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(Article begins on next page)

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

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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 Multi-criteria 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.

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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 the alternatives can be rather vague, thus making it difficult to see clearly the classification for a couple of alternatives. For instance, an alternative could belong to a given class, although it has also some similarities with the alternatives of the subsequent class. To handle this vagueness, the Fuzzy-AHPSort ("FAHPSort") [30] and Analytic Hierarchy Process-fuzzy Sorting use fuzzy theory to quantify the intensity of preference in this process [31].

Last, but not least, when a sorting evaluation exercise contains several conflicting criteria—e.g. maximization versus minimization targets among them—the "cost-benefit AHPSort" [32] provides better insights, as it separates the unique hierarchy of the AHPSort in a cost and benefit hierarchy. In the next section, we present GAHPSort II, for 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_{js} are derived via the eigenvalue method of AHP (Eq. 1):

$$A_s w_s = \lambda_s w_s, \tag{1}$$

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

5) For each criterion j, the group of DMs selects a small number of representative points $s_{oj}, o = 1, \ldots, rp_j$, 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_{ijs} 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_{oj} and s_{o+1j}, the local priority p_{kjs} can be derived as shown below:

$$p_{kjs} = p_{ojs} + \frac{p_{o+1js} - p_{ojs}}{s_{o+1js} - s_{ojs}} \left(g_j(a_k) - s_{oj} \right) \tag{2}$$

where s_{oj} 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_{ks}.

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):

$$p_{ks} = \sum_{j=1}^{m} p_{kjs} w_{js}, \tag{3}$$

$$lp_{is} \ or \ cp_{is} = \sum_{j=1}^{m} p_{ijs} w_{js} \tag{4}$$

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:

(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):

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

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

$$p_{ks} < lp_{n-1s} \implies a_k \in C_n \tag{5}$$

(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.

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

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

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

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

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

$$p_{ks} < cp_{ns} \implies a_k \in C_2 \tag{6}$$

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-
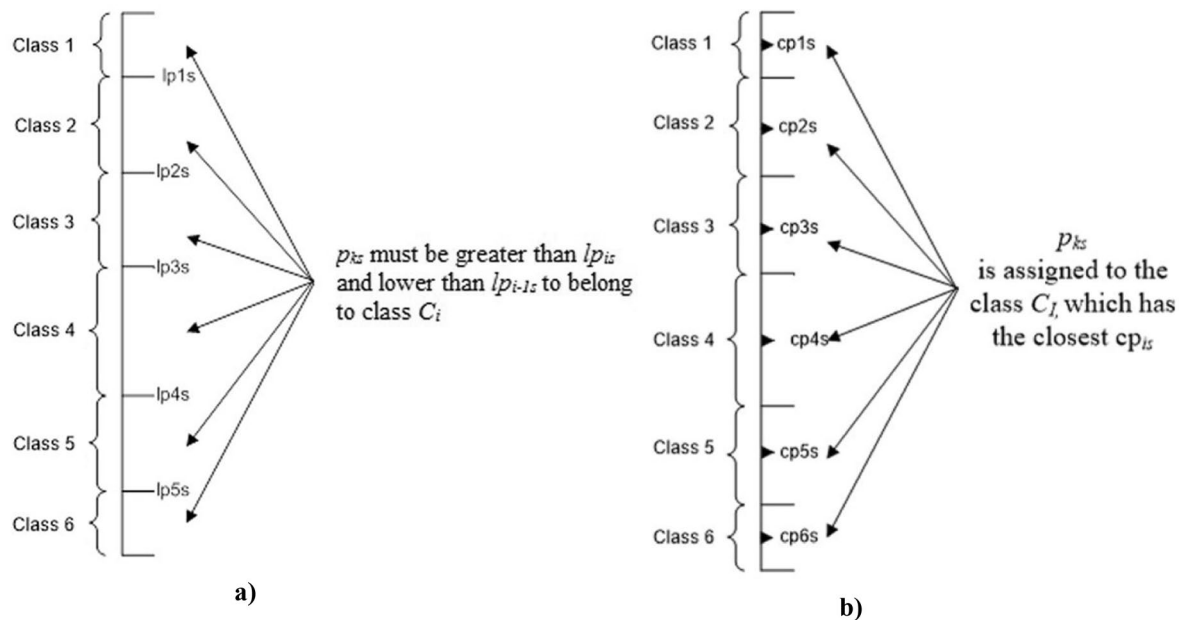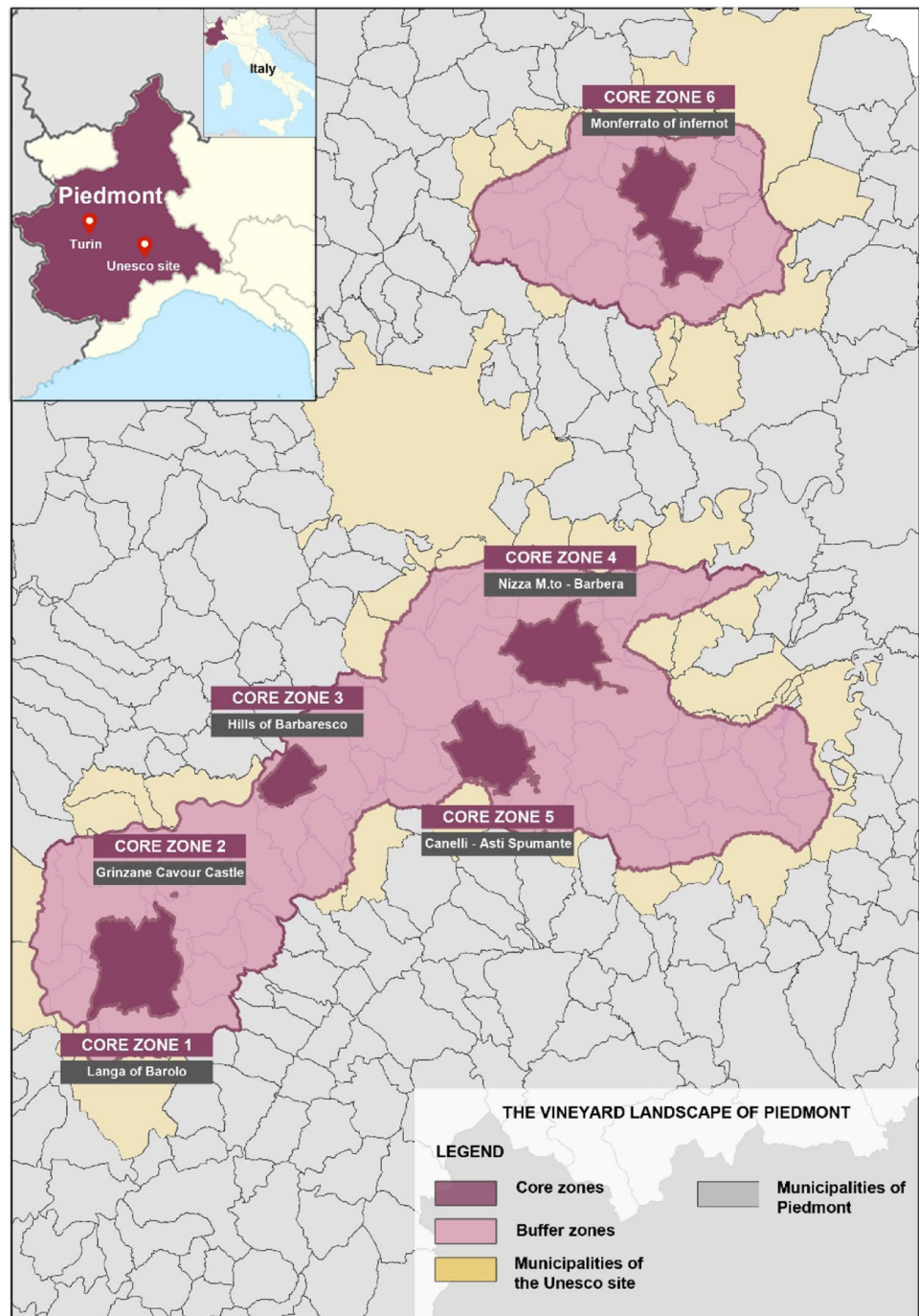

Fig. 1 Sorting with limiting profiles (**a**) and sorting with central profiles (**b**)

Fig. 2 The vineyard landscape of Piedmont (elaboration on Geoportale Piemonte data)


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

Fig. 3 Structure of the evaluation model. Note: PDO-Product Designation of Origin; PGI-Protected Geographical Indication
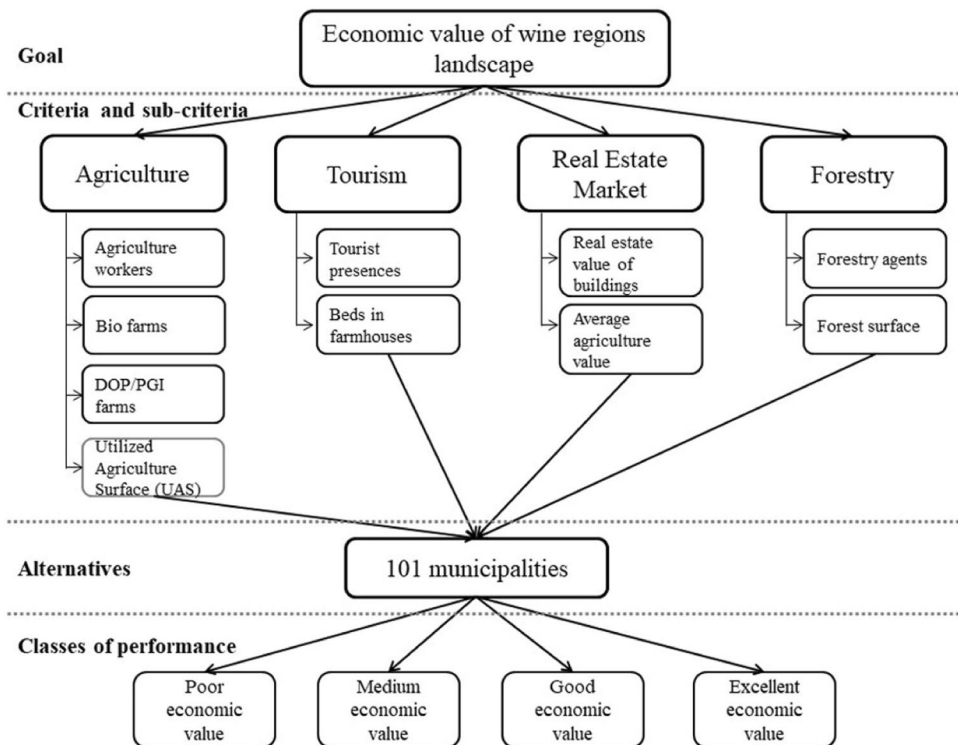
of the case study according to the economic value of their landscape [34, 35]. The set of indicators considers the main economic dimensions which generate multiple benefits to landscape.

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

Table 1 Limiting profiles for the indicator "Tourist presences" given by DM4

Indicator	Poor	lp_{ij}	Medium	lp_{ij}	Good	lp_{ij}	Excellent
Tourist presences		150		20,000		40,000	

Table 2 Example of pairwise comparisons by DM4 at level of sub-criteria (top) and criteria (down)

Tourism					
Sub-criteria	Tourist presences		Beds in farmhouses		Weights
Tourist presences	1		1/5		0.167
Beds in farmhouses	5		1		0.833
					CR = 0.00
Landscape economic value	Agriculture	Tourism	Real estate market	Forestry	Weights
Agriculture	1	7	3	4	0.584
Tourism	1/7	1	1	3	0.037
Real estate market	1/3	1	1	2	0.086
Forestry	1/4	1/3	1/2	1	0.294
					CR = 0.09

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 "Tourists presence". 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 liming 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_{kjs} for DM4 on a municipality k that records 1112 tourist presences is calculated as follows:

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

8) For each expert, the weighted local priorities were calculated, and the global priorities p_{ks} 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

Table 3 Set of weights obtained after the pairwise comparisons of the panel of experts

Economic value of the wine region landscape				
Experts	Agriculture	Tourism	Real estate	Forestry
DM1 (real estate)	0.584	0.294	0.086	0.037
DM2 (agriculture)	0.547	0.088	0.113	0.252
DM3 (tourism)	0.594	0.087	0.163	0.087
DM4 (urban planning)	0.584	0.037	0.086	0.294
DM5 (forestry)	0.690	0.178	0.088	0.043

Fig. 4 Clusters of the indicator "Tourist presences" with representative points and limiting profiles given by DM4

Number of Tourist Presences
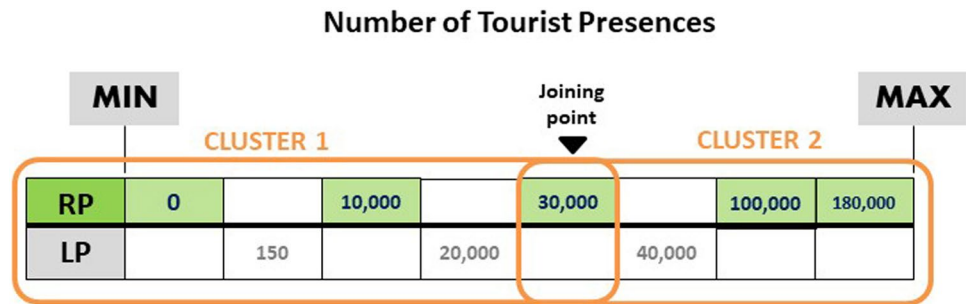
values between 1.049 and 4.811; (iv) excellent, with values equal or major than 4.811;

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.

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

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
						CR = 0.080
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 = 0.090

Table 5 Calculation of normalized local priorities

Clusters	Tourist presences	Priorities	Joining point	Local priorities	Normalized local priorities
Cluster 1	0 presences	0.032		-	0.006
	150 presences	0.050		-	0.009
	10,000 presences	0.138		-	0.024
	20,000 presences	0.267		-	0.047
	30,000 presences	0.513	9.865	-	0.091
Cluster 2	30,000 presences	0.052		0.513	-
	40,000 presences	0.092		0.908	0.160
	100,000 presences	0.282		2.782	0.491
	180,000 presences	0.574		5.663	1.000

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

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.
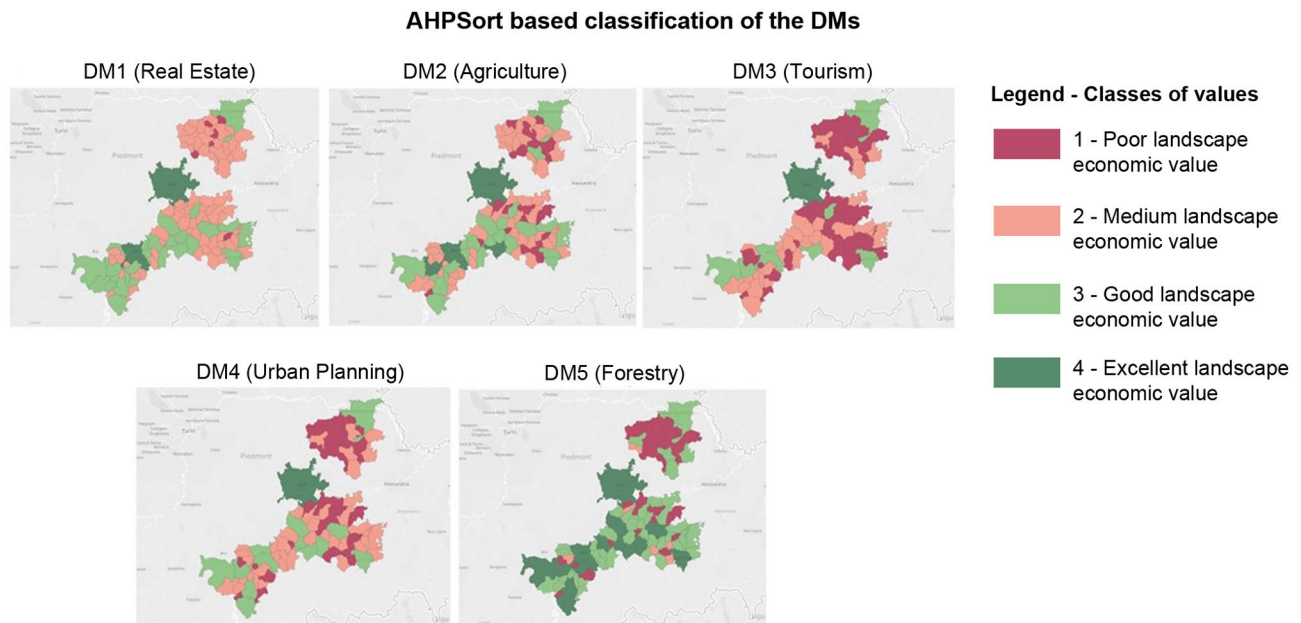
Appendix 1

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 (€/m²)	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/

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

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

[d]SIFOR –Sistema Piemonte 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)
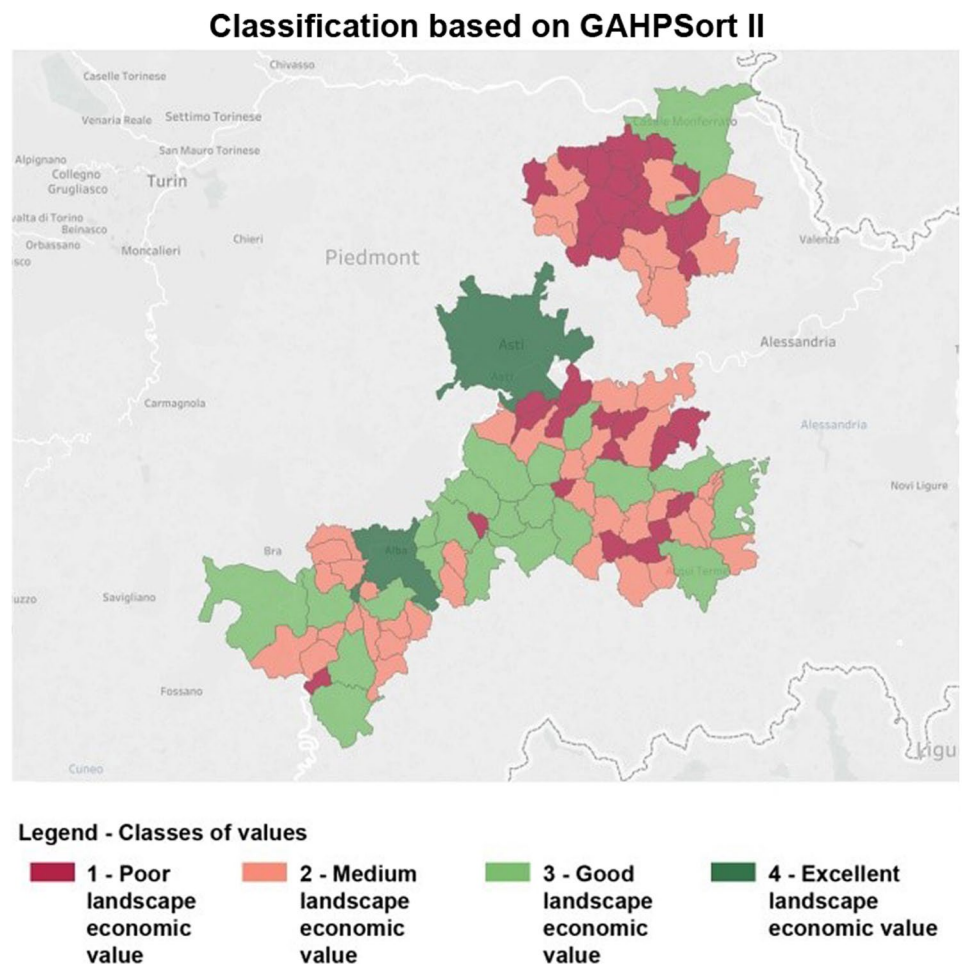

Classification based on GAHPSort II

Legend - Classes of values

- 1 - Poor landscape economic value
- 2 - Medium landscape economic value
- 3 - Good landscape economic value
- 4 - Excellent landscape economic value

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

Declarations

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

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