THE SHEEP TRACKS OF TRANSHUMANCE IN THE APULIA REGION (SOUTH ITALY): STEPS TO A STRATEGY OF AGRICULTURAL LANDSCAPE CONSERVATION

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Abstract. Transhumance is a very old form of pastoralism where livestock is moved seasonally between higher and lower pastures. The historical sheep track represents a valuable ecological asset that needs to be maintained. This study consisted in the agro-ecological characterization of the sheep tracks landscape and the detection of areas having higher conservation value. A planning framework was arranged and the sheep track system of the Apulia region (Italy) was characterized with the support of a Geographic Information System. Plain areas, mainly associated with transhumance in the past, are today much less involved in the residual presence of these sheep tracks; conversely, the most abundant presence and the best conservation status was detected in the hilly and marginal agricultural areas. Moreover, those biotopes having prevailing semi-natural traits closely associated with transhumance are today under-represented in the landscape and largely surpassed in extent by biotopes pertaining to agricultural land use. This work is a preliminary step in detecting the traits of the residual sheep track network in Apulia. Actions are required converging in a preservation plan that supports the recovery of the sheep track system according to an integrated land management perspective. Therefore, a new dimension in the sheep track conservation should be accomplished, not related to pastoralism, but able to deliver ecological services and promoting rural development in marginal areas.
Keywords: *agroecological planning, analytic hierarchy procedure (AHP), corine biotopes; geographical information system (GIS), high nature value farmland (HNV), land ecological network (LEN)*

Introduction

Transhumance is a very old form of pastoralism consisting in the seasonal movement of livestock and herders between higher pastures, in summer, and lower pastures, during winter (Ruiz and Ruiz, 1986). In Southern Italy, since the 15th century, long and grassy paths were connecting Abruzzo and Molise (in the Central Apennines) to the Southern Apulia region (down to the Tavoliere plain), and then in the reverse way (de Iulio and Biscotti, 2015). *Figure 1* provides a general representation of all the historical sheep tracks once traceable in Southern Italy. This practice dates back to time immemorial, but a long documented history is also available. In the middle of the 15th century, no less than 3.0 million sheep and 30 thousand shepherds travelled annually along the transhumance paths, while in the 17th century the sheep were about 5.5 million (de Iulio and Biscotti, 2015). Transhumance was practiced until the 1950-1960s, and abandoned

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later, at least according to the original model, while much shorter trips of herds are still observed (between higher pastures in summer and lower valleys in winter), albeit quite rarely.

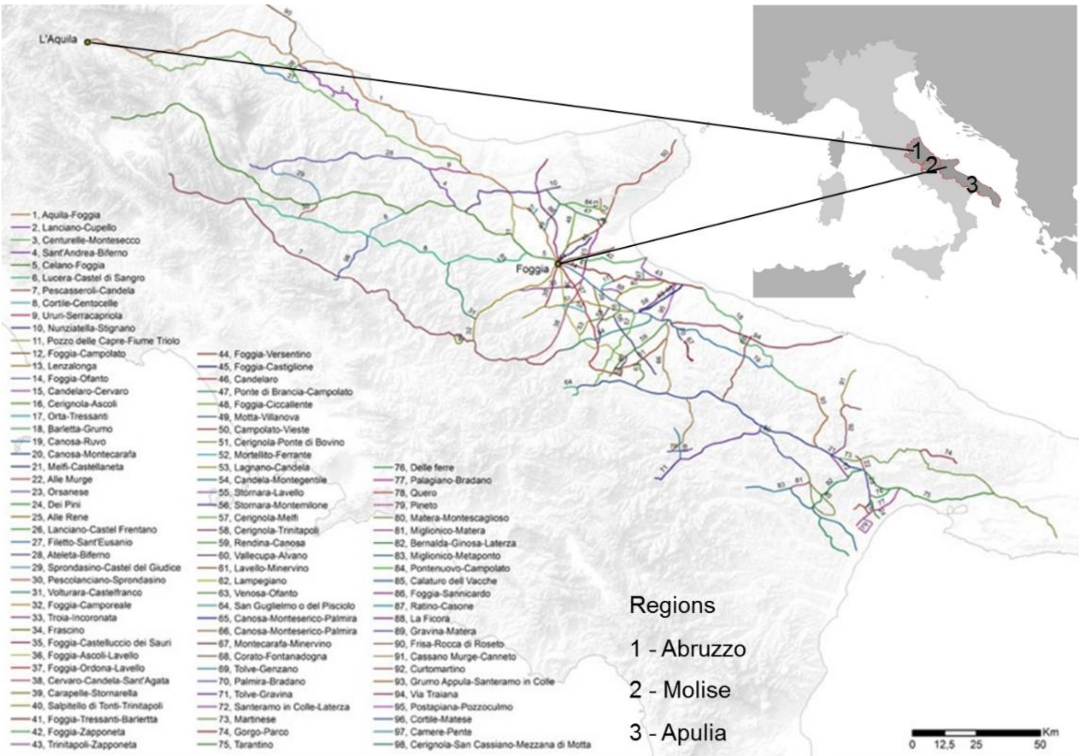

Figure 1. *Comprehensive map of the historical South Italian transhumance network. The name and dislocation of the most important sheep tracks in the three involved Italian regions (Abruzzo, Molise and Apulia, respectively) are displayed. (Adaptation from: I tratturi (n. d.): http://www.leviedeitratturi.com/i-tratturi/)*

Transhumance took place in several areas of the world and in almost every continent, particularly in Europe and Western Asia. These grassy routes travelled by drovers and herds assumed specific names in the language of various regions: *tratturi* in Italy, *cañadas* in Spain, *carraires* in France and *drumul oierilor* in Romania, all having the same features and functions (Paone, 2006).

The main *tratturi* (the so-called "royal" paths) have a precise width of 111 m, and are generally longer than 100 km, crossing longitudinally the southern part of the Italian peninsula. Secondary paths (named *tratturelli*) and lower order "branches", connecting the higher order paths, complete the dense and intricate sheep track network (*Fig. 1*).

Over the centuries, flocks, but also herds, were following this complex network of sheep tracks that developed progressively, adapting to the natural shape of the landscape. This provided the environmental "warp" to a "weft" made of relevant historical and cultural heritage. Natural environment and human culture, affecting each other, are closely interconnected and represent the two main landscape dimensions driving the coevolution processes. A vast scientific literature highlights the strategic importance of this landscape heritage, also with respect to the Mediterranean regions, including the relevant remaining of historical rural infrastructures, such as routes and lanes, stone-made terraces, field enclosures, ancient buildings and architectures, and much more (Moreira et al., 2006; Brown et al., 2007; Cullotta and Barbera, 2011; Petanidou et al., 2008). Historically, transhumance has created a truly peculiar agricultural landscape, as clearly demonstrated by Melini et al. (2014) who presented an interesting case study in Molise, a southern region of Italy. Large open fields, lean (steppic) pastures, *maquis* and *garrigue* shrubland, animal resting places, woods and glades, single or clustered trees with broad and shadowing canopies, dry stone walls serving as land ownership boundaries, etc. are all elements jointly characterizing this landscape systems. One of the key features of this type of landscape is its strong semi-natural trait, resulting from the limited human interference, apart grazing management. Both over- and under-grazing may represent degrading factors leading to ecological disruption, but when grazing was well managed, semi-natural ecosystems resulted from a dynamic equilibrium between wildlife and human activities (Pykälä, 2000; Sutherland, 2002). Today, these landscapes are recognised as key habitats for maintaining biodiversity in the European agricultural areas (Bakker, 1989; Poschlod and Bonn, 1998; Pykälä, 2000).

Semi-natural ecosystems, with specific reference to permanent pastures, are a treasure chest of exceptional biodiversity and are the source for the majority of the environmental public goods generated by European farming (EC, 2014). This considering, they are fundamentally different from pastures under more intensive agricultural use (Beaufoy et al., 2011) and need to be protected from land use change due both to intensification, with the consequent conversion into arable land, and abandonment, frequently followed by natural afforestation. Indeed, the rapid technological changes experienced by more intensive agricultural practices proved to be one of the major threats to biodiversity in the last decades (Luoto et al., 2003; Butler et al., 2007), thereby altering the composition, structure and function of these valuable agro-ecosystems (Vitousek et al., 1997; Kremen and Ostfeld, 2005). On the other hand, a widespread agricultural land abandonment due to extra-marginal economic conditions can result in forest transition (Kauppi et al., 2006). Land intensification and land dereliction are the combined, double-sided process largely explaining the current agricultural land-use changes. Therefore, halting the loss of these semi-natural ecosystems, and specifically permanent pastures, is a key action for stopping the decline of biodiversity in Europe as a whole.

Transhumance, being connected to pasture maintenance and utilization, particularly along the sheep track network, largely contributed in forming a valuable set of pastoral landscapes and associated habitats. Some of these habitats are crucial, today, for the conservation of many “endangered” animal and vegetal species (Garzon, 2001), i.e. species which has been categorized as likely to become extinct.

The importance played by the sheep track system formed with transhumance in the conservation of semi-natural ecosystems and its associated biodiversity have been rarely analysed (Olea and Mateo-Tomás, 2009). Despite being present in many European countries, from Balkans to Scotland, this practice is currently a declining activity in Europe (Ruiz and Ruiz, 1986; Liberatori and Penteriani, 2001) due to the shift from old and traditional breeding practices to modern ones.

Although transhumance, today, is no longer carried out, Mediterranean countries retain significant traces of these sheep tracks, together with historical and cultural artefacts linked to transhumance. Therefore, the legacy of such a peculiar resource should be considered a valuable regional asset that needs to be properly maintained and relaunched through a systemic strategy, made of both conservation and valorization,

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altogether promoting new or renewed forms of rural development in those involved areas.

Generally, *tratturi* have the juridical status of public property and are preserved thanks to specific regulations protecting cultural heritage. After the 1930s, they were included in the enfranchisement law. Agriculture thus began to occupy the space of the traditional greenways that, until then, were under protection by numerous national regulations (Russo, 2002). In 1977, with the Presidential Decree n. 616 (Art. 66), sheep routes and tracks passed under the authority of the regional governments.

The management of this asset in the Apulia region is, today, in charge of the Regional Land Property Department that recently endorsed a new regulation framework (L.R. 4/2013) through which the entire regional sheep track system should be characterized and classified in order to promote, soon after, integrated actions of recovery and development. The first need (preliminary to every other kind of analyses and measures) was to consider the current conservation status of the sheep track system, discerning those portions still able to be recognized and not yet impaired from those stretches degraded by now and irremediably lost.

As part of a more general planning procedure on the sheep track network in the Apulia Region, the present study was specifically focused on the agroecological analysis and landscape characterization. This task was assigned to the University of Foggia (Department of Agriculture, Food and Environment) in collaboration with other institutional entities, forming a panel that included experts from the public administration of the Apulia Region (Land Property Department), the Foggia Province (Planning Department), the National Ministry of Cultural Heritage (Department of archaeology, fine arts and landscape). Colleagues from the Polytechnic University of Bari, specialized in architectural design (Department of Engineering and Architecture) and from the University of Foggia, specialized on cultural anthropology (Department of Humanistic Studies, Letters, Cultural Heritage) coordinated the team and contributed to the work, financially supported by the Apulia Regional Administration.

In parallel with the agroecological analysis, other studies and investigations were performed, involving this wide range of experts and scholars, mostly considering the current territorial arrangement of the land ownership, a survey of historical records and remaining, traditions and cultural heritage, arts and historical buildings, and much more.

The specific objective of the present study was to identify, characterize, classify and select land areas pertaining to the sheep track regional network, having higher conservation value according to agroecological criteria, still in good status of maintenance, and featuring less intensive farming practices or semi-natural conditions, similar (at least approximately) to the original landscapes at the times of transhumance.

The purpose of collecting a significant amount of information and defining a coherent and comprehensive framework of knowledge was considered a precondition, the final goal being developing an effective planning model to address the establishment of a protected natural area (called “Sheep track regional park”) to be connected to the regional ecological network and the “Natura 2000” (Habitat Directive 92/43/CEE) biodiversity system.

The study area

The study area is the Apulia region, placed in the Southeast of Italy and about 20.000 km^2 wide. It can be divided into 11 sub-regions according to the Regional

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Landscape Plan (PPTR, 2013). This subdivision takes into account the geo-morphological, hydrological, environmental, as well as the anthropic and cultural traits of the region. Over the centuries, all these assorted characteristics contributed to the development of a landscape heritage consisting of a wide range of natural and semi-natural environments (habitats and species), as documented by several national and regional publications (ISPRA, 2013; PPTR, 2013). The typical climate is Mediterranean, although several peculiar local conditions can be detected. Altitude varies from 0 to about 1,200 m above the sea level. The region is mostly characterized by plain areas (53%), while hilly and mountainous surface covers the remaining part (47%). *Figure 2* displays the 11 sub-regions together with the Apulian sheep track network.

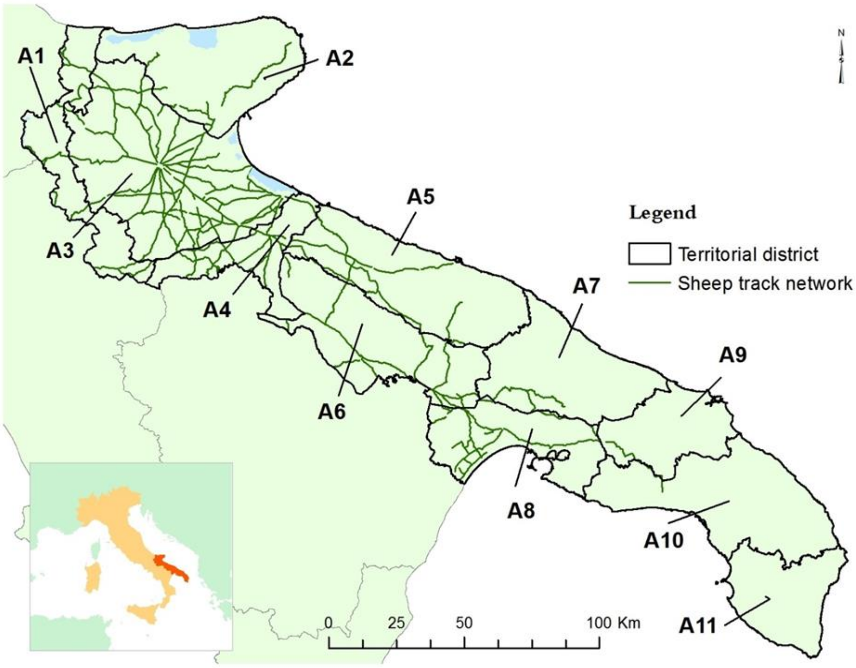

Figure 2. *Map of the Apulian sheep track network. Sub-regions according to the Apulian Landscape Plan are also represented. Monti Dauni (A1), Gargano (A2), Tavoliere (A3), Ofanto (A4), Puglia Centrale (A5), Alta Murgia (A6), Murgia dei Trulli (A7), Arco Ionico Tarantino (A8), Campagna Brindisina (A9), Tavoliere del Salento (A10), Salento delle Serre (A11)*

Material and methods

A landscape planning procedure is the methodological approach carried out in this work. It was applied to a peculiar set of agriculture, natural and semi-natural ecosystems (defined "biotopes"). A Geographic Information System (GIS) supported the analysis and allowed the processing of georeferred information, thus obtaining properly designed thematic maps. The software "ArcGis 10.1" was used for these purposes.

After a survey of the land use/land cover databases available from both regional and national digital cartographic portals, the Apulian Biotope Map (ISPRA, 2013) was the one selected to be used in the analysis. This database is focused on the spatial representation of the ecological and naturalistic traits of lands, specifically considering the range of ecosystems and biotopes detected in the region. This kind of information was judged particularly fitted to the scope of the considered land planning procedure.

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Schematically, the applied methodology is composed of a sequence of steps, as represented in *Figure 3*. Starting from the historical sheep track network (step 1), the spatial analysis was restricted to a buffer zone of 1 km outlined around each path of the network (step 2).

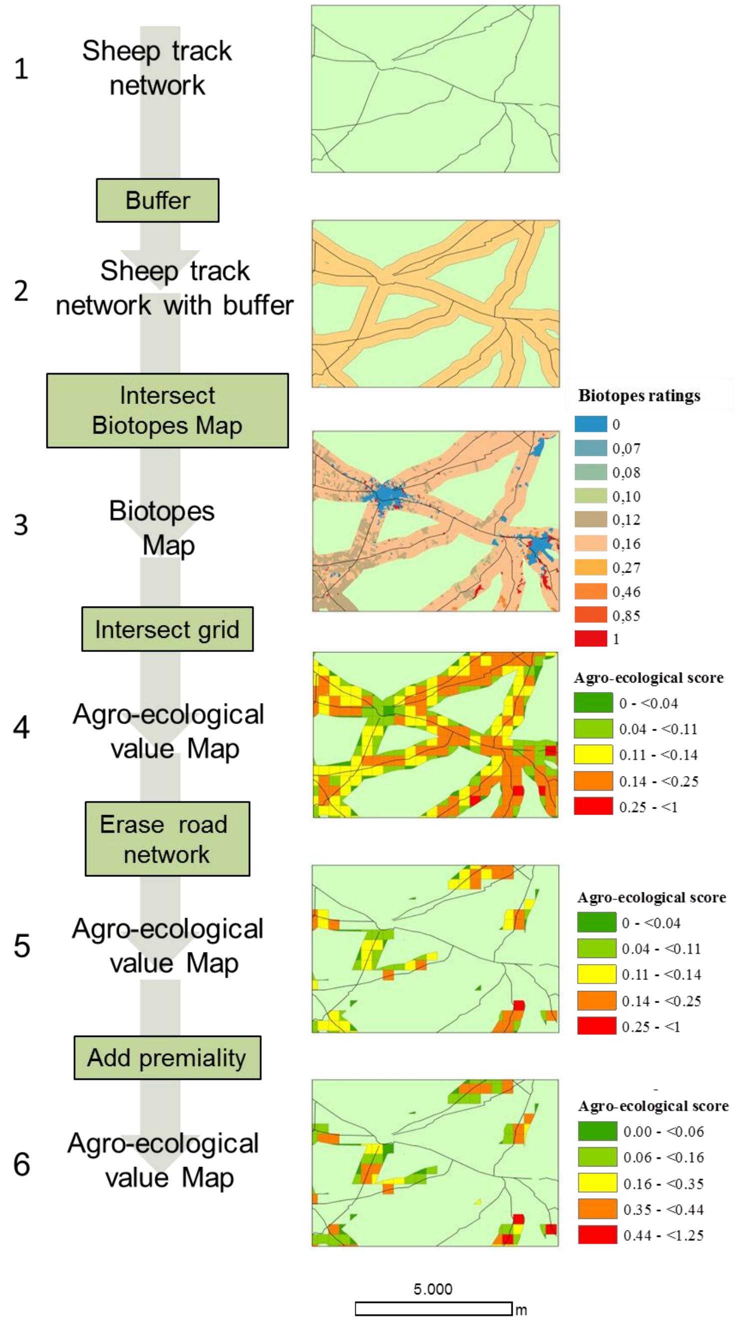

Figure 3. *Flow chart explaining the six consecutive steps of the applied methodology: identification of sheep track network (step 1); creation of a buffer area around the sheep paths (step 2); spatial intersection between the buffer area and the biotope map (step 3); overlapping with a grid to define the agro-ecological score for each mesh (step 4); erasing of the modern road network (step 5); adding premiality for those meshes belonging to protected areas (step 6). Concerning step 3, the exact rating assigned to the 11 biotope categories is reported (see the legend), while about steps from 4 to 6, the agroecological scores (see the legends) are partitioned according to a quintile distribution*

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The biotope units within the buffer areas were selected. Then, an aggregation of the original biotope categories was performed, thus identifying 11 biotope categories (or biotope "categories"), in total. Each cluster was ranked with respect to all the others by assigning an "agroecological rating", ranging from 0 to 1, according to the opinion of experts who have adopted a set of shared criteria. The applied ranking procedure is a rearrangement of the methodology by Berthoud et al. (1989) originally developed to define the environmental naturalness value for conservation priorities.

The Biotope Map was obtained accordingly (step 3). A grid with a squared mesh of 1 km by side was overlapped to the Biotope Map. The surface fraction of each biotope occurring in every cell of the mesh was determined. Then, the "agroecological score" of every cell was computed as the average rating of all the featuring biotopes, each weighted by its corresponding surface fraction. A quintile classification of the cell-scores was performed (each class having 20% of the total number of cells), and 5 consecutive score-classes were therefore identified. In this way, the Agroecological Value Map was obtained (step 4). Those stretches of the sheep tracks currently no longer physically recognizable or irrecoverably impaired were discarded and consequently removed from the map (step 5). This occurred when a complete overlapping between a sheep truck path and a modern road segments was detected. Finally, the "agroecological score" was increased only for those cells placed inside protected natural areas. A score re-classification (according to the same quintile breakdown) was consequently performed (step 6).

Some critical methodological features of the applied procedure probably need to be better clarified. The following are further explanations, by bullet points, about these issues:

(A) *Biotope data source and their aggregation*. The Apulian Biotope Map (ISPRA, 2013) was obtained at 1:50.000 scale, it accounts for 80 detected habitats, arranged according to the European classification system called CORINE Biotopes. In the CORINE system, each habitat is classified within a hierarchical structure made of several embedded levels. The Apulian Biotope Map reached the 6th hierarchical level of habitat classification. Considering all the habitats featured in the sheep track network, a clustering of them was arranged, according to similarity criteria. In this way, 11 aggregated biotope categories were defined, each with a larger or smaller number of habitats. *Table A1* (see *Appendix*) reports this clustering. The categories "woods and forests" is the one with the larger number of habitats (16), followed by "meadows and pastures" (7), "dunal vegetation" (7), "bush and garrigue" (6), "riparian vegetation areas" (6). For the sake of simplicity, the habitats listed in *Table A1* are reported only with their CORINE Biotope code, while the specific name assigned to each habitat is reported in *Table A2* (see *Appendix*), according to the CORINE biotopes (Version 2000) database. A detailed description of these habitats can be found in ISPRA (2013).

(B) *Spatial scale of the analysis* (reason why a 1 km mesh-size). The appropriate size of the landscape analysis may vary according with the objectives of the work. The main advantage of using a grid of regular mesh superimposed to the regional digital map in the GIS assisted procedure is represented by the equal area of each cell, thus creating statistically similar units across the area being analysed. The choice of 1 km as the mesh size of the grid overlapped to the Biotope Map was associated to the corresponding size of 1 km of the buffer applied to both sides of each sheep track. Considering that the largest *tratturo*, the first order sheep track, was originally 111 m width, the buffer dimension is about nine time larger. This should be considered a proper dimension to

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perform a planning analysis at regional scale, an optimal trade off allowing capturing both good amount of internal variability as well as heterogeneity of biotopes among adjacent cells of the grid.

(C) *Biotopes ranking procedure* (how coherently evaluating the rating distance between pairs of biotope categories). An Analytic Hierarchy Procedure (AHP) was applied (Saaty, 2008) with the main goal of estimating the correct rating to be assigned to each biotope category or, in other words, valuing the distance, in terms of a quantitative rating, between the agroecological values of all possible pairs of biotope categories. In this kind of analysis, expert judgement played a key role in estimating the relative importance of a biotope category with respect to another (Delivand et al. 2015). Therefore, a panel of 10 experts belonging to the “Regional Committee on the Sheep track Network” and mostly composed by naturalists, ecologists and agronomists, was asked to perform the AHP under the coordination of the Authors. In other words, each single expert was asked to compare the biotope categories two by two, according to the following set of criteria (Spitaleri et al. 1991):

a) Level of naturalness (fully artificial, semi-artificial, semi-natural; fully natural although of secondary origins)
b) Degree of diversity (low, medium, high richness of species)
c) Rarity status (low, medium, high number of species demanding protection or precious biocenosys)
d) Biotope representativeness (presence of endemic species or species associations characterizing the Mediterranean type of environment)

Consecutive pairwise comparison between criteria produced a resulting symmetric matrix of judgment (Delivand et al. 2015). In this way, the AHP generates a “weight” for each evaluation criterion: the higher the weight, the more important the corresponding criterion. Then, for each criterion, a “value” to every biotope category was assigned, again according to the AHP expert pairwise comparisons: the higher the “value”, the better the performance of the biotope category with respect to the considered criterion. Finally, the AHP combines the criteria “weights” and the biotope “values”, thus determining a global “rating” for each biotope category, and a consequent ranking. Saaty (2008) presents a complete description on how to lay out and solve AHP analysis (matrix operations, eigenvalue extraction and normalization). When many pairwise comparisons are performed, some inconsistencies may typically arise. The AHP incorporates an effective technique for checking the consistency of the evaluations made by the experts when building each of the pairwise comparison matrices. The technique relies on the computation of an index called “consistency ratio” (CR). A perfectly consistent expert should always obtain CR = 0, but small values of inconsistency may be tolerated. If CR is smaller or equal to 0.1 the combination of weights or the combination of biotope values should be considered satisfactory. Differently, some pair comparisons have to be revised (Saaty, 2008; Ying et al., 2007).

(D) *Reason why long stretches of the sheep track network were discarded*. By using the geo-referred database and comparing the historical sheep track system with the modern road network it was observed that, today, not only secondary roads but also highways and main national roads of intense motorized traffic are overlaid to the original sheep paths. Roads have physically occupied the original settlement of the sheep paths and roadside facility services their adjacent areas. This happens both quite often and for long distances, thus representing a very serious impairment, almost

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irreversible, to the integrity of the sheep path system. Therefore, whenever such conditions were detected and stretches of the sheep track were no longer physically discernible, it was determined not to consider them furthermore in the analysis and to remove them from the processing map.

(E) *Reward assigned to cells inside natural protected areas*. Those cells of the mesh whose surface was inside protected natural areas (both National and Regional Parks, as well as SCI and SPA of "Natura 2000" network) were rewarded by increasing of 0.25 their "agroecological score". The total score of each cell was therefore re-classified into new 5 intervals, according to the corresponding quintile.

Having conveniently prepared the comprehensive set of spatial data useful for the analysis, the final step of the analytical procedure was the following: cells belonging to the upper score class (i.e. those corresponding to the highest agroecological scores) were selected and further examined. These cells were appropriately mapped at a smaller scale, and studied, more in detail, in their biotope composition. Considering those remaining cells, the percentage of land assigned to each biotope categories was determined as well as the percentage of land attributed to each Apulian sub-region; a combination of the two factors (biotope category and sub-region) was also analysed in terms of surface fraction allotted to each biotope category in each sub-region. A double entry table was then obtained and the corresponding matrix was processes through a factorial analysis. The outcomes of this multivariate statistical procedure were very useful in detecting the main characters of the agricultural landscape of the region with respect to the areas pertaining to the sheep track network.

Results

The main findings related to the ranking of the biotope categories, the selected areas to be preserved and their characteristics and distribution among the territorial districts are presented below.

Ranking of biotope categories

Figure 4 reports the 11 clustered biotope categories ranked according to their agroecological "rating" assigned by the expert panel as the result of the AHP.

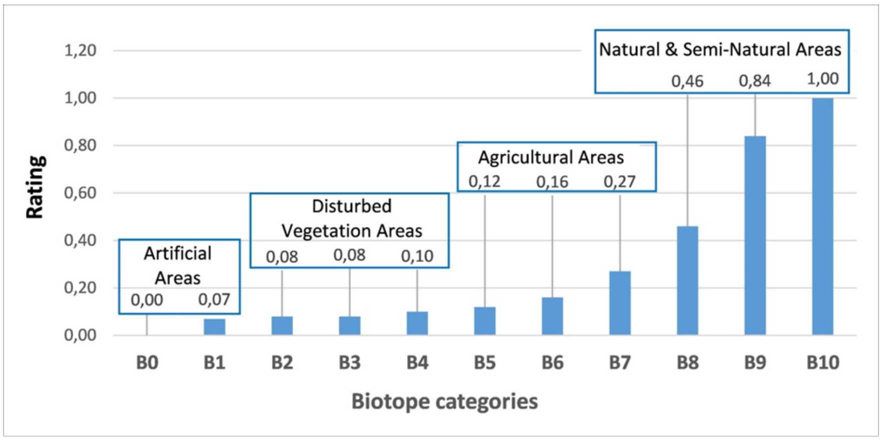

Figure 4. *Rank of the agroecological "rating" assigned to biotope categories by the expert panel as a result of the Analytic Hierarchy Procedure (AHP). More details about the applied procedure and the list of biotopes are available in the Appendix*

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As a general outcome, lower ratings were assigned to artificial biotope categories, while higher ratings were associated to natural and semi-natural biotopes. Finally, the ratings of farmland biotopes are placed in a central position along the ranking (the complete list of the detected biotopes in reported in *Tables A1* and *A2* in the *Appendix*).

However, the main interesting comment to *Figure 4* is not the ranking *per se*, but the relative rating distance between biotope categories. The highest agroecological rating, indeed, was attributed to “meadows and pasture” (B10), followed by “bush and garrigue” (B9). Those biotope categories (such as permanent pasture, grassland and other semi-natural vegetation types) are clearly associated to transhumance. Their remarkable rating (1.00 and 0.84, respectively) is considerably higher than that of other natural or semi-natural biotopes, represented by “woods and forests” (B8), whose rating was estimated equal to 0.46, i.e. approximately half the values of B10 and B9. This impressive difference, detected by the joint expert evaluation, can be justified in the light of the so called “forest transition” process. Land abandonment (especially in traditional agricultural landscapes) and forest expansion often lead to lower landscape heterogeneity with negative effects on biodiversity, particularly for those species benefitting from open habitats and edge environment (Giampietro, 1997; Marull et al., 2010 and 2014). Biotope B10 is characterized by the presence of priority habitat types (i.e. habitat types in danger of disappearance) with single species or plant associations that, according to the Directive 92/43/CEE, need special protection. These species are represented by *Brachypodium retusum*, *Brachypodium ramosum*, *Trachynia distachya*, *Bromus madritensis* e *Lagurus ovatus*. Moreover, these species are often associated with the presence of rare wild orchids. Biotope B9 is frequently present in ‘Natura 2000’ areas (Habitat Directive 92/43/CE) that are part of an ecological network of protected zones, safeguarded against potentially damaging developments.

These considerations, largely prevailing among the experts, motivated the biotope ranking, and the lower ecological rating attributed to wood and forest as compared to pasture, garigue, maquis and meadows.

Moreover, among biotope categories associated to farmland, a higher rating was credited to “complex cultivation patterns” (B7), agricultural systems characterized by higher heterogeneity as compared to “tree crops” (B6) and “annual crops” (B5), more specialized farming systems. B7, indeed, is a traditional form of agricultural land utilization, marked by a rich assortment of crop patterns and diversified cultivation managements, strictly associated with higher biodiversity degrees, preserving and attracting wild species, both animals and plants. Finally, lower ratings were assigned to other biotope categories considered of poorer agroecological relevance, being artificial habitats, or habitats frequently subjected to human disturbance, or in any case habitats difficult to correlate with pastoral use, although natural or semi-natural.

Selected fractions of the original sheep track network

Figure 5 represents the outcome of the overall analytical procedure. The results obtained consist in the selection and location on the map of those areas characterized by the highest agroecological value within the sheep track network of the Apulia region (identified as “red” colored spots on the map). The geographical distribution of these areas appears self-evident and leads to make further assessment about the most involved sub-regions as well as about the most represented biotope categories (see the following sub-sections).

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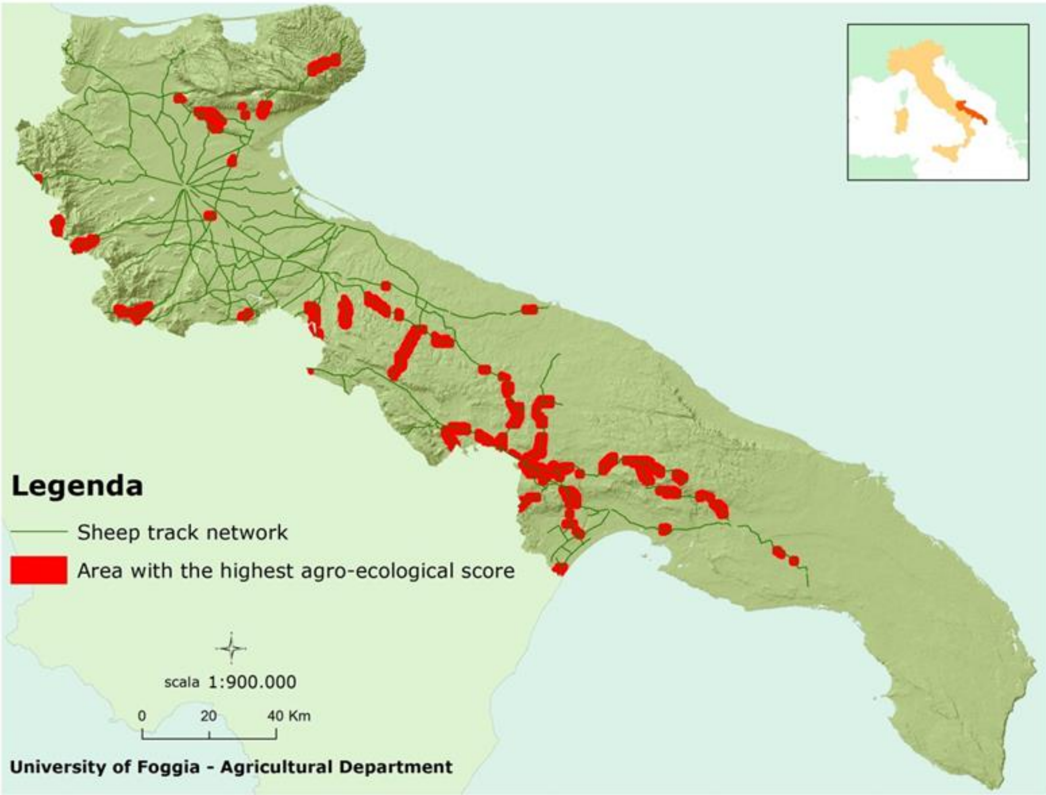

Figure 5. *Outcome of the planning analysis. Geographical dislocation of the selected portions of the sheep track network of the Apulia region credited with the highest agroecological score*

Considering the total historical sheep track network in the region, approximately 51% of the pertaining areas were excluded from the original system due to irreversible impairments and loss of physical integrity of the paths. Approximately, another 38% was discarded considering that these areas showed lower agroecological value (below the upper quintile assumed as benchmark). Therefore, the remaining 11% is the relative amount of the original network that was considered deserving specific attention through protective policies and development strategies. From about 350 thousand hectares originally assigned to the network, roughly 170 thousand hectares are still functional and clearly detectable, while 40 thousand hectares are the surfaces in the best agroecological conditions (totals reported in *Table 1*).

Surface breakdown by sub-regions

Table 1 reports the absolute and relative surface coverage of the sheep track network by sub-regions. Column TA1 accounts for the total area pertaining to the buffer zone considering the historical sheep track network, while column TA2 reports its breakdown percentages. Column RA1 offers the remaining areas of the buffer zone after the exclusion of the impaired and degraded lands that showed overlapping stretches with the road network (highways and main national roads), while Column RA2 reports its breakdown percentages. Finally, Column SA1 represents the selected areas of the buffer zone, i.e. those lands belonging to the class with the highest agroecological score, while Column SA2 reports its breakdown percentages.

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***Table 1.** Absolute and relative surface coverage of the sheep track network by sub-regions. The following variables are considered: total buffer area (TA); remaining buffer area after the exclusion of the portions overlapping with the road network (RA); selected buffer area having the highest agroecological score (SA)*

Apulian sub-regions	**Code**	**Total area**		**Remaining area**		**Selected area**	
		(ha) TA1	**(%) TA2**	**(ha) RA1**	**(%) RA2**	**(ha) SA1**	**(%) SA2**
Monti Dauni	A1	22,523	6.37	11,923	6.88	4,194	10.44
Gargano	A2	20,536	5.81	9,123	5.26	3,582	8.91
Tavoliere	A3	142,823	40.42	65,758	37.92	456	1.13
Ofanto	A4	33,603	9.51	15,503	8.94	1,609	4.00
Puglia centrale	A5	37,594	10.64	17,933	10.34	3,033	7.55
Alta Murgia	A6	39,691	11.23	22,581	13.02	17,217	42.85
Murgia dei trulli	A7	13,442	3.80	9,060	5.22	4,966	12.36
Arco Jonico Tarantino	A8	34,604	9.79	16,542	9.54	4,849	12.07
Campagna brindisina	A9	5,834	1.65	3,336	1.92	9	0.02
Tavoliere Salentino	A10	2,708	0.77	1,661	0.96	265	0.66
Salento delle Serre	A11	-	-	-	-	-	-
Total (Apulia Region)		**353,358**	**100.00**	**173,420**	**100.00**	**40,180**	**100.00**

With reference to the historical areas of the network, about 40% of the overall buffer area falled within Tavoliere (*Table 1,* A2). Only other three sub-regions showed quite high percentages, approximately in the range 9-11%, i.e. Alta Murgia, Puglia Centrale and Arco Jonico Tarantino. About the remaining not degraded areas of the network (*Table 1,* RA2), Tavoliere significantly decreased its surface contribution to approximately 38% of the total, while Alta Murgia increased its contribution reaching about 13%; approximately the same was observed considering Murgia dei Trulli, with a percentage that increased to 5%. Radically different are the percentages that marked the best agroecological areas of the network, i.e. those finally selected (*Table 1*, SA2). In this case, Tavoliere collapsed to 1% only, while Alta Murgia impressively increased its allocation to roughly 43%; quite remarkable are the percentages contributed by Murgia dei Trulli and Arco Jonico Tarantino (approximately 12%), together with Monti Dauni that reached the 10% of the total surface of the network. The most important transformation to be considered in comparing the sheep track initial condition (i.e. the historical network) with the final one (the selected agroecological network) is the drastic overturning in the surface contribution of Tavoliere and Alta Murgia. The former almost disappeared in its contribution, while the latter became unconditionally the most relevant. What was observed, indeed, is part of a wider “modernization” process also involving the transformation of the agricultural landscapes from several decades until now. Agricultural intensification and the expansion of built areas rarefied the agroecological zones of higher value in the plains (Tavoliere) and concentrated these residual but valuable agro-ecosystems in the inner areas of the region (Alta Murgia), more hilly and mountainous. These latter areas, mostly characterized by marginal agricultural systems, show still suitable conditions for the persistence of such extensive ecosystems. The same kind of transformation was observed also considering other internal and marginal sub-regions, such as Monti Dauni and Gargano, whose surface

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contribution has shown an increase from the initial condition (the historical network) to the final one (the selected network). Other two sub-regions showed similar surface fraction increases, i.e. Murgia dei Trulli and Arco Jonico Salentino, respectively.

Table 2 was derived from *Table 1,* but is useful to highlight other specific traits about the agricultural landscape dynamic and its transformation processes over the last decades. Having fixed equal to 100, in each sub-region, the total surface of the sheep track network, *Table 2* gives the share of "land losses" (Column LL) in consequence of degradation processes due to the road network entirely covering the sheep paths, together with the share of "land discarded" (Column LD) in consequence of agroecological impoverishment due to farmland intensification. The residual share, pertaining to the "land selected" (reported in Column LS), account for the relative extent of the sheep track network still in good ecological conditions (and therefore selected in the course of the planning procedure).

Two different dimensions of the comprehensive process of landscape deterioration were considered:

i) Land "consumption" (LL) related to human settlements and infrastructures (expansion of built-up area and road constructions, in particular), on the one hand;
ii) Degraded land (LD) due to over-exploitation for agricultural intensive use, on the other hand.

Table 2. *Shares of land surface pertaining to the sheep track network by sub-regions. The following classes are considered: buffer area losses due to road network overlapping (LL); buffer area discarded due to lower agroecological score (LD); buffer area selected because of higher agroecological conditions (LS)*

Apulian sub-regions	**Code**	**Land losses LL (%)**		**Land discarded LD (%)**		**Land selected LS (%)**	
Tavoliere	A3	53.96	*	45.72	*	0.32	
Ofanto	A4	53.86	*	41.35	*	4.79	
Puglia centrale	A5	52.30	*	39.63	*	8.07	
Alta Murgia	A6	43.11		13.51		43.38	*
Murgia dei trulli	A7	32.60		30.46		36.94	*
Monti Dauni	A1	47.06		34.32		18.62	*
Gargano	A2	55.57	*	26.99		17.44	*
Arco Jonico Tarantino	A8	52.20	*	33.79		14.01	
Campagna brindisina	A9	42.82		57.03	*	0.15	
Tavoliere Salentino	A10	38.65		51.56	*	9.79	
Salento delle Serre	A11	-		-		-	
Average (Apulia Region)		**47.21**		**37.44**		**15.35**	

Percentages marked by a star are higher than the average value of the class

The sub-regional areas of the network where the two landscape degradation typologies jointly occurred (both LL and LD), resulted in very limited percentages of areas still ecologically valuable to be selected (LS). This condition was detected in sub-regions such as Tavoliere (A3), Ofanto (A4) and Puglia Centrale (A5). It is worth

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noting that these sub-regions are flat areas marked by intensive agriculture and large and expanding urban centers. The opposite was shown in the case of Alta Murgia (A6) and Murgia dei trulli (A7), where the two degradation processes limitedly affected the agricultural landscape (neither LL, nor LD) or, their incidence was below the average regional value. Murgia, indeed, is one of the inner and marginal areas of the Apulia region, today largely included into a National Natural Park. The same trend, but somewhat lower, is observed also considering Monti Dauni (A1), another inner area of the Apulia region. This double effect explains the highest (in A6 and A7) and relatively high (in A1) surfaces selected at the end of the planning procedure in the mentioned sub-regions. Intermediate conditions also occurred, such as Gargano (A2) and Arco Jonico Tarantino (A8), marked by higher landscape degradation due to road infrastructures rather than agricultural intensification (LL, but not LD). Campagna Brindisina (A9) and Tavoliere Salentino (A10), conversely, showed a higher degradation level related to agriculture intensification coupled with a lower than average damage to the sheep track network due to road construction (not LL, but LD).

Surface breakdown by biotope categories

Considering the selected areas of the sheep track network (the areas represented as “red spots” in *Fig. 5*), the most abundant biotope category, in terms of covered surfaces, corresponds to “Complex cultivation patterns” (B7), accounting for 47% of the total considered network (*Table 3*). Far behind, that is to say much less represented than the former, are biotopes such as Tree crops (B6), about 18%, then followed by “Woods and forests” (B8), together with “Meadows and pastures” (B10), both around 15% of the total surface. The other biotope categories showed very limited diffusion and can be considered negligible in this discussion.

Table 3. *Biotope categories with codes, their corresponding surface coverage and percentage breakdown with respect to the total selected area*

Biotope categories	Code	Biotope areas (ha)	Biotope percentages (%)
Complex cultivation patterns	B7	18,937	47.13
Tree crops	B6	7,055	17.56
Woods and Forests	B8	6,232	15.51
Meadows and pastures	B10	5,986	14.90
Annual crops	B5	1,087	2.70
Bush and garrigue	B9	648	1.61
Riparian vegetation areas	B4	235	0.58
Total		**40,180**	**100.00**

The ranking process and the selection procedure assigned the maximum rating to “Meadows and pastures” (B10 = 1.00) as compared to other biotope categories (B8 = 0.46; B7 = 0.27; B6 = 0.16), in order to get the presence of these semi-natural ecosystems as much as possible, considering their strict relevance in association with transhumance. The supposed consequence was to include this biotope category, with all its inherent habitats, within the selected portion of the sheep track network, the one with the best agroecological value. The outcomes of the analysis were both unexpected and worrisome. B10, indeed, is much less represented in terms of surface, while agricultural

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land use (B7 and B6) and forest cover (B8) are the most abundant biotope categories observed along the sheep track network, and specifically in that fraction of the network selected because of the best agroecological conditions. The presented data confirmed, from a different perspective, the well-known progressive trend in pasture rarefaction and forestry expansion, together with farmland. Considering farmland, however, the ecosystem quality is significantly increased due to the large surface fraction of "Complex cultivation patterns" (B7) as compared to "Tree crops" (B6) and "Annual crops" (B5).

Surface breakdown by sub-regions and biotope categories

Table 4 shows the percentage breakdown of the surfaces allocated to every biotope featuring within each sub-regions. These data arrangement allows an accurate characterization of the Apulia region, specifically concerning the "red spots" of higher agroecological value.

Table 4. *Breakdown of relative surface coverage allotted to every biotope category (Bi) within each sub-region (Ai). All the reported values are expressed in percentages*

Apulian sub-regions	Code	B4	B5	B6	B7	B8	B9	B10
Monti Dauni	A1	0.11	3.51	1.42	67.77	19.39	0.00	7.79
Gargano	A2	0.03	11.66	10.08	5.80	46.14	2.27	24.02
Tavoliere	A3	1.88	65.73	3.28	0.00	3.10	0.00	26.01
Ofanto	A4	11.29	13.81	21.03	26.90	0.44	0.36	26.17
Puglia Centrale	A5	0.00	0.00	64.48	20.92	1.67	0.67	12.26
Alta Murgia	A6	0.05	0.00	11.56	62.39	5.93	0.00	20.06
Murgia dei Trulli	A7	0.00	0.00	5.73	46.38	46.27	1.41	0.21
Arco Jonico Tarantino	A8	0.59	0.00	39.34	36.27	7.74	9.71	6.36
Campagna Brindisina	A9	0.00	0.00	60.05	0.00	0.00	0.00	39.95
Tavoliere Salentino	A10	0.00	0.00	51.77	5.96	0.00	0.00	42.27
Salento delle Serre	A11	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The same double entry table (reported in *Table 4*) was also the matrix employed in performing a "factor analysis" based on variables correlations. The first two independent and uncorrelated factors were selected, considering that their corresponding eigenvalues were higher than 1. This multivariate procedure accounted for 60% of the total variance (F1 35% and F2 25%, respectively). The resulting "biplot" is shown in *Figure 6*.

Very clearly, Tavoliere (A3) is predominantly associated to Annual crops (B5), confirmed by the high percentage of B5 in A3 (62%) in *Table 4*. Alta Murgia (A6) and Monti Dauni (A1) are the territorial districts where Complex cultivation patterns (B7) is the dominant biotope (B7 > 60%). Murgia dei Trulli (A7) presents a hybrid condition, with a similar share of "Complex cultivation patterns" (B7), on one hand, and "Woods and forest" (B8), on the other one (B7 = B8 = 46%). Gargano (A2) is mainly characterized by a larger occurrence of "Woods and forest" (B8 = 46%). Puglia centrale (A5) is characterized by a considerable prevalence of "Tree crops" (B6 = 64%), while Arco Jonico Tarantino (A8) showed a remarkable combination between "Tree crops" (B6 = 39%) and "Bush and garrigue" (B9 = 10%), respectively. Campagna Brindisina

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(A9) and Tavoliere Salentino (A10) are characterized by a combination of Tree crops (B6 = 52 and 60%, respectively) together with “Meadows and pasture” (B10 = 42 and 40%, respectively). Ofanto (A4) is strictly associated with “Riparian vegetation areas” (B4 = 11%), although shows a high incidence of “Complex cultivation pattern” (B7 = 27%) and “Meadows and pasture” (B10 = 26%). Lastly, Salento delle Serre does not present any significant portions of the sheep track network within its land.

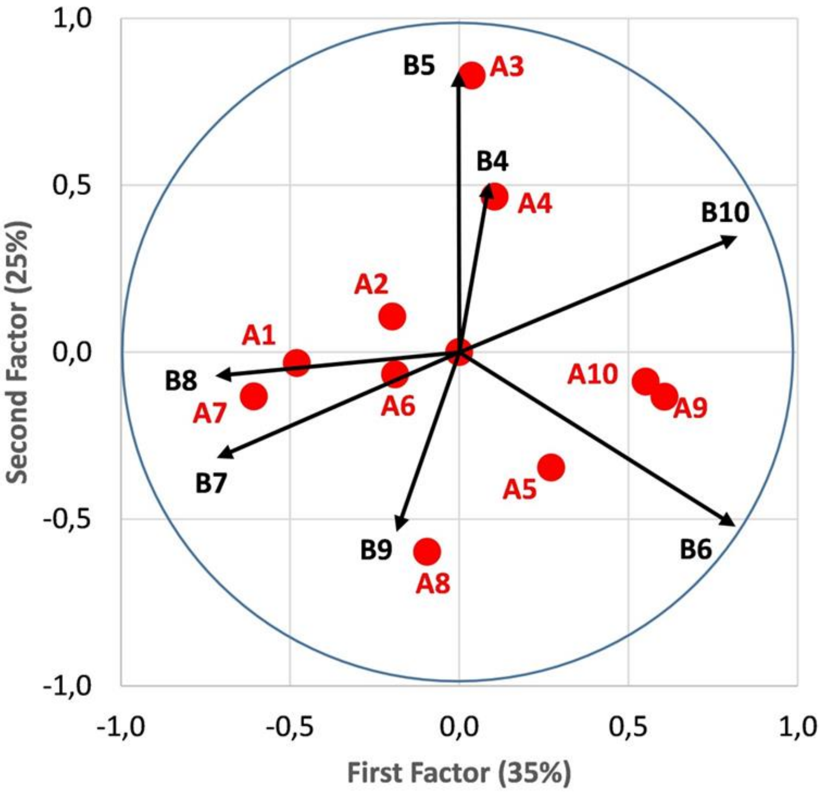

Figure 6. *Biplot of the factor analysis representing both the scores (points) and the factorial weights (arrows). Each point in the graph corresponds to one of the Apulian sub-regions (11 in total). A11 is not represented in the plot because scored zero (see Table 4)*

Discussion

This study performed an agroecological characterization of the sheep track landscape of the Apulian region and the identification of areas with higher conservation value was the subsequent goal.

Two overturning results came out from the analysis of the selected sheep track network: the first pertains to geography, while the second is related to biotopes.

1) The best conservation status of the sheep track network was detected in Alta Murgia (a hilly and marginal agricultural area), whereas sub-regions such as Tavoliere, but also Monti Dauni and Gargano, that were the geographical areas historically associated with transhumance and pastoralism are, today, much less involved in the conservation of these ancient sheep and shepherd paths. Unfortunately, in these latter sub-regions, large portions of the network are fragmented, hidden, covered, impaired and partially ruined by road construction and roadside infrastructures. Alternatively,

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land conversion to intensive agricultural systems is the other factor affecting the ecological integrity of the lands along the sheep tracks.

2) Despite a higher agroecological rating was attributed to those biotope categories with prevailing semi-natural traits and in strict association with transhumance, the biotopes with the highest occurrence and the largest extents were those pertaining to agricultural systems and, in particular, “Complex cultivation patterns” (B7). Surprisingly, “Meadows and pastures” (B10) as well as “Bush and garrigue” (B9) are under-represented in terms of surface and outnumbered in terms of units by “Woods and forests” (B8) and “Tree crops” (B6).

Among agricultural systems, B7 should be considered very valuable in preserving a high degree of biodiversity, strongly connected to cultivation practices and strictly dependent on farming management, this latter being clearly based on extensive agricultural systems. The agricultural traits shown by B7 are very similar to “type 2” High Nature Value Farmland (HNVF), sensu Andersen et al. (2003). This type of HNVF, indeed, are characterized by a farming landscape with a large proportion of semi-natural vegetation (wood, forests, meadows and pastures) which insists in a rich mosaic of arable and/or tree crops. Such inherently biodiversity and rich farming systems, including livestock, arable, permanent crop or mixed farming, usually rely on traditional low intensity practices (Andersen et al., 2003; Beaufoy et al., 1994; EEA, 2004; Pedroli et al., 2007; Van Doorn and Elbersen, 2012). Low grazing densities of livestock, the use of fallow inserted in a sequence of arable crops, low inputs of fertilizing nutrients per unit of cultivated area, reduced use of agrochemicals and rainfed condition in arable and permanent crop systems are the main features (Beaufoy et al., 1994; Van Doorn and Elbersen, 2012). Such farming systems are referred to as HNVF since they contribute to maintain natural habitats and viable populations of wild species of the highest conservation value, together with the diversity of the land cover types (Beaufoy et al., 1994; Bignal and McCracken, 1996, 2000; Henle et al., 2008; Plieninger and Bieling, 2013).

The conservation of the sheep track landscapes is just one *tessera* of a complex mosaic that relates to the need of preserving the agricultural landscape as a whole. A socio-geographical double bound is observed: agricultural abandonment in marginal, hilly sub-regions (and the consequent forest expansion), on the one hand; agricultural intensification on flat, alluvial and fertile areas (and the consequent competition with urban expansion), on the other hand. They shall be considered the two sides of the same coin. The sheep track landscape is affected by exactly the same risks and the same threats.

The abandoning of pastures at higher altitudes has led to an expansion of woodland areas, and the loss of open spaces, which are important not only for the landscape itself, but also for biodiversity conservation. Conversely, the areas on the plain have been affected by urban expansion and the loss of traditional crop and inter-cropping, with a notable worsening of the landscape quality (Agnoletti et al., 2011).

With respect to agricultural abandonment, some authors suggest that forest expansion should be favored given their potential for slowing down soil erosion, improving water quality, and mitigate climate change through carbon sequestration (Rudel et al., 2005). Similarly, some authors judge land abandonment an opportunity for biodiversity conservation. While American ecologists and naturalists are commonly more focused on the conservation of post-abandonment ecosystems, European landscape ecologists generally consider land abandonment, and the consequent secondary naturalization

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process, mainly as a threat (Marull et al., 2015). The uncontrolled expansion of unmanaged forests leads to social and ecological negative impacts, causes damages to biodiversity (Marull et al., 2015) and increases wildfire hazard (Pausas et al., 2008).

Concerning agricultural intensification/extensification dynamics, depending on the cultivation management, farming systems may entail either a decrease or an increase in biological diversity (Marull et al., 2015). It is generally recognized, today, that farm systems may provide environmental services as well as productive goods. In this respect, ensuring both agricultural production and ecological services might trigger the well-known “sparing” vs. “sharing” opposite strategies (Marull et al., 2015):

i) The land-sparing approach is based on increasing agricultural intensification in some areas so as to devote the others to nature conservation and forest transition (Green et al., 2005; Matson and Vitousek, 2006); conversely:
ii) The land-sharing approach is based on a wildlife-friendly farming able to provide complex agroecological matrices connected with natural sites that jointly maintain high species richness at landscape level (Bengston et al., 2003; Marull et al., 2010; Perfecto and Vandermeer, 2010; Tscharntke et al., 2012).

This latter strategy (i.e. the land sharing approach) can be seen allied with the strategy of HNVF identification and protection; extensive farmland and semi-natural ecosystems are the most important indicators in selecting HNVF. Sound ecological sheep tracks can be considered the very first candidate to be identified as HVVF, thus providing very useful ecological services, including regulatory, support, cultural and aesthetic functions (Lomba et al., 2014), i.e. positive externalities and environmental benefits. Preserving at least some selected portions of the sheep tracks implies keeping farming systems that use traditional agricultural practices.

Another relevant dimension pertaining to the protection of the sheep track network is related to the cultural heritage it represents and the historical legacy that should be transmitted to future generations.

According to Oppermann et al. (2012), the characteristics of HNVF landscapes make them central to the European identity and culture. Following these characteristics, HNVF landscape are considered, at least throughout Europe, “cultural” landscape (Plieninger and Bieling, 2012). If this is true with respect to HNVF (and no doubt, it is), then, even more this applies to the sheep track landscapes.

Considering the historical and cultural values of the agricultural landscape, the Italian Ministry of Agricultural Food and Forestry Policies recently started a survey for the compilation of a National Catalogue of Historical Rural Landscapes. It aims at creating a list of landscapes having historical importance in terms of significance, integrity and vulnerability (www.reterurale.it). A valuable site (“Pasture of Northern Alta Murgia”) linked to transhumance was identified in Apulia, characterized by the presence of large, open, semi-grazed pastures and small rural buildings, remains of the *tratturo* “Melfi-Castellaneta” that crossed the area. Another relevant example concerns the Molise region that applied the *tratturi* system to the UNESCO world heritage, considering them a combined work of nature and man, areas including outstanding value from the historical, aesthetic, ethnological and anthropological point of view.

One of the main problems with the conservation and valorization of the Italian rural landscapes, is the lack of perception of their importance, both among the public administrators and civil society. Anyway, their protection should not to be postponed any longer. Above all, what is needed is to promote their active but sustainable

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utilization, i.e. their original function as well as alternative forms of development. This means that the key to a sustainable future for semi-natural farmland (including the sheep tracks) is their socio-economic viability and the possibility to find a stable or growing market for local products and services. Nature, history, culture are important component of the product panel.

Conclusion

Maintaining the sheep track network areas and the ecosystem services they can offer is a way to preserve, synergistically, not only relevant biotopes but also a complex and long lasting cultural system, traditionally linked to transhumance. The analysis worked out in this paper was performed at regional scale, in the frame of a planning assignment by the Apulian Land Property Department. The work achieved its target: an agroecological characterization of the sheep track landscape connected to transhumance was carried out and the selection and location on the map of those portions of the network characterized by the highest agroecological value was thus obtained.

This work should be considered a preliminary, although essential step to promote further actions, mostly in terms of policy measures, to encourage the recovery and requalification of the sheep track system in a perspective of both integrated land management and rural development.

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APPENDIX

Table A1. *Clustered biotope categories and list of their corresponding biotopes identified according to the CORINE Biotope codes*

Biotope codes	**Biotope categories**	**Pertaining biotopes (identified with the CORINE Biotope codes)**
B0	Artificial areas	86.1 – 86.3 – 86.41
B1	Artificial vegetated areas	83.31 – 83.322 – 85.1
B2	Dunal vegetation	15.1 – 15.83 – 16.1 – 16.21 – 16.28 – 16.29 – 18.22
B3	Bare rock	62.11
B4	Riparian vegetation areas	22.1 – 24.225 – 24.53 – 44.14 – 44.61 – 53.1 - 89
B5	Annual crops	82.1
B6	Tree crops	83.11 – 83.15 – 83.16 – 83.21
B7	Complex cultivation patterns	83.2
B8	Woods and forests	32.11 – 41.18 – 41.41 – 41.782 – 41.737B 41.7511 – 41.7512 – 41.782 – 41.86 -41.9 – 42.84 – 45.1 – 45.31 – 45.324 – 45.42 – 83.325
B9	Bush and garrigue	31.81 – 31.863 – 32.211 – 32.219 – 32.4 – 32.6
B10	Meadows and pastures	31.8A – 34.323 – 34.326 – 34.5 – 34.75 – 34.81 – 84.6

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Table A2. *Complete list of biotopes featuring in the Apulian Biotope Map, properly clustered according to the aggregation criteria applied in the work. The Corine Biotope cedes are also displayed*

Biotope categories	Corine biotope codes	Biotope names
B0 Artificial areas	86.1	Towns
	86.3	Active industrial sites
	86.41	Quarries
B1 Artificial vegetated areas	85.1	Large parks
	83.31	Conifer plantations
	83.322	Eucalyptus plantations
B2 Dunal vegetation	15.1	Annual salt pioneer swards
	16.1	Sand beaches
	16.21	Shifting dunes
	15.83	Clay areas with accelerated erosion
	16.28	Dune sclerophyllous scrubs
	16.29	Wooded dunes
	18.22	Mediterraneo-Pontic sea-cliff communities
B3 Bare rock	62.11	Western EU-Mediterranean and oro-Iberian calcareous cliffs
B4 Riparian vegetation areas	22.1	Permanent ponds and lakes
	24.53	Mediterranean river mud communities
	44.14	Mediterranean tall willow galleries
	44.61	Mediterranean riparian poplar forests
	24.225	Mediterranean river gravel communities
	53.1	Reed beds
	89	Industrial lagoons and reservoirs, canals
B5 Annual crops	82.1	Unbroken intensive cropland
B6 Tree crops	83.11	Olive groves
	83.15	Fruit orchards
	83.16	Citrus orchards
	83.21	Vineyards
B7 Complex cultivation patterns	82.3	Complex cultivation patterns
B8 Woods and forests	41.9	Chestnut woods
	41.18	Southern Italian beech forests
	41.41	Medio-European ravine forests
	45.1	Olive-carob forests
	45.42	Italian kermes oak woodland
	45.31A	Southern Italian holm-oak forests
	41.737B	Eastern sub-Mediterranean white oak woods
	41.86	Thermophilous ash woods
	42.84	Aleppo pine forests
	41.782	Apulian Trojan oak woods
	45.324	Italian supra-Mediterranean holm-oak forests
	83.325	Other broad-leaved tree plantations
	41.7511	Southern Italic Quercus cerris woods
	41.7512	Southern Italic Quercus frainetto woods
	32.11	Evergreen oak matorral

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B9 Bush and garrigue	32.4	Western meso-Mediterranean calcicolous garrigues
	32.6	Supra-Mediterranean garrigues
	31.81	Medio-European rich-soil thickets
	32.211	Oleo-lentisc brush
	32.219	Thermo-Mediterranean kermes oak brushes
	31.863	Supra-Mediterranean bracken fields
B10 Meadows and pastures	84.6	Sardinian woody pasture (Dehesa)
	34.323	Middle European Brachypodium semi-dry grasslands
	34.326	Sub-Mediterranean Mesobromion
	34.75	Eastern sub-Mediterranean dry grasslands
	34.81	Mediterranean subnitrophilous grass communities
	34.5	Mediterranean xeric grasslands
	31.8A	Tyrrhenian sub-Mediterranean deciduous thickets

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