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# How does the type of MCDM method affect the results of the prioritization and assessment of ecosystem services? A case study in the Ebro River Delta (Spain)

David Jorge-García [a,*], Vicente Estruch-Guitart [a], Pablo Aragonés-Beltrán [b]

[a] Departamento de Economía y Ciencias Sociales, Universitat Politècnica de València, Camí de Vera, s/n, 46022, València, Spain
[b] Project Management, Innovation and Sustainability Research Center (PRINS), Universitat Politècnica de València, Camí de Vera s/n, València, 46022, Spain

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ABSTRACT

The prioritization and assessment of ecosystem services allow governments to apply public policies on target to improve these natural areas' sustainable development and human well-being. It also enhances the environmental, socio-cultural and agricultural management of ecosystems. Previous research has proved that geographical and socio-cultural factors could influence the results obtained in real study cases. However, other factors should be studied since stakeholders have differing views on the most suitable method to prioritize ecosystem services. Regarding how stakeholders structure criteria, networked processes are, theoretically, more appropriate than the hierarchical techniques such as AHP, since they capture all the relationships among criteria. Consequently, nowadays ANP has become one of the most common MCDM methods in this field. Moreover, this technique also analyzes the consistency of the decision-makers' judgements. Nonetheless, the use of this method also encompasses some weak points: it is too laborious and time-consuming. Additionally, it is not easy to manage when the number of criteria per cluster is too large. It is why some researchers prefer using other techniques such as AHP in spite of the fact that it does not capture the relationships among criteria, or a hybrid DEMATEL-Based ANP technique, better-known as DANP, which does not utilize pairwise comparisons and hence is not able to study judgments' inconsistencies. Therefore, this study aims to analyze how each method (AHP, ANP and DANP) influences the prioritization of ecosystem services in a real case conducted in the Ebro River Delta (Spain). Once all priorities are obtained, the results are compared through a statistical analysis of compatibility and correlation. Regarding the results of the three techniques, they show no compatibility among them. However, the correlation between the rankings obtained with ANP and DANP is reasonably correlated for seven of the eleven experts participating in the study. Besides, when the results are aggregated, their compatibility and correlation increase. On the contrary, the results obtained in AHP differ from the other two methods. Finally, and contrary to the initial hypothesis, most experts agreed more with the results obtained with DANP and AHP than with ANP.

## 1. Introduction

The prioritization and assessment of ecosystem services (ESs) provided by natural areas offer viable solutions to help decision-makers (DMs) introduce environmental policies to preserve them (Sinclair et al., 2021; Walters et al., 2021). They are also vital to achieving Sustainable Development Goals (Gong et al., 2022). Additionally, Kumar et al. (2013) concluded that the ecosystem service concept is a strong tool to translate unnoticed benefits of nature into aspects of human wellbeing. As Bitoun et al. (2022) conclude, fulfilling sustainable development strongly depends on the preservation and good management of ESs. Therefore, the study and valuation of ESs have become a powerful instrument to integrate ecological needs into public procedures, reinforcing their effect on human well-being (van Oudenhoven et al., 2018). These studies also could reveal changes in the benefits of ecosystem services which can enhance positive impacts and minimize negative ones (Lin et al., 2022).

Nonetheless, these studies are strongly influenced by the ecosystem's properties and even social factors (Burkhard et al., 2012; Castro-Martínez et al., 2013), including ecological, geographical and

* Corresponding author.
*E-mail addresses:* dajorga2@etsiamn.upv.es (D. Jorge-García), vestruch@esp.upv.es (V. Estruch-Guitart), aragones@dpi.upv.es (P. Aragonés-Beltrán).

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sociocultural factors such as DMs' perceptions or biases due to their personal and professional backgrounds (Cebrián-Piqueras et al., 2017). Previous research has proved that 'the choice of the study area could change the results depending on its heterogeneity' (Jorge-García et al., 2023). Moreover, 'decision-makers' perceptions or professional backgrounds could also influence the results depending on sociocultural factors' (Jorge García et al., 2023). Consequently, any study case related to ecosystem services has to be implemented from a global to a local scale considering all the potential factors which could influence the results obtained. However, not only these elements influence these studies, but also the methodology depending on the technique used (Nimawat and Gidwani, 2021; Daneshparvar et al., 2022; Jorge-García and Estruch-Guitart, 2022). Therefore, the selection of the methodology analyzing the benefits and downsides of each method is vital to improve the accuracy of the results obtained, reducing potential biases.

Multiple Criteria Decision Making (MCDM) methods are the procedures by which multiple criteria can be formally incorporated into the management planning process (Wang et al., 2009; Kou and Peng, 2009; Mateo, 2012; Kumar et al., 2017). These methods aim to sort alternatives or a finite set of criteria into a preference order by assessing a mathematical model, typically structured through a decision matrix (He et al., 2016; Kumar et al., 2017). MCDM methods can be divided into two groups: Multiple Objective Decision Making (MODM) and Multiple Attribute Decision Making (MADM). On the one hand, 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 solve discrete problems with a finite number of alternatives or criteria (Zavadskas and Turskis, 2011; Behzadian et al., 2012; He et al., 2016). The main problem is to find the most efficient MCDM method among nearly a hundred alternatives (Baydaş et al., 2022).

Within MADM approaches, the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) are descriptive approaches to decision-making based on the relative measurement on absolute scales of tangible and intangible criteria founded on the judgements of experts (Greco et al., 2016). Both methods are well-known multi-criteria decision tools proposed by Thomas Saaty (Saaty, 1980; Saaty, 2005; Saaty, 2008). AHP is one of the most common MCDM methods for prioritizing or ranking specific criteria (Janeš et al., 2018; Khan and Ali, 2020; Fountzoula and Aravossis, 2022). However, this method only assumed that each criterion only influences the hierarchical criterion or set it depends on (Saaty, 2004; Greco et al., 2016). On the contrary, ANP can draw a network incorporating feedback and interdependent affinities within and between clusters (Hajkowicz and Collins, 2007; Reig et al., 2010; de Brito and Evers, 2016). Despite the use of AHP due to its simplicity, most complex real-world decision-making issues have numerous interconnected elements which can only be captured using ANP (Ishizaka & Nemery, 2013; Tjader et al., 2014; Saaty and Ozdemir, 2021).

Regarding these characteristics, ANP is considered more appropriate than AHP for the economic valuation of natural areas (Bennett et al., 2009; Villa et al., 2014). Moreover, it is crucial when any study seeks to prioritize the ESs as ANP underlines the existing power synergies and relationships among them. Further, it reduces biases and particular potential inflexions (Palomo et al., 2016; Bennett et al., 2021; Jorge-García and Estruch-Guitart, 2022). Moreover, all the studies related to ESs require a robust technique, given their uncertainty and inherent subjectivity (Raymond et al., 2014). Nevertheless, some drawbacks arise when ANP is used. One is its intricacy when the method must be developed in practice due to the extensive and time-consuming questionnaires decision-makers (DMs) must elaborate on (Zhu et al., 2010). For particular situations, pairwise comparison questions might be even meaningless or difficult to interpret (Gölcük and Baykasoğlu, 2016). These drawbacks make DMs prefer to work with a manageable hierarchical sample, although most decision problems should not be structured in that way (Schulze-González et al., 2021). Thus, research on possible hybrid methods allows the relationships between ESs to be incorporated into the model but simplifies its complexity and reduces the number of questions (Schulze-González et al., 2021; Ransikarbum et al., 2021; Ransikarbum and Khamhong, 2021). Some studies show satisfactory results when AHP or ANP are combined with other multi-criteria techniques (Komazec and Petrović, 2019; Popovic et al., 2018; Mihajlović et al., 2019).

On the other hand, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method was proposed by Fontela and Gabus to visualize the structure of complicated causal relationships with matrices or digraphs (Falatoonitoosi et al., 2013; Si et al., 2018; Koca and Yildirim, 2021). In this strategy, the relationships are causally dependent. It means that DMs survey all the connections among criteria to select the existent interdependence and their strength using a 0–4 scale (Pourhejazy, 2020). In the field of sustainable development, for instance, Xiao et al. (2022) proposed a plus-minus DEMATEL to incorporate indirect interactions among the Sustainable Development Goals (SDGs). In contrast, Sobhanifard and Vaeysi (2020) used this tool to improve the sustainable development of tourism. Besides, Kandasamy et al. (2022) have used the Fuzzy-DEMATEL to prioritize the challenges investigated in medical waste management and Giri et al. (2022) in the field of supply chain management. This method is especially useful when ANP's limitation arise, particularly in the achievement of consistent pairwise comparisons for a matrix with higher order due to the limitations in human cognition in the used one-to-nine scale (Hu and Tsai, 2006).

Different proposals have been developed to combine DEMATEL with ANP (Gölcük and Baykasoğlu, 2016; Mavi and Standing, 2018; Guo et al., 2018), even in the fields of renewable energies, ecology, sustainable development and environmental management (Büyüközkan and Güleryüz, 2016; Ghosh et al., 2021; Mubarik et al., 2021). In some cases, DEMATEL is used as a first step to analyze better the relationships among criteria, followed by ANP afterwards to prioritize them (Khoshnava et al., 2020). Among the proposals for hybridization between the two methods, the so-called DANP (hybrid DEMATEL-Based ANP technique) stands out, which is distinguished by the application of DEMATEL in all their stages (Gölcük and Baykasoğlu, 2016). For instance, Jiang et al. (2018) demonstrated the usefulness of utilizing a grey variant of DANP in a case study of a selection of alternatives for the sustainable development of the automotive industry. The number of articles published using this hybrid method has a growing trend. For example, 81 indexed articles using DANP were globally published in 2021 (Schulze-González et al., 2022).

Within these hybrid techniques, Kadoić et al. (2019) created a variant of DANP to simplify its complexity and duration by lowering the number of questions to be answered by DMs but maintaining a network structure. Additionally, these changes can also help experts to better understand the method. Kadoić et al. (2019) suggested this integrated technique as a simplified alternative to the traditional multi-criteria methods through a real case example and showing a satisfactory implementation. Afterwards, Schulze-González et al. (2021) tested this method by applying it to forty-five ANP cases published in the literature showing that the values of the priorities obtained were analogous to the initial results obtained by ANP. Some other studies have likewise used this hybrid approach in sustainable development (Aragonés-Beltrán et al., 2022).

Consequently, the objective of this paper is to study how each method influence the prioritization and assessment of ecosystem services in a real study case conducted in the Ebro River Delta, a RAMSAR Mediterranean wetland where all ESs are strongly interconnected. As mentioned before, three techniques are conducted in this study: AHP, ANP, and the hybrid DANP technique. For this purpose, the compatibility of the priorities and the correlation between the rankings obtained will be analyzed. This case study also wants to verify whether DANP could simplify the complexity of ANP, obtaining similar results. Secondarily, this comparison wants to confirm that, despite being the least time-consuming method, AHP is unsuitable for complex processes where most criteria are interconnected.

These objectives are based on the theoretical hypothesis that ANP is the method that can best capture DMs' judgments according to the literature review in comparison to the other two methods studied. Unlike AHP, the networked methods consider all the existing relationships among elements, and unlike DANP, ANP determine the consistency of the DMs' judgements. This hypothesis is also tested through feedback from DMs about the results obtained. The case study has been conducted.

## 2. Material and methods

Fig. 1 shows the flowchart, which summarizes the process performed in this study. The same eleven DMs partook in the three methods. All the phases have been run from May to July 2022 to avoid misinterpretation while comparing the results.

### 2.1. Selection of criteria and decision-makers

The study considered the public list broadcasted by the Catalonian regional government based on the Millennium Ecosystem Assessment (MEA, 2005). This checklist is internationally recognized by the United Nations and created in an agreement of scientists from more than 95 countries. Nonetheless, it has been adapted to the study area through meetings with some technicians and local farmers. The ESs prioritized in

**Table 1**
Ecosystem services (ESs) prioritized in this case study.

| Code | Ecosystem services (ESs) |
|---|---|
| C11 | Biodiversity and geodiversity |
| C12 | Ecological connectivity and complementarity |
| C13 | Primary production |
| C21 | Provision of food resources *(it involves rice production, fishing, hunting and salt production)* |
| C31 | Protection of the coast and against salinity |
| C32 | Improved water quality |
| C33 | Climate change mitigation and carbon sequestration |
| C34 | Pollination and biological control |
| C41 | Landscape enjoyment |
| C42 | Knowledge, activities of environmental awareness, leisure and ecotourism |
| C43 | Historical and cultural heritage |
| C44 | Identity and sense of belonging |

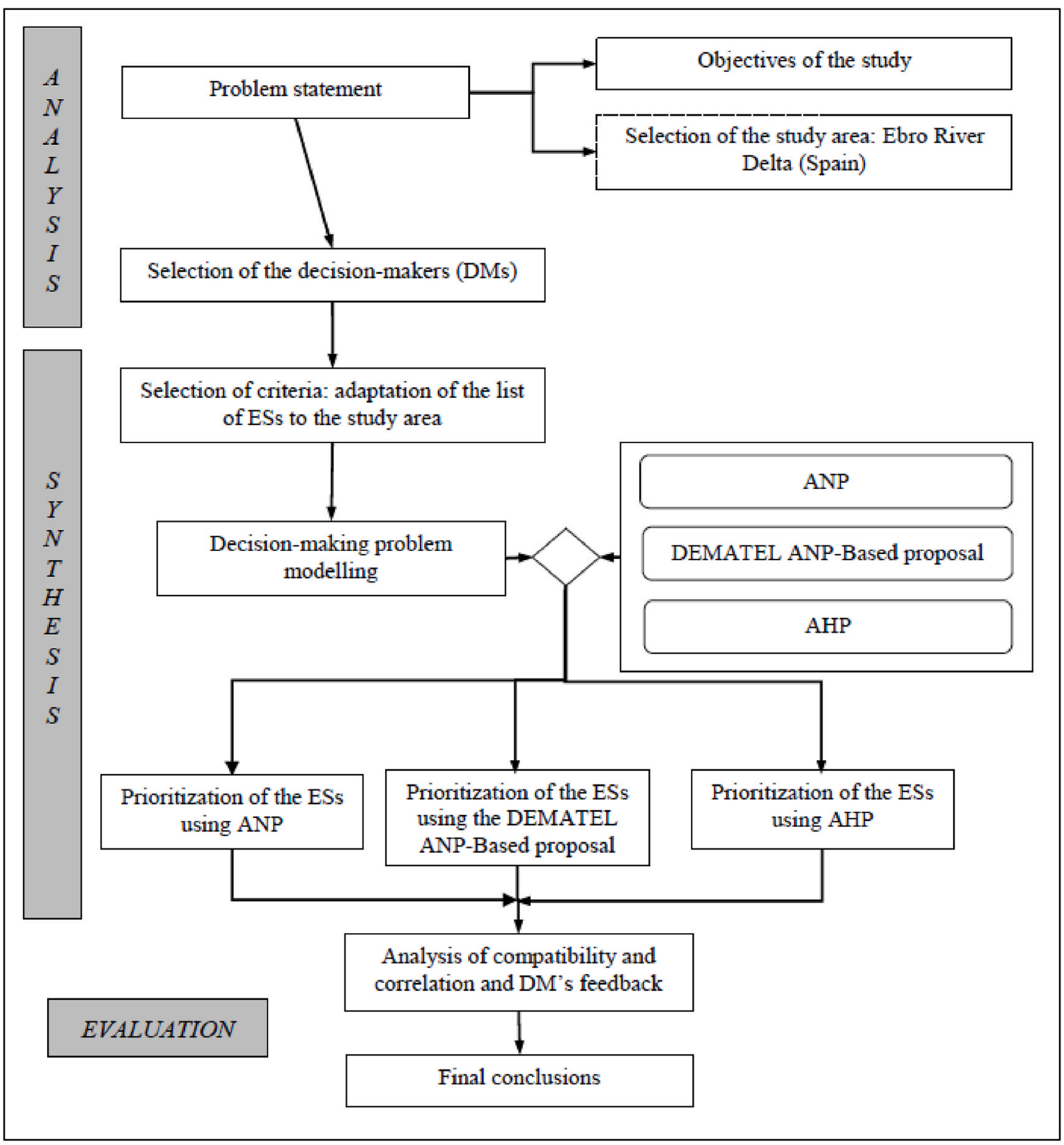



**Fig. 1.** Flowchart summarizing the methodology.

this case study are presented in detail in Table 1.

On the other hand, eleven DMs were chosen to participate in the study. According to Bitoun et al. (2022), ecosystem-based management should be inclusive, negotiated, flexible, and adaptive to local circumstances. Moreover, DMs must come from diverse spaces and integrate diverse knowledge sources (Kruijf et al., 2022). Therefore, in this study, all DMs are local experts who have provided a broad vision of the area's social, ecological and economic reality. This selection has likewise guaranteed a significant range of points of view and backgrounds. These are the eleven DMs who have participated in the case study, ordered alphabetically (this order does not correspond to the one shown in the results).

- Manager and member of the association of ecotourism companies of the Ebro Delta
- Researcher in the Department of Climate Change in EURECAT (technological centre)
- Researcher specialized in aquaculture in IRTA – La Ràpita
- Researcher specialized in environmental economy
- Researcher specialized in fishing in IRTA La Ràpita
- Researcher specialized in regulation services in rice field areas in IRTA – Amposta
- Researcher specialized in rice production IRTA – Amposta
- Technical director in the Consortium of environmental policies of 'Terres de l'Ebre'
- Technician in a conservationist NGO: SEO-Bird Life
- Technician expert in artificial purification wetlands (green filters) in AGBAR
- Technician in a local conservationist NGO: 'Picampall'

### 2.2. Analytic Hierarchy Process (AHP)

In AHP, the decision-making problem is structured as a hierarchy divided into several levels. Two levels form this study. On the one hand, the four clusters or groups of ESs (supporting, provisioning, regulating and culture). On the other hand, the twelve selected ESs are to be prioritized (criteria). Once the hierarchy is clearly built, the following steps take place next:

- Pairwise comparisons among criteria: Each expert compares the criteria per cluster using the one-to-nine Saaty's scale. A matrix comparison is obtained for each cluster based on the DMs' judgements $a_{ij}$. Additionally, each matrix has a consistency ratio (*CR*) associated with guaranteeing that no significant inconsistencies arise. An acceptable consistency has been considered when CR is below 5% for matrices of rank $n = 3$ and 8% for rank $n = 4$.

$$A_k = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix}$$

where:

$$a_{ji} = {}^{1}/_{a_{ij}} \text{ and } i, j = 1, \dots, n$$

where $k = 1, \dots, 4$ (the four clusters or groups of ESs)

$n$ = number of criteria in the cluster.

The priority vectors are calculated using the eigenvectors of the pairwise comparisons (Saaty, 1988). However, these priorities obtained are partial as they are referred to the same level of the hierarchy, this is to say, over its cluster or group.

- Pairwise comparisons among clusters: The process is carried out among the four groups of ESs, obtaining a pairwise comparison matrix C. The same consistency for the CR is demanded. The priorities among the four clusters are also obtained in the same way.
- Decision matrix: This final matrix is built using the priorities of both hierarchy levels: the clusters and the criteria. The aggregation is carried out through the weighted sum model. If necessary, Ishizaka and Labib (2011) edited an in-depth revision of the AHP method.

All the calculations have been carried out using the Super Decisions V3.2 software (www.superdecisions.com).

### 2.3. Analytic Network Process (ANP)

In ANP, the decision problem is structured as a network. Firstly, the ESs are grouped into their clusters or groups (supporting, provisioning, regulating and culture). Fig. 2 shows the network model constructed on Super Decisions software.

Once the network is structured, the following steps take place next:

- Elements' Relationship matrix (12x12): It is also known as the Interfactorial dominance matrix. In this step, each DM has to build its 12x12 matrix determining the existing influences among the ESs. The coefficients of this matrix $C_i$,$C_j$ take the value 1 or 0 depending on whether the element $C_i$ influences element $C_j$, respectively. If an existing influence is irrelevant enough, its coefficient similarly takes 0. In many cases, this step is carried out under the consensus of all the DMs resulting in a unique Interfactorial dominance matrix so that they all have the same starting point. Nonetheless, in this study, each DM has its personalized model to better compare the results with the DEMATEL-Based ones.

$$N(12x12) = \begin{bmatrix} r_{C11,C11} & r_{C11,C12} & \cdots & r_{C11,C44} \\ r_{C12,C11} & r_{C12,C12} & \cdots & r_{C12,C44} \\ \vdots & \vdots & \ddots & \vdots \\ r_{C44,C11} & r_{C44,C12} & \cdots & r_{C44,C44} \end{bmatrix}; r_{ij} \in \{0,1\}$$

where:

$r_{ij}$= 0 indicates that $C_i$ has no influence on $C_j$ or it is not relevant enough.

$r_{ij}$= 1 indicates that $C_i$ has some influence on $C_j$.

- Cluster's Relationship matrix (4x4): The same process has to be carried out among the four clusters. Nevertheless, according to the complexity of the study area and the large amount of relationships among criteria, the same Cluster's Relationship matrix (C) has been considered for the eleven DMs.

$$C\ (4X4) = \begin{bmatrix} r_{G1,G1} & r_{G1,G2} & r_{G1,G3} & r_{G1,G4} \\ r_{G2,G1} & r_{G2,G2} & r_{G2,G3} & r_{G2,G4} \\ r_{G3,G1} & r_{G2,G3} & r_{G3,G3} & r_{G3,G4} \\ r_{G4,G1} & r_{G4,G2} & r_{G4,G3} & r_{G4,G4} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}; r_{ij} \in \{0,1\}$$

where:

$r_{ij}$= 0 indicates that $G_i$ has no influence on $G_j$ or it is not relevant enough.

$r_{ij}$= 1 indicates that $G_i$ has some influence on $G_j$.

- Unweighted supermatrix: DMs conduct all the pairwise comparisons using the one-to-nine Saaty's scale as in AHP to compare the relative importance of two elements over another. The priority vectors obtained substitute the 'ones' and 'zeros' of the Element's Relationship matrix. Moreover, as in AHP, an acceptable consistency has been considered when CR is below 5% for matrices of rank $n = 3$ and 8% for rank $n = 4$. All the calculations have been carried out using the Super Decisions V3.2 software (www.superdecisions.com).

The questionnaire consisted of between 194 and 281 questions depending on the DM according to their personalized Interfactorial dominance model. Here, there is a concrete example of a question: *Given the ecosystem service 'C31 – Provision of food resources', in your opinion,*

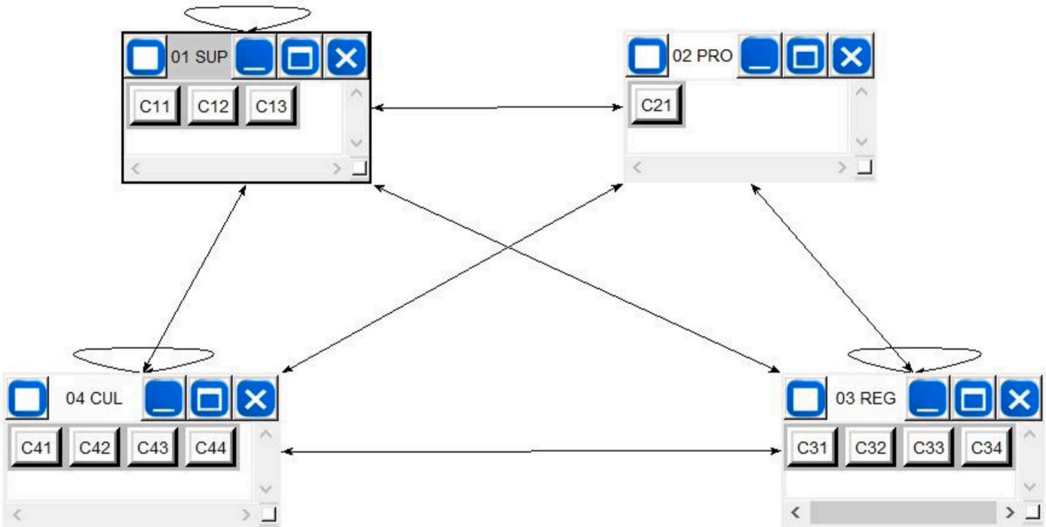



**Fig. 2.** ANP network model constructed on Super Decisions software.

*which criterion, 'C41 – Landscape enjoyment' or 'C44 – Identity and sense of belonging', better satisfies it and to what extent according to Saaty's 1–9 scale?*

The same has to be done among clusters substituting the Cluster's Relationship matrix and obtaining the Cluster's Weighted Matrix.

- Normalized and Weighted Supermatrix (Original supermatrix): Firstly, the Unweighted Supermatrix is weighted by the corresponding priorities of the clusters using the Clusters' Weighted Matrix. Afterwards, it has to be normalized by the sum per column.
- Limiting supermatrix: The supermatrix is raised to limiting powers until weights converge and remain stable. The Limiting Supermatrix is the absolute priority of criteria.

### 2.4. DANP (Kadoić et al. (2019) proposal)

This method starts by creating a network structure of the decision method as in ANP. Nevertheless, the Elements' Relationship matrix is ignored and substituted by a matrix of influences which uses part of the DEMATEL algorithm and scale. These are the steps followed:

- Matrix of influences (12x12): Each DM complete its matrix, determining the level of influence of the element $C_1$ over the element $C_j$. Unlike ANP, this matrix gathers not only the existence of the influences but also their level of importance. Concretely, DMs introduce an integer value from zero to four with the following meaning: 0-no influence; 1-low influence (not relevant enough); 2-medium influence; 3-high influence and 4-very strong influence. The diagonal elements of each expert answer matrix are all set to zero.

$$I(12x12) = \begin{bmatrix} r_{C11,C11} & r_{C11,C12} & \cdots & r_{C11,C44} \\ r_{C12,C11} & r_{C12,C12} & \cdots & r_{C12,C44} \\ \vdots & \vdots & \ddots & \vdots \\ r_{C44,C11} & r_{C44,C12} & \cdots & r_{C44,C44} \end{bmatrix}; \; r_{ij} \in \{0,4\}$$

where:

$r_{ij}$= 0 indicates that $C_i$ has no influence on $C_j$
$r_{ij}$= 1 indicates that $C_i$ has low influence on $C_j$ or it is not relevant enough.
$r_{ij}$= 2 indicates that $C_i$ has medium influence on $C_j$
$r_{ij}$= 3 indicates that $C_i$ has high influence on $C_j$
$r_{ij}$= 4 indicates that $C_i$ has very high influence on $C_j$

- Weighted and Normalized matrix: The proposal carried out by Kadoić et al. (2019) allows the possibility of clustering the decision-making problem and hence the Unweighted matrix and the Cluster's matrix to be calculated. However, they determine that all the criteria as one cluster are preferable. Therefore, in this case, the ANP-Based matrix is directly obtained. The Weighted and Normalized supermatrix can be calculated by applying the normalization by the sum or using a transition matrix. In this study, the first alternative has been carried out. Consequently, each element is divided by the sum of its column, obtaining a stochastic by-column Weighted and Normalized Supermatrix.
- Limiting supermatrix: It is obtained as in ANP by raising the Weighted and Normalized matrix to limit powers until weights converge and remain stable. The absolute priorities are thus obtained.

### 2.5. Comparison of the results obtained by the three MCDM methods

Statistical analysis is carried out to compare the results obtained using AHP, ANP and DANP. Concretely, the compatibility of the values and the correlation of the ranking order per DM are compatible.

Firstly, the compatibility between both methods is studied through the Saaty Compatibility Index ($S$) and the Garuti Compatibility Index ($G$). Both are compatibility indices between priority vectors. Saaty and Peniwati (2007) proposed defined the calculation procedure to obtain the Saaty Compatibility Index ($S$) as: "Given two sets of positive numbers, take the transpose of the second matrix, multiply the two matrices element-wise (Hadamard Product), add all the numbers and divide by n2". When $S = 1$, the two sets of numbers are the same. Moreover, two sets of numbers are considered compatible when $S \leq 1.1$, according to Saaty and Peniwati (2007). This coefficient is particularly useful when comparing results obtained with different MCDM methods (Garuti and Salomon, 2012).

On the other hand, Garuti (2007) proposed the Garuti Compatibility Index ($G$) based on a physical interpretation of the inner product of two vectors. Two sets of numbers are considered very highly compatible when $G \geq 0.9$. An advantage of this coefficient comes when small elements are compared since the Saaty Compatibility Index ($S$) has a strong sensitivity to vectors with small elements (Garuti and Salomon, 2012).

$$G = \frac{1}{2}\sum_{i=1}^{n}\left[(x_i + y_i)\frac{\min\,(x_i, y_i)}{\max\,(x_i, y_i)}\right]$$

where:

$x_i$ = value of an ES in the first method
$y_i$ = value of an ES in the second method
n = number of criteria (ESs) = 12

Secondly, to study the rank correlation, two coefficients have been calculated: Spearman's rank correlation ($\rho_s$) and Kendall's rank correlation ($\tau$) coefficients. The Spearman's Rank Correlation coefficient ($\rho_s$) can take a value from +1 to −1, where 0 means no association between the two ranks, +1 means a perfect association, and −1 is a perfect negative association. There is a very high correlation when $0.9 < |\rho_s| \leq 1$ and a high correlation when $0.7 < |\rho_s| \leq 0.9$. The statistical significance can be tested using a Student's t-distribution.

$$\rho_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} = 1 - \frac{\sum_{i=1}^{12} d_i^2}{286}$$

where:

$\rho_s$ = Spearman's rank correlation coefficient
$d_i$ = difference between the two ranks of each criterion
n = number of criteria (ESs) = 12

Finally, Kendall's Rank Correlation coefficient ($\tau$) can also take a value from +1 to −1 as for Spearman's Rank Correlation ($\rho_s$). There is a very high correlation when $0.9 < |\tau| \leq 1$ and a high correlation when $0.7 < |\tau| \leq 0.9$.

$$\tau = \frac{n_c - n_d}{n(n-1)/2} = \frac{n_c - n_d}{66}$$

where:

$\tau$ = Kendall's rank correlation coefficient
$n_c$ = number of concordant pairs
$n_d$ = number of discordant pairs
n = number of criteria (ESs) = 12

### 2.6. Decision-makers' feedback

In the last step, the results have been individually shown to the eleven DMs participating in the study. They did not know at any time which method corresponded to each result. Once they studied the results, they decided which method better captured their view of the values obtained and the ranking order. Precisely, these are the two questions DMs have individually answered:

- *According to the three results (A, B or C), which one best reflects your judgement regarding the order of priority?*
- *According to the three results (A, B or C), which best reflects your judgment regarding the numerical values (expressed by one)?*

## 3. Results and discussion

The priorities obtained from each ecosystem service per expert and method are displayed in Appendix I. According to them, in ANP and DANP, the criterion 'C11 – Biodiversity and Geodiversity' is the most relevant ES in the study area, followed by 'C21 – Provisioning of food resources. Concretely, five out of eleven and six out of eleven DMs have ranked C11 in the first position in ANP and DANP respectively. Additionally, the group average also verifies this tendency. Regarding the provisioning service, two out of eleven DMs have ranked it in the first position when using ANP and four out of eleven in DANP. The overall impression, focusing the attention on the top of the list, corroborates that, in broad strokes, DANP follows a similar tendency to ANP, maintaining a coherence when ordering the ESs in order of importance. This coherence between both methods increases when the results are aggregated. However, these similarities are not always so evident when the results are case-by-case analyzed. Moreover, when the numerical values are analyzed, it is observable that they differ from one method to the other. Concretely, the differences among ESs lessen when DANP is used for all DMs.

On the other hand, this fact turns around regarding AHP since the criterion 'C21 – Provisioning of food resources' has been considered as the most valued for eight out of eleven DMs. Therefore, the results obtained in AHP do not follow the same overall tendency as the other two methods. For instance, only one DM has ranked C1 in the first position, whereas it is the most valued one according to the other two methods. These results corroborate that a hierarchical methodology tends to overestimate the most visible ESs, as in this case happens with 'C21 – Provisioning of food resources'. Moreover, this technique also overestimates the group with fewer criteria, as analyzed in a previous study (Jorge-García and Estruch-Guitart, 2022). Therefore, despite its benefits in rapidity and easiness, AHP is not the suitable method for this purpose due to its hierarchical modelling, which simplifies the complexity of the interconnected network that ESs form.

Furthermore, DANP *grosso modo* maintains an overall tendency regarding the order of importance of the ESs, especially on the top of the ranking. In contrast, it does not happen the same with their values. The complete statistical analysis of compatibility and correlation among the results obtained by the three methods is displayed in Appendix II. A summary is shown in Fig. 3.

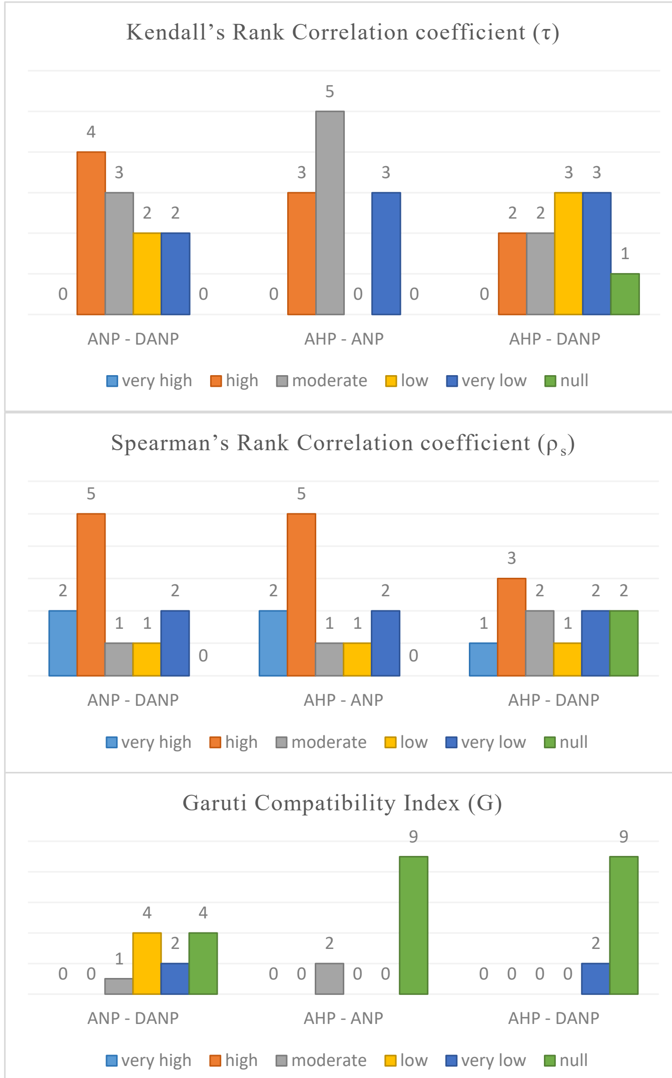
Firstly, there is a high or a very high correlation between the results obtained using ANP and DANP in seven out of eleven (64%) cases according to the Spearman's Rank Correlation coefficient. Regarding Kendall's Rank Correlation coefficient, which is somewhat stricter, there is a high correlation in four out of eleven (36%) cases. Moreover, the highest correlation occurred if the results were aggregated in a hypothetical group result. In this case, Spearman's Rank Correlation coefficient takes a value of 0.958, meaning there is only a 4.2% incompatibility.

Secondarily, comparing AHP with DANP and also ANP with AHP, some high correlations have been detected but in a smaller proportion than in the previous case. However, these analyses help corroborate that there are also high correlations when the results are aggregated in a group result. Therefore, it is noticeable that the results of the three methods tend to converge when they are studied as a group. However, this convergent correlation is much higher between ANP and DANP.

Regarding compatibility, it is observed that no high compatibilities have been found between any method and for any DM. With regards of AHP and ANP, it follows the theoretical background since AHP does not consider the relationships among elements simplifying the reality and overestimating the most visible and abstract ESs.

On the other hand, the different values obtained in ANP and DANP are partly due to the effect of the scale used in the pairwise comparisons, as DEMATEL only takes values from 0 to 4, reducing the range of nuances of interpretation. In contrast, Saaty's scale does it from 1 to 9. Moreover, the questions DMs have answered in their respective questionnaires are different. In ANP, the questions are more explicit and direct, as they constantly compare the importance of two ESs or clusters over a third one. On the contrary, when using DEMATEL, DMs have to value the strength of the influence between two ESs over the whole study area without any third element which serves as a visible reference. Therefore, DMs have tended to give the values 3 or 4 to most influences studied. This fact has lessened the differences among the ESs compared to the traditional multi-criteria methods.

Nevertheless, the Saaty and the Garuti Compatibility Indexes show that, although there are no high compatibilities, the major ones mainly occur when the results are aggregated. Concretely, the results show almost a high compatibility for ANP and DANP (S = 1.1427) for ANP and AHP (S = 1.1576). When the results of AHP and DANP are compared, their compatibility is lower than in the other two cases. However, the group compatibility (S = 1.3995) is higher than for all the DMs




| | | | |
|---|---|---|---|
| $\lvert\tau\rvert \geq 0.9$ | **very high correlation** | $\lvert\rho_s\rvert \geq 0.9$ | **very high correlation** |
| $0.7 \leq \lvert\tau\rvert < 0.9$ | **high correlation** | $0.7 \leq \lvert\rho_s\rvert < 0.9$ | **high correlation** |
| $0.5 \leq \lvert\tau\rvert < 0.7$ | moderate correlation | $0.5 \leq \lvert\rho_s\rvert < 0.7$ | moderate correlation |
| $0.3 \leq \lvert\tau\rvert < 0.5$ | low correlation | $0.3 \leq \lvert\rho_s\rvert < 0.5$ | low correlation |
| $0.1 \leq \lvert\tau\rvert < 0.3$ | very low correlation | $0.1 \leq \lvert\rho_s\rvert < 0.3$ | very low correlation |
| $\lvert\tau\rvert < 0.1$ | null correlation | $\lvert\rho_s\rvert < 0.1$ | null correlation |

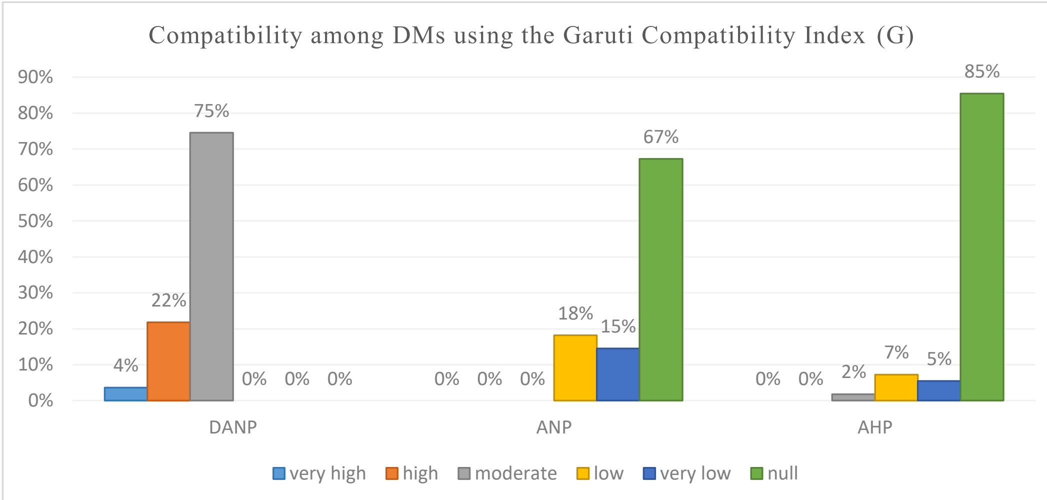
| | |
|---|---|
| $G \geq 0.9$ | **very high compatibility (Garuti, 2007)** |
| $0.85 \leq G < 0.9$ | high compatibility |
| $0.75 \leq G < 0.85$ | moderate compatibility |
| $0.65 \leq G < 0.75$ | low correlation compatibility |
| $0.6 \leq G < 0.65$ | very low compatibility |
| $G < 0.6$ | null compatibility |

| | |
|---|---|
| $S \leq 1.1$ | **compatible (Saaty & Peniwati, 2007)** |

**Fig. 3.** Histograms which synthetize the statistical analysis of the compatibility and correlation among the results obtained by the three methods.

according to the Saaty Compatibility Index. This finding also corroborates the tendency to converge when the individual results are aggregated for the three methods.

Moreover, Fig. 4 shows a summary of the analysis of compatibility among DMs using the Garuti Compatibility Index (G). All the data related to this statistical analysis is displayed in Appendix III. These results corroborate how DEMATEL's scale tends to harmonize the criteria values. In the methods where Saaty's scale is used, this is ANP and AHP; the compatibilities among DMs are all moderate or low, except for DM8, with the group result in ANP. On the contrary, when DANP is used, some high and very high compatibilities arise. Moreover, in all cases, the compatibility among experts is higher than in the other two




| | |
|---|---|
| G ≥ 0.9 | **very high compatibility (Garuti, 2007)** |
| 0.85 ≤ G < 0.9 | **high compatibility** |
| 0.75 ≤ G < 0.85 | moderate compatibility |
| 0.65 ≤ G < 0.75 | low compatibility |
| 0.6 ≤ G < 0.65 | very low compatibility |
| G < 0.6 | null compatibility |

**Fig. 4.** Histograms which synthetize the statistical analysis of compatibility among DMs using the Garuti Compatibility Index (G).

methods.

Finally, Table 2 shows the feedback obtained by ten DMs who have participated in this stage. According to it, ANP has been the method that has worst captured their judgements, unlike the hypothesis contemplated based on the literature review. Regarding the order of the ESs, only one DM has chosen ANP to best capture its judgements. Moreover, as for the values, any DM has preferred this method. DANP has resulted the preferred method (six out of eleven), followed by AHP. This finding has particular conditions and limitations, so it is specific for this case study and cannot be directly extrapolated However, it disagrees with the hypothesis contemplated opening thus a future field of work.

Regarding both the theoretical background and the results of this study case, Table 3 summarizes the comparison among the three MCDM methods.

## 4. Conclusions

Firstly, AHP simplifies reality when it comes to giving more priority to some services than others. In contrast, the two networked methods, ANP and DANP can better capture DM judgements by considering the interactions among all ESs. The DANP questionnaire has considerably reduced the number of inputs of the questionnaire and the duration and complexity of the interviews with DMs.

Secondarily, the results obtained by the three methods have differed from one to another. The statistical analysis shows that there is not any compatibility among the priorities obtained by the three methods. Regarding the two networked methods, the differences obtained can partially be explained due to the effect of the different numerical scales DMs used to complete their respective comparisons of ESs. On the one hand, DEMATEL's zero-to-four scale reduces the nuances of interpretation (five levels) compared with the one-to-nine Saaty's scale used in ANP (nine levels). However, on the contrary, DEMATEL's scale is easier to use and understand, as has been proven during the interviews with the eleven DMs.

On the other hand, in ANP, DMs must always compare two ESs over a third one, whereas in DANP, the influences analyzed are over the whole ecosystem. Additionally, there are also some differences regarding the procedures of each method that are remarkable. For instance, the pairwise comparisons in ANP include inconsistency checking, which is impossible in DANP. This tool helps DMs be more accurate, guaranteeing the consistency of their judgements, although it does not necessarily imply that they have to be correct. On the contrary, the matrix used in DANP is easier to be completed and implies a better comprehension of the methodology. Finally, it is also remarkable that the sense of tediousness and monotony implicit in ANP questionnaires could somewhat disrupt the results when the number of criteria is too large.

Considering all these factors, the results obtained using DANP are more homogeneous, with the values of all ESs being closer to each other. In the future, it is necessary to deepen the effect of the scales by testing some alternatives to study how approximate the results. However, concerning the priority order, there is a pattern, broadly speaking, between the two networked methods as similar rankings have been obtained. The statistical analysis corroborates it as both results are highly correlated for most decision-makers. Besides, when the results of each DM are aggregated, forming a group result, the correlation increases considerably, obtaining a very high correlation between the two networked methods. This trend with the group also occurs for ES values that show a higher compatibility, than among individuals, although it remains low.

Finally, when DMs were asked which method best reflected their priorities, none of them chose ANP and when asked about ordinations,

**Table 2**
DM's feedback comparing the three methods.

| | Number of DMs who prefer each method according to the results obtained | | | |
|---|---|---|---|---|
| | ANP | DANP | AHP | Total of DMs |
| Preferences on the order | 1 (9.09%) | 6 (54.55%) | 4 (36.36%) | 11 (100%) |
| Preferences on the values | 0 (0%) | 6 (54.55%) | 5 (45.45%) | 11 (100%) |

**Table 3**
Comparison of the three MCDM methods studied.

| | AHP | ANP | DANP |
|---|---|---|---|
| Theoretical appropriateness | This method groups criteria using a hierarchical structure. Therefore, it is unsuitable when criteria are connected, such as in ecosystem services. However, some studies use it because of its minor duration and the number of pairwise comparisons needed despite simplifying reality. | As networked methods, they can capture all the relationships among criteria. It is, therefore, more appropriate to the study of ecosystem services. (e.g. study case by Jorge-García and Estruch-Guitart, 2022) | |
| Duration and number of inputs | Due to its hierarchical structure, DMs spend less time completing the pairwise comparisons since they do not have to analyze the influences among criteria grouped on different clusters. In this study, the AHP questionnaire consisted of 21 questions (approx. 90% less than in ANP). | This is the most complex and time-consuming method. Additionally, the questionnaires are too tedious if the criteria are too large. Hence DMs tend to perceive a feeling of monotony and repetition. In this study, the ANP questionnaire consisted of between 194 and 281 questions, depending on the DM (individualized questionnaires). | The process is slower than AHP since it considers all the relationships among criteria. However, it simplifies the process compared to ANP as it does not include pairwise comparisons. Moreover, DEMATEL's scale is easier to use than the Saaty's one. In this study, the DANP questionnaire consisted of 144 (12x12 matrix) questions (between 26% and 49% less than in ANP). |
| Inconsistency analysis | Each matrix (pairwise comparisons) has an associated consistency ratio (CR), which guarantees that no significant inconsistencies arise. This fact ensures that the judgments given by DMs within the same matrix are consistent. Despite it, a consistent matrix does not guarantee that it perfectly captures DMs' judgements, especially when they are exhausted due to a large quantity or the difficulty of understanding Saaty's scale. | | This method does not analyze inconsistencies since no pairwise comparison matrices exist. However, this technique (both the matrix and the scale) is more accessible to complete and more understandable by DMs, which can considerably reduce methodological misinterpretations. |
| Scale used to compare criteria | Most of the DMs who have participated in this study case have indicated that they have needed help understanding Saaty's scale due to its complexity (exponential scale). Sometimes they completely understand the method when they have completed part of the questionnaire. Nevertheless, this scale allows DMs nuance their comparisons since Saaty's scale is formed by nine levels (insensitivity of importance), increasing the range of nuances of interpretation in comparison with the DEMATEL's scale used in the hybrid technique. | | This method uses DEMATEL's scale to complete the Element's Matrix of Influences. This scale is easier to understand. However, it is limited to only five levels, reducing the range of nuances of interpretation. In this study case, it has provoked that the value of the priorities of each ecosystem service is closer to one another. |
| Compatibility and correlation among methods | In this study case, there has not been high compatibility among the results obtained by the three methods. Regarding correlation, the ranking order of criteria regarding the two networked methods (ANP and DANP) is similar. Both compatibility and correlation among methods increase when all priorities are aggregated by using the geometric average of the results obtained by each DM. | | |
| DMs preferences | Most experts have agreed more with the results obtained with DANP and AHP than with ANP. | In this study case, this technique has become the least-liked one among the DMs participating. | Most experts agreed more with the results obtained with DANP and AHP than with ANP. Specifically, DANP has been the preferred method. |

only one of them chose ANP. Moreover, DANP has resulted the preferred method for six out of eleven DMs. Consequently, this finding disagrees with the theoretical hypothesis based on the appropriateness of ANP according to the advantages (also disadvantages) mentioned before. However, this finding has specific conditions and limitations, so it cannot be directly extrapolated to other areas or scopes without previous research. Due to the ecosystem specificity, this study has limited DMs participating in the process. Similarly, all of them have been consistent in their pairwise comparisons due to their expertise. Nevertheless, this finding also opens a future field of work.

## CRediT authorship contribution statement

**David Jorge-García:** Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Supervision, Software, Validation, Writing – review & editing. **Vicente Estruch-Guitart:** Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Supervision, Software, Validation, Writing – review & editing. **Pablo Aragonés-Beltrán:** Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Supervision, Software, Validation, Writing – review & editing, All authors have equally contributed to this article.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The data that has been used is confidential.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.139637.

## APPENDIX I. Results/priorities of ecosystem services

*ANP*

Results obtained using ANP (relative importance)

| DM1 | | DM2 | | DM3 | | DM4 | | DM5 | | DM6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value |
| C32 | 0.2173 | C32 | 0.1862 | C11 | 0.3126 | C12 | 0.2438 | C11 | 0.2021 | C11 | 0.2282 |
| C11 | 0.1709 | C33 | 0.1859 | C21 | 0.2010 | C11 | 0.1895 | C44 | 0.1589 | C12 | 0.1658 |
| C12 | 0.1459 | C31 | 0.1772 | C12 | 0.1423 | C13 | 0.1853 | C43 | 0.1435 | C21 | 0.1466 |
| C31 | 0.1240 | C21 | 0.1048 | C13 | 0.1419 | C21 | 0.1188 | C34 | 0.1119 | C13 | 0.1453 |
| C21 | 0.1085 | C11 | 0.0815 | C31 | 0.0476 | C32 | 0.1164 | C33 | 0.0901 | C32 | 0.0893 |
| C13 | 0.0745 | C13 | 0.0774 | C41 | 0.0292 | C31 | 0.0430 | C31 | 0.0681 | C44 | 0.0563 |
| C33 | 0.0426 | C34 | 0.0720 | C34 | 0.0263 | C33 | 0.0357 | C12 | 0.0551 | C41 | 0.0463 |
| C34 | 0.0413 | C41 | 0.0327 | C33 | 0.0219 | C41 | 0.0287 | C13 | 0.0500 | C33 | 0.0445 |
| C42 | 0.0292 | C12 | 0.0321 | C32 | 0.0215 | C34 | 0.0200 | C42 | 0.0432 | C31 | 0.0426 |
| C41 | 0.0206 | C42 | 0.0276 | C43 | 0.0201 | C44 | 0.0094 | C41 | 0.0359 | C42 | 0.0263 |
| C43 | 0.0134 | C44 | 0.0145 | C42 | 0.0188 | C42 | 0.0092 | C32 | 0.0235 | C34 | 0.0047 |
| C44 | 0.0117 | C43 | 0.0080 | C44 | 0.0169 | C43 | 0.0002 | C21 | 0.0177 | C43 | 0.0042 |
| **DM7** | | **DM8** | | **DM9** | | **DM10** | | **DM11** | | **Group** | |
| ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value |
| C21 | 0.23499 | C11 | 0.20013 | C32 | 0.14343 | C21 | 0.23981 | C11 | 0.15445 | C11 | 0.198331 |
| C11 | 0.148 | C12 | 0.14526 | C34 | 0.1381 | C44 | 0.219996 | C13 | 0.14576 | C21 | 0.139772 |
| C31 | 0.12147 | C21 | 0.13351 | C11 | 0.13215 | C11 | 0.10015 | C21 | 0.12358 | C12 | 0.124232 |
| C12 | 0.09392 | C31 | 0.10408 | C13 | 0.10887 | C42 | 0.086538 | C12 | 0.09334 | C13 | 0.103788 |
| C42 | 0.09218 | C32 | 0.07478 | C12 | 0.10542 | C31 | 0.08536 | C31 | 0.09014 | C31 | 0.095359 |
| C44 | 0.07993 | C13 | 0.06812 | C41 | 0.08228 | C12 | 0.067414 | C42 | 0.07594 | C32 | 0.082618 |
| C43 | 0.05849 | C41 | 0.06449 | C21 | 0.0751 | C13 | 0.061892 | C34 | 0.07125 | C33 | 0.054595 |
| C33 | 0.05761 | C34 | 0.0604 | C42 | 0.06442 | C41 | 0.043098 | C43 | 0.05869 | C34 | 0.049745 |
| C32 | 0.03909 | C33 | 0.05488 | C31 | 0.05752 | C34 | 0.032191 | C32 | 0.05721 | C42 | 0.047342 |
| C34 | 0.03612 | C42 | 0.05361 | C43 | 0.037 | C32 | 0.029697 | C44 | 0.0554 | C41 | 0.043966 |
| C13 | 0.0252 | C44 | 0.0281 | C33 | 0.0352 | C33 | 0.026093 | C41 | 0.05222 | C44 | 0.043665 |
| C41 | 0.01301 | C43 | 0.01265 | C44 | 0.02051 | C43 | 0.007761 | C33 | 0.02204 | C43 | 0.016587 |

**Criteria (Ecosystem services):** C11 (Biodiversity and geodiversity); C12 (Ecological connectivity and complementarity); C13 (Primary production); C21 (Provision of food resources); C31 (Protection of the coast and against salinity); C32 (Improved water quality); C33 (Climate change mitigation and carbon sequestration); C34 (Pollination and biological control); C41 (Landscape enjoyment); C42 (Knowledge, activities of environmental awareness, leisure and ecotourism); C43 (Historical and cultural heritage) and C44 (Identity and sense of belonging).
NOTE: The codes for the DMs do not correspond to the order presented in the Materials and Methods section.

*DANP*

Results obtained using DANP (relative importance)

| DM1 | | DM2 | | DM3 | | DM4 | | DM5 | | DM6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value |
| C11 | 0.1376 | C32 | 0.0994 | C11 | 0.1077 | C11 | 0.1171 | C11 | 0.1285 | C11 | 0.1168 |
| C32 | 0.1335 | C31 | 0.0985 | C21 | 0.1011 | C12 | 0.1125 | C13 | 0.1050 | C32 | 0.1087 |
| C21 | 0.1209 | C21 | 0.0942 | C13 | 0.0956 | C13 | 0.1081 | C41 | 0.1011 | C13 | 0.1063 |
| C13 | 0.1128 | C11 | 0.0939 | C31 | 0.0899 | C41 | 0.0931 | C21 | 0.1005 | C21 | 0.1045 |
| C12 | 0.0912 | C33 | 0.0885 | C34 | 0.0893 | C32 | 0.0909 | C12 | 0.0995 | C31 | 0.0970 |
| C31 | 0.0888 | C13 | 0.0881 | C32 | 0.0863 | C33 | 0.0836 | C44 | 0.0834 | C12 | 0.0960 |
| C42 | 0.0883 | C12 | 0.0878 | C12 | 0.0861 | C21 | 0.0814 | C32 | 0.0819 | C44 | 0.0851 |
| C33 | 0.0870 | C34 | 0.0857 | C33 | 0.0787 | C31 | 0.0785 | C31 | 0.0791 | C41 | 0.0780 |
| C34 | 0.0582 | C42 | 0.0800 | C44 | 0.0726 | C34 | 0.0759 | C42 | 0.0743 | C42 | 0.0736 |
| C41 | 0.0326 | C44 | 0.0695 | C42 | 0.0700 | C42 | 0.0713 | C34 | 0.0600 | C34 | 0.0521 |
| C44 | 0.0318 | C41 | 0.0694 | C41 | 0.0619 | C44 | 0.0681 | C43 | 0.0445 | C33 | 0.0494 |
| C43 | 0.0173 | C43 | 0.0450 | C43 | 0.0609 | C43 | 0.0195 | C33 | 0.0423 | C43 | 0.0326 |
| **DM7** | | **DM8** | | **DM9** | | **DM10** | | **DM11** | | **Group** | |
| ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value |
| C21 | 0.1422 | C21 | 0.1280 | C11 | 0.1188 | C21 | 0.1199 | C21 | 0.1255 | C11 | 0.1139 |
| C11 | 0.1213 | C11 | 0.0973 | C12 | 0.1125 | C34 | 0.1069 | C13 | 0.1064 | C21 | 0.1122 |
| C42 | 0.1115 | C32 | 0.0942 | C21 | 0.1046 | C13 | 0.1056 | C12 | 0.0990 | C13 | 0.1008 |
| C31 | 0.1032 | C41 | 0.0879 | C13 | 0.0979 | C32 | 0.1015 | C11 | 0.0954 | C12 | 0.0977 |
| C12 | 0.1026 | C33 | 0.0867 | C32 | 0.0965 | C11 | 0.1010 | C31 | 0.0924 | C32 | 0.0947 |
| C13 | 0.0885 | C42 | 0.0864 | C31 | 0.0795 | C12 | 0.0960 | C34 | 0.0862 | C31 | 0.0902 |
| C33 | 0.0824 | C13 | 0.0773 | C44 | 0.0723 | C31 | 0.0921 | C32 | 0.0829 | C42 | 0.0813 |
| C44 | 0.0724 | C31 | 0.0773 | C41 | 0.0674 | C42 | 0.0914 | C42 | 0.0726 | C34 | 0.0723 |
| C32 | 0.0617 | C12 | 0.0755 | C42 | 0.0664 | C33 | 0.0769 | C44 | 0.0647 | C33 | 0.0713 |
| C34 | 0.0553 | C44 | 0.0744 | C34 | 0.0635 | C44 | 0.0554 | C41 | 0.0600 | C44 | 0.0677 |
| C43 | 0.0332 | C34 | 0.0658 | C43 | 0.0614 | C41 | 0.0359 | C43 | 0.0590 | C41 | 0.0609 |
| C41 | 0.0257 | C43 | 0.0491 | C33 | 0.0591 | C43 | 0.0173 | C33 | 0.0558 | C43 | 0.0369 |

**Criteria (Ecosystem services):** C11 (Biodiversity and geodiversity); C12 (Ecological connectivity and complementarity); C13 (Primary production); C21 (Provision of food resources); C31 (Protection of the coast and against salinity); C32 (Improved water quality); C33 (Climate change mitigation and carbon sequestration); C34 (Pollination and biological control); C41 (Landscape enjoyment); C42 (Knowledge, activities of environmental awareness, leisure and ecotourism); C43 (Historical and cultural heritage) and C44 (Identity and sense of belonging).
NOTE: The codes for the DMs do not correspond to the order presented in the Materials and Methods section.

*AHP*

| Results obtained using AHP (relative importance) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DM1 | | DM2 | | DM3 | | DM4 | | DM5 | | DM6 | |
| ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value |
| C21 | 0.3950 | C31 | 0.2782 | C11 | 0.3466 | C12 | 0.3999 | C21 | 0.2820 | C21 | 0.3715 |
| C11 | 0.2907 | C33 | 0.1694 | C34 | 0.1763 | C11 | 0.1719 | C11 | 0.1415 | C11 | 0.2654 |
| C12 | 0.0744 | C21 | 0.1199 | C31 | 0.1229 | C21 | 0.0858 | C12 | 0.1415 | C31 | 0.0821 |
| C31 | 0.0642 | C32 | 0.1181 | C21 | 0.0719 | C41 | 0.0833 | C13 | 0.1415 | C41 | 0.0690 |
| C32 | 0.0642 | C11 | 0.0895 | C13 | 0.0620 | C31 | 0.0658 | C32 | 0.0874 | C12 | 0.0531 |
| C13 | 0.0320 | C13 | 0.0895 | C32 | 0.0579 | C44 | 0.0580 | C34 | 0.0636 | C13 | 0.0531 |
| C34 | 0.0264 | C34 | 0.0339 | C12 | 0.0554 | C42 | 0.0446 | C31 | 0.0495 | C44 | 0.0328 |
| C41 | 0.0187 | C41 | 0.0276 | C33 | 0.0353 | C13 | 0.0443 | C42 | 0.0341 | C32 | 0.0239 |
| C42 | 0.0187 | C42 | 0.0276 | C41 | 0.0180 | C32 | 0.0247 | C41 | 0.0226 | C42 | 0.0189 |
| C33 | 0.0077 | C43 | 0.0193 | C42 | 0.0180 | C33 | 0.0089 | C43 | 0.0171 | C33 | 0.0095 |
| C44 | 0.0077 | C12 | 0.0179 | C43 | 0.0180 | C43 | 0.0076 | C33 | 0.0127 | C34 | 0.0095 |
| C43 | 0.0022 | C44 | 0.0091 | C44 | 0.0180 | C34 | 0.0051 | C44 | 0.0064 | C43 | 0.0043 |
| **DM7** | | **DM8** | | **DM9** | | **DM10** | | **DM11** | | **Group** | |
| ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value | ESs | Value |
| C21 | 0.6291 | C21 | 0.5068 | C34 | 0.1713 | C21 | 0.4763 | C21 | 0.3170 | C21 | 0.3035 |
| C44 | 0.1376 | C11 | 0.0929 | C32 | 0.1588 | C44 | 0.2359 | C31 | 0.2059 | C11 | 0.1563 |
| C41 | 0.0552 | C12 | 0.0929 | C11 | 0.1389 | C11 | 0.0861 | C41 | 0.0892 | C12 | 0.0976 |
| C31 | 0.0524 | C31 | 0.0813 | C12 | 0.1389 | C41 | 0.0742 | C11 | 0.0784 | C31 | 0.0962 |
| C34 | 0.0284 | C32 | 0.0813 | C13 | 0.1389 | C42 | 0.0303 | C12 | 0.0784 | C32 | 0.0623 |
| C42 | 0.0237 | C13 | 0.0310 | C21 | 0.0833 | C31 | 0.0301 | C32 | 0.0503 | C13 | 0.0595 |
| C11 | 0.0175 | C33 | 0.0271 | C33 | 0.0613 | C13 | 0.0222 | C43 | 0.0409 | C34 | 0.0525 |
| C32 | 0.0162 | C34 | 0.0271 | C41 | 0.0335 | C33 | 0.0155 | C33 | 0.0317 | C44 | 0.0508 |
| C13 | 0.0139 | C41 | 0.0186 | C31 | 0.0253 | C43 | 0.0103 | C42 | 0.0297 | C41 | 0.0464 |
| C12 | 0.0110 | C42 | 0.0186 | C42 | 0.0193 | C12 | 0.0095 | C34 | 0.0291 | C33 | 0.0349 |
| C43 | 0.0100 | C44 | 0.0186 | C43 | 0.0193 | C34 | 0.0070 | C13 | 0.0262 | C42 | 0.0258 |
| C33 | 0.0051 | C43 | 0.0037 | C44 | 0.0112 | C32 | 0.0025 | C44 | 0.0232 | C43 | 0.0139 |

**Criteria (Ecosystem services):** C11 (Biodiversity and geodiversity); C12 (Ecological connectivity and complementarity); C13 (Primary production); C21 (Provision of food resources); C31 (Protection of the coast and against salinity); C32 (Improved water quality); C33 (Climate change mitigation and carbon sequestration); C34 (Pollination and biological control); C41 (Landscape enjoyment); C42 (Knowledge, activities of environmental awareness, leisure and ecotourism); C43 (Historical and cultural heritage) and C44 (Identity and sense of belonging).
NOTE: The codes for the DMs do not correspond to the order presented in the Materials and Methods section.

## APPENDIX II. Statistical analysis of compatibility and correlation

**Analysis of compatibility and correlation among the results obtained using ANP and DANP**

| DMs | Saaty Compatibility Index (S) | Garuti Compatibility Index (G) | Kendall's Rank Correlation coefficient (τ) | | Spearman's Rank Correlation coefficient ($\rho_s$) | | Mean Squared Error |
|---|---|---|---|---|---|---|---|
| | | | Coefficient | p-value | Coefficient | p-value | |
| DM1 | 1.2999 | 0.6703 | 0.758 | 0.001 | 0.909 | 0 | 0.0017 |
| DM2 | 1.8471 | 0.6009 | 0.788 | 0.000 | 0.902 | 0 | 0.0029 |
| DM3 | 2.0912 | 0.4355 | 0.606 | 0.006 | 0.755 | 0.005 | 0.0066 |
| DM4 | 8.8988 | 0.5128 | 0.727 | 0.001 | 0.881 | 0 | 0.0041 |
| DM5 | 2.0642 | 0.5022 | -0.152 | 0.493 | -0.182 | 0.572 | 0.0039 |
| DM6 | 2.3178 | 0.6063 | 0.636 | 0.004 | 0.804 | 0.002 | 0.0026 |
| DM7 | 1.2765 | 0.7258 | 0.667 | 0.003 | 0.818 | 0.001 | 0.0014 |
| DM8 | 1.3903 | 0.6829 | 0.424 | 0.055 | 0.559 | 0.059 | 0.0019 |
| DM9 | 1.2838 | 0.7447 | 0.364 | 0.100 | 0.476 | 0.118 | 0.0011 |
| DM10 | 1.7444 | 0.5935 | 0.182 | 0.411 | 0.294 | 0.354 | 0.0048 |
| DM11 | 1.1184 | 0.8300 | 0.727 | 0.001 | 0.881 | 0 | 0.0006 |
| Group | 1.1427 | 0.7559 | 0.848 | 0.000 | 0.958 | 0 | 0.0015 |

**Analysis of compatibility and correlation among the results obtained using ANP and AHP**

| DMs | Saaty Compatibility Index (S) | Garuti Compatibility Index (G) | Kendall's Rank Correlation coefficient (τ) | | Spearman's Rank Correlation coefficient ($\rho_s$) | | Mean Squared Error |
|---|---|---|---|---|---|---|---|
| | | | Coefficient | p-value | Coefficient | p-value | |
| DM1 | 1.9828 | 0.4412 | 0.667 | 0.003 | 0.833 | 0.001 | 0.1049 |
| DM2 | 1.2132 | 0.7566 | 0.769 | 0.001 | 0.909 | 0.000 | 0.0380 |
| DM3 | 1.9984 | 0.5750 | 0.540 | 0.017 | 0.708 | 0.010 | 0.0716 |
| DM4 | 8.5944 | 0.5512 | 0.515 | 0.020 | 0.615 | 0.020 | 0.0720 |
| DM5 | 9.7250 | 0.3783 | -0.295 | 0.189 | -0.387 | 0.214 | 0.1086 |
| DM6 | 1.8678 | 0.5275 | 0.554 | 0.013 | 0.712 | 0.009 | 0.0824 |
| DM7 | 3.7843 | 0.3571 | 0.152 | 0.493 | 0.224 | 0.484 | 0.1290 |
| DM8 | 1.6182 | 0.4776 | 0.826 | 0.000 | 0.931 | 0.000 | 0.1158 |
| DM9 | 1.3432 | 0.7567 | 0.750 | 0.001 | 0.889 | 0.000 | 0.0289 |
| DM10 | 2.3590 | 0.5931 | 0.667 | 0.003 | 0.790 | 0.002 | 0.0764 |
| DM11 | 1.7801 | 0.4970 | 0.168 | 0.450 | 0.235 | 0.463 | 0.0806 |
| Group | 1.1576 | 0.6831 | 0.697 | 0.002 | 0.867 | 0.000 | 0.0557 |

| Analysis of compatibility and correlation among the results obtained using AHP and DANP | | | | | | | |
|---|---|---|---|---|---|---|---|
| DMs | Saaty Compatibility Index (S) | Garuti Compatibility Index (G) | Kendall's Rank Correlation coefficient (τ) | | Spearman's Rank Correlation coefficient ($\rho_s$) | | Mean Squared Error |
| | | | Coefficient | p-value | Coefficient | p-value | |
| DM1 | 2.6615 | 0.4268 | 0.729 | 0.001 | 0.872 | 0.000 | 0.1016 |
| DM2 | 2.1032 | 0.5759 | 0.646 | 0.004 | 0.814 | 0.001 | 0.0684 |
| DM3 | 1.8356 | 0.4934 | 0.795 | 0.000 | 0.918 | 0.000 | 0.0821 |
| DM4 | 2.9175 | 0.5390 | 0.424 | 0.055 | 0.052 | 0.060 | 0.0939 |
| DM5 | 2.3964 | 0.6070 | 0.481 | 0.032 | 0.599 | 0.040 | 0.0661 |
| DM6 | 2.5034 | 0.4358 | 0.615 | 0.006 | 0.744 | 0.006 | 0.0981 |
| DM7 | 4.1625 | 0.2802 | 0.121 | 0.583 | 0.175 | 0.587 | 0.1545 |
| DM8 | 2.6845 | 0.4854 | 0.413 | 0.070 | 0.545 | 0.067 | 0.1175 |
| DM9 | 1.9143 | 0.6228 | 0.250 | 0.267 | 0.388 | 0.213 | 0.0505 |
| DM10 | 7.6658 | 0.2971 | -0.062 | 0.681 | -0.075 | 0.767 | 0.1313 |
| DM11 | 1.6237 | 0.5189 | 0.229 | 0.303 | 0.298 | 0.347 | 0.0744 |
| Group | 1.3995 | 0.5859 | 0.636 | 0.004 | 0.839 | 0.001 | 0.0738 |

| | | | |
|---|---|---|---|
| $\lvert\tau\rvert \geq 0.9$ | **very high correlation** | $\lvert\rho_s\rvert \geq 0.9$ | **very high correlation** |
| $0.7 \leq \lvert\tau\rvert < 0.9$ | **high correlation** | $0.7 \leq \lvert\rho_s\rvert < 0.9$ | **high correlation** |
| $0.5 \leq \lvert\tau\rvert < 0.7$ | moderate correlation | $0.5 \leq \lvert\rho_s\rvert < 0.7$ | moderate correlation |
| $0.3 \leq \lvert\tau\rvert < 0.5$ | low correlation | $0.3 \leq \lvert\rho_s\rvert < 0.5$ | low correlation |
| $0.1 \leq \lvert\tau\rvert < 0.3$ | very low correlation | $0.1 \leq \lvert\rho_s\rvert < 0.3$ | very low correlation |
| $\lvert\tau\rvert < 0.1$ | null correlation | $\lvert\rho_s\rvert < 0.1$ | null correlation |

| | |
|---|---|
| $G \geq 0.9$ | **very high compatibility (Garuti, 2007)** |
| $0.85 \leq G < 0.9$ | high compatibility |
| $0.75 \leq G < 0.85$ | moderate compatibility |
| $0.65 \leq G < 0.75$ | low correlation compatibility |
| $0.6 \leq G < 0.65$ | very low compatibility |
| $G < 0.6$ | null compatibility |

| | |
|---|---|
| $S \leq 1.1$ | **compatible (Saaty & Peniwati, 2007)** |

. (*continued*).

**APPENDIX III. Statistical analysis of compatibility among dms using the garuti compatibility index (G)**

| | ANP | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 | DM11 | Group |
| DM1 | 0.65 | 0.55 | 0.63 | 0.43 | 0.62 | 0.57 | 0.74 | 0.61 | 0.45 | 0.59 | 0.71 |
| DM2 | | 0.35 | 0.43 | 0.39 | 0.41 | 0.41 | 0.52 | 0.52 | 0.41 | 0.49 | 0.51 |
| DM3 | | | 0.62 | 0.40 | 0.72 | 0.52 | 0.61 | 0.49 | 0.49 | 0.58 | 0.64 |
| DM4 | | | | 0.38 | 0.74 | 0.42 | 0.63 | 0.56 | 0.37 | 0.59 | 0.65 |
| DM5 | | | | | 0.45 | 0.49 | 0.54 | 0.49 | 0.51 | 0.52 | 0.55 |
| DM6 | | | | | | 0.50 | 0.73 | 0.56 | 0.45 | 0.68 | 0.78 |
| DM7 | | | | | | | 0.61 | 0.50 | 0.69 | 0.68 | 0.63 |
| DM8 | | | | | | | | 0.62 | 0.53 | 0.71 | **0.88** |
| DM9 | | | | | | | | | 0.45 | 0.67 | 0.64 |
| DM10 | | | | | | | | | | 0.58 | 0.55 |
| DM11 | | | | | | | | | | | 0.75 |
| | **DANP** | | | | | | | | | | |
| | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 | DM11 | Group |
| DM1 | 0.77 | 0.76 | 0.77 | 0.76 | 0.79 | 0.79 | 0.77 | 0.76 | **0.85** | 0.77 | 0.79 |
| DM2 | | **0.90** | 0.84 | 0.80 | 0.84 | 0.79 | **0.87** | 0.84 | 0.84 | **0.86** | **0.85** |
| DM3 | | | **0.85** | 0.83 | 0.84 | 0.78 | 0.84 | **0.89** | 0.84 | **0.90** | **0.88** |
| DM4 | | | | **0.86** | 0.84 | 0.76 | 0.82 | **0.87** | 0.81 | 0.82 | 0.83 |
| DM5 | | | | | **0.89** | 0.77 | 0.81 | **0.88** | 0.76 | 0.84 | 0.82 |
| DM6 | | | | | | 0.79 | 0.80 | **0.88** | 0.81 | 0.84 | 0.84 |
| DM7 | | | | | | | 0.79 | 0.78 | 0.80 | 0.78 | 0.83 |
| DM8 | | | | | | | | 0.83 | 0.80 | 0.83 | 0.83 |
| DM9 | | | | | | | | | 0.79 | **0.87** | **0.86** |
| DM10 | | | | | | | | | | **0.86** | **0.85** |
| DM11 | | | | | | | | | | | **0.85** |
| | **AHP** | | | | | | | | | | |
| | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 | DM11 | Group |
| DM1 | 0.33 | 0.55 | 0.38 | 0.59 | 0.81 | 0.47 | 0.70 | 0.35 | 0.51 | 0.58 | 0.69 |
| DM2 | | 0.41 | 0.30 | 0.45 | 0.32 | 0.22 | 0.39 | 0.48 | 0.27 | 0.51 | 0.44 |
| DM3 | | | 0.38 | 0.41 | 0.52 | 0.18 | 0.38 | 0.56 | 0.19 | 0.40 | 0.53 |
| DM4 | | | | 0.43 | 0.47 | 0.25 | 0.33 | 0.42 | 0.31 | 0.38 | 0.49 |
| DM5 | | | | | 0.53 | 0.36 | 0.58 | 0.66 | 0.41 | 0.56 | 0.70 |
| DM6 | | | | | | 0.48 | 0.61 | 0.32 | 0.55 | 0.59 | 0.73 |
| DM7 | | | | | | | 0.61 | 0.18 | 0.67 | 0.43 | 0.45 |
| DM8 | | | | | | | | 0.38 | 0.65 | 0.62 | 0.65 |
| DM9 | | | | | | | | | 0.23 | 0.34 | 0.45 |
| DM10 | | | | | | | | | | 0.52 | 0.50 |
| DM11 | | | | | | | | | | | 0.74 |

| | |
|---|---|
| $G \geq 0.9$ | **very high compatibility (Garuti, 2007)** |
| $0.85 \leq G < 0.9$ | **high compatibility** |
| $0.75 \leq G < 0.85$ | moderate compatibility |
| $0.65 \leq G < 0.75$ | low compatibility |
| $0.6 \leq G < 0.65$ | very low compatibility |
| $G < 0.6$ | null compatibility |

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