Knowledge, science, and education', a pattern also repeated for 100% of decision-makers.

Moreover, there are differences between the two methods when relevant situations or issues affect the study area. ANP has decreased the ESS value directly linked to the problems previously highlighted by decision-makers. For instance, in the Guadalquivir marshes, there has been a clear pattern of overrating the freshwater supply, which is detrimental to rice and crayfish production in the AHP. This situation cannot be compared with the study carried out in the Albufera Natural Park in València, as the comparison was only performed per group and not per ecosystem service.

In the Guadalquivir marshes, provisioning services represent approximately half of the total value of the rice fields in the marshes (similar results in both methods). Therefore, 50% of the farming value provided to the area was not considered by the market. Decision makers, including local, regional, and national governments, should consider optimizing the ESS. This will allow them to better manage the area by considering the externalities and correct social or environment-related market failures.

Future research will be directed to verify these findings in other similar areas, where rice production is the most relevant economic activity. However, there are other issues, such as the extent to which the chosen multi-criteria method is linked to them, and how to reduce possible biases. Moreover, once it is clear that ANP helps decision-makers to improve their valuation when many interdependencies arise, it is crucial to decrease uncertainty and the feeling of repetition and exhaustion. These drawbacks are caused by the time needed to make pairwise comparisons, in contrast to the simplicity of the AHP. However, interdependence among elements is a vital factor in the obtained differences. Consequently, AHP is not advisable because it cannot consider the relationships among ESS as a network. Therefore, an integrated approach of MADM based on ANP benefits must be developed for ecosystem services. Research combining ANP and the Decision Making Trial and Evaluation Laboratory (DEMATEL) method could be interesting to see if this integrated method is able to consider all interdependence using a more straightforward scale to compare the elements without significantly differing from the traditional methodology.

Declaration of Competing Interest

None.

Data availability

The data that has been used is confidential.

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