Group Analytic Hierarchy Process Sorting II Method: An Application to Evaluate the Economic Value of a Wine Region Landscape

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Received: 19 June 2019 / Accepted: 14 December 2020 / Published online: 17 April 2021
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Abstract
In the ongoing context of climate change, there is an increasing need to support decision-making processes in the domain of landscape planning and management. Suitable evaluation techniques are needed to take into account the interests of actors and stakeholders in shared policy decisions. An important methodological contribution to the field is given by the Multicriteria Decision Analysis (MCDA), due to its ability to combine multiple aspects of a decision problem with the values and opinions expressed by different Decision Makers. The present paper develops the “Group Analytic Hierarchy Process Sorting II method” (GAHPSort II), which aims to sort a group of municipalities included in the UNESCO site “Vineyard Landscape of Piedmont: Langhe-Roero, and Monferrato” (Italy) according to the economic attractiveness of the landscape. Extending the previous versions AHPSort I, AHPSort II and GAHPSort, the GAHPSort II optimizes multi-stakeholder evaluations on large databases by reducing the number of comparisons. Moreover, the GAHPSort II method is proposed as a novel spatial decision support system because it combines a set of economic indicators for landscape and GIS methods for aiding the Decision Makers to better understand the case study and to support the definition and localization of policies and strategies of landscape planning and management.

Keywords GAHPSort II · MCDA · Sorting · Spatial decision support system · Multi-stakeholder evaluation · Landscape indicators

1 Introduction

Over the last decades, landscape has been at the centre of the international debate to find suitable solutions, in terms of conservation, valorization and management in the ongoing climate change context. Landscape has been defined as “everything” intended as the result of human-natural relations, varying from the terrestrial landscapes to the marine landscapes and from the outstanding to the ordinary ones [1]. In particular, wine regions are considered simultaneously strong and fragile landscapes. In fact, those wine regions are inscribed as cultural landscapes in the World Heritage List (WHL) by UNESCO to satisfy specific requirements and criteria, and the main challenge is to preserve and manage their Outstanding Universal Value (OUV) over time. The value of the wine regions has been shaped by past and present communities, favouring the economic growth of these regions. In recent years, the impact of climate change on the wine regions, e.g. drought periods or temperature imbalances, has become a very topical issue [2–7]. Local actors and stakeholders are concerned about the potential cumulative impacts of climate, environmental and socio-economic variables, which may cause irreversible changes to these systems. Therefore, the adoption of long-term adaptation strategies at a local scale is required more than ever today. For these reasons, the decision-making process requires the support of suitable evaluation models in the definition of policies and strategies in the field of landscape planning and management. As landscape planning and management is a complex operation based on multi-dimensional and multi-perspective views, Multicriteria Decision Analysis (MCDA) methods are particularly suitable for this exercise.
This paper presents a new MCDA method, the Group Analytic Hierarchy Process Sorting II method (GAHPSort II), which supports the decision-making process in the assessment of the economic attractiveness of a wine region landscape. From a methodological point of view, the GAHPSort II method is derived from the AHPSort methodology [8], which is considered an effective technique in the evaluation process of complex phenomena when large number of alternatives are considered. The AHPSort and, even more, AHPSort II are able to reduce the number of pairwise comparisons [9] and aid the individual Decision Maker to explore the most sensitive areas and cross-scale dynamics [10, 11]. GAHPSort inherits these characteristics and, moreover, it can incorporate the view of multiple stakeholders in the same decision problem [12]. Therefore, the GAHPSort II method shapes the previous version by incorporating evaluations of several Decision Makers in a comprehensive and spatial outcome.

In this study, the GAHPSort II method is employed to sort a group of municipalities in the Piedmont region (Italy), belonging to the UNESCO site “Vineyard Landscape of Piedmont, Langhe-Roero, and Monferrato” [13]. More precisely, the GAHPSort II method employs a set of economic indicators to assess the economic attractiveness of the landscape [14, 15] and it integrates a Geographic Information System (GIS) that aids the Decision Makers in better interpreting the final results through a visualization of those municipalities in priority classes.

The paper is divided into the following sections: Sect. 2 reviews the AHPSort methodology and its extensions; Sect. 3 describes in detail the methodology of the GAHPSort II method; Sect. 4 presents its application to the case study and Sect. 5 discusses the findings of the research. The paper concludes with some final remarks and future perspectives of the presented methodology.

2 Literature Review: AHPSort and Its Extensions

As problems are often based on several criteria, Multicriteria Decision Analysis (MCDA) has been developed to help Decision Makers in choosing, ranking, sorting or describing a set of alternatives [16]. This paper mainly focuses on the sorting aspect of MCDA methods; thus, the discussion will solely revolve around this problem type and particularly around the sorting variant of the Analytic Hierarchy Process (AHP) [17, 18].

AHP, developed by Saaty in the late 1970s, is an MCDA method that is used for ranking and, occasionally, for choice problems. It is particularly useful when the Decision Maker is unable to construct a utility function [19]. As the authors argue (p.13), one of its merits is that the Decision Maker can use a “relative verbal appreciation” when comparing criteria or alternatives, so that they can avoid giving too specific numerical judgments when it comes to the criteria importance or the alternatives' benchmarking. At the same time, it offers a powerful tool in the hands of a Decision Maker, as it permits structuring a decision problem clearly into a hierarchy, and encapsulates a ‘consistency check’ that evaluates the cognitive ability of the Decision Maker and better guides one in the evaluation process [20]. As witnessed by its utilization and recognition in several applications (see, e.g. [21–23], for surveys and mapping of the applications in the literature), AHP has met with a huge success.

Despite this very interest and whilst its MCDA counterparts had developed sorting variants soon after their conception, AHP did not witness any sorting variant until several years from its first development in the late 1970s. In fact, the first attempt to adapt AHP for sorting the alternatives came from Bottani and Rizzi [24]. Using cluster analysis to form groups based on their similarities permits applying AHP to the clusters ex-post, thereby reducing the total count of pairwise comparisons. However, this clustering technique is based on the distance only and not on the preferences. An AHP sorting preference-based approach was later introduced by Ishizaka et al. [8] with “AHPSort”. It has been used for sorting cars [25] and risk levels [26]. It aids the Decision Maker in sorting a set of alternatives into a number of classes, given his/her preferences on ‘limiting’ or ‘central profiles’ of each class’s benchmark. AHPSort reduces the number of pairwise comparisons needed which in AHP were increasing quadratically with the number of alternatives. AHPSort requires prior information from the Decision Maker regarding the number and benchmark of the classes, in which the alternatives will be classified and sorted. In the lack of such information, one could use the “AHP-K” (and “AHP-K-veto”) variant [27] where items are clustered automatically according to the number of ordered classes.

Following the stream of methodological advancements in the literature, a second version of the AHPSort—namely, “AHPSort II”—was introduced by Miccoli and Ishizaka [9], significantly reducing the number of pairwise comparisons required by the Decision Maker and thus the cognitive effort associated with it. It compares only a handful representative points among the range of the alternatives’ performance, and then, interpolation of the scores of the real ones at hand takes place. In an environmental-related sorting application, the authors present how the AHPSort-II variant would require only 1.54% of the pairwise comparisons that would have been necessary with the originally introduced AHP, thus delivering a vast reduction of the Decision Makers’ cognitive input. Such contribution could certainly be regarded impactful, as it permits a realistic application of the AHP with a large number of alternatives, rather than the previous suggestion of using AHP in evaluating only 7 ± 2 alternatives with the originally introduced method (see, e.g. [28]).

Extending the latter for cases in which an evaluation exercise requires the inclusion of several Decision Makers, López and Ishizaka [29] present the “GAHPSort”. As its name
suggests—“G” stands for “Group”—it permits the handling of a group of Decision Makers, e.g., any type of committee, task force, etc., to name a few. Surely, it inherits all the benefits of its previous variant for an individual Decision Maker, i.e. the consistency check to better guide (or dismiss) the input of one of the group’s Decision Makers. A sophisticated variant serving as a Group Decision Support System (GDSS) is presented by Lolli et al. [12], using a Bezier curve-fitting approach to construct the preference functions of Decision Makers based on reference points and a 0-1 knapsack to select the alternatives from the generated classes.

Furthermore, a drawback associated with AHPSort is that it may sometimes appear that linguistics in benchmarking of group decisions with AHPSort II.

2.1 The GAHPSort II Method

The new GAHPSort II method consists of 11 steps.

2.1.1 Problem Definition

1) A cluster of $h$ Decision Makers (hereafter "DMs"), $S = 1, \ldots, h$ define the objective, the attributes $c_j$, $j = 1, \ldots, m$ and the alternatives $a_k$, $k = 1, \ldots, l$ with respect to the decision problem evaluated;

2) The cluster of DMs defines the classes $C_i$, $i = 1, \ldots, n$, with $n$ being the number of classes. These are ordered and labelled, e.g. "excellent", "good", "medium" and "poor";

3) Every DM defines the profiles of the considered classes. This entails providing a local limiting profile $lp_{ijs}$ that shows the minimum attainable performance required in each criterion $j$ for an alternative $k$ to belong to a class $C_i$, or with a local central profile $cp_{ijs}$ that is given by a typical example of an element belonging to a class $C_i$ based on the criterion $j$. There is a requirement of $m \cdot (n - 1)$ limiting profiles or $m \cdot n$ central profiles defining each class.

2.1.2 Evaluation

4) Each DM evaluates the importance of an attribute $c_j$ in a pairwise manner and the weights $w_s$ are derived via the eigenvalue method of AHP (Eq. 1):

$$A_s w_s = \lambda_s w_s,$$

where $A_s$ denotes the comparison matrix, $w_s$ is the priorities/weight vector and $\lambda_s$ means the maximal eigenvalue.

5) For each criterion $j$, the group of DMs selects a small number of representative points $s_{ojs}$, $o = 1, \ldots, rp_j$ which are well-distributed in each attribute’s range.

6) In a pairwise comparison matrix, every DM compares the representative points and the limiting or central profiles. For each DM, the local priority $p_{ojs}$ for the representative points and the local priority $p_{kjs}$ of the limiting profiles or central profiles are derived from the comparison matrices with the eigenvalue method in Eq. 1:

7) Should the alternatives $a_k$ fall into the range of two consecutive representative points, say $s_o$ and $s_{o+1}$, the local priority $p_{kjs}$ can be derived as shown below:

$$p_{kjs} = p_{ojs} + \frac{p_{o+1js} - p_{ojs}}{s_{o+1js} - s_{ojs}} \left( g_j(a_k) - s_{ojs} \right)$$

where $s_{ojs}$ and $s_{o+1js}$ are the two consecutive representative points for criterion $j$, whereas $p_{ojs}$ and $p_{o+1js}$ are the local priorities of the two consecutive representatives, $g_j(a_k)$ denotes the score of the alternative $a_k$ on criterion $j$ and $p_{kjs}$ is the local priority of $a_k$.

2.1.3 Aggregation

8) For each DM, aggregation of the weighted local priorities provides a global priority $p_{ks}$ for each alternative $k$ (Eq. 3) and a global priority $lp_{is}$ for the limiting profile or $cp_{is}$ for the central profiles (Eq. 4):

$$p_{ks} = \sum_{j=1}^{m} p_{kjs} w_{js},$$

$$lp_{is} \text{ or } cp_{is} = \sum_{j=1}^{m} p_{jjs} w_{js}$$

2.1.4 Assignment to Classes

9) For every DM, the comparison of $p_{ks}$ with $lp_{is}$ or $cp_{is}$ helps assigning of an alternative $a_k$ to a class $C_i$.

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(a) Limiting profiles: If limiting profiles are defined, alternative $a_k$ is assigned to the class $C_i$ which has a $lp_{is}$ just below the global priority $p_{ks}$ (see Fig. 1a):

$$p_{ks} \geq lp_{1s} \implies a_k \in C_1,$$

$$lp_{2s} \leq p_{ks} < lp_{1s} \implies a_k \in C_2,$$

$$p_{ks} < lp_{n-1s} \implies a_k \in C_n$$

(b) Central profiles: If the DM finds it difficult to define a limiting profile, (s)he can provide a typical example of a class, i.e. the central profiles $cp_{is}$. The limiting profiles can be deduced by $(cp_{is} + cp_{i+1s})/2$. An alternative $a_k$ is then assigned to a class $C_i$ with the nearest central profile $cp_{is}$ to $p_{ks}$ [8]. Should there be an equal distance among two central profiles, an optimistic assignment may allocate $a_k$ to the upper class, whilst a pessimistic assignment may allocate $a_k$ to the lower class instead.

$$p_{ks} \geq cp_{1s} \implies a_k \in C_1,$$

$$cp_{2s} \leq p_{ks} < cp_{1s} \text{ AND } (cp_{1s} - p_{ks}) < (cp_{2s} - p_{ks}) \implies a_k \in C_1,$$

$$cp_{2s} \leq p_{ks} < cp_{1s} \text{ AND } (cp_{1s} - p_{ks}) = (cp_{2s} - p_{ks}) \implies a_k \in C_1 \text{ in the optimistic version},$$

$$cp_{2s} \leq p_{ks} < cp_{1s} \text{ AND } (cp_{1s} - p_{ks}) = (cp_{2s} - p_{ks}) \implies a_k \in C_2 \text{ in the pessimistic version},$$

10) Repeat steps 5 to 9 for each alternative to be classified.

2.1.5 Fine-tuning

11) As GAHPSort II uses linear approximation in Eq. 2, a fine-tuning to check the alternatives that are just above and below the limiting profiles with GAHPSort is essential to ensure an exact classification. If the classification is similar to the GAHPSort, then the GAHPSort II classification is correct and the process is terminated. Otherwise, the alternatives right above or below the first checked alternative need to also be classified with GAHPSort until the classification is identical to the GAHPSort II one.

3 Application

3.1 Description of the Case Study

The vineyard landscape of Piedmont, Langhe-Roero and Monferrato is located in Northern Italy with a surface of about 80,000 ha. Its gentle hills are a testimony of an important know-how of the viticulture and wine-making process, which was transmitted from generation to gen-
eration through the centuries. In 2014, it was included in the UNESCO World Heritage List for its Outstanding Universal Value (OUV). This site consists of six core zones and two buffer zones (Fig. 2), and its boundaries were defined according to the Landscape Units by the Regional Landscape Plan of Piedmont [33], which aims to preserve the elements of the wine-making process (WHL, 2014). UNESCO brand has brought great opportunities and benefits, in terms of economy, tourism, media impact, education and events that contribute to the economic attractiveness of this wine region. The site includes 101 municipalities, which constitute the alternatives for the evaluation in this study.

3.2 Definition of the Problem

This research has selected specific indicators to integrate the GAHPSort II method in order to sort the municipalities
of the case study according to the economic value of their landscape [34, 35]. The set of indicators considers the main economic dimensions which generate multiple benefits to landscape.

The “Agriculture” dimension considers both rural employment and local investment [36, 37]. The “Tourism” dimension analyses the capability of landscape to attract tourism flows [38]. The “Real Estate” dimension considers the contribution of landscape on real estate markets, assuming that landscape and natural amenities are conceived as positive externalities that generate benefits on property values [39–41]. Lastly, the “Forestry” dimension refers to those benefits generated by forest management.

The indicators were carefully chosen on the basis of geographical location, territorial resources and landscape policies in territories with similar features [42, 43]. The set of indicators was organized into a value tree (Fig. 3) [18] where:

- the goal refers to the assessment of the economic value of the wine region landscape under investigation;
- the criteria represent the economic dimensions of the wine region landscape (i.e. agriculture, tourism, real estate and forestry);
- the sub-criteria are the indicators which measure the economic value of this landscape;
- the alternatives are the 101 municipalities, which are sorted according to four classes of performance, i.e. poor, medium, good and excellent landscape economic value.

### 3.3 Evaluation

The GAHPSort II method was employed following the 11 steps described in section 3.2 with the aim to sort the municipalities of this wine region, according to their landscape economic performance.

1) A multidisciplinary group of experts was involved in a survey to collect relevant information on the case study and investigate the importance of the elements of the decision problem. First, the set of indicators and the dataset were illustrated to the five experts (Table 6, see

| Indicator            | Poor   | Medium | Good    | Excellent |
|----------------------|--------|--------|---------|-----------|
| Tourist presences    | 150    | 20,000 | 40,000  |           |
Appendix). Each expert answered a questionnaire, where each section referred to specific expertise;

2) The experts agreed with the four classes of landscape economic value;

3) In the questionnaire, the individual expert has defined a limiting profile for each indicator of the evaluation model. As an example, Table 1 shows the limiting profiles identified by the urban planning expert (DM4) for the indicator “Tourist presences”. According to the expert opinion: (i) if the number of tourist presences is lower than 150, the municipality $k$ is considered to have a poor landscape economic value; (ii) if the number of tourist presences is between 150 and 20,000, $k$ is considered to have a medium landscape economic value; (iii) if the number of tourist presences is between 20,000 and 40,000, $k$ records a good landscape economic value; (iv) if the number of tourist presences is greater than 40,000, $k$ records an excellent landscape economic value;

4) The experts attributed importance to the four dimensions and their indicators using the “Fundamental Scale of Saaty” (1980), where the value 1 is used to award the “same importance” to both criteria, whereas the value 9 is used to define the “extreme importance” of the criterion $i$ over the criterion $j$. All the experts’ responses were imported into the Expert Choice software to derive a set of weights. Table 2 shows the pairwise comparisons attributed by DM4 to the tourism dimension and indicators. An overview of the pairwise comparisons attributed by the remaining experts is provided in Table 3;

5) Subsequently, the experts selected a number of well-distributed representative points. Figure 4 illustrates the representative points by DM4 about the indicator “Tourist presences”. The representative points were selected from a range between 0 and 180,000, which are the minimum and the maximum values recorded in the dataset. The clustering and joining point methods reduced the number of comparisons between limiting profiles and representative points [8, 9]. Both limiting profiles and representative points were divided into two clusters (Fig. 4);

6) Each expert compared the representative points and the limiting profiles, thus deriving the local priorities (Table 4). The local priorities of cluster 2 were linked to cluster 1 by multiplying the priorities by the ratio of the scores of the joining point “30,000 presences” in the two clusters (Table 4). The priorities were then normalised (Table 5). Figure 5 illustrates the tourist presence function;

7) This step aims to deliver the local priorities for the alternatives using Eq. 2. As an example, the local priority $p_{kj}$ for DM4 on a municipality $k$ that records 1112 tourist presences is calculated as follows:

$$p_{kj} = 0.009 + \left( \frac{0.024 - 0.009}{10,000 - 150} \right) \times (1112 - 150) = 0.010 \quad (7)$$

8) For each expert, the weighted local priorities were calculated, and the global priorities $p_{ki}$ were provided for all municipalities. The municipalities were then sorted according to the four classes of landscape economic value: (i) poor, with values less than 0.337; (ii) medium with values between 0.337 and 1.049; (iii) good, with
values between 1.049 and 4.811; (iv) excellent, with values equal or major than 4.811;
9) The steps from 5 to 9 were repeated for each alternative (Table 7);
10) The alternatives classified just above and below the limiting profiles have been checked with the individual DMs to validate their sorting, thus obtaining a classification based on AHPSort II;
11) The DMs classifications have been grouped as GAHPSort. The obtained results have been confirmed by the DMs through GAHPSort II, thus concluding the process.

4 Discussion of Results

The results were plotted as maps through Tableau software, in order to aid the Decision Makers in better interpreting the GAHPSort II outputs. Figure 6 (see Appendix) illustrates the maps of the evaluations performed by each DM.

| Table 4 | Pairwise comparisons of the tourist presences as given by DM4 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Indicator: number of tourist presences |
| Cluster 1 | 0 | 150 | 10,000 | 20,000 | 30,000 | Priorities |
| 0 presences | 1 | 1/3 | 1/5 | 1/7 | 1/9 | 0.032 |
| 150 presences | 3 | 1 | 1/5 | 1/7 | 1/9 | 0.005 |
| 10,000 presences | 5 | 5 | 1 | 1/3 | 1/5 | 0.138 |
| 20,000 presences | 7 | 7 | 3 | 1 | 1/3 | 0.267 |
| 30,000 presences | 9 | 9 | 5 | 3 | 1 | 0.513 |
| Cluster 2 | 30,000 | 40,000 | 100,000 | 180,000 | Priorities |
| 30,000 presences | 1 | 1/3 | 1/5 | 1/7 | 0.052 |
| 40,000 presences | 3 | 1 | 1/5 | 1/7 | 0.092 |
| 100,000 presences | 5 | 5 | 1 | 1/3 | 0.282 |
| 180,000 presences | 7 | 7 | 3 | 1 | 0.574 |
| CR = 0.080 |
| CR = 0.090 |

DM1 sorted most of the municipalities between the classes “poor” and “medium” for the real estate dimension. The real estate prices of properties and terrains increase in certain zones of this wine region (e.g. Asti), due to their strong economic attractiveness and to their agriculture value, determined by the presence of vineyards of certified grapes. The remaining municipalities are satellites of the main poles, thus influencing the sale prices. DM2 and DM3 sorted several municipalities between the “good” and “medium” classes. The tourism performance in this wine region is consolidated by traditions, food and wine and cultural events all year and is also encouraged by the UNESCO brand. Only a few municipalities were sorted in the “poor” class because they are relatively unpopulated, and tourism is almost or totally absent. Both tourism and agriculture are closely dependent on each other in this wine region and this is confirmed by DM2 and DM3 sorting. DM4 sorted several municipalities included in the buffer zones of the UNESCO site between the “medium” and “poor”. DM5 sorted most of the municipalities between the classes “good” and “excellent” in the forestry dimension, due to the presence of...
forestry surfaces in the municipalities located in buffer zone 1 of the UNESCO site. The municipalities included in buffer zone 2 were sorted by DM5 between the classes “good” and “poor”. The difference between buffer zones 1 and 2 is due to the presence of relatively small forestry surfaces which therefore influences the number of forestry agents.

Figure 7 illustrates the grouping of the individual evaluations of the DMs (AHPSort) into a final map. The performance of the municipalities of Asti and Alba is sorted as “excellent value” because they represent the main poles of this wine region and provide characteristic territorial resources (e.g. PDO-PGI products, cultural heritage, protected areas, among others).

The municipalities of Canelli, Cherasco, Diano d’Alba, Dogliani, La Morra, Monforte d’Alba, Nizza Monferrato and Santo Stefano Belbo are sorted as “good”, thus confirming their added value to the core zones of the UNESCO site. The municipalities sorted in the “medium” class, such as Lu and Occimiano, are affected by depopulation and an increasingly sectorial local economy based on agriculture. The remaining municipalities, such as Quaranti and Terruggia, are sorted in the “poor” class because they are strongly unpopulated, and the tourism flows and the real estate trade are almost absent. The municipalities classified as “medium” or “poor” should be the focus of attention by Decision Makers and the priority object of specific policy interventions. These policies should increase the economic attractiveness of the landscape and offer solutions to the monoculture approach which affects this wine region (vineyards vs other permanent cultivations) [44].

Some possible examples of policies could be the repopulation of small municipalities [45] by offering greater job stability within the wine-making sector, a tourism offer which does not compromise the carrying capacity of the region [46] or the implementation of technologies to limit the impacts of climate change and avoid potential alterations of the products [47].

### 5 Conclusions

The GAHPSort II method has proved to be a versatile and reliable method to sort large amounts of data. In this research, the role of the GAHPSort II method was fundamental to sort the 101 municipalities of the UNESCO site of Langhe-Roero and Monferrato according to the economic value of their landscape. The integration of a recognized set of indicators [43] was fundamental for the evaluation, by considering specific economic dimensions that guarantee multiple benefits on local communities. The landscape attractiveness is their natural consequence. An important contribution of this study is the versatility of this set of indicators which can also be applied to a wide range of fields, such as landscape planning and management, regional and urban planning [48, 49], urban resilience [50], cultural heritage [51], siting decisions and local development processes [52, 53] or energy planning [54]. It is interesting to highlight that the results coming from the present GAHPSort II application on the UNESCO site of Langhe-Roero and Monferrato confirm the outcomes of previous studies on the

![Fig. 5 “Tourist presences” function based on the limiting profiles and representative points as given by DM4](image-url)
same area. In particular, the classification of the municipalities developed in this study is aligned with the priorities delivered by the calculation of a synthetic index named Landscape Economic Attractiveness (LEA) [43], and good performances of Asti and Diano d’Alba are confirmed in both studies.

The involvement of a panel of experts provided useful information for the case study and contributed to the evaluation of the landscape of this wine region. During the evaluation process, the panel experienced some difficulties in setting the limiting profiles and were sometimes hesitant to simply provide a number. The introduction of an interval or a fuzzy limiting profile could help reduce this type of difficulty.

Future researches could consider development of a sensitivity analysis to review the evaluations of the experts and test the changing impact of criteria weights [8]. A survey is planned with real local actors and stakeholders with the aim of promoting the discussion on shared policy decisions. The authors will focus on scenario building and Geodesign tools for supporting the GAHPSort II method to aid the Decision Makers in the envision of suitable policies of landscape planning and management [55, 56]. Finally, the authors will focus on further studies on the Group Analytic Network Process Sorting II method (GANPSort II) [57] for its dynamic approach and ability to investigate the interdependencies between complex features related to the resilience of wine regions.

**Appendix 1**

**AHPSort based classification of the DMs**

![Spatial visualization of the DMs classification based on AHPSort II](image)

*Fig. 6  Spatial visualization of the DMs classification based on AHPSort II*
Table 6  Descriptive statistic of the municipalities of the vineyard landscape of Langhe-Roero and Monferrato

|                        | Agriculture\(^a\) | Tourism\(^b\) | Real estate\(^c\) | Forestry\(^d\) |
|------------------------|------------------|---------------|------------------|----------------|
|                        | Agriculture workers (No.) | Bio farms (No.) | PDO-PGI farms (No.) | SAU (ha) | Tourist presences (No.) | Beds in farmhouses (No.) | Real estate market value (€/m\(^2\)) | Average agriculture value (€/ha) | Forestry agents (No.) | Forest surface (ha) |
| Average                | 115.04           | 1             | 75                | 818.36 | 9831.80 | 36.91 | 1004.85 | 18,521,457.76 | 2               | 285.91           |
| Standard deviation     | 149              | 7             | 72                | 918    | 27,247 | 48    | 335    | 19,881,784   | 1               | 425               |
| Minimum                | 0                | 0             | 3                 | 114    | 0      | 0     | 570    | 2,069,875,760 | 0               | 2                |
| Maximum                | 834              | 68            | 344               | 5,413  | 185,556 | 216   | 2,400  | 100,566,811  | 5               | 3.874             |

\(^a\)ISTAT – 6°Censimento dell’Agricoltura, [http://dati-censimentoagricoltura.istat.it/](http://dati-censimentoagricoltura.istat.it/)

\(^b\)Osservatorio del Turismo Piemonte; [http://www.sistemapiemonte.it/cms/privati/turismo/servizi/497-osservatorio-del-turismo](http://www.sistemapiemonte.it/cms/privati/turismo/servizi/497-osservatorio-del-turismo)

\(^c\)Osservatorio Mercato Immobiliare -Agenzia delle Entrate; [https://www.agenziaentrate.gov.it](https://www.agenziaentrate.gov.it)

\(^d\)SIFOR –Sistema Piemonte [http://www.sistemapiemonte.it/cms/privati/territorio/servizi/526-sistema-informativo-forestale-regionale](http://www.sistemapiemonte.it/cms/privati/territorio/servizi/526-sistema-informativo-forestale-regionale)
Fig. 7 Spatial visualization of the results based on GAHPSort II (Elaboration through Tabloid Software)

Table 7 Extract of the final results of the GAHPSort II method

| Municipalities | Score DM1 | Class | Score DM2 | Class | Score DM3 | Class | Score DM4 | Class | Score DM5 | Class | GAHPSort II | Class |
|----------------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|-------------|-------|
| Alba           | 3.56      | G     | 5.51      | E     | 5.97      | E     | 2.93      | G     | 6.44      | E     | 4.88        | E     |
| Asti           | 6.52      | E     | 6.52      | E     | 7.79      | E     | 2.97      | E     | 8.13      | E     | 6.39        | E     |
| Canelli        | 0.80      | M     | 1.97      | G     | 2.71      | G     | 1.93      | G     | 2.98      | E     | 2.08        | G     |
| Diano d’Alba   | 0.54      | M     | 1.44      | G     | 2.25      | G     | 1.38      | M     | 2.65      | E     | 1.65        | G     |
| Lu             | 0.23      | M     | 0.46      | M     | 0.64      | M     | 0.57      | M     | 0.97      | G     | 0.57        | M     |
| Occimiano      | 0.18      | P     | 0.31      | M     | 0.45      | M     | 0.47      | M     | 0.48      | P     | 0.38        | M     |
| Quaranti       | 0.04      | P     | 0.86      | P     | 0.11      | P     | 0.20      | P     | 0.30      | P     | 0.30        | P     |
| Terruggia      | 0.07      | P     | 0.24      | M     | 0.31      | M     | 0.27      | P     | 0.29      | P     | 0.24        | P     |

P poor landscape economic value, M medium landscape economic value, G good landscape economic value, E excellent landscape economic value, DM1 expert in real estate, DM2 expert in agriculture, DM3 expert in tourism, DM4 expert in urban planning, DM5 expert in forestry
Authors Contributions All authors contributed equally to the study conception and design of this paper. Material preparation, data collection and analysis were performed by Vanessa Assumma, Marta Bottero, Alessio Ishizaka and Menelaos Tasiou. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding Open Access funding provided by Politecnico di Torino This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Data Availability The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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References

1. European Landscape Convention: Council of Europe (2000). European Landscape Convention. Report and Convention Florence. http://conventions.coe.int/Treaty/en/Treaties/Html/176.htm
2. Tonietta, J., & Carbonne, A. (2004). A multicriteria climatic classification system for grape-growing regions worldwide. Agricultural and Forest Meteorology, 124(1–2), 81–97. https://doi.org/10.1016/j.agrformet.2003.06.001
3. Jones, G. V., & Alves, F. (2012). Impact of climate change on wine production: A global overview and regional assessment in the Douro valley of Portugal. International Journal of Global Warming, 4, 383–406. https://doi.org/10.1504/IJGW.2012.049448
4. Fraga, H., Malheiro, A. C., Moutinho-Pereira, J., & Santos, J. A. (2014). Climate factors driving wine production in the Portuguese Minho region. Agricultural and Forest Meteorology, 185, 26–36. https://doi.org/10.1016/j.agrformet.2013.11.003
5. Mazzotta, M. R., & Thachin, L. (2014). The impact of climate change on the global wine industry: Challenges & solutions. Wine Economics and Policy, 3(2), 81–89. https://doi.org/10.1016/j.wep.2014.08.001
6. IPCC. (2019). Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change. ipcc - Sr15. Retrieved from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf
7. Van Leeuwen, C., Destac-Irvine, A., Dubernet, M., Duchêne, E., Gowdy, M., Marguerit, E., & Ollat, N. (2019). An update on the impact of climate change in viticulture and potential adaptations. Agronomy, 9(514), 1–20. https://doi.org/10.3390/agronomy900514
8. Ishizaka, A., Pearman, C., & Nemery, P. (2012). AHP-based method for sorting problems. International Journal of Production Research, 50(17), 4767–4784. https://doi.org/10.1080/00207543.2012.657966
9. Miccoli, F., & Ishizaka, A. (2017). Sorting municipalities in Umbria according to the risk of wolf attacks with AHPSort II. Ecological Indicators, 73, 741–755. https://doi.org/10.1016/j.ecolind.2016.10.034
10. Malezewski, J. (2006). GIS-based multicriteria decision analysis: A survey of the literature. International Journal of Geographical Information Science, 20(7), 703–726. https://doi.org/10.1080/13658810600661508
11. Borouchaki, S., & Malezewski, J. (2010). Using the fuzzy majority approach for GIS-based multicriteria group decision-making. Computers and Geosciences, 36(3), 302–312. https://doi.org/10.1016/j.cageo.2009.05.011
12. Lolli, F., Ishizaka, A., Gamerini, R., Rimini, B., Balugani, E., & Prandini, L. (2017). Requalifying public buildings and utilities using a group decision support system. Journal of Cleaner Production, 164, 1081–1092. https://doi.org/10.1016/j.jclepro.2017.07.031
13. Committee, W. H. (2014). The vineyard landscapes of Piedmont: Langhe-Roero and Monferrato - Official document for evaluating the inscription into the UNESCO WHL. Qatar: Doha.
14. Bottero, M. (2011). Assessing the economic aspects of landscape. In Landscape Indicators: Assessing and Monitoring Landscape Quality (pp. 167–192). https://doi.org/10.1007/978-94-007-0366-7
15. Assumma, V., Bottero, M., & Monaco, R. (2016). Landscape economic value for territorial scenarios of change: An application for the Unesco Site of Langhe-Roero and Monferrato. Procedia - Social and Behavioral Sciences, 223, 549–554. https://doi.org/10.1016/j.sbspro.2016.05.340
16. Roy, B. (1981). The optimisation problem formulation: Criticism and overstepping. Journal of the Operational Research Society, 32, 427–436. https://doi.org/10.1057/jors.1981.93
17. Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology, 15(3), 234–281. https://doi.org/10.1016/0022-2496(77)90033-5
18. Saaty, T. L. (1980). The Analytic Hierarchy Process. Mc-Graw-Hill, New York. https://doi.org/10.3414/ME10-01-0028
19. Ishizaka, A., & Nemery, P. (2013). Multi-criteria decision analysis: Methods and software. Multi-Criteria Decision Analysis: Methods and Software. https://doi.org/10.1002/9781118644898
20. Ishizaka, A., & Labib, A. (2011). Review of the main developments in the analytic hierarchy process. Expert Systems with Applications, 38(11), 14336–14345. https://doi.org/10.1016/j.eswa.2011.04.143
21. Ho, W. (2008). Integrated analytic hierarchy process and its applications - A literature review. European Journal of Operational Research, 186(1), 211–228. https://doi.org/10.1016/j.ejor.2007.01.004
22. Sipahi, S., & Timor, M. (2010). The analytic hierarchy process and analytic network process: An overview of applications. Management Decision, 48(5), 775–808. https://doi.org/10.1108/00251741010043920
23. Emrouznejad, A., & Marra, M. (2017). The state of the art development of AHP (1979–2017): a literature review with a social network analysis. International Journal of Production Research, 55(22), 6653–6675. https://doi.org/10.1080/00207543.2017.1334976
55. Amer, M., Daim, T. U., & Jetter, A. (2013). A review of scenario planning. *Futures, 46*, 23–40. https://doi.org/10.1016/j.futures.2012.10.003

56. Durance, P., & Godet, M. (2010). Scenario building: Uses and abuses. *Technological Forecasting and Social Change, 77*(9), 1488–1492. https://doi.org/10.1016/j.techfore.2010.06.007

57. Ishizaka, A., & Pereira, V. (2019). Utilisation of ANPSort for sorting alternative with interdependent criteria illustrated through a researcher’s classification problem in an academic context. *Soft Computing*. https://doi.org/10.1007/s00500-019-04405-5

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