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RESEARCH ARTICLE

Landscape conservation in the natural-rural interface. A social-ecological approach in Natural Parks of Andalusia (Spain)

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Abstract

Context Multifunctional rural landscapes are social-ecological systems that represent a link between nature and culture. They are characterized by the conservation and protection of ecological processes, natural resources and biocultural diversity. The conservation of these landscapes is mainly based on the establishment of Protected Natural Areas (PAs) whose regulatory schemes have often promoted their degradation.

Objectives We evaluate the effectiveness of the conservation strategies of the Natural Park category in the protection and maintenance of rural cultural landscapes. We analyse at a regional and local scale both the dynamics of land-uses and the socioeconomic structure of the local populations involved, identifying the main social-ecological indicators of change in the protected landscape.

Methods We apply a methodological approach, based on geoprocessing tools and multivariate analysis, to examine social-ecological changes in rural cultural landscapes after the establishment of a network of PAs. The designed method allows us to infer the ecological and socioeconomic resilience of protected landscapes.

Results Conservation efforts have tended to underestimate rural landscapes in favour of natural ones, mainly forest systems, and have not been able to prevent the processes of abandonment and degradation of protected landscapes. A simplification of the land-use systems dependent on traditional farming practices is observed. This implies the loss of both the multifunctionality of rural landscapes and their resilience to environmental changes. The key socioeconomic indicators identified highlight the deterioration of the rurality of protected landscapes.

Conclusions Our social-ecological approach is a useful tool to evaluate the effectiveness of PAs. Protection of landscape is related to the decline of traditional agricultural systems and rewilding through land abandonment. Culturalness is necessary to promote the management and conservation of rural landscapes from a holistic perspective.

Keywords Culturalness · Forest expansion · Social-ecological indicators · Rural abandonment · Rewilding · Protected area effectiveness

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Introduction

Rural cultural landscapes have emerged as a result of the secular interaction between human society

and nature (Antrop 2005; Lacitignola et al. 2007; Petrosillo et al. 2015; Arnaiz-Schmitz et al. 2018a), leading to diverse traditional land-use systems well adapted to the environmental conditions (Pinto-Correia 2000). These traditional land-use systems, often considered as "low intensity land use systems", optimise the use of natural resources, minimise risks through different multiple uses and provide a wide range of ecosystem services to society (Plieninger et al. 2006; Hartel et al. 2014). Thus, the distinction between natural and cultural landscapes is a difficult task (Küster 2004).

A main characteristic of these multifunctional landscapes is that they evolved as tightly coupled social-ecological systems, developing both a strong interdependence between local ecosystems and the rural communities that inhabit them (Fischer et al. 2012) and a high persistence based on their social-ecological resilience (Holling 2001; Walker et al. 2002). In fact, the maintenance over time of these rural systems has been mainly due to the generational transmission of traditional ecological knowledge (TEK), supported by a deep empirical knowledge of the sustainable use of natural resources and the conservation of ecological processes and biocultural diversity (Berkes et al. 2000; Gómez-Baggethun et al. 2013; Biró et al. 2014; Hernández-Morcillo et al. 2014; Vlami et al. 2017). Not only the specific components of the rural cultural landscape (such as agrosilvopastoral systems, drove roads or hedgerow networks, among others) depend directly on human use (Bunce et al. 2012; Sheeren et al. 2009; Minotti et al. 2018), so do numerous priority habitats and protected species (Halada et al. 2011; Kleijn et al. 2011; Amici et al. 2015). Thus, the high nature conservation value of most of traditional rural landscapes is unquestionable (Plieninger and Bieling 2013; Lomba et al. 2020; Schmitz et al. 2021).

In Europe, rural landscapes comprise 95% of its territory (Agnoletti 2014) and represent a highly valued natural, cultural and historical heritage that must be safeguarded (Rössler 2006; Agnoletti and Rotherham 2015; Sarmiento-Mateos et al. 2019). However, for decades, most of these traditional rural landscapes have been experiencing a rapid dynamic of change related mainly to socioeconomic driving forces, which are the dominant forces leading to land-use transitions (Lambin and Meyfroidt 2010). In this way, the main trends of change in cultural landscapes in Europe are a consequence of three interrelated processes: agrarian intensification, rural abandonment and urban expansion (Van Eetvelde and Antrop 2004; Antrop 2005, Antrop and Eetvelde 2008; Plieninger and Bieling 2012; Arnaiz-Schmitz et al. 2018b). Many valuable cultural and ecological components of rural landscapes and the ecosystem services they provide may be altered or lost due to these main drivers of land-use change and habitat loss (Díaz et al. 2006; Seto et al. 2012; Hartel et al. 2014; van Vliet et al. 2015). In this sense, the regulatory framework of land planning includes schemes and instruments for the control of land use changes. Among these land planning strategies, the establishment of Natural Protected Areas (PAs) stands out.

The PA concept arises from the need to safeguard territories considered valuable from progressive degradation, especially due to irresponsible human activities (Lausche and Burhenne 2009). A literature review of research works carried out in this regard reflects the interest of the international community in the establishment of PAs and its commitment to conservation from a mainly biological perspective. Although protection has indeed been the main objective of PAs, the importance of adopting environmentally, socially and economically sustainable development models has progressively reached a growing consensus (Saviano et al. 2018). However, on many occasions, conservation schemes have been implemented through the establishment of nature reserves whose regulations and management plans have frequently generated conflicts between land-use planning and rural development, mainly due to access restrictions for the local populations to natural resources and the provision of ecosystem services (Schmitz et al. 2012; Sarmiento-Mateos et al. 2019). Therefore, it seems necessary to promote the process of effective conservation from a social-ecological approach since in many occasions PAs do not meet the requirements to be effective tools in terms of protecting and maintaining traditional rural landscapes (Verdú et al. 2000; Sims 2010; Schmitz et al. 2012, 2021; Arnaiz-Schmitz et al. 2018a; Sarmiento-Mateos et al. 2019).

Within this social-ecological framework, the main goal of this research is to empirically analyse the

effectiveness of the management strategies of a network of Natural Parks (NPs) for the conservation of rural cultural landscapes. The study has been carried out in Andalusia (southern Spain), a territory that has experienced a progressive process of rural abandonment throughout the second half of the twentieth century and in recent decades, causing alterations in the traditional spatial patterns of cultural landscapes (Navarro-Cerrillo et al. 2020). On this basis, the specific objectives of our research include the analysis and identification, at a regional and local scale, of the following aspects: (i) the dynamics of land-use changes in the protected rural landscapes studied; (ii) the influence of nature conservation strategies on the socioeconomic structure of the local populations involved; (iii) the main social-ecological drivers and indicators of landscape change.

The information provided by this study will be a useful basis for designing effective PA management strategies aimed at conserving traditional rural landscapes.

Methods

Study area

This study has been carried out in the Andalusia region (Southern Spain), which covers an area of 87,600 km^2 (Fig. 1). The vegetation is represented by Mediterranean forest with different species of deciduous trees, such as Holm and cork oaks and conifers, as well as large areas covered by Mediterranean shrubland. More than 50% of the land is used for rural land-uses uses (crops and agrosilvopastoral systems, highlighting pastures and wooded pastures or "dehesas"). In recent decades, traditional land-uses have been substituted by intensive crops or have been abandoned, leading to a significant increase in extensive grasslands and wooded landscapes. In addition, forced greenhouse cultivation has become very widespread (Muñoz-Rojas et al. 2011; Navarro-Cerrillo et al. 2020).

The study case is part of the Andalusian Network of Protected Natural Areas (RENPA, for its acronym in Spanish), located in southern Spain (Fig. 1a). RENPA is one of the largest regional administrative

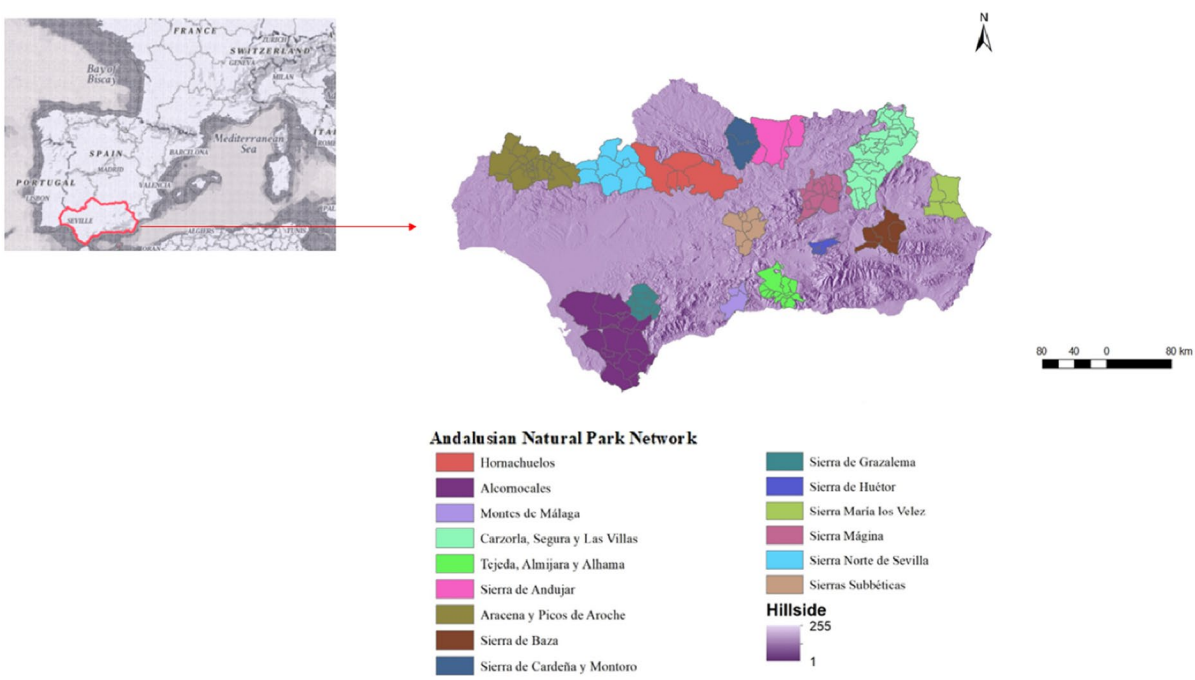

Fig. 1 Location of the study area in the Andalusia region (Southern Spain). Municipalities belonging to each of the 15 Natural Parks selected for the study are shown

networks of PAs in the European Union, covering an area of nearly 2,84 million hectares, which represents 17% of all the Spanish protected territory. This PA network is configured as a system of nature reserves that have a special protection regime based on the sustainable use of the resources, the improvement of scientific knowledge of its natural and cultural values, and the promotion of new development initiatives. RENPA contains 243 PAs, classified into different categories according to their values and management objectives, at regional, national and international level.

We focus our study on the category of Natural Park (Fig. 1b), which is equivalent to category V of the IUCN (Protected Landscapes) (Europarc-Spain 2020). In Andalusia, this category of protection comprises a total of 24 NPs, which represent about 84% of the land protected by RENPA. This protection status refers to cultural landscapes that have co-evolved with the human societies that inhabit them and in which the effectiveness of their management depends both on environmental conservation and on safeguarding the socioeconomic conditions of the local population (Brown et al. 2005). These are landscapes that, in view of their natural and heritage values and the ecological and social functions they house, require the establishment of specific measures to guarantee their conservation through an adequate protection regime. In Spain, NP is the second hierarchical level of nature protection categories, and is the responsibility of regional legislation. The Andalusian Regional Government conceived the figure of NP as a tool for the protection of nature and also for promoting sustainable local development (Mulero 2003). The objective of the establishment of the NP network was to link the conservation of nature with the promotion of public use and the socioeconomic development of local communities (Santiago-Ramos and Feria-Toribio 2021).

In this paper we selected 15 NPs integrated in the RENPA, located in inland areas and with similar social-ecological features. All the selected NPs are called "Sierras", a series of high and medium mountain formations with high levels of anthropisation and, at present, subjected to a process of economic marginalization and depopulation. The Mediterranean vegetation of oak and pine forests is distributed in mosaic and alternating with areas of scrubland with trees and traditional land-uses, such as pastures, wooded pastures (dehesas) and herbaceous and woody crops (mainly olive groves) (Fig. 1; Online Appendix 1).

Methodological design and data collection

Figure 2 shows a scheme of the quantitative methodological design followed to evaluate the effectiveness of NP protection plans, from the double perspective of the conservation of rural cultural landscapes and the maintenance and socioeconomic development of associated local populations.

The social-ecological evolution experienced by the NPs studied was carried out considering a set of 12 land use-land cover (LULC; collected from the European database CORINE Land Cover, CLC) and 20 socioeconomic descriptors (compiled from the Andalusian Multiterritorial Information System, SIMA) (Fig. 2, Sect. 1). These descriptors are sensitive to land use changes (Larondelle and Haase 2013; Herrero-Jáuregui et al. 2019) and have proven to be useful as indicators to identify the dynamics of change in the structure of rural landscapes and local populations (De Aranzabal et al. 2008; Schmitz et al. 2012, 2021; Arnaiz-Schmitz et al. 2018a, b; among others).

We recorded the selected descriptors (detailed in Table 1) in two consecutive periods of 20 years each, 1980–1999 and 2000–2020 (Fig. 2, Sect. 3). These periods covered the time intervals, respectively, before and after the establishment of the set of Natural Parks belonging to the RENPA.

Social-ecological dynamics of Natural Parks. Regional scale analysis

To quantify the regional land-use change determined by the effect of nature protection efforts, we elaborated two LULC maps of the NP network studied, one for each considered period (Fig. 2, Sect. 4).

The similarity between the spatial patterns of both maps was calculated by means of a geostatistical analysis of spatial correlation using the Rv coefficient, which is a multidimensional equivalent of the ordinary correlation coefficient between two variables (Robert and Escoufier 1976). For this, raster layers containing the LULC of the study area (Table 1a) were used in the two periods considered and the geoprocessing tool "Band Collection Statistics" (Spatial Analyst; ArcGis Pro) was applied. This tool provides

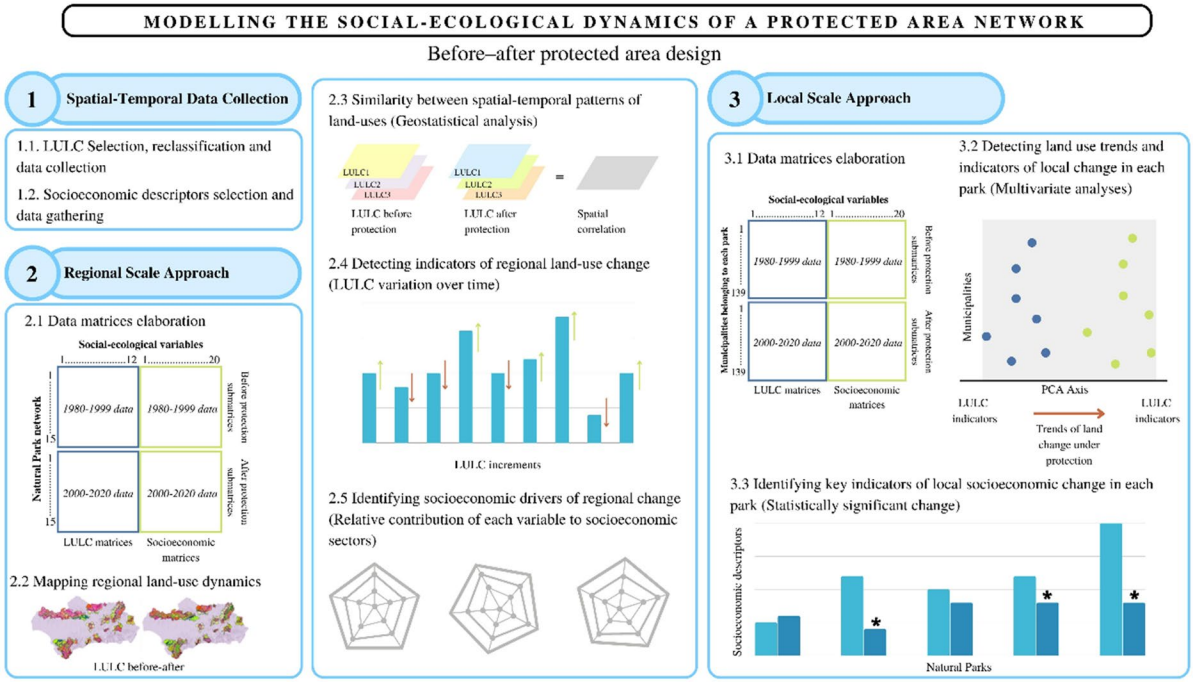

Fig. 2 Schematic overview of the methodological procedure focused on the social-ecological analysis of the effectiveness of natural parks for the conservation of rural landscapes

statistics for the multivariate analysis of a set of input raster bands and returns the result of the statistic that is computed from them as a single-band output raster (see Fig. 2). In this case, we generate covariance and correlation matrices. The covariance matrix contains values of variances and covariances of all raster bands. To calculate these variances, the squares of the differences between each cell value and the mean value of all cells are averaged. The variances are expressed in cell-value units squared.

The correlation matrix provides the correlation coefficients between each combination of two input bands. Thus, a symmetric correlation matrix was obtained with the cell values of one of the raster layers in relation to the cell values of the other layer. The correlation between two layers is a measure of dependency between them. The Eq. (1) to calculate the correlation between the two layers (Rv) is the ratio of the covariance between the two (Cov_{ij}) divided by the product of their standard deviations (δ_i, δ_j).

$$Rv = \frac{Cov_{ij}}{\delta_i \delta_j} \quad (1)$$

As usual, the correlation values between maps vary from + 1 to −1, indicating a direct or inverse relationship between them. A correlation of zero means that two maps are independent of each other.

In order to identify the main indicators of the land-use change occurred in the study region as a result of the establishment of the current natural park network, we calculated the increment (increases or decreases) in LULC descriptors as a percentage of their variation over time. For this, the aggregated data of land-uses in the periods before and after the declaration of each park were considered (Fig. 2). The statistical significance of the changes identified was tested using Student's t-tests for the comparison of two means (two series of quantitative measurements on the same units of analysis).

To explore the socioeconomic drivers of change of the NP network on a regional scale, the socioeconomic descriptors of the municipalities were grouped into three categories: demographic variables, economic activities linked to the primary sector (considering variables representative of agricultural and livestock activities) and economics linked to the service sector (Fig. 2). The spatial–temporal variability

Table 1 Social-ecological descriptors recorded in each municipality of the study area. a) Land-uses, expressed as area occupied in relation to municipal area (%); reclassified from CLC database; b) Variables related to the socio-economic structure of the local population; SIMA database. Units used for each variable are indicated

a) LULC variables	Description
Coniferous formations	Montane pine forests and plantations of Scots pine (*Pinus sylvestris*) and black pine (*P. nigra*) in hillside slopes and pinaster pine (*P. pinaster*) in the valley bottoms
Mixed and broad-leaved forest formations	Mediterranean broad-leaved sclerophyllous and deciduous forests. Forests with a mixture of species such as holm oak (*Quercus ilex subsp ballota*), cork oak (*Q. suber*), gall oak (*Q. faginea*), gall oak (*Q. canariensis*), Pyrenean oak (*Q. pirenaica*) and beech (*Fagus sylvatica*)
Agrosilvopastoral systems	Pasture systems, meadows and prairies composed of grasses and leguminous plants, *Dehesas* (open formations with a mixture of pastures and mosaics of scrub and tree species, mainly with the presence of holm oaks (*Q. ilex subsp ballota*) and cork oaks (*Q. suber*)
Mining areas	Areas used for mineral extraction
Systems in scrub-forest transition	Transitional wooded scrubland. Shrubby and woody vegetation. Associations of scrub-coniferous, scrub-broadleaf tree species, scrub-coniferous and broadleaf tree species
Sclerophyllous shrubland	Shrub formations of sclerophyllous species such as common juniper (*Juniperus communis*), prickly juniper (*J. oxycedrus subsp. oxycedrus*), black broom (*Cytisus scoparius*), boxwood (*Buxus sempervirens*)
Crop/natural vegetation mosaics	Lands of dominant agricultural use, whether rainfed or irrigated, in which there are areas of natural vegetation
Olive trees	Olive plantations (*Olea europea*)
Inland saline areas	Land whose soils have a high content of salts and gypsum, which motivates the presence of halophyte and gypsophilous plants that coexist with reed beds and saline grasslands
Irrigated crops	Irrigated arable crops, market gardens and forced crops
Herbaceous and woody crops	Fruit tree plantations, vineyards and arable land
Urban areas	Urbanized areas, industrial areas and artificial green areas

b) Socioeconomic variables	Description	Units
Land dedicated to agrarian systems		Hectares
Distribution of farms by size	0.1–10 ha	Number
	10–50 ha	
	> 50 ha	
Owners of farms by age	< 35 years	Number
	35–64 years	
	> 64 years	
Phone lines and Internet connections	BTN	Number
	ISDN	
	ADSL	
Population density		Inhabitants/km^2
Emigration	< 16 years	Number of people in each age class
	16–64 years	
	> 64 years	
Hotels and rural tourism establishments		Number
Restaurants		Number
Livestock	Cattle	Livestock units
	Sheep	
	Goats	
	Pigs	
	Poultries	
	Horses	

of the economic and social descriptors of the park network was expressed using radial graphs, useful for simultaneously evaluating and comparing multiple quantitative variables. Radial graphs allow us

to know the relative contribution of each variable to the set of socioeconomic sectors studied and identify high priority indicators (Yoo et al. 2014). In this way, we were able to identify the main drivers of socioeconomic change in the NP network.

Social-ecological change of protected landscapes. Local scale analysis.

In the study of the social-ecological dynamics of the NP network at a local scale, the spatial reference units were the municipalities included within the limits of the parks studied and their socioeconomic influence areas, in accordance with the delimitation established by the RENPA. The socioeconomic influence area of a NP is the territory constituted both by the municipalities that belong sensu stricto to a PA and by those directly related to the park (Peripheral Protection Zone, in which land-uses compatible with conservation are promoted) (Moreno 2010). This zoning depends on the declarative laws of each park. In the municipalities affected by the land protection the public administration has to carry out active policies for landscape conservation and development, through the Master Plan for Use and Management and the Sustainable Development Plan (PRUG and PDS, respectively, according to their Spanish acronyms). The first document includes norms and guidelines for land planning and management, designating the specific activities that should be promoted or prohibited (Sarmiento-Mateos et al. 2019). The second one has the objective of revitalizing socioeconomic structures, safeguarding ecological stability, in accordance with the provisions of the PRUG.

Municipalities are an effective local scale of analysis due to the fact that in most territories they represent the administrative level of local management and governance decisions, and, furthermore, generally the socioeconomic information is recorded at this scale. Municipal spatial units are also easily interpretable by land-use policy makers and regional planning decision makers (Serra et al. 2014). Thus, different authors encourage the use of these administrative units in landscape studies (Salvati and Zitti 2009; Schmitz et al. 2012; Salvati and Serra 2016; Arnaiz-Schmitz et al. 2018a,b; Zúñiga-Upegui et al. 2019, among others). The PA network studied has a total of 144 municipalities distributed in the 15 NP belonging to the eight provinces of Andalusia (Online Appendix 1). In the local scale analysis of the PN network, two parks have been excluded due to the small number of municipalities covered by their area (NPs Sierra de Cardeña-Montoro and Montes de Málaga, with 2 and 3 municipalities respectively).

With the social-ecological data collected at the municipal level (LULC and socioeconomic descriptors), we elaborated two data matrices for each of the 13 selected parks (Fig. 2). Each matrix was composed of two temporal sub-matrices, one for each period studied (1980–1999 and 2000–2020): 1) LULC data matrix, whose dimensions were, for each case, those corresponding to the number of municipalities belonging to each park × 12 LULC; 2) socioeconomic data matrix, which also considered the municipalities belonging to each one of the parks × 20 socioeconomic descriptors of local populations. We have, therefore, a total of 30 data matrices.

Data matrices providing information on the temporal evolution of LULC of each natural park were analysed using Principal Component Analysis (PCA) (Fig. 2). This analysis provides the main trends of land-use variation in the territory in each period studied. Hence, 13 PCAs were carried out considering the temporal dynamics of land-uses in each park (matrix dimensions: number of municipalities in each park × 12 land-uses × 2 time periods). The PCAs were of the Pearson type (n) and were performed using the XLSTAT statistical package. Factor loadings of the initial sets of descriptors in the main axes of the PCAs allowed identifying the indicators of protected rural landscapes and their changes over time.

To identify the key indicators of the local socioeconomics of each NP and their dynamics of change, we took as a reference the socioeconomic driving factors detected on a regional scale (Fig. 2). At this local level, the statistical significance of the magnitude of socioeconomic change in response to the established protection status was calculated using Student's *t*-tests.

Results

Implications of land protection on social-ecological change of the landscape. Regional scale

Figure 3 shows the spatial projection of land-uses before and after the establishment of the NP network. The geostatistical process developed to calculate the similarity between the LULC maps of the regional

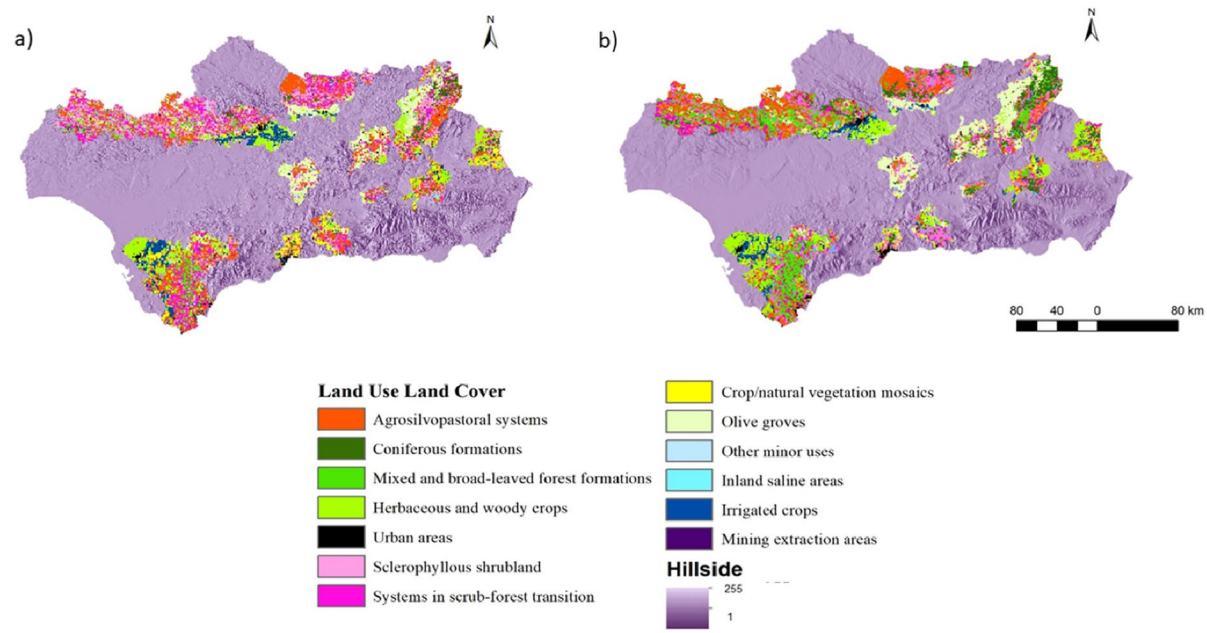

Fig. 3 Mapping of land-uses of the study area before and after the establishment of the Natural Park network. **a** 1980–1999 period; **b** 2000–2020 period

network in the two time periods considered resulted in a correlation value of 0.33. This low value reflects an important spatial–temporal change experienced by the territory linked to its protection, indicating the dissimilarity and independence of the two temporal moments studied.

The detailed analysis of the dynamics of change in land use over time highlights the important, and statistically significant, increase of forest systems, both coniferous formations and broad-leaved and mixed forests. (Fig. 4). Conifers show an increase of 98.74% in relation to their abundance values prior to the declaration of the park network, doubling their area throughout time (ratio: 1.99). In the case of broad-leaved and mixed forests the increase of their abundance was 200.21%. These systems have tripled their area from the first to the second period studied (ratio: 3). Crops have also increased significantly, reaching a variation of 37.95%, and a ratio of increase in area of 1.38. The variation of olive groves and urban areas do not present statistical significance (increase of 17, 90%, ratio: 1.18 and increase of 6.15%, ratio: 1.06, respectively). On the other hand, a significant decrease in agrosilvopastoral systems and scrubs in transition to forest can be seen over time. The reduction of these systems reaches values of − 32.55% (ratio: − 0.68) and − 57.78% (ratio: 0.42), respectively. Another traditional land-use in the study area that has suffered a drastic and significant decrease is interior salt pans, with a decrease close to 100% (− 99.99%, ratio: 8.1×10^{-5}). The decrease detected in the area dedicated both to mining (− 77%, ratio: 0.23) and sclerophyllous scrub (− 31.10%, ratio: 0.69) are not statistically significant.

By analysing the demographic descriptors and socioeconomic sectors of the study area before and after the PA establishment, we were able to identify the main drivers of socioeconomic change in the PN network (Fig. 5). At this scale, after land protection, stand out as the main drivers of change in the agricultural sector: the decrease in the area of land dedicated to agrarian systems, the decrease in small-sized farms (0.1–10 ha) and the increase of those larger than 50 ha (Fig. 5a). In the livestock sector there has been a significant decrease in the number of sheep, cattle and pigs and an increase in the number of equine and poultry farms. The decrease in pig farming is the most important driver of change in this sector (Fig. 5b). In the services sector, there was an increase in all the variables after the land protection

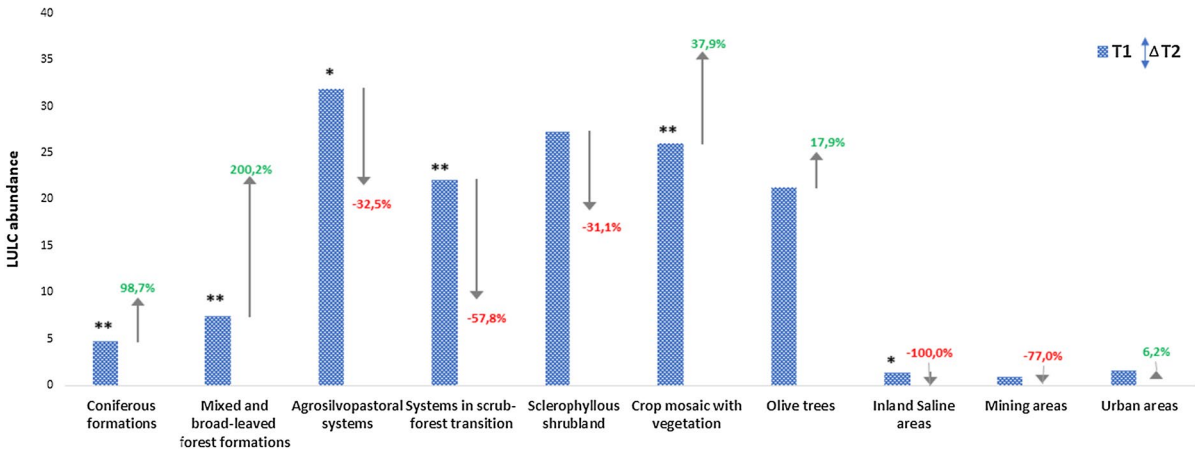

Fig. 4 Increase in the main land-uses, expressed as a percentage of change, in the Natural Park network of Andalusia. For the analysis, the periods before and after the declaration of protected landscapes were considered. Statistical significance of change is indicated by asterisks (*two-tailed p-value < 0.05; **two-tailed p-value < 0.01)

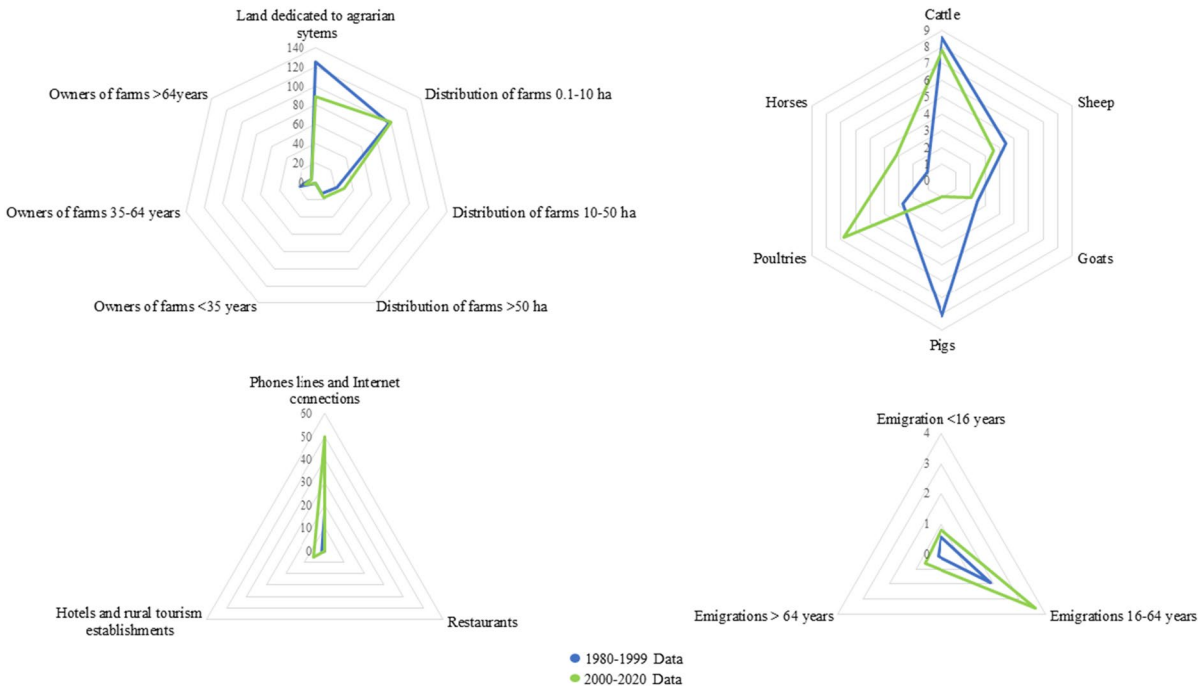

Fig. 5 Socioeconomic evolution of the study area on a regional scale. Identification of the main drivers of change in the agricultural (**a**), livestock (**b**) and services (**c**) sectors, as well as population dynamics (**d**)

status, highlighting the number of telephone lines and Internet connections as the most relevant indicator of change (Fig. 5c). Regarding the demographic dynamics of the region, we observe a notable increase in emigration associated with the establishment of the NP network, especially highlighting the emigration carried out by the working-age population (age range between 16 and 64 years). (Fig. 5d). The graph does not consider the population density of the NP

network, characterized by a slight downward trend with some local increases of little significance.

Identifying social-ecological tendencies and key indicators of local change in protected landscapes. Local Scale

The PCAs carried out on the land use data matrices in the periods before and after the declaration of each NP have allowed us to identify the main landscape change trajectories in each of them. In all the cases analysed, the variance explained by the first axis of the PCA was greater than 30%, so we have considered this dimension to synthetically explain the main variation in rural landscapes as a consequence of their protection (Arnaiz-Schmitz et al. 2018b; Schmitz et al. 2021).

Figure 6a and b show the distribution of the municipalities of each NP along the PCA-axis 1 calculated for each case. Online Appendix 2 includes both the

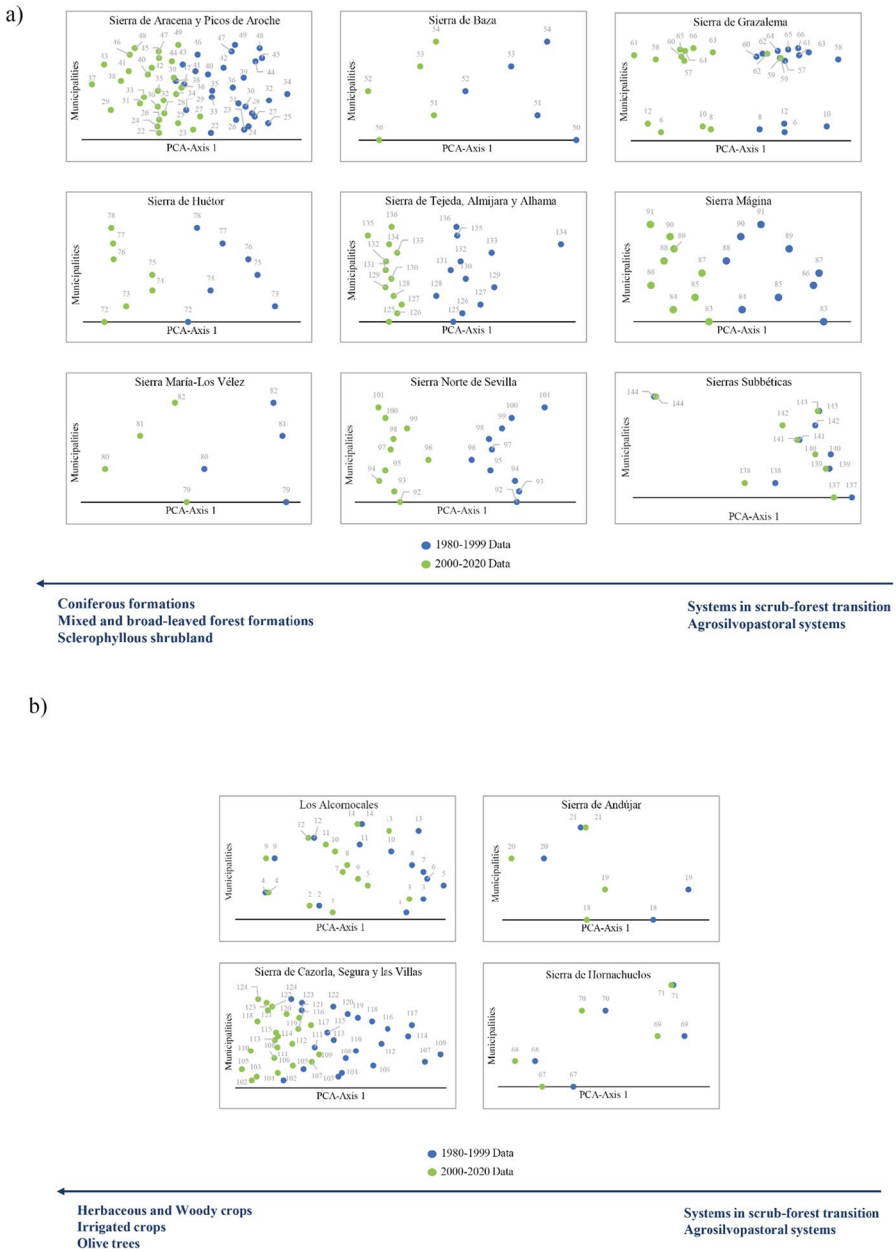

Fig. 6 Analysis of the landscape at a local scale. Change of coordinates of the municipalities of the study area of each one of the selected natural parks along the PCA-axes 1. The position of the municipalities before and after the establishment of the parks is shown. In each case, the main indicators of land use change are indicated at the end of the axes. Arrows show the direction of landscape change after protection. **a** Set of parks characterized by the abandonment and scrub encroachment of agrosilvopastoral systems and their transformation into forest systems; **b** set of parks characterized by the abandonment of agrosilvopastoral systems and their transformation into arable lands. Municipal codes are indicated in Online Appendix 1

variance absorption values of the PCA-axis 1 and the factor loadings of the LULC descriptors in each park. The highest values of the factor loadings at the positive and negative end of the axes have allowed us to identify the land uses that are indicators of the change that occurred in each of the landscapes studied. The projection of the observations (municipalities) only on the first axis of the PCA has allowed us to express a high percentage of the total variability of the original multidimensional data matrices and highlight the main variation trends of the data subsets corresponding to the NPs studied. The procedure followed has also made it easier for us to make a simple comparison of the most relevant changes experienced by the different protected landscapes under the NP category.

The results obtained reveal the state of degradation of rural landscapes prior to their declaration as NPs. The LULC identified as indicators of change, based on their factor loadings, have allowed us to recognize the process of abandonment of traditional uses and activities, mainly agrosilvopastoral systems, with evident signs of scrub encroachment. From the establishment of the network of natural parks we can identify two main trends in landscape change: Landscape change (1) Increase in the process of abandonment of agrosilvopastoral systems and other traditional uses, such as saline grasslands or mountain olive groves that characterize the landscape of some of the NPs studied (e.g. Sierra de Baza and Sierras Subbéticas, respectively). The analyses carried out clearly show the transformation of the traditional rural landscape structure towards an eminently forested and naturalized landscape (Fig. 6a). Thus, coniferous formations and mixed and broad-leaved forests predominate after the land protection (Sierra de Huetor, Sierras de Tejeda-Almijara-Alhama, Sierra de Baza, Mágina; Sierra de Grazalema and Sierra María-Los Vélez). It also highlights the evolution towards forest expansion of areas in which the processes of rural abandonment and scrub encroachment were already evident at the time of their protection, characterized by systems of sclerophyllous scrub and scrub in forest transition (cases of Sierra Norte de Seville and Sierra de Aracena-Picos de Aroche); Landscape change (2) Transformation of traditional land-use systems into arable lands (Fig. 6b), mainly irrigated crops, herbaceous and woody crops and olive groves (cases of Sierra de Hornachuelos, Sierra de Andujar; Sierras de Cazorla-Segura-Las Villas and Los Alcornocales).

In order to quantify the influence of the establishment of the park network on the local socio-economy, we have analysed the dynamics of each NP considering the main drivers of socioeconomic change previously detected on a regional scale. We have been able to observe that, in accordance with the regional trend, in the agricultural sector the key indicators of change are both the decrease in agricultural land area and the number of small farms, as well as the increase in the number of large farms (> 50 ha) (Fig. 7a, b, c, respectively). The decrease in livestock in all the parks is noteworthy, especially pigs, one of the main traditional extensive productive uses in the study area (Fig. 7d). In some parks this decrease has been drastic (Sierra de Aracena-Picos de Aroche and Sierra Norte de Sevilla), and has been completely lost in others (Sierra de Baza, Sierra Mágina and Sierra María-Los Vélez). The emigration of working-age population proves to be a key indicator of the social reality of the local populations that inhabit the parks studied. In all of them, the emigratory flows of the active population have increased over time, evidencing the weakness of the rural labor markets linked to protected areas (Fig. 7e). Regarding the service sector, all the indicators of change considered show notable increases over time (Fig. 7f, g, h).

Discussion

Rural cultural landscapes have a high conservation value that is closely linked to the maintenance of traditional agrarian systems and associated farming practices, which are beneficial to the maintenance of the diversity and resilience of ecosystems (van Oudenhoven et al. 2011; Plieninger and Bieling 2013; Agnoletti 2014; Lomba et al. 2020; Schmitz et al. 2021, among others). In this sense, the valuation and conservation of rural landscapes should be a pressing concern. However, in Europe, despite the rich heritage of its rural landscapes, the trends of social and economic changes have favoured both the abandonment and the industrialization of the landscape. These processes are linked to the globalization of agriculture, the decline of rural social and economic conditions and the consequent migratory fluxes of rural population to the cities, which have left rural landscapes in a vulnerable position (Antrop 2006; Plieninger et al. 2006; Schmitz et al. 2012; Agnoletti

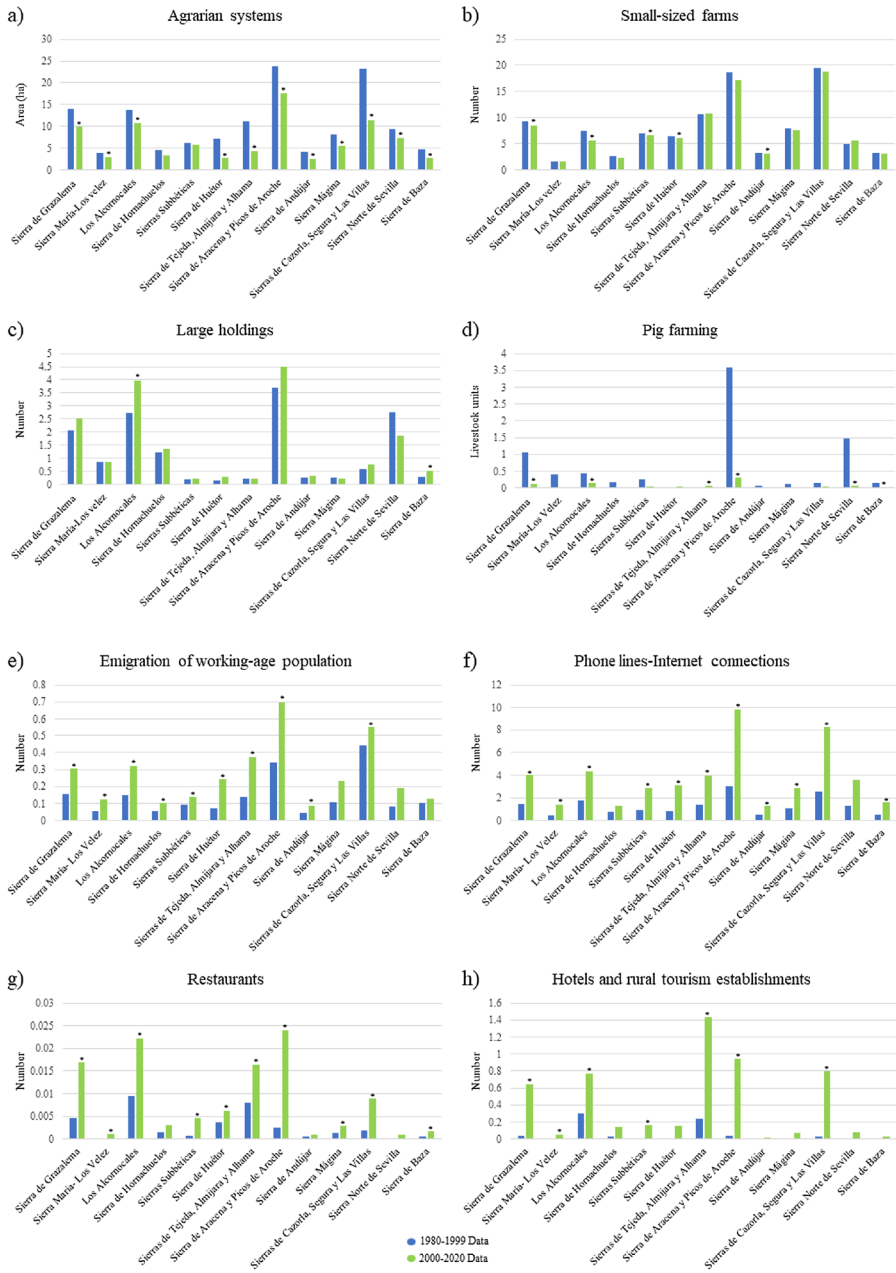

Fig. 7 Local socioeconomic dynamics. Identification of key indicators of socioeconomic change after landscape protection. Statistical significance of change is indicated by asterisks (*two-tailed p-value < 0.05)

2014; Vizzari and Sigura 2015). Essential to understand these changing land trends is the notion of rural cultural landscapes as coupled social-ecological systems, whose integrity and resilience depend as much on their social, economic and ecological dimensions as on their interactions (Gunderson and Holling 2002; Arnaiz-Schmitz et al. 2018b).

PAs are the cornerstone of conservation efforts. They are considered one of the key strategies to prevent habitat degradation, biodiversity decline and alteration of ecological processes (Bruner et al. 2001; DeFries et al. 2005; Nelson and Chomitz 2011). The establishment of some categories of PA networks aims to protect rural landscapes by stopping and avoiding the processes of transformation, degradation and neglect that affect them. For this purpose, PAs planning and management must be adequate and effective. However, numerous studies carried out in

recent decades show that land-use change inside PAs can be similar to that observed outside their boundaries and question the effectiveness of PAs for the conservation of nature and biodiversity, especially in the conservation of the heritage of cultural landscapes and their valuable biocultural diversity (Agnoletti and Rotherham 2015; Marull et al. 2015; Arnaiz-Schmitz et al. 2018a; Voronvecii 2018). All of this evidences that the mere establishment of PAs may not guarantee effective protection.

In this paper we analyse the effectiveness of the conservation strategies of a PA network from a social-ecological approach, considering a combination of ecological, social and economic dimensions. For this purpose, we have designed an easily replicable methodological procedure that has allowed us to quantify the evolution of the study territory and the degree to which it is affected by the establishment of a network of natural parks. A central challenge of social-ecological analysis is the possible spatial and/or temporal scalar mismatch between ecological processes, human drivers, and the data that represent them (Steger et al 2021). Here, we examine the change dynamics in the study area at the regional and local scales. Our outcomes indicate the existing coherence between both scales. Municipal-level has proven to be an effective local analysis scale, with an adequate spatial resolution to incorporate the human drivers of change in the modelling of the landscape-socioeconomic interactions. The limitation in the applicability of the developed method is inherent to the availability in each territory of the databases and cartography necessary to have adequate and reliable land-use and socioeconomic descriptors.

Our findings indicate that current conservation efforts in the PA network studied, both at a regional and a local scale, have tended to underestimate rural landscapes in favour of natural ones and have not been able to fully prevent the processes of abandonment, degradation and loss of rurality of protected landscapes. In the stages prior to their protection, the studied rural landscapes, mostly composed of traditional agrosilvopastoral systems, already showed signs of abandonment, denounced by the wide distribution of scrub areas and scrub in transition to forest (Fig. 3a). With the establishment of the PN network, the process of abandonment of traditional rural landscapes continues, which implies in most cases a notable decrease in agrosilvopastoral systems, the consequent scrub encroachment and the forest expansion. Some forest landscapes have also changed in many areas, now characterised by coniferous formations rather than broad-leaved trees. On occasions, the scrub encroachment process of the rural landscape gives way to the transformation of traditional land-use systems into crops (Figs. 6a, b). Therefore, a noticeable simplification of the wide variety of land-use systems and habitats dependent on traditional farming activities is observed. This implies the loss in rural landscapes of both their characteristic multifunctionality (the ability to simultaneously provide multiple ecosystem services) and their resilience to retain ecological functions and processes under environmental changes (Cerreta et al. 2021; Messier et al. 2022). Figure 8 summarizes these two main land-use change tendencies detected in Andalusian rural landscapes under the NP protection category: forest promotion and agricultural transformation.

The rewilding and forest expansion processes identified are often induced and supported by the widespread idea of the transformation and degradation of the territory caused by humans and the need to return to a natural state (Schmitz et al. 2012; Agnoletti 2014). In many cases, even the declaration of protected areas implies the management of an eminently rural landscape, initially valued for its cultural characteristics, according to the concept of naturalness, and transformed into another in which both the ecological dynamics and the natural aspect become predominant (Küster 2004; Agnoletti 2014; Schmitz et al. 2021). Thus, naturalness and wilderness concepts have been widely used as a reference point for the conservation, restoration and management of ecosystems, especially in nature conservation strategies promoted by PA regulatory schemes (Pressey et al. 2015). Among the main arguments against rewilding are the loss of valuable cultural landscapes and high nature value farming systems, the decrease in landscape heterogeneity or the negative impacts on biodiversity and ecosystem services (Conti and Fagarazzi 2005; Corlett 2016; Schmitz et al. 2021, among others).

The conservation guidelines frequently do not contemplate the concept of culturalness (landscapes with culturally modified features and habitats) in land protection processes (Jansen et al. 2009; Vlami et al. 2017). However, the cultural attributes of the landscape, produced by long-term traditional management, are strongly represented in most PAs, as the

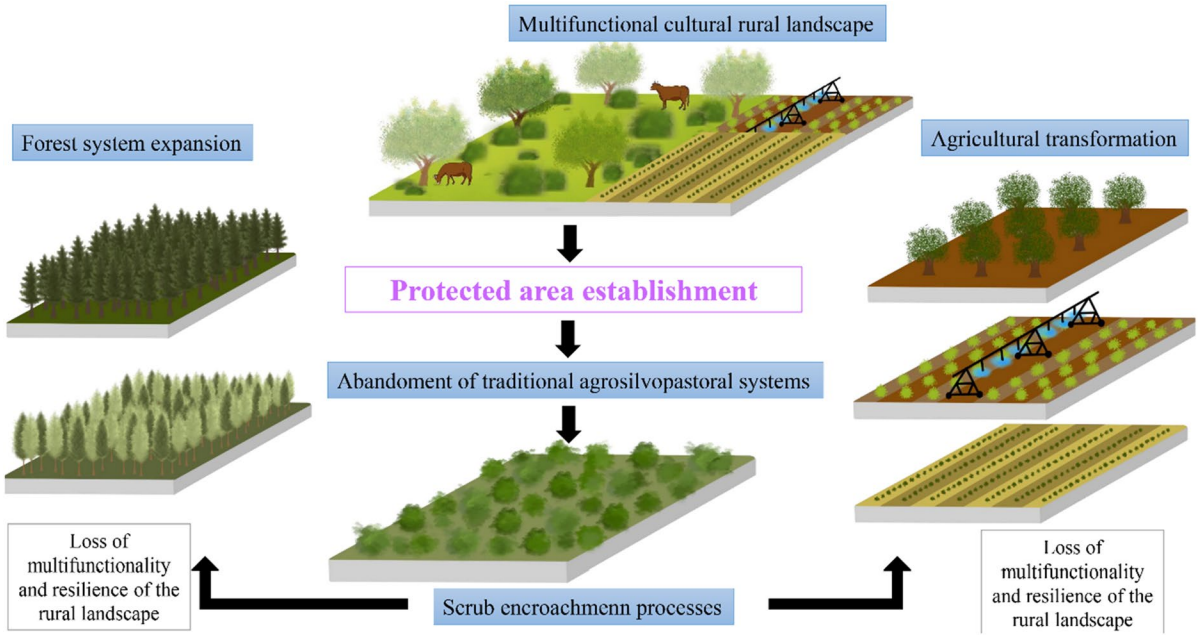

Fig. 8 Explanatory scheme of the main land-use change tendencies detected in Andalusian rural landscapes under the protected area category of natural park: forest expansion and agricultural transformation

legacy of human land use over millennia remains in the spatial patterns of habitats and in the functioning of ecosystems (Foster et al. 2003; Sarmiento-Mateos et al. 2019). For this reason, the nature-culture divide, called "cultural severance" has been described as a serious problem in the conservation of natural and cultural heritage (Bridgewater and Rotherham 2019).

In the study area, both the identified processes of abandonment of the agrosilvopastoral systems and the consequent rewilding, as well as the agricultural intensification, result in a shift from multifunctional to monofunctional land-uses, the degradation of the rural landscape with the decrease in the richness and quality of the ecosystem services provided, the neglect of a valuable cultural and natural heritage and the interruption of the traditional ecological knowledge (TEK); a key process for the maintenance of cultural landscapes (Berkes et al. 1994; Carver 2019). The resilience of rural cultural landscapes has been strengthened by this transmission of empirical knowledge of resource use and, therefore, their loss affects the conservation of biocultural diversity (Loh and Harmon 2005; Heckenberger et al. 2007; Rescia et al. 2009). It is known that for centuries the intangible knowledge and the socioeconomic structure of rural populations have shaped traditional cultural landscapes and their associated high natural value farming systems. Thus, local socioeconomic conditions are essential driving forces influencing land-use changes, since the rural landscape and the underlying socioeconomic components are coevolving systems (Lacitignola et al. 2007; Gual and Norgaard 2010; Ropero et al. 2014).

The main socioeconomic indicators identified, both at a regional and a local scale, highlight the loss of the rural character of the protected landscape. This process is characterized by the aging of the rural population, the out-migration of working-age population and the significant reduction in agricultural area and small-sized farms, while the area occupied by large farms has increased. In traditional Mediterranean landscapes, farm units are often managed by smallholders. The progressive degradation and marginalization of the rural landscape and the associated deterioration of environmental and social conditions are factors correlated with the increasing land abandonment of smallholder farming over the past decades (Schmitz et al. 2012; Lasanta et al. 2017; Lomba et al. 2020). European statistics indicate that in recent years small-scale farming has declined and has been

replaced by large industrial agriculture. In general, this situation responds to the distribution of EU subsidies, based on the agricultural area under cultivation and which mainly favours large-sized holdings (Heider et al. 2021).

Along with the decrease in small farms and the agricultural area, other socioeconomic indicators recognized as factors affecting land-use stand out. This is the case of the increase in rural out-migration (Lambin et al. 2001) and the decline of traditional livestock farming, a key socioeconomic indicator in the study area. Both indicators are related to the abandonment of traditional rural livelihoods (Robson and Berkes 2011). In this socioeconomic context, the degradation of the rural landscape continues to advance and benefited scrub encroachment and forest expansion processes (Petanidou et al. 2008; Bugalho et al. 2011; Pallota et al. 2022). It is undoubtedly a trend associated with the commented reduction of traditional low-intensity agrosilvopastoral uses and practices in favour of woodland and forest and also their replacement by intensive exploitation systems. The observed loss of rurality is also related to the development of the service sector, which has important ecological, social and economic consequences in the rural landscape (Schmitz et al. 2012; 2021).

The described process of protected rural landscape change is assisted both by social and economic driving factors and by the lack of political and economic support for the rural population, which hinders the profitability of traditional agricultural practices (Plieninger et al. 2006; Ruiz-Labourdette et al. 2010; Hodge et al. 2015). Therefore, the implementation of integrative models, such as the one developed here, are necessary and useful to understand the social-ecological feedback that regulates land-use changes (De Aranzabal et al. 2008; Lambin and Meyfroidt 2010).

Conclusions

The complexity of the social-ecological interactions inherent in historic rural landscapes and the ecosystem services they provide give them a high natural, cultural and heritage value. In this study, the dynamics of rural landscapes after their protection under the category of Natural Park have been analysed, identifying the main social-ecological indicators of the change occurred. The results obtained at different spatial scales show that the protection of rural cultural landscapes through the establishment of a NP network have not prevented the loss of multifunctionality and resilience of the rural cultural landscape. In the study area, this landscape degradation has been mainly characterized by the decline of traditional agricultural systems of high natural value and the consequent forest expansion and rewilding processes through land abandonment.

The conservation efforts of rural landscapes through the declaration of PA, contradictorily, can compromise their future due to a reductionist approach focused on the land management according to the concepts of naturalness and wilderness. However, the consideration of rural landscape culturalness is necessary to promote landscape management and conservation from a holistic social-ecological perspective. Maintaining the diversity of traditional land uses and practices and the complex and close interrelationship between humans and cultural landscapes are probably better benchmarks for managing areas with a long history of human influence than the criteria of naturalness that are often applied. For this reason, it is important not only to establish extensive PA networks, but also to adapt their policies and regulatory schemes to the characteristics and history of the territories to be conserved.

Effective management of PAs also implies the existence of a favourable socioeconomic context. PA regulation that frequently restricts or inhibits rural activities generates serious damage to the socioeconomic structure of rural communities, compromising opportunities for sustainable local development, quality of life and social well-being of local populations. The future success of the conservation of rural cultural landscapes depends on the capacity of public policies and society to understand, support and use traditional ecological knowledge and beneficial agricultural practices for the maintenance of biocultural diversity and social-ecological resilience of protected landscapes.

The method developed, based on a social-ecological approach of spatial and temporal scalar dynamics, has proven to be a useful tool to assess the effectiveness of PAs in the conservation of rural cultural landscapes and their resilience.

Author contributions MV: performed the data collection; CA-S and MV performed the data analyses and wrote the methodology; MFS, MV and CAS developed the study conception and design; MFS, MV and CAS wrote the paper. All of the authors read and corrected the paper and gave their final approval for publication.

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Data availability The datasets analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare no conflict of interest or competing interests.

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