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Planning restoration in a cultural landscape in Italy using an object-based approach and historical analysis

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Abstract

We present a proposal for a standardized method to develop restoration practices capable of increasing the efficacy of landscape management and create the necessary bridge between restoration planning and landscape ecology. This methodology was developed in order to identify the reference landscape and to define areas within that landscape that possess different degrees of potential for restoration purposes in a cultural landscape. We utilized retrospective data to compare former ecosystem arrangements, taking into account ecological, spatial and temporal issues, such as historical information on changes in land use, in addition to diachronically analyzed aerial photos taken between 1954 and 2002, using an object-based approach. The test area is a Nature Reserve in Tuscany (Italy) that preserves the cultural landscape of *biancane* badlands – erosion forms generated on Plio-Pleistocene marine clay outcrops – which is characterized by a high erosion rate. In the first step, a land cover map was obtained by image segmentation on the 1954 photographs and the patches classified as "target habitats" were used as a selection mask on the 2002 image. As a second step, a more detailed land cover map was created for the areas selected as masks in the previous step. Hence, the target habitats that showed stability (persistence) between the two dates were excluded from the analysis, as well as the land cover classes not suitable for restoration (broad-leaved forests, arable land, artificial and other agricultural areas). The selected sites, covered by four vegetation types in the 2002 land cover map, accounted for approximately 91 ha. The method focuses on selecting sites for restoration in order to reduce efforts and negative impact and to maximize the restoration results.

Keywords: *Biancane* badlands; Erosion management; Image object approach; Landscape diversity; Prioritization methods; Restoration ecology

1. Introduction

From a European perspective on nature conservation, cultural landscapes created by low-intensity farming contain a mosaic of significant wildlife habitats (Antrop, 2005; Moreira et al., 2006). The recent abandonment of traditional management techniques in favour of the intensification of agriculture is quickly reducing the amount of traditional cultural landscape units within the landscape matrix, producing an overall homogenization of the landscape (Vos and Stortelder, 1992; Debussche et al., 1999; Stoate et al., 2001; Van Eetvelde and Antrop, 2004; Antrop, 2005). The loss of the traditional state of dynamic equilibrium between human intervention and natural dynamics (Mazzoleni et al., 2004; Tatoni et al., 2004; Romermann et al., 2005), accompanied by the regeneration of natural systems (e.g. shrub encroachment), has direct implications on biodiversity (Svenning, 2002; Mac Dougall et al., 2004; Naveh, 2005; Vandvik et al., 2005; Rocchini et al., 2006). As a result, both scientists and the public are calling for restoration action.

For cultural landscapes the choice of the reference landscape can be highly arbitrary (Aronson and Vallejo, 2005). We define reference landscape as the reference system that helps identify restoration targets (Moreira et al., 2006). White and Walker (1997) identify different types of reference for ecosystems combining space and time, which are also applicable to

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landscapes: in this paper we refer to a "same place, different time" type, where integrative research on land use changes can inform landscape restoration (Moreira et al., 2006). Hence, temporal transformation and environmental heterogeneity need to be considered to define the reference landscape and identify sites in which different management techniques can be tested (Bell et al., 1997; Briske et al., 2003; Freckleton, 2004; Lane and LeJeune, 2005; Moreira et al., 2006). To establish a reference landscape it is crucial to locate its corresponding period of origin: historical information such as early cadastral documents and aerial photographs can be used to characterize the local landscape's historical range of variability (Antrop, 2005; Käyhkö and Skånes, 2006). A comparison between the current state and the range of variability can then be used to prioritize restoration objectives (Swetnam et al., 1999; Mac Dougall et al., 2004) and guide restoration efforts.

In restoration ecology, the selection and prioritization of sites for restoration is a major issue (Chapman and Underwood, 2000; Society for Ecological Restoration International Science and Policy Working Group, 2004). The prioritization of sites for the restoration of cultural landscapes is particularly sensitive because of the restricted availability of land due to agriculture and urban expansion. When dealing with cultural landscapes, a strict ecosystem restoration approach has limited application (Aronson and Vallejo, 2005; Moreira et al., 2006). Moreover, restoration of the disturbance regime may be critical, considering that management techniques that fight against successional trends (i.e. shrub encroachment) are far less likely to succeed than those that work with them (Bakker and Berendse, 1999; Young et al., 2005). Despite the fact that an inadequate site selection can result in restoration failure and wasting limited financial support (Russell et al., 1997; Moerke and Lamberti, 2004), few papers specifically address this issue (Palik et al., 2000; Burnside et al., 2002), except perhaps for wetland restoration (Kentula, 1997; Russell et al., 1997; Pieterse et al., 2002). The objective of our study is to identify a method for applying restoration principles to a cultural landscape, defining the reference landscape and delimiting areas with different degrees of potential for restoration purposes, taking into account spatial and temporal issues.

As Geographic Information Systems (GIS) and landscape pattern analysis are increasingly being incorporated into ecological management to support decision making (Freckleton, 2004; Romero-Calcerrada and Perry, 2004), the need for rapid mapping operations is increasing continuously. Object-oriented approaches (e.g. image segmentation) can assist the development of methods for selecting areas to be prioritized for restoration purposes, since they act on images using a predefined, and thus repeatable, algorithm (Blaschke and Strobl, 2001; Burnett and Blaschke, 2003; Laliberte et al., 2004; Schiewe and Ehlers, 2005; Langanke et al., 2007). The objects obtained, namely the "patches" in landscape ecology (Devereux et al., 2004), are readily available at multiple scale, allowing consistent and fast definition of sites, minimizing time and costs.

We present a case study on the use of historical information, present day observation and an object-oriented approach to select sites where non-recurring disturbances (e.g. bush clearing and small-scale fires) are expected to promote a controlled increase of the erosion rate, hampering the natural vegetation growth. The test areas are *biancane* badlands ecosystems, a traditional cultural landscape in Tuscany, central Italy.

2. Materials and methods

2.1. Study area

Lucciola Bella Nature Reserve (1165 ha, N43°02′00″, E11°44′50″, Datum WGS84) is located in the Val d'Orcia (Tuscany, central Italy, Fig. 1), a tectonic depression filled with sea sediments during the upper Pliocene (Calzolari and Ungaro, 1998). Elevation ranges from 320 to 680 m asl and the climate is sub-humid, with a summer drought. Mean mid-summer temperature reaches 24–25 °C and falls to 5–6 °C in January (Barazzuoli et al., 1993). The mean annual rainfall is 700–800 mm, peaking in October–December. The soil moisture deficit is around 200 mm/annum (Robinson and Phillips, 2001). The erosion rate is estimated as 2–3 cm/year (Alexander, 1982), but a 100-fold increase is reported after the removal of superficial soil (Bazzoffi et al., 2003). The prevailing land use is arable cultivation for durum wheat. The vegetation of the badlands is mostly influenced by human activity and erosion processes (for a brief review, see Chiarucci et al., 1995; Maccherini et al., 2000).

Fig. 1. Lucciola Bella Natural Reserve is located in the Val d'Orcia (Tuscany, central Italy): grey dot indicates the study area.

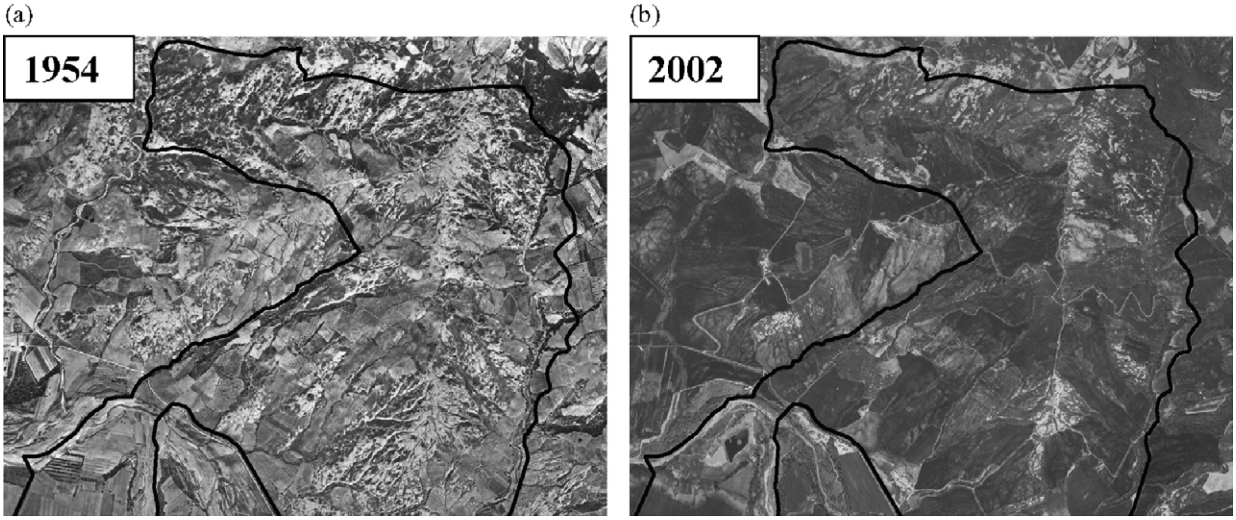

Fig. 2. (a) Aerial photos of the area of Lucciola Bella Nature Reserve in 1954, recognized as the reference landscape; (b) the situation in 2002, in black are the Nature Reserve's boundaries. Land reclamation for arable cultivation and shrub encroachment are evident.

The Val d'Orcia is registered in the UNESCO World Heritage List as a cultural landscape; the Reserve, part of the Natura 2000 network of special areas of conservation (European Commission, 1992), was established in 1996 to maintain the *biancana* landscape and its priority habitats. The re-vegetation dynamic has recently become evident in the Nature Reserve, threatening the conservation of the cultural landscape and priority habitats and causing the managers of the Reserve to take action. Therefore a restoration plan is needed to control shrub overgrowth: the study area has been included in a conservation project promoted by Siena Province and involving local stakeholders.

2.2. Ecological foundation and selection rationale

Biancane (singular *biancana*) are peculiar erosion forms, generated on Plio-Pleistocene marine clay outcrops, produced by the combined effects of digitate, retreating gullies and pipes, usually grouped together in fields (Figs. 2 and 3). The extreme erodibility of these outcrops is due to a network of tectonic

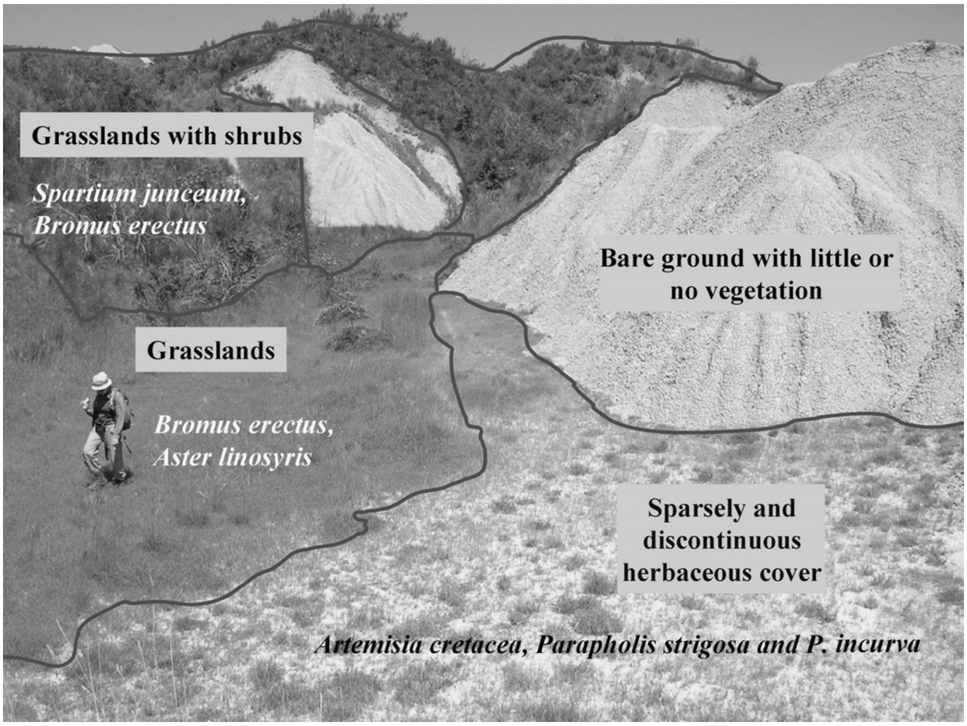

Fig. 3. *Biancane* appear as small dome-shaped hills, not higher than 20 m, generally devoid of vegetation on the southern slope (Val d'Orcia, Tuscany, Italy) with characteristic vegetation types and dominant species.

joints (Colica and Guasparri, 1990; Farifteh and Soeters, 1999), relaxation cracks, weathering rate (Torri and Bryan, 1997) and dispersive sodium (Guasparri, 1978; Torri et al., 1994). *Biancane* fields have traditionally been used as poor quality winter pastures: shrub encroachment was controlled by sheep, cattle and goats foraging, and by burning and cutting. These activities, together with physical features of the substrate and alternation of intense periods of drought and wetness (Guasparri, 1978; Calzolari and Ungaro, 1998), contributed to creating a mosaic of several vegetation types, which were linked to a variety of morphologies resulting from erosion processes (Chiarucci et al., 1995). Over the last 50 years the typical cultural landscape has been progressively transformed through land reclamation for arable cultivation; the main land use change is imputable to the land reforms of the 1950's (Bazzoffi et al., 1997; Phillips, 1998). As in many European cultural landscapes, the major land use modification occurred during the post-war period (Antrop, 2005; Moreira et al., 2006). For this reason, basing the choice on historical information, we established the 1950's condition of the *biancane* fields of Lucciola Bella as the reference landscape (Fig. 2a).

In the 1990s, the high subsidies available under the European Union's Common Agricultural Policy (CAP) for durum wheat (Regulation EEC 1766/92) induced farmers to reclaim further tracts of badlands and almost completely abandon sheep and cattle farming on *biancane* fields: the last scattered *biancane* fields have begun to be overgrown with shrubs (mostly *Spartium junceum* and *Prunus spinosa*).

The *biancane* fields are a dynamic landscape shaped by two major driving forces (Bürgi et al., 2004): an extrinsic one, due to the management practices such as grazing and burning and the intrinsic natural succession that leads from pioneer communities to shrub encroachment.

The surface of the *biancane* on the southern slope is characterized by scanty vegetation, marked soil erosion and mass movement (typical clayey Xerorthents, see Chiarucci et al., 1995). The pioneer annual vegetation (i.e. sparse and discontinuous herbaceous cover) occurs on micropediments near the feet of the *biancane* and represents the equilibrium area between plant colonization and soil sedimentation (Fig. 3). This vegetation, mostly composed of miohalophytes, is closely related to the environmental characteristics, such as high salt content and shallow soils, in contrast to the other plant communities that have higher ecological amplitude (Chiarucci et al., 1995). These characteristics are unfavourable for perennial vegetation such as *Bromus erectus* grasslands (Maccherini et al., 2000). The reduction of erosion processes, due to vegetation dynamics and shrub encroachment, induces a loss of bare ground and pioneer vegetation, promoting other vegetation types.

By promoting a controlled increase of the erosion rate in selected sites, in which appropriate experimentation can be conducted, we can positively interfere with natural vegetation processes. However, it must be stressed that the *biancana* landscape is very fragile. Interactions between vegetation, soil and erosion processes are quite complicated: a long wet period, with snow and snow melting, can trigger superficial mass movement that can remove the soil and accelerate erosion. On the other hand, violent storms have a stronger impact on eroded spots, while joints, relaxation fissures and shrinking–welling cracks act as runoff sinks, bringing water to pipes. The only factor contrasting erosion is the relatively slow pace at which the water front penetrates the still scarcely weathered rock (Torri et al., 1994, 2002). Vegetation facilitates water infiltration and leaching of sodium: this stabilizes the topmost centimeters of soil but at the same time allows more water to reach the pipe system. Disturbing the existing vegetation can trigger a series of feedbacks that must be monitored carefully. If the target is rejuvenation of the cultural landscape by means of managing the erosion rate in such a dynamic environment, sites must be selected with caution. The precautionary principle suggests that one should start with a small sector of the areas defined as suitable for restoration, proposing *ad hoc* prescribed burns, hand cutting or a combination thereof, in order to create and maintain a certain degree of heterogeneity in the system.

To propose a reliable restoration investment, we defined the sites with the greatest potential for restoration as the areas capable of being re-converted by introducing a low-intensity disturbance, considering ecological evaluations. We focused on transformation of the land cover classes that constitute the peculiarity of the *biancana* landscape (i.e. target habitats): sparsely vegetated areas and *biancana* surface with little or no vegetation. We assumed that introducing disturbance events to sites that were barren and sparsely vegetated 50 years ago would induce a moderate runoff rate, re-establishing the target habitats and, accordingly, restoring the existent landscape to the condition of the 1950's reference landscape.

2.3. Object-oriented approach and land cover map generation

The analysis was based on panchromatic nadir aerial photos taken in 1954 and 2002. The 1954 aerial photos, available at a resolution of 600 dpi, were orthorectified by means of 20 Ground Control Points (GCPs) and a 10 m Digital Terrain Model (DTM), in order to obtain an accurate co-registration with the most recent digital orthophotos available, which date back to 2002. Images were projected into the (Italian) National Coordinate System (Gauss Boaga Projection, datum Roma 40).

Notice that in the case of ortho-rectification (rather than rectification by polynomial functions, rubber-sheeting, etc . . .), a few GCPs should be adequate to approximately correct nadir aerial photos, since inner and exterior orientation information is given (Toutin, 2004; Rocchini, 2004). In other cases (e.g. polynomials) the use of a few GCPs can provide a low root mean square error (RMSE) in a few cases, but as the number of points increases the RMSE should stabilize (Chong and Pearson, 1998; Duggin and Robinove, 1990). Reaching a lower RMSE value is almost impossible, because RMSE is simply sensitive to the function applied (Rocchini and Di Rita, 2005). However the stabilizing error is an iterive process, i.e. as long as GCPs are added error undergoes changes, until its trend reaches an asymptote. In such a case, the operator could not know when this asymptote will be reached *a priori*. For this reason, we first chose 20 GCPs covering the whole photo, ensuring scattering within the photo, without clumping/clustering effects. Then, a DTM with a pixel dimension of 10 m was derived from 1:10000 topographic maps (as suggested by NIMA parameters; Defense Mapping Agency, 1990). Here notice that choosing a final pixel resolution of 2 m is also related to the relative coarseness of the DTM. Finally, commonly used functions first made by Konecny (1979) and then by Novak (1992) were applied within Erdas Imagine 8.5.

Even though we had good knowledge of the area and the vegetation types in the study area, it was difficult to define repeatable rules for the establishment of boundaries between vegetation types. The landscape under study is extremely fragmented and vegetation changes occur in very small spatial lags. In particular, the target habitats (sparsely vegetated areas and *biancana* surface with little or no vegetation) show a contiguous spatial pattern defined by the weathering processes: the erosion, starting on top of *biancane* (bare outcrops) and depositing the sediments on the pediment (sparse annual vegetation, see Fig. 3), creates an adjacency rule (Chiarucci et al., 1995; Calzolari and Ungaro, 1998). Hence, to capitalize on this issue, we adopted an image segmentation technique to generate polygons (image objects) representing patches of different vegetation types (Abeyta and Franklin, 1998; Blaschke and Hay, 2001). The object-oriented approach, as opposed to the pixel-centric approach (see Fisher, 1997 for a critique), emphasizes groups of pixels that are spatially contiguous and spectrally similar. Object-oriented approaches use contextual information and can be adjusted to scale, offering the user polygons generated by segmentation of the original image for interpretation (Blaschke and Strobl, 2001; Benz et al., 2004; Langanke et al., 2007). Due to the different spatial resolution, deriving from different flight heights for the aerial photographs in 1954 ($\sim$2 m) and 2002 ($\sim$1 m), we applied different scale parameters to each image in order to achieve a comparable grain size (i.e. the same Minimum Mapping Unit, MMU), defined *a priori* as 500 m^2 for both maps. A trial and error approach was adopted to empirically define the segmentation rules at multiple scale, thus addressing the problem of analyzing different aerial photographs (1954/2002). The low spectral resolution of the 1954 images allowed us to define polygons, but not to automatically and correctly classify the image (see also Langanke et al., 2007). Consequently, each resulting polygon (image object) was manually classified according to the physiognomic characteristics of the vegetation, also relying on the described adjacency rule for target habitats. For the definition of the land cover classes, we adopted the CORINE (CORdination of INformation on the Environment) Land Cover legend (European Environment Agency, 2000), applying some revisions to describe typical land cover types, such as "*biancana* surface with little or no vegetation" to describe the bare surface of *biancana* (Fig. 3).

Limited to the 2002 land cover map, classification agreement was measured by applying two tests based on 72 field control points (Marignani et al., 2007): the overall agreement (Eq. (1)) and the non-zero Cohen's K coefficient, which takes into account the probability of agreement obtained by chance (see

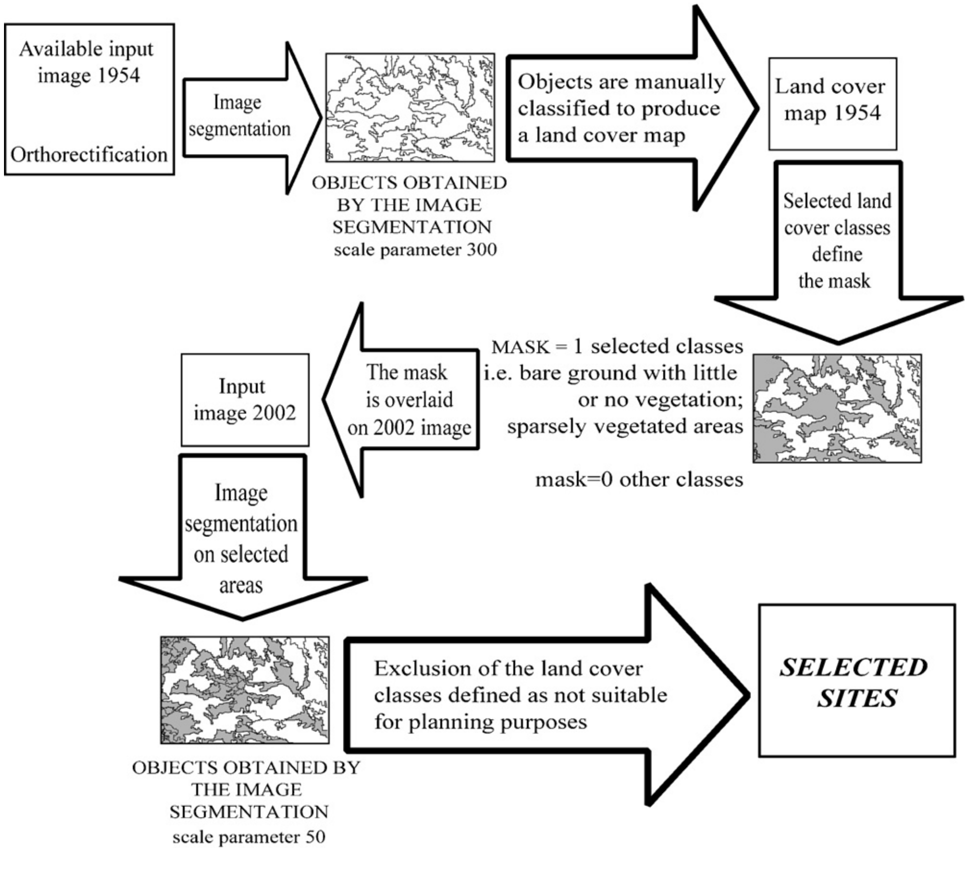

Fig. 4. Site selection method illustrated step by step.

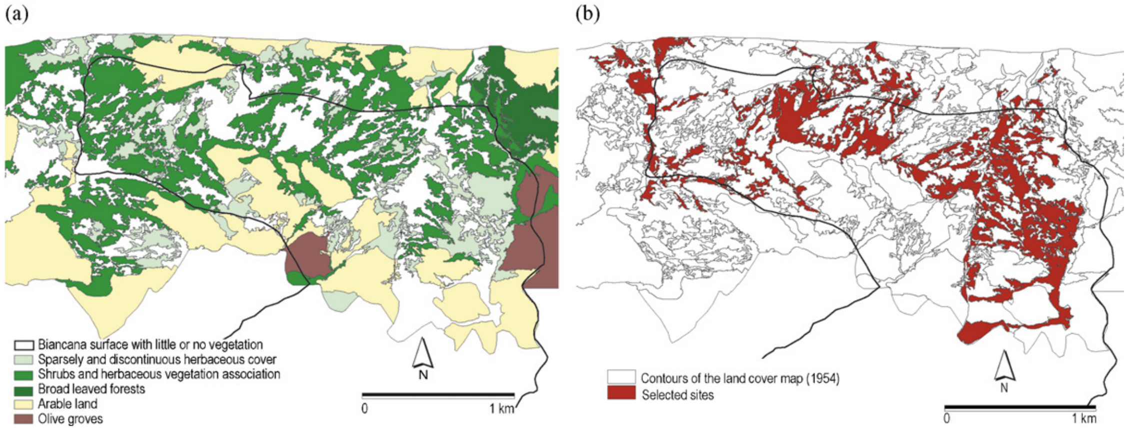

Fig. 5. (a) Land cover map of the area of Lucciola Bella Nature Reserve in 1954, in black are the Nature Reserve's boundaries; (b) map of the selected sites: the dark color defines areas suitable for the reintroduction of disturbance to restore and rejuvenate the *biancana* landscape; the Nature Reserve's boundaries are in black. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Eq. (2) for K calculation) (see Cohen, 1960 for further details and Congalton, 1991 for a comprehensive review of the matter).

$$a\% = \frac{\sum a \times 100}{N} \quad (1)$$

where a is the raw agreement and N is the total number of cases.

$$K = \frac{\sum a - \sum \mathrm{ef}}{N - \sum \mathrm{ef}} \quad (2)$$

where K is the Cohen's K coefficient and ef is the expected frequency of agreement by chance. The index ranges from 0 (no agreement) to 1 (perfect agreement).

2.4. Site selection procedure

The method was decomposed into (a) a segmentation process performed using eCognition software (Definiens Imaging, Munich, Germany) and (b) a classification and post-processing procedure with ARC/INFO software (ESRI) (Fig. 4). Following the image segmentation technique, we first derived a land cover map from 1954 images.

As a second step, we reclassified the 1954 land cover map, according to the rationale of selection, obtaining a mask defined as:

$$\mathrm{mask}_{1954} = \begin{cases} 1, & \text{for land cover class} = \text{biancana surface with} \\ & \quad \text{little or no vegetation; sparsely vegetated areas} \\ 0, & \text{for land cover class} \neq \text{biancana surface with} \\ & \quad \text{little or no vegetation; sparsely vegetated areas} \end{cases}$$

We then overlaid the mask_{1954} on the 2002 images and conducted a segmentation analysis only on those areas where $\mathrm{mask}_{1954} = 1$, obtaining a detailed 2002 land cover map restricted to the areas that in 1954 were covered by sparsely vegetated areas and *biancana* surface with little or no vegetation. In the 2002 land cover map, we adopted a more detailed legend for natural and semi-natural classes than the one used for 1954, allowing a more detailed characterization of land cover. To complete the definition of the selected sites, the target habitats that showed stability (persistence) between the two dates were excluded from the analysis, together with some land cover classes not suitable for restoration (broad-leaved forests, arable land, artificial and other agricultural areas, Fig. 4). In particular, for the areas remodeled to arable land, the results of an investigation indicate that after this reclamation, the soils stabilize as exchangeable sodium levels decrease and this is likely to be an irreversible transformation (Phillips, 1998).

3. Results

3.1. Object-oriented land cover maps

We produced a land cover map of 1954 representing the northern part of the Reserve and a buffer area of about 200 m around the Reserve boundaries, covering 754 ha (Fig. 5a). In 1954, arable land predominated in the territory, covering approximately 30% of the area, followed by shrubs and herbaceous vegetation (23%) and bare weathered outcrop (22%). The areas

Table 1
Transformation matrix 1954/2002 of *biancana* surfaces with little or no vegetation and sparsely vegetated areas

	1954/2002							
	Arable land	Grassland	Grassland with shrubs	Sparsely vegetated areas	*Biancana* surfaces with little or no vegetation	Scrubland	Broad-leaved forests	Others
Biancana surfaces with little or no vegetation	45.5	13.6	10.5	10.0	8.9	8.8	1.8	0.9
Sparsely vegetated areas	42.9	10.1	12.7	4.0	2.6	14.9	11.2	1.6

Data expressed in percentages.

selected, defined as $\text{mask}_{1954} = 1$ and represented by *biancana* surface with little or no vegetation and sparsely vegetated areas, amounted to 245 ha, with bare surfaces covering 68%.

Field validation conducted by high precision GPS surveying (2002 land cover map, 72 random points) corroborated the classification adopted and confirmed the performance of the segmentation process (land cover map overall accuracy was 74%). Cohen's K coefficient showed a value of 0.682819, significantly different from zero ($p < 0.0001$), indicating that agreement was significantly different from a purely haphazard classification.

In 2002, the selected area ($\text{mask}_{1954} = 1$) was massively converted to arable land (45%), while sparsely vegetated areas and *biancana* surface with little or no vegetation accounted for barely 15%. The transformation rate shows the degree of permanence and conversion for each class (Table 1).

3.2. Priority sites for land restoration

The following 1954–2002 transformations were considered as priority sites:

- sparsely vegetated areas transformed by 2002 into grasslands, grasslands with shrubs and scrublands;
- *biancana* surface with little or no vegetation, transformed by 2002 into sparsely vegetated areas, grasslands, grasslands with shrubs and scrublands.

The resulting area occupies about 91 ha (Fig. 5b). The polygons composing the selected area were extremely patchy, according to the distribution of different vegetation types recognized by the segmentation of the 2002 land cover map.

4. Discussion and concluding remarks

4.1. Method assessment

The object-oriented approach adopted in this research appeared to be a reliable tool for performing standardized site selection for restoration with a consistent partition of vegetation types throughout the map. In addition, the object-oriented approach allowed us to coherently integrate historical and spatial information in the selection process. In fact, the analysis of diachronical aerial photos provides an invaluable historic record for monitoring land cover change (Ihse, 1995; Hudak and Wessman, 1998; Antrop, 2000; Goslee et al., 2003; Laliberte et al., 2004; Langanke et al., 2007), as well as providing consistent hints for the selection of target areas for the reintroduction of disturbance (Mac Dougall et al., 2004).

The segmentation technique is particularly efficient for the delineation of image objects, on the strength of the adjacency rule described. Nevertheless, it would require complete unmixing in order to automatically assign classes (Langanke et al., 2007; Small, 2004, 2005; Schiewe, 2005, for discussions on unmixing issues). In fact, while a threshold based on simple variance measures could be performed in order to create boundaries (and thus polygons), major problems would arise when aiming to classify pixels only considering spectral properties (Fisher, 1997; Blaschke and Strobl, 2001; Burnett and Blaschke, 2003; Ivits et al., 2005), even if spectral unmixing is not concerned with the structural properties of the landscape (Feingersh et al., 2007). This could not be achieved using panchromatic images, despite their general quality, due to their low spectral resolution (Rocchini, 2004).

The multi-scale and multi-temporal approach is suitable to different planning situations, including monitoring programs that require detailed and reliable information on land transformation following restoration activities (Chapman, 1999; Langanke et al., 2007). The application of the proposed methodology to different temporal, spatial and spectral resolutions of the images could allow a customized approach to specific restoration and monitoring actions.

4.2. Restoration issues

To plan successful restoration actions it is critical to consider the rate of formation of environmental gradients: if environmental gradients have strong and rapid impacts on species distribution, then the restoration of spatial patterns can be considered as a natural outcome of restoring the appropriate abiotic environment (Seabloom and Van Der Valk, 2003). In this study, the target habitats chosen were closely related to environmental characteristics: the introduction of a controlled disturbance in selected areas should promptly trigger erosion in shallow soils, especially on southern slopes, and consequently generate bare *biancana* surfaces. In addition, periodically or continually disturbed environments are usually colonized and often dominated by annual plants in late successional stages (Symonides, 1988), as in the case of sparsely vegetated areas in the basal micropediment. Following this basic principle, the cutting and burning prescription in small sectors (non-recurring management) can be associated with the reintroduction of grazing (recurring management), also in areas not previously selected during this first survey.

The consecutive monitoring program for impact assessment also relies on the proposed method for unit definition, which would help in the selection of control, reference and restored sites (Underwood, 1997; Chapman, 1999; Chapman and Underwood, 2000).

Recent research on the dynamics of vegetation in Mediterranean landscapes (Traba et al., 2003; Tatoni et al., 2004; Romermann et al., 2005; Vandvik et al., 2005; Rocchini et al., 2006; Maccherini et al., 2007) has led managers to rethink conservation goals. They have begun to prioritize the restoration of open vegetation and cultural landscapes over the maintenance of forests (Aronson and Vallejo, 2005; Moreira et al., 2006). In this context, restoration programs and active landscape management practices are commonly used, but frequently without an adequate planning scheme (Russell et al., 1997; Moerke and Lamberti, 2004). On the contrary, experience with the restoration of a range of habitats has demonstrated that restoration programs need to rely on a coherent and consistent method for site selection in order to have a chance of success (Kentula, 1997; Russell et al., 1997; Palik et al., 2000; Burnside et al., 2002). The method we presented for the *biancane* cultural landscape rejuvenation focuses on the objective of selecting specific areas to introduce a moderate external prescribed disturbance. The work responded to requests by local managers for precise indications in terms of localization and extension of the sites to devote to restoration projects. The objective was the convergence of financial investments for land lease and rights with restoration activities.

The proposal for a standardized method aims to develop restoration practices capable of increasing the efficacy of landscape management (Underwood, 1997; Chapman, 1999; Chapman and Underwood, 2000; Opdam et al., 2001; Leibold et al., 2004) and create the necessary bridge between restoration planning and landscape ecology (Bell et al., 1997). The challenge for landscape managers and planners is to optimize the protection of diversity in a dynamic and multi-use landscape (Fuhlendorf and Engle, 2004; Romero-Calcerrada and Perry, 2004).

Controlled, replicated and manipulative experiments are considered to be a trait of good science and they increasingly represent the standard in ecology (Young, 2000). Ecological restoration is a manipulative activity and explicitly experimental: we need to pursue the opportunities to turn long-term restoration projects into more powerful scientific research (Michener, 1997; Chapman and Underwood, 2000).

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