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Rural landscape planning through spatial modelling and image processing of historical maps

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ABSTRACT

Rural land has been affected over the years by profound, complex and difficult to understand transformations due to natural events, human intervention and changes in natural cycles. Nowadays, the analysis of rural land as well as the environment and landscape is made easier and more complete through the use of powerful and reliable tools; many changes can be considered to be models of territorial development that may prove useful in the appropriate planning of interventions in a rural area. In this paper the land use changes in a rural area located in Southern Italy were analysed by comparing some historical cartographic supports produced by the Italian Geographic Military Institute at different periods over about 160 years with modern maps, in order to evaluate the morphological and vegetation variations of agro-forestry land. The results in terms of landscape modification of the study area show significant changes: the agricultural and forestry land has been affected by deep transformations. Land use and morphological changes at four time steps were conducted through the implementation of digital terrain models, which were enriched by draping land cover pictures over them; these finally enabled an evaluation in a scenic way of the morphological and vegetation variations of the agro-forestry landscape, allowing a virtual jump back to periods when digital aerial photography was not yet possible. Multitemporal analysis with the support of GIS techniques has great potential for assessing and monitoring landscape diversity and typical changes of vegetation and for planning sound interventions in landscape structures.

Introduction

Human activities have imposed a transformation on extra-urban land that may lead to the modification of the frail equilibrium of whole ecosystems. Sound planning strategies should therefore be pursued, employing a multidisciplinary approach that takes into account geographical, environmental and landscape factors as variables interacting among themselves and with social and economic aspects (Tortora et al., 2006). Over recent years different systems have been developed with the aim of providing support to policy makers in the field of agricultural development (Van Delden et al., 2010). According to this scenario, an accurate analysis of the performed variations and the global monitoring of all ecosystems is necessary to propose suitable environmental protection politics (Picuno et al., 2011). The visualization of spatial information in the form of maps is critical to facilitating decision making in environmental management (Iosifescu-Enescu et al., 2010).

Moreover, the technical and spatial analysis methodologies that have been recently developed could ensure both the proper management and planning of land, especially if tailored to environmental protection and to efficient control of the agricultural and forestry resources. Suitable models for policy impact assessment (Brown and Brabyn, 2012) should help harmonize the EU agricultural policies and socio-economic processes at different levels and in different sectors (i.e. local zoning regulations, infrastructure planning and interaction between these sectors) as well as external factors such as climate change and socio-economic drivers (Van Delden et al., 2010). Landscapes are spatially diverse, leading to the unequal distribution of landscape services over an area. An evaluation of the policy effects should therefore be spatially explicit as policies are likely to have a location-specific effect on the provision of landscape services (Willemen et al., 2010). An *ex ante* evaluation of the consequences of spatial planning and policy on the supply of landscape services can support effective decision making (Bockstael et al., 1995; Verburg et al., 2009).

The analysis of the historical landscape and the influential driving factors of landscape development may provide an essential basis for tackling current environmental questions in spatial planning (Haase et al., 2007). The landscape should be understood

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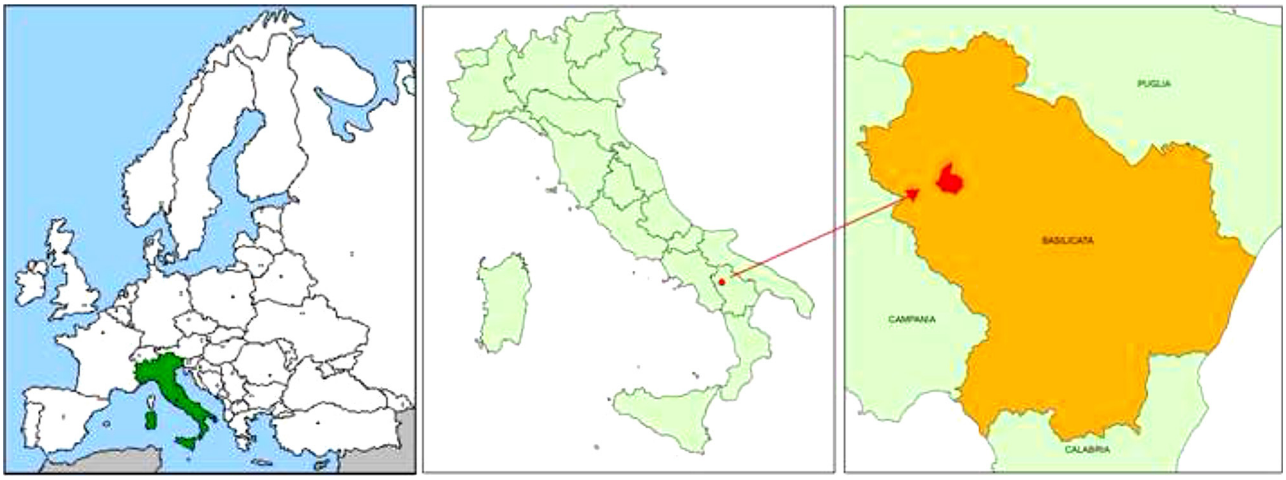

Fig. 1. Map of the study area within the Basilicata region.

as a dynamic and open system where biophysical, social and economic factors interact to define the current structure. The knowledge of historical landscape development ought therefore to be a starting point for long-term landscape monitoring (Neubert and Walz, 2002). In most landscapes, large-scale patterns of geological, topographical and morphological alteration are overlaid by smaller-scale variations in microclimate and disturbance patterns. Landscape processes are nested in a spatio-temporal hierarchy, from large-scale, slow processes like geological change, to smaller-scale, rapid processes like plant competition and succession (Gillson, 2009).

In order to evaluate the processes involved, suitable information about the landscape, the land-use structure and the environment are required. The results of investigating historical developments primarily consist of quantitative, statistical information on land-use change (Pelorosso et al., 2009), which can, for instance, be used for the continuous monitoring of comparable metrics and indices in time series (Geri et al., 2010). The spatio-temporal dynamics of traditional rural mountain landscapes reflect the land use evolution over the centuries resulting from the longstanding interaction between people and the environment, and recent changes due to the impact of population migrations and policies influencing land use (Cullotta and Barbera, 2011). That interaction between man and environment led to the development of traditional landscapes whose characteristics are closely linked to many features of the local geography, climate, water availability, soils and the historical occupation of a region (Pôças et al., 2011). A time series can be used to predict future general trends in the case of assumed constant political and economic frameworks. Scenarios that are generated to make projections of future land-use changes or to identify land-use patterns with certain optimal characteristics are based on narrative story lines that consistently describe the relationships between the driving forces of environmental changes and their evolution (Lambin et al., 2003). In order to generate these future scenarios, the dynamics of urban land use patterns can be "simulated" taking into account the initial state of the system, the participating factors in land-use dynamics, and the rules that produce the dynamics that drive the evolution of actual cities (Barredo et al., 2003).

Regional and local investigations of landscape change (Schneeberger et al., 2007) enable land-use trends and developments to be differentiated by region and hence support analysis of the causes of the changes (Haase et al., 2007). A multitemporal analysis of land, with the support of GIS and historical documents, is very important for monitoring landscape diversity (Yeh and Huang, 2009) and for investigating changes in vegetation and landscape structure (Leyk et al., 2006).

Vegetation plays an important role in human life and economic activity. The economic role of vegetation is dependent on its ecological function, which is of particular importance like determines the top priority of taking them into account in the system of rational nature management. The role of vegetation is directly associated with its specific purpose in addressing the required social and production tasks. It is appropriate to identify the particular roles of vegetation within these groups according to vegetation-specific nature management practices such as conservation, protection and resource management (Belov and Sokolova, 2009). In addition to vegetation, there are other elements that have a correlation with the landscape, such as buildings, which should be appropriately considered in data processing (Picuno, 2012). There is often a difficult relationship between rural buildings and the landscape (Jeong et al., 2012). European landscape planning policy has particular building codes that protect local cultural identity and promote landscape quality (Council of the European Union, 2001).

To understand the territorial and landscape changes that have occurred over the years, especially in Europe, it is important to recognize the limits of expert approaches and to integrate them with the use of various tools (participatory GIS, semi-directed meetings, photo-elicitation, cognitive mapping, etc.), which allow individual evaluations to be established (Domon, 2011). Geographical Information Systems (GIS) are excellent tools for landscape modelling, for knowing about changes of vegetation and conducting three-dimensional analyses. They allow an easy digitalization of geographical information and coverage structure, and they facilitate graphical representation (Hernández et al., 2004). The morphological and vegetation variations of agro-forestry in the landscape may be evaluated through the implementation of a digital terrain model (DTM), over which the land cover picture is draped; further elements can be successively introduced in a rural landscape and may be included with the aim of understanding the changes occurring in the landscape. Spatial data combined with GIS-based modelling and interpretation using detailed digital elevation models (DEMs) and orthophotos are very useful tools as well. Spatial information is, as a rule, visualized using photographic and thematic maps (Batson, 1990; Gehrke et al., 2006). While photographic maps claim to be an accurate reproduction of the original settings, thematic maps portray their content in an abstract form, while the topology of spatial units is maintained (Olbrich et al., 2002). Here, GIS was used to integrate and manage different kinds of data and to create high quality maps that incorporated many

Fig. 2. Historical map of 1848 preserved by a protective film.

other layers of information. Also, orthophotos, maps and models were integrated in a 3D viewer to improve interpretations. Partial results from each approach were coordinated and iterated to obtain the best fitting result (Elez et al., 2013). Strengthened by the knowledge of the importance of time as a dimension, and relying on the advances in the field of cartography and spatial analysis, numerous studies have examined the dynamics generated by the transformation of agricultural or forest exploitation contexts, as much for landscape (spatial composition and organization) as for ecological (in support of biodiversity) reasons (Domon, 2011).

However, specifically during the last two decades, three strong tendencies have led to the relative importance of these resources to local rural economies being questioned. Firstly, the increased mechanization and concentration of exploitation have resulted in a general decrease in the importance of the primary sector (agriculture and forestry) within rural communities, with their socioprofessional structure increasingly resembling that of more urban environments. For a long time the majority group in the rural environment were farmers, but today farmers are generally a minority, even to the point of becoming the orphans of rural-to-urban migration in many countries (Hervieux, 2008). Secondly, and as a consequence, the acceleration in the demise of traditional rural life has distanced individuals from farm work and substantially modified the foundations of contemporary rural landscape appreciation. Thus, while the ability to work the soil and the capacity to produce goods previously formed the basis of landscape appreciation, aesthetic, environmental, and heritage qualities are now pre-eminent factors of appreciation among rural inhabitants. Finally, the last few decades have also been marked by an increase in the mobility of individuals (Domon, 2011).

The aim of the present paper is to analyse land use dynamics and topographic changes over almost two centuries (from 1848 to 2012) by a comparative examination of different historical cartographic supports and more recent maps, in order to obtain conclusions about the changes that have occurred in the rural landscape, their connection to human activities and natural events, and the consequences for the agricultural land and the extra-urban environment.

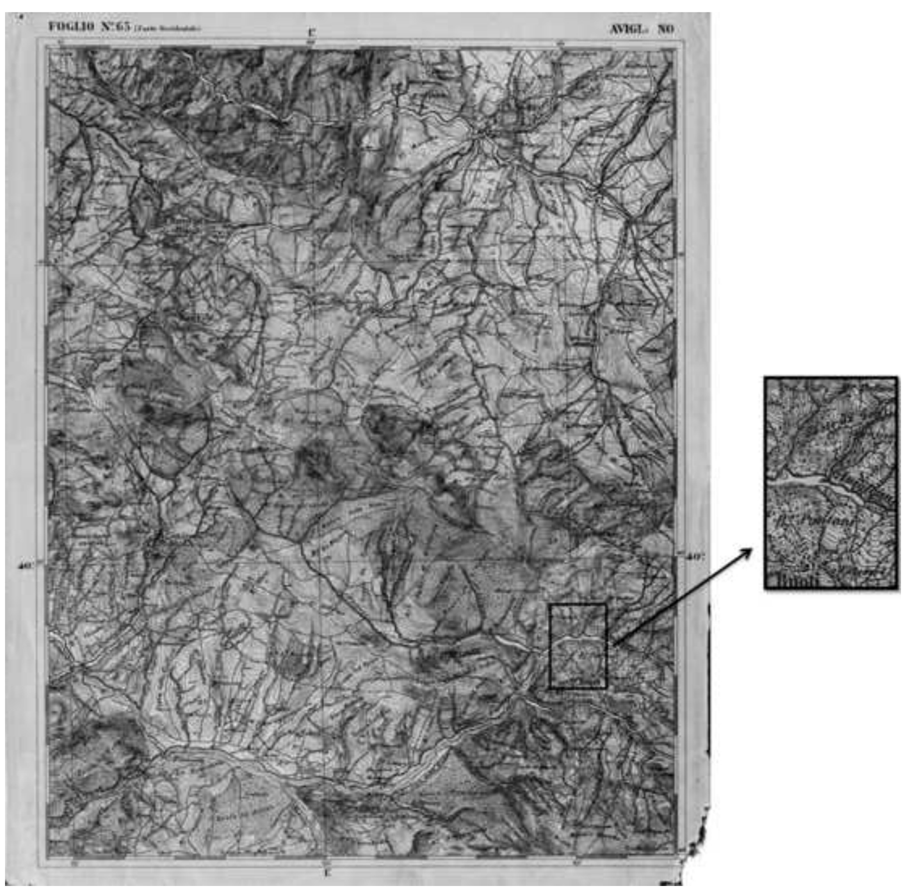

Fig. 3. Cartographic map of year 1877 produced by the ITMI.

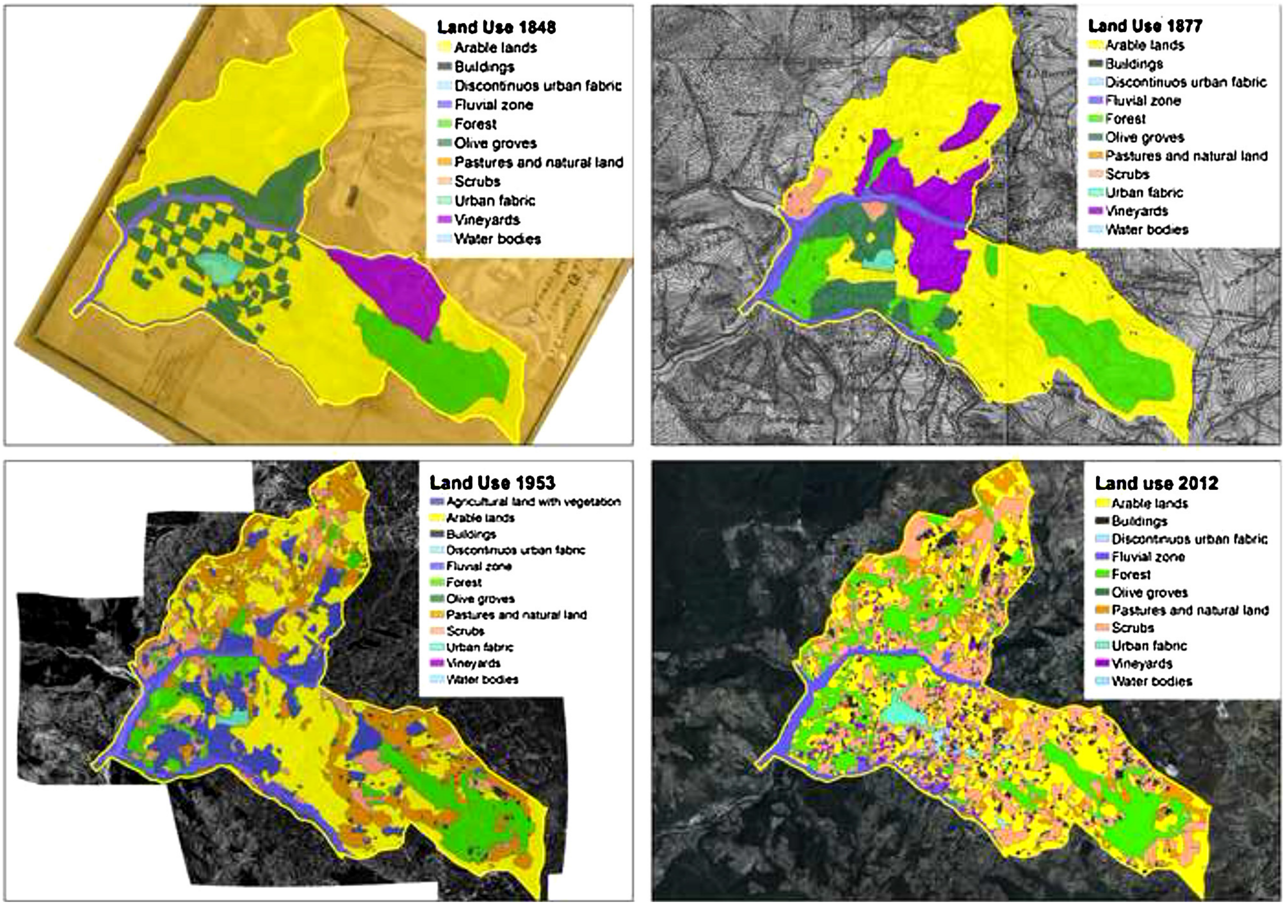

Fig. 4. Land use in different time periods.

Materials and methods

Study area

The study area (about 25 km^2) is a part of the Ruoti Municipality (Fig. 1), located in the central-western part of the Basilicata Region of southern Italy (40°43′05.43″ N, 15°40′32.12″ E). The Basilicata region embodies much of the variability of landscapes found in southern Italy. In addition to the geological variability, the territory of the region has a remarkable morphological variability, with the presence of surfaces dating to very different ages and a great variability of soils that were formed within these environments. This area is characterized by a hilly/mountainous terrain and elevations are in the range 400–1000 m. The rainfall during the year is on average 751 mm. Autumn and winter have a distribution typical of the whole region and the wettest months are November and December, with monthly averages of 97 and 92 mm respectively. The less rainy months are July and August, with 28 and 34 mm respectively. The annual average number of rain days is 98. The average annual temperature is 12.5 °C. The average monthly temperature is lowest in January (3.8 °C). The hottest months are July and August, which record an identical monthly average of 21.8 °C. The thermo-rainfall data show that a period of water shortage affects the region in the months of July, August and a part of June.

The Municipality of Ruoti is characterized by an economy that is mainly based on agriculture, but some industrial activities are present. Cereal crops are widespread, as well as herds of sheep and goats, and whose milk gives excellent cheese. Wheat, fodder and vegetables are grown, and there are olive groves, orchards and vineyards, the latter producing the well-known *Asprino* wine. The industry is mostly aimed at the food sector, the main product being milk.

Ruoti is a centre of ancient origin, dating back to pre-Roman times, as demonstrated by a series of finds. The territory has been subjected over the centuries to domination by different groups, as evidenced by historical and architectural finds such as churches and monuments.

Morphology

This area includes two fundamental complexes, one limestone and dolomite (carbonate series), and the other is largely terrigenous and defined by flysch. The geomorphological features of this area are related to the character of the outcrops. However, the geomorphological survey has also shown the presence of several landslides along the slopes. The hydrogeological instability is caused by three main factors interacting with each other:

- steepness of the slopes, due to the action of superficial incision of the river system;
- decay of the mechanical properties of soils, a consequence of the history of geological–structural and lithological units outcropping; and,
- fluctuations in the groundwater due to the amount of precipitation.

Hydrography

The study area is crossed by the *Fiumara di Avigliano* and is bounded in the south by the *Fiumara di Ruoti.* Both rivers are part on the hydrographic basin of the River Sele, interesected in the mountainous west-central region by approximately 833 km^2 of the

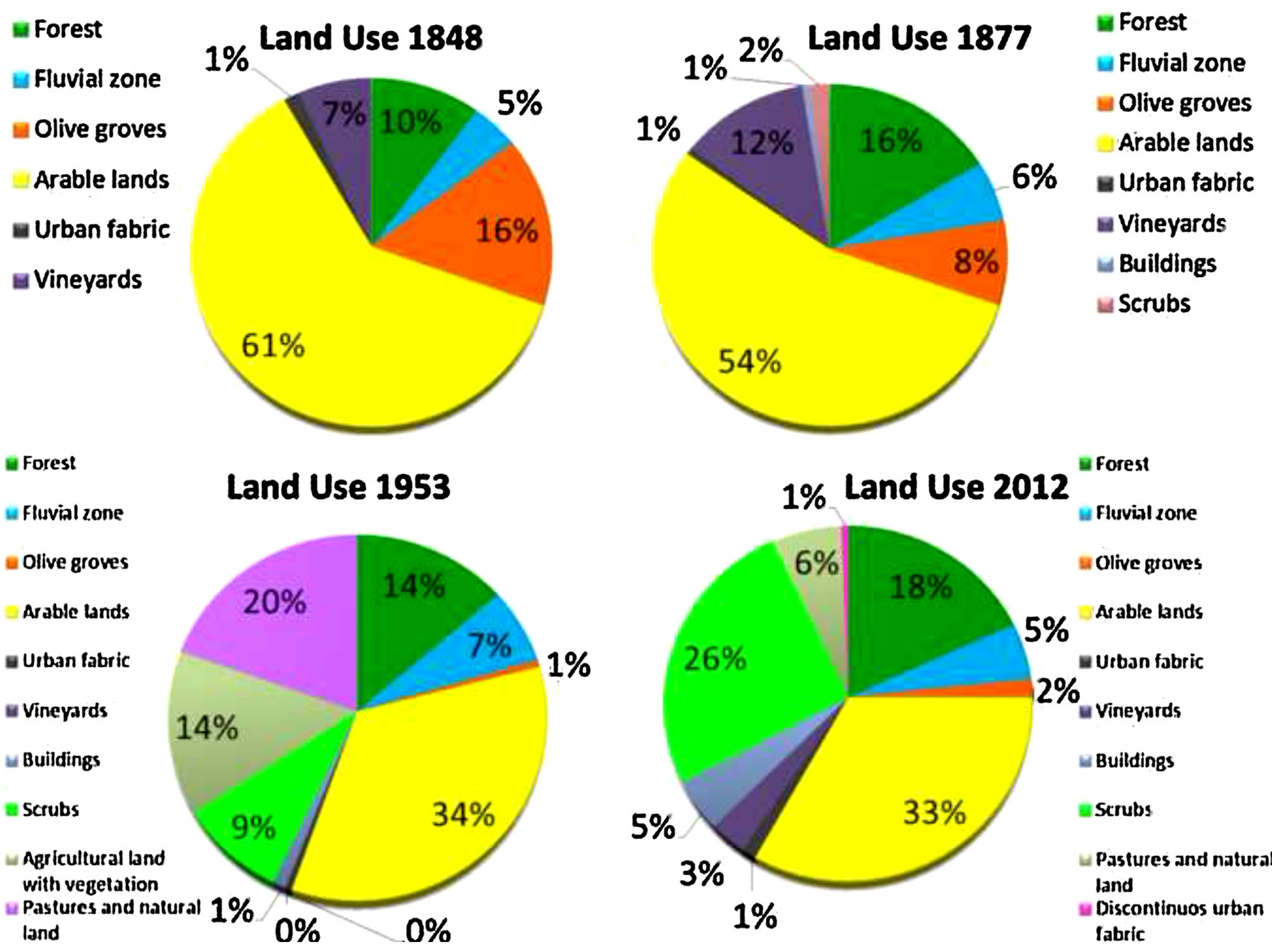

Fig. 5. Land use categories in different time periods.

subtributaries Marmo Platano and Melandro, which are tributaries of the Tanagro, the left tributary of the Sele. Its basin is bordered to the north by the Ofanto river and to the east by the Basento and Agri rivers.

Land use and forestry

The study area is predominantly occupied by agricultural land (57%), forested and semi-natural land area (38%) and artificial surfaces (5%). The high hilly landscape of the study area is characterized by arable land, which is present especially in the hills, with wide pastures and vineyards in the northern area. The mountains are covered with rich woodlands, consisting mainly of underwood, such as fir-wood, with elements of *Abies Alba* (a biotope surveyed by the Italian Botanical Society).

The cartography

To understand the changes that have affected the study area during the last two centuries, four different time steps (years) were analysed: 1848, 1877, 1953 and 2012. The maps were firstly scanned and digitized within a Geographic Information System, then the land-use categories and elevations from each map were extracted and the differences among the different time levels were evaluated (Tucci and Giordano, 2011). Through the digital processing of the maps that were found it was possible to reconstruct the three-dimensional shape of the land in the study area and, thanks to a photo-mosaic procedure, achieve a virtual reconstruction of the land during these different time periods (Capobianco et al., 2004). However, before using the information contained in old maps for historical studies its quality had to be assessed. According to Blakemore and Harley (1980), three different aspects should be assessed. The first aspect is the topographic accuracy that denotes the quantity and quality of information about landscape objects. Every map contains only that part of the geographic features that were selected and symbolized by the cartographer according to the goal of the map. Hence, the question is about whether the maps depict all features of a certain class, and how accurately the cartographer classified the features thematically (Laxton, 1976). The second aspect is the chronometric accuracy, in other words, the dating of the map as a physical artefact (by watermark analyses or other techniques) and the dating of the information contained in the map. Dating the age of map information is often difficult, as the production or the revision of a map commonly takes several years. The third aspect is the planimetric completeness (or geometric accuracy) (Jenny and Hurni, 2011).

The 1848 historical map

The first historical maps were produced after border disputes by legal experts; they represented a combination between a documentary tradition, such as diplomatic writings, the feudal judicial system and investigation of the soil. With a law of September 1806, feudalism was abolished in Southern Italy (at that time, the Bourbon Kingdom) and the operation of the division of domains was initiated, governed by the ministerial instructions of March 1810. As a consequence, extensive geometric surveys were prepared for each municipality.

An historical map of the Municipality of Ruoti (Fig. 2) was produced in 1848 to resolve border disputes and it remained the main

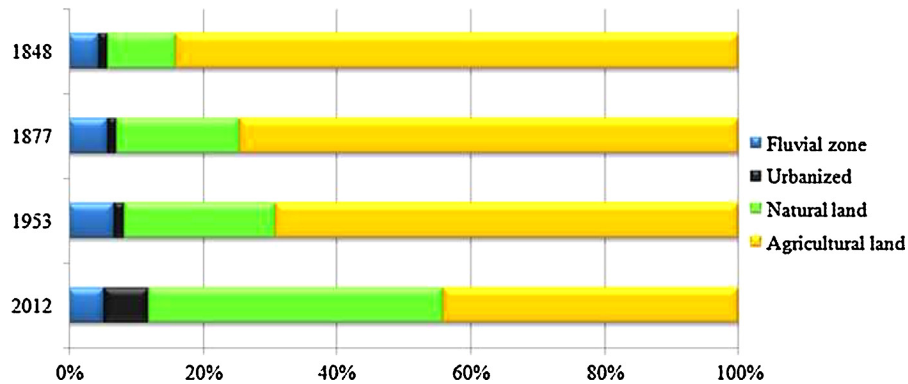

Fig. 6. Analysis of elements over the years.

document of the historical memory, representing the whole territory for investigations of the land. This map shows the land that was studied and measured during the division of the former feudal domains and the subsequent controversy. It constitutes a complete cartographic support with thematic information about the land use at that time. The map reports on the town and the surrounding area and shows the following: the main rivers in the area (*Fiumara di Ruoti* and *Fiumara di Avigliano*); in the north of the area, there are lands present that can be classified as non-irrigated arable land and irrigated land; in the central part of the territory, there is an alternation of olive groves and arable crops; while, in the eastern part a set of symbols describes the layout of the vineyards. It also appears that a portion of land is classified as woodland. The legend located with the western part of the map shows the territorial extension of the categories of vegetation that are here represented. The place names of various districts are reported too; however, the farms and the roads within the area are unfortunately not reported at all.

The 1877 map

The morphology and land use for 1877 was analysed through a topographic map (Fig. 3) of the Italian Topographic Military Institute (ITMI), named after the 1882 Italian Geographic Military Institute (IGMI). The scale of the map was 1:50.000; it has been digitized through a process of scanning and georeferencing. The map shows in black and white contour lines with an equidistance of 10 m and gives some information about the toponyms and the presence of farms. The projection is Flamsteed as amended, and the coordinate's origin is at the intersection of the meridian of Naples with the 40th parallel. This map should not be regarded as an artistic publication. It is the reproduction of the minutiae of the countryside which were found on the ground, that is, for the most part without being copied in equity. The publication of these topographic documents was done in an economical and fast way to make them available for engineers, naturalists and administrators. The altimetry was represented with contour lines. The study area falls into two sheets (Sheet 65 "Avigliano", both the western and eastern parts).

The 1953 map

The stereoscopic aerial coverage of the national territory was made through photogrammetry (each photogram was shot with a camera equipped with a lens with focal length of 152 mm, the size of the photo is 230 mm × 230 mm and its approximate scale is 1:33.000). The analysis of the land use relative to 1953 was possible

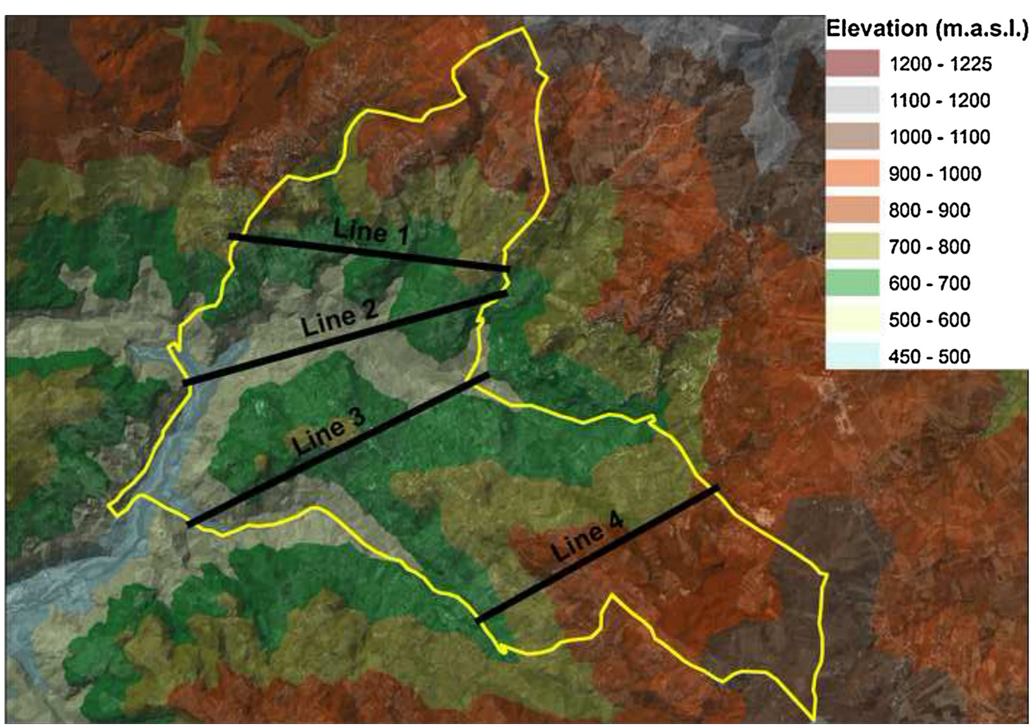

Fig. 7. Digital elevation model with the four section lines.

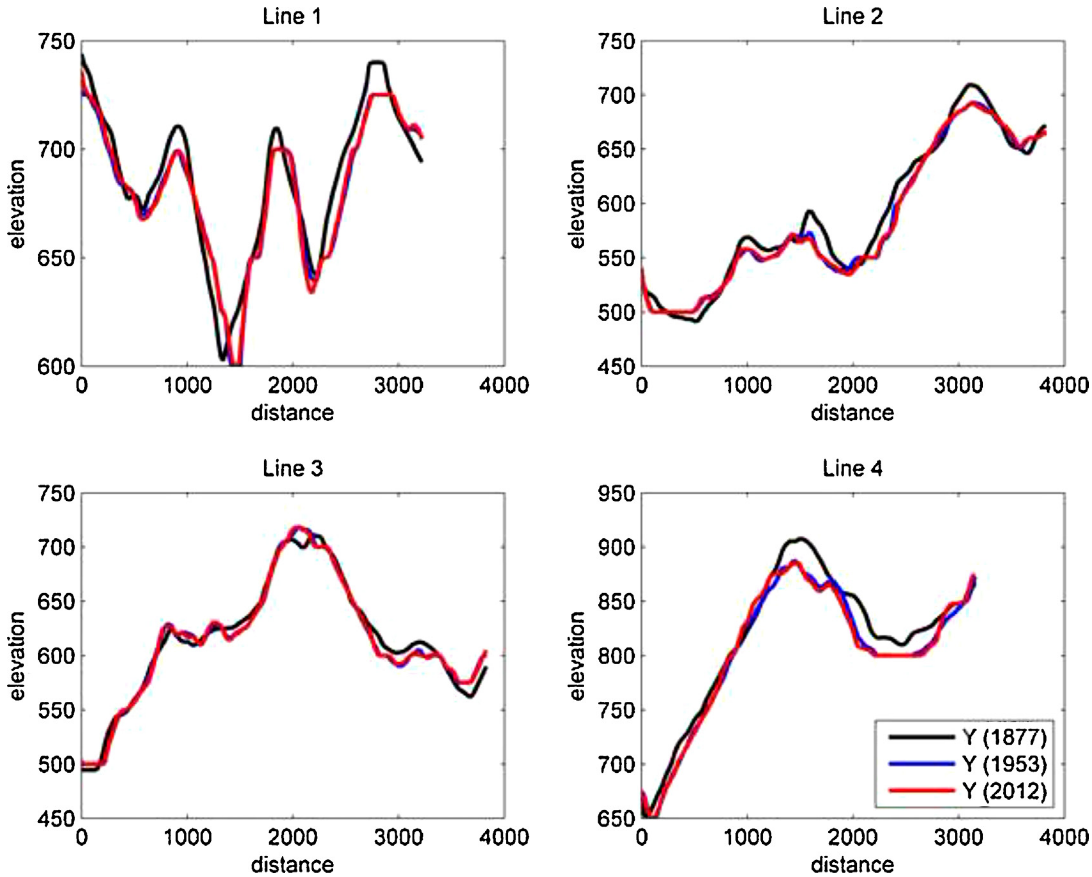

Fig. 8. Elevation profiles for different time periods.

by an aerial photogrammetric survey that was performed in the 1950s, from which the different categories of land use of the study area were obtained. From the morphological point of view, a map of IGMI (scale 1:25.000) was used as the basis for entering the contour lines. So, it was possible from this to derive the elevations of the area and subsequently, through appropriate GIS elaborations, to derive the digital elevation model.

The 2012 map

To determine the land use for 2012, digital orthophotos were utilized. Digital orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. Unlike a standard aerial photograph, relief displacement in orthophotos has been removed so that ground features are displayed in their true ground position. This allows for the direct measurement of distance, areas, angles and positions. The orthophotos are able to display actual ground features; in the ideal situation, one aerial photograph will be used to create an entire orthophoto which allows the identification of a great level of detail. An orthophoto also displays features that may be omitted or generalized on maps. The photography is scanned and converted into a digital image from which it is subsequently possible to identify a great number of elements: land use, farms, vineyards, olive groves and basins for water collection. The morphology of the land was derived from the digital elevation model (DEM, with a cell size of 20 m). In addition, using specific tools, namely, *slope* (the inclination of a surface) and *aspect* (that can be generated from continuous elevation surfaces, usually measured in degrees from north) the main features of the studied area were evaluated.

Theory/calculations

Data analysis

For each considered time period, and taking into account the different base maps above, various categories of land use were identified, considering the symbols present on the map and the level of detail of the cartographic base. In the case of the historical map, the different categories of land use were well marked and six categories have been identified. Through the Italian Topographic Military Institute (ITMI) map analysis even the suburban nucleus in the area has been identified, in addition to various forms of vegetation. Eight different categories of land use have been therefore identified. The land use for 1953 was derived from the analysis of georeferenced aerial photos, which showed a greater degree of detail, where it is possible to identify 10 categories; finally, in the colour orthophotos for the 2012 map 11 different categories of land use have been identified. In order to make the data more uniform and allow a more direct comparison, the main categories of land use have been therefore aggregated and defined as “elements”.

In the study area four major “elements” were identified. For each of them, using the GIS function, the total area expressed in hectares (ha) and the percentage of the study area were calculated. Their variation over the years was also calculated. The most important elements found in the area are rivers, urbanized areas, natural land and agricultural land described as follows:

Rivers. These were considered in their areal extent, that is, the bed of the river and the vegetation present along the river, both as their linear extension. Streams and rivers cause erosion, sediment

Table 1
Analysis of elements over the years.

Year	Elements			
	Fluvial zone	Urbanized area	Natural area	Agricultural land
1848	4%	1%	10%	84%
1877	6%	1%	18%	74%
1953	7%	2%	22%	69%
2012	5%	7%	44%	44%

transport, changes in the flood plain and floods. Most of the erosion process is accomplished both by rainwater and by surface waters that flow downstream. Streams and rivers, through their action, are able to change the morphological structure through their erosive action by creating channels, canyons and valleys, and by transporting deposits of solid material to flood plains and deltas. Much of the current landscape is the result of an erosion process.

Urbanized area. This includes the town, the old buildings and those from recent expansion, and the buildings and farms present in rural areas. Most of the current urbanized land is covered by structures. The appropriate integration of manmade constructions into their surroundings is not yet a common consideration in general planning practice (Tassinari et al., 2007; De Vries et al., 2012). Buildings, roads and artificially surfaced areas are associated with vegetated areas and bare soils, which occupy discontinuous but significant surfaces.

Natural land. This includes forest and transitional woodland and shrubland. Forests are mainly composed of vegetation, principally trees, but also include shrub and bush understoreys where broad-leaved species are prevalent. Transitional woodland can represent either woodland degradation or forest regeneration/recolonization. Natural land is formed by bushy or herbaceous vegetation with scattered trees.

Agricultural land. This comprises arable land, olive groves, vineyards, pastures and natural grassland. Arable land includes cereals, legumes, fodder crops, root crops and fallow land. It includes trees crops and vegetables, whether in open fields or in greenhouses. The olive groves consist of areas planted with olive trees, where the simultaneous presence of olive trees and vineyards can be detected as well. Natural pastures are areas with spontaneous herbaceous vegetation.

Results

Land use

From the superimposition of the different base maps it was possible to identify the different categories of land use. The number of classes identified has increased at each step in time, mainly due to the improved detail provided by the evolving cartographic information. Some categories are not present in the historical maps because of the low level of detail. The results of this territorial analysis are presented in Figs. 4 and 5.

The analysis of data related to land use in different periods shows that the forested area has increased from about 10% in 1848 to 18% in 2012. However, the river area increased to 7% in 1953 and then fell to 5% in 2012. The urban fabric has increased over the years, while the percentage of land used for arable land has decreased significantly, from 61% in 1848 to 33% in 2012.

To make the analysis and comparison of the categories of land use over the years more uniform, they were suddenly aggregated into only four main "elements": agricultural land, natural area, fluvial zone and urbanized area. Table 1 shows, over the years and for each element, the variation in terms of the percentage with respect to the entire area. The urban area has increased significantly especially after the Second World War. In many cases, valuable elements

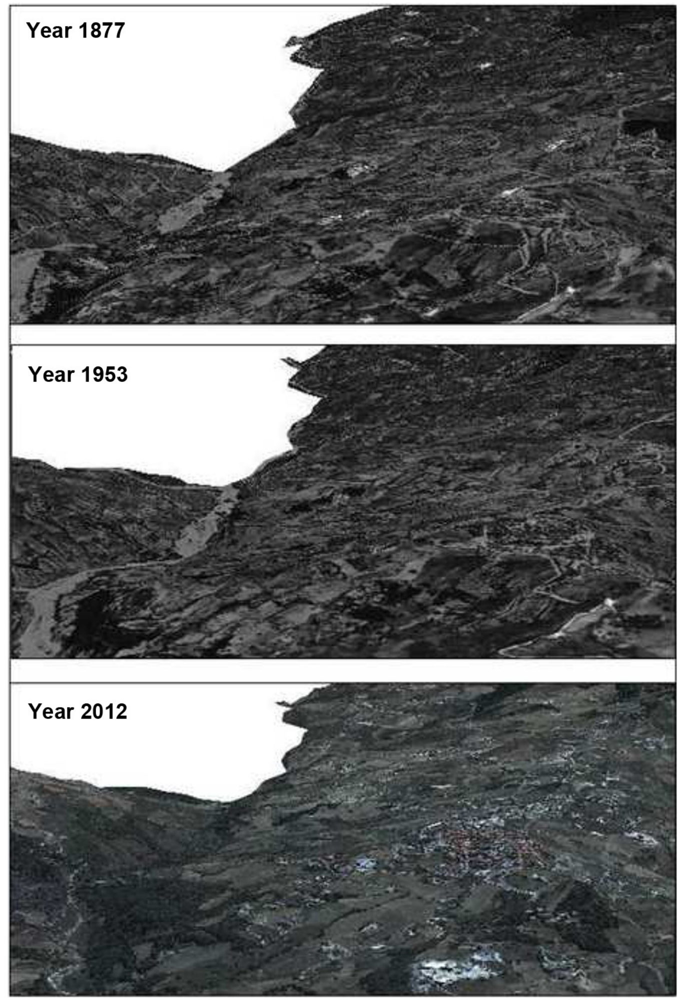

Fig. 9. Comparison of three-dimensionally landscape.

of the urban and rural landscape have been destroyed or severely degraded, making the landscape difficult to recover. However, it is always possible to generate graphic reconstructions to show what was and what could be a certain historical element that is damaged or missing (San-Antonio-Gómez et al., 2014). The main difference that occurred, as part of a widespread trend also detected in other areas of the Basilicata Region, was a mutual exchange between the areas of agriculture and crops, which reduced by almost a half, giving more space to the natural areas (Fig. 6).

The linear extension of the rivers did not follow a linear pattern over time, increasing until 1953 and then reducing from 1953 to the present. However, the length of the roads has instead increased significantly over the years (Table 2).

Morphology

From the analysis of the contour lines derived from maps from the years 1877, 1953 and 2012, it is possible to obtain the digital terrain models (DTMs), thanks to an appropriate processing.

Table 2
Linear extension of rivers and roads in different time.

Year	Rivers (m)	Roads (m)
1877	40.283	81.754
1953	62.817	95.611
2012	60.614	126.478

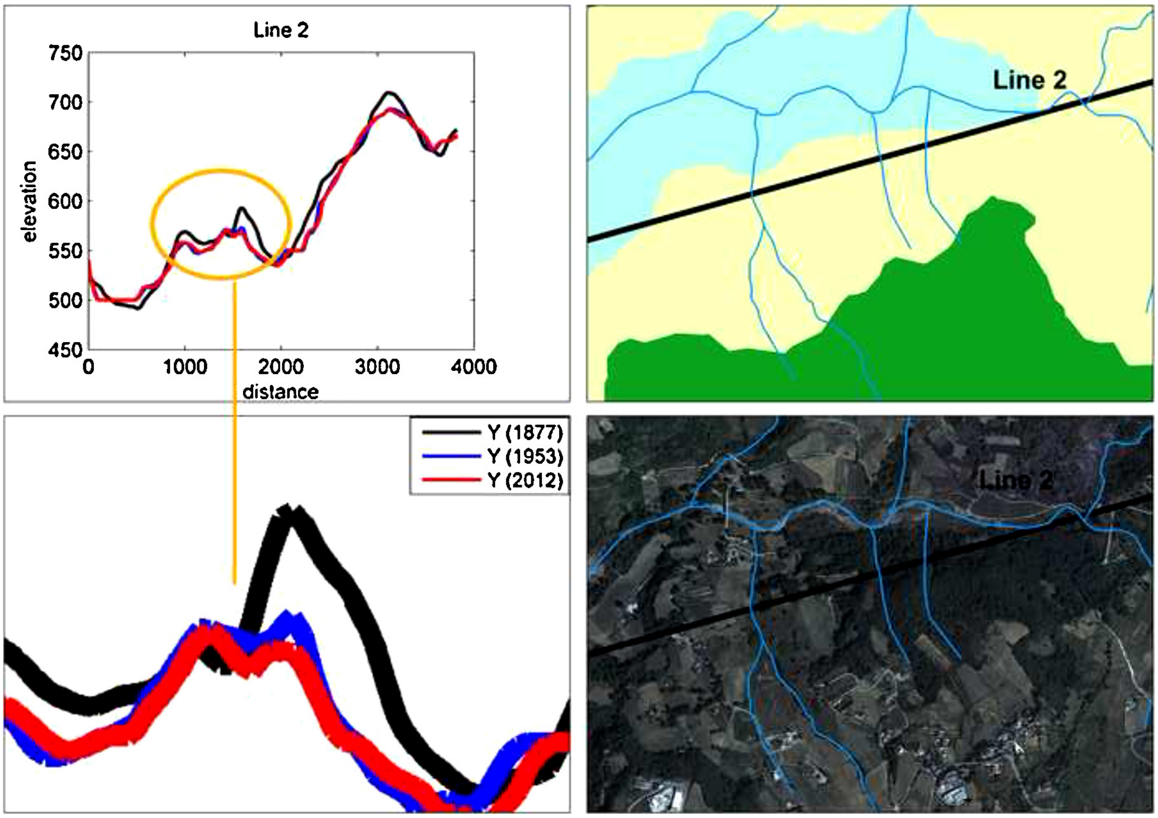

Fig. 10. Profile graph with zoom of an area on line 2.

These data, adequately treated with spatial analysis procedures, allowed us to evaluate the morphological changes in terms of elevation of the study area. Altimeter data require a model of spatial interpolation to represent the characteristics of the ground surface.

The models used were: TIN (triangulated irregular network) representing the surface as a network of adjacent triangles whose vertices are the sampled points, and GRID (regular grid), which represents the surface of the ground by means of a regular grid. In the territory under study, four section lines were selected, for which the elevation profiles were determined (Fig. 7).

As reported in Fig. 8, all the four elevation profiles have changed over the years. The altimetry has changed, mainly when the lines for the periods 1877–1953 are compared, showing a general reduction of the altimetry of the examined area. This event should be probably connected with the general evolution over time of the morphology of the land, mainly connected with natural events like floods, landslides, soil erosion and so on that are frequent within this area and cause most of the morphological changes that have occurred over the years. During the last of the analysed periods (1953–2012) the height differences seem lower. This trend could be connected to changes in the morphological structure as well as the different degree of accuracy of the cartographic base.

The contour lines obtained from the digitization of the map for 1877 have allowed the development of digital terrain models. Using spatial analysis functions the map for 1877 was appropriately correlated to the altimetry (DEM) of this year (Tortora et al., 2006). Some differences of results derive from the different level of detail, considering that historical maps typically carry a higher degree of inaccuracy and uncertainty when compared to contemporary cartographic databases of them. Proper spatial analysis procedures have enabled the realization of three-dimensional views in order to appreciate the landscape changes. Fig. 9 shows an image obtained from the solid modelling of the 1877 map on which a "virtual ortophoto" of the same year was draped. The virtual ortophoto reported here was associated with the visualization of the land use in 1877 on the aerial photo, so obtaining the reconstruction of the landscape for 1877. The picture was compared with the same images for 1953 and 2012. From the comparison between the three-dimensional reconstructions it is possible to appreciate the landscape changes qualitatively and the aesthetic quality of the study area in terms of the morphological and vegetative variations of the agro-forestry landscape.

Discussion

Land-use evolution

From the analysis of land-use evolution it can be noticed how, during the investigated time span of about 160 years, the land used for agricultural production has progressively decreased, to the benefit of the natural areas that have in the meantime expanded, occupying most of the area lost by the former. This phenomenon was probably due to the constant increase of agricultural mechanization and diffusion of chemical products into intensive agriculture, which led many traditional farmers to abandon their estates and to consequently transfer into the urban area. Thus, this phenomenon has allowed a natural vegetation to grow over the years, spontaneously covering areas that were cultivated in the past. The trend towards this has increased steadily over the last 50 years. The increase is also attributable to Community policies in the agricultural sector, and especially to the *set-aside* regime (Regulation EEC 1272/88). This regime was based on the practice of leaving an agricultural area uncultivated, gaining public subsidies for periods up to 20 years aimed at controlling the overproduction of cereals and other crops, so avoiding the effect of lowering the prices of these agricultural products. After this regime, many soils have not been cultivated anymore as there was no guarantee of an economic return, so natural vegetation has definitively got the upper hand. Modern agricultural practices, urbanization and recreation have all threatened the existence of valuable cultural landscapes, but simple solutions to conserve many of these landscapes are not at hand (Vos and Meekes, 1999).

On the other hand, the urbanized area has grown from 361,192 m^2 (1%) to 1,629,630 m^2 (7%). This increase has occurred mainly in the last 50 years. It is mainly due to two aspects strongly linked to each other: the first is related to the economic well-being, which has gradually increased over the last 80 years; the second comes from the ease of getting to places that were previously considered apart. Thanks to the popularity of the car, the road network has been extended about 50%, from 81,754 m in 1900 to 126,478 m in 2000. This increase in urbanization is the result of the development of this territory, but its expansion without a proper development policy has facilitated the proliferation of residential areas with the consequent abandonment and fragmentation of the rural territory and its landscape.

Concerning the hydrographic network, the territorial extension in the different periods is, most likely, attributable mainly to a different degree of detail in the cartographic support, rather than a real change occurring over the years (Locke and Wyckoff, 1993). The measurement and management of positional accuracy and positional uncertainty is especially problematic in historical cartography and historical GIS applications, for at least two reasons: first, historical sources, and especially historical maps, generally carry a higher degree of positional inaccuracy and uncertainty compared to contemporary geographic databases; second, it is always difficult and often impossible to reliably measure the positional accuracy and positional uncertainty of the spatial attribute of historical data (Tucci and Giordano, 2011).

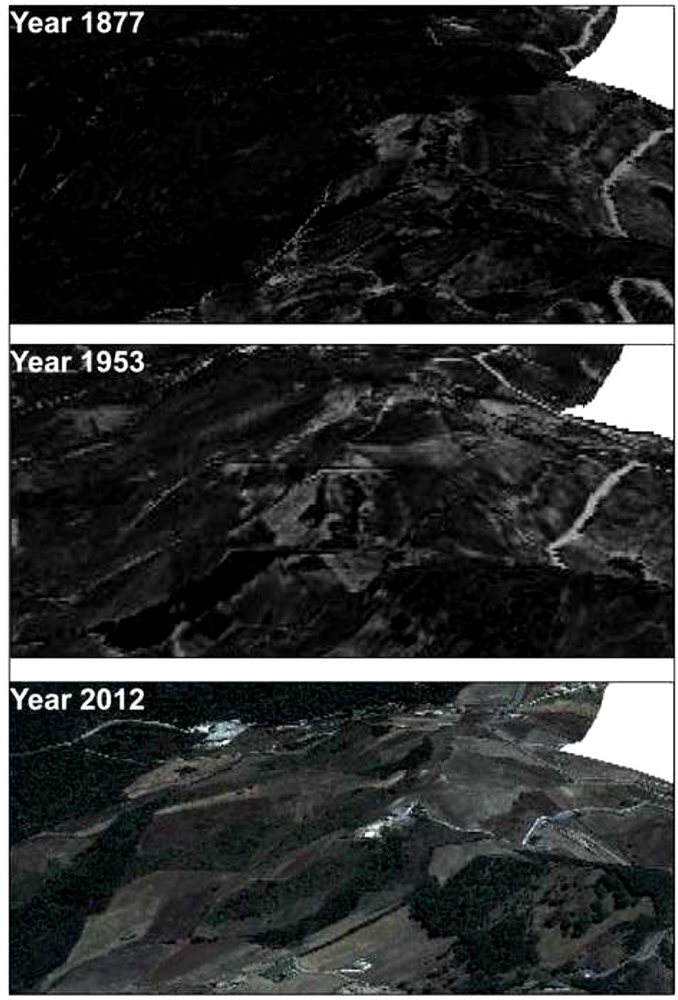

Fig. 11. Landscape changes over the year in the east part.

Environmental modifications

The analysis of the changes of vegetative cover and land-use evolution that have occurred in the study area during the last 160 years also offers useful hints that contribute to the understanding of the effects on the environment.

With the advent of industrialized agriculture, which involves an extensive mechanization and use of synthetic chemistry, most of the traditional farming practices have been abandoned and a large number of varieties of plants and breeds of animal have disappeared. As a result, the ancestral equilibrium between agriculture and biodiversity has thus been put at risk. So far, about 75% of the crop varieties in the world have been lost, and three-quarters of global nutrition depends on only 12 plant species and five animals. To protect biodiversity in agriculture and in rural areas it is necessary to first protect the ecosystems that contain the important agricultural species and *cultivars* of rare use or endangered species. In Italy, the country with the highest percentage of cultivated area in the European Union (about 44%), conservation in situ is possible in the areas of traditional agriculture located inside protected areas; in this way these areas, in addition to access to support schemes for production, may contribute to guaranteeing the continuity of land use and the sustainable management of the agricultural landscape.

An appropriate environmental approach could also be revealed to be useful if focused on the balance of carbon dioxide fixation connected to different crop strategies. All the land changes detected in the study area have caused a progressive decrease in carbon dioxide sequestered by the biotic agents embedded in the soil. The cultivation conversion occurred over time and the increase of urban areas caused a consequent constant loss of the CO_2 fixation value, while the heavy emission of greenhouse effect gas in the atmosphere by urban settlements has been increasing at the same time (Statuto et al., 2013).

Other similar studies that have been conducted have led to similar conclusions. Tortora et al. (2006) analysed a comparable situation in a different area of the Basilicata Region, concluding that the greatest changes in land use occurred after the establishment of large orchard growing areas, mainly consisting of orange tree plantations. The percentage rise in arable land was equally considerable with increases as high as 30–40%, to the detriment of woodland and shrubland. Olive groves reached their peak from the late 19th century until after the First World War, since they were one of the early livelihood sources of farm families of that time. As a result of the different performance in terms of CO_2 fixation relative to the investigated study area, all the land changes have caused a progressive decrease in carbon dioxide. The authors concluded that the sequestration of carbon by the land in the past was higher than in more recent periods, and that over time the land carbon balance has worsened.

The use of this approach with other environmental factors, such as water, soil and so on, would lead to a more comprehensive understanding of the dynamics of landscape development through its principal environmental components, contributing to the proposal for production-oriented landscape planning politics that are able to achieve a suitable compensation for alterations to the natural balance, as well as a real application of the concept of sustainable development.

Fig. 12. Landscape changes over the year in the west part.

Landscape changes

Looking at the elevation profiles obtained (Fig. 8), it is possible to observe that the altimetry data relating to 1877 was consistently higher than for later periods. This trend is most marked at the points of minimum and maximum altitude. The profiles obtained from the elevations of 1953 and 2012 are very similar to each other, and in some parts of the graph the lines almost overlap (see Fig. 10 and lines 2); while based on different surveying techniques, the data for these two different time periods seems nearly coincident.

In this territorial context (Fig. 10), it is possible to attribute these differences to the presence of small rivers (blue lines in the figure) that, over the years, have had a deepening of their beds. This situation is typical of the whole area of the Apennines and is connected to a strong hydro-geological instability, mainly due to two factors: the geological nature of the substrate and the erosion of the land surface. These phenomena have been increasing in the last half century.

The landscape analysis using the three-dimensional modelling allowed the evaluation, over the years, of the simultaneous changes in both land use and in the morphological variations that involve landscape modification. Fig. 11 shows that a great part of the territory has significantly changed: some of the areas that in 1877 were covered by forests have, over the years, turned into arable land, so determining a clear change in the visual quality of the rural landscape.

The area crossed by the river has undergone changes, the riverbed having been affected by some landscape variations. It is possible to see, in the left part of each image in Fig. 12, that the urbanized area is clearly extended.

The analysis that was performed over the three-dimension images of the territory has been revealed to be a powerful means of interpretation, since it allows some dynamic effects to be created in a virtual reality system, in which the operator has the opportunity to navigate as if he or she is walking or flying over the area at that time; thus, the operator is able to visit – with a virtual jump back in time enabled by the simulation of an *ante litteram* flight – real life scenarios, that would be otherwise difficult to imagine and/or reach. By doing so, all the aspects that characterized an area can be examined in suitable detail and completeness, starting from the analysis of topography and land cover and leading to anthropic components (buildings, roads, and railways, hydraulic infrastructure such as dams, aqueducts, etc.).

Conclusions

The role of territorial analysis is extremely important and delicate, especially if carried out to pave the way for proper planning activities. The understanding of the landscape's evolution over the years, both in morphological and vegetation terms, represents a highly valuable database usable by public decision makers in the normal processes of making economic and political choices for the government of the territory. All of this should be in harmony with the historical changes in the rural territory that current events, according to the modern ways of conceiving the suburban areas, bring into play over social aspects closely related to the traditions and customs of the past.

The evolution of computer technology, coupled with the availability of historical maps, has proved to be a decisive tool in the creation of appropriate instruments for the representation of agricultural land and forest, which could allow an effective step forward to be taken in the process of encouraging sustainable economic development.

Over the time interval analysed in the present research, the general situation that has been evaluated allows us to say that over the years the landscape has gone from extensive use of areas for agricultural purposes to land use that is intended more for residential purposes. A consequent abandonment of the areas that were cultivated until a few decades ago has occurred.

This phenomenon has caused a corresponding increase in the natural vegetation area, but also an increase in surface erosion due to improper land management. The various stages of agricultural processing contributed to limiting soil erosion. The deepening of the surfaces of river beds is an obvious result of widespread surface erosion, and the most evident territorial changes occurred from 1953 to 2012. As a result of this consideration, it is therefore easy to imagine an increase in these phenomena in the coming years, resulting in a deepening of the river network and even more marked hydro-geological instability.

The lack of attention to the correct policies for territorial management has led to the necessity of undertaking expensive and difficult to implement actions to safeguard the territory. The hazard for populations increases if events of considerable intensity occur. With proper management it would be possible to limit the damage that an extreme event might cause.

In addition, considering the ecological and natural changes occurring in a territory, it would be desirable to identify the most suitable plant formations (*climax*), their distribution and the time required for their success. The policies of territorial management must be aimed at safeguarding these aspects.

The analysis of the evolution of land use over a long time period, as in this case, where nearly two centuries were considered, can show how the results of the applied agronomic practices, in terms of CO_2 fixation, would be able to compensate for heavy emissions of greenhouse effect gases in the atmosphere by urban settlements. This would demonstrate how correct rural site management could efficiently balance environmental pollution brought about by human development.

The spatial analysis that was conducted allowed us to understand the landscape dynamics of the past, current developments and possible future trends. Similar information should be adequately considered to help address the need for suitable development policies and appropriate land management planning.

References

Barredo, J.I., Kasanko, M., McCormick, N., Lavalle, C., 2003. Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata. Landsc. Urban Plan. 64, 145–160.

Batson, R., 1990. Cartography. In: Greeley, R., Batson, R. (Eds.), Planetary Mapping. Cambridge University Press, New York, pp. 60–95.

Belov, A.V., Sokolova, P., 2009. The socio-economic role of vegetation in the cartographic substantiation of rational management of nature in the geobotanical forecasting system. Geogr. Nat. Resour. 30, 119–125.

Blakemore, M.J., Harley, J.B., 1980. Concepts in the history of cartography. A review and perspective. Cartographica 17, 1–120.

Bockstael, N., Costanza, R., Strand, I., Boynton, W., Bell, K., Wainger, L., 1995. Ecological economic modeling and valuation of ecosystems. Ecol. Econ. 14, 143–159.

Brown, G., Brabyn, L., 2012. An analysis of the relationships between multiple values and physical landscapes at a regional scale using public participation GIS and landscape character. Landsc. Urban Plan. 107, 317–331.

Capobianco, R.L., Tortora, A., Picuno, P., 2004. Analisi del territorio, dell'ambiente e del paesaggio rurale mediante tecniche di modellizzazione spaziale ed image processing di cartografie storiche (Analysis of rural land, environment and land scape through spatial modelling techniques and hystorical cartography image processing). Riv. Ing. Agr. 35 (3), 71–77 (in Italian).

Council of the European Union, 2001. Council resolution on architectural quality in urban and rural environments (2001/C 73/04). Off. J. Eur. Commun., C73, 6/3/2001.

Cullotta, S., Barbera, G., 2011. Mapping traditional cultural landscapes in the Mediterranean area using a combined multidisciplinary approach: method and application to Mount Etna (Sicily, Italy). Landsc. Urban Plan. 100, 98–108.

De Vries, S., de Groot, M., Boers, J., 2012. Eyesores in sight: quantifying the impact of man-made elements on the scenic beauty of Dutch landscapes. Landsc. Urban Plan. 105, 118–127.

Domon, G., 2011. Landscape as resource: consequences, challenges and opportunities for rural development. Landsc. Urban Plan. 100, 338–340.

Elez, J., Cuezva, S., Fernandez-Cortes, A., Garcia-Anton, E., Benavente, D., Cañaveras, J.C., Sanchez-Moral, S., 2013. GIS-based methodology to quantitatively define an adjacent protected area in a shallow karst cavity: the case of Altamira cave. J. Environ. Manage. 118, 122–134.

Gehrke, S., Wahlisch, M., Lehmann, H., Albertz, J., Neukum, G., HRSC-Team, 2006. Planetary mapping with "Pimap". In: 5th International Symposium Turkish–German Joint Geodetic Days.

Geri, F., Rocchini, D., Chiarucci, A., 2010. Landscape metrics and topographical determinants of large-scale forest dynamics in a Mediterranean landscape. Landsc. Urban Plan. 95, 46–53.

Gillson, L., 2009. Landscapes in time and space. Landsc. Ecol. 24, 149–155.

Haase, D., Walz, U., Neubert, M., Rosenberg, M., 2007. Change to Central European landscapes: analysing historical maps to approach current environmental issues, examples from Saxony, Central Germany. Land Use Policy 24, 248–263.

Hernández, J., García, L., Ayuga, F., 2004. Integration methodologies for visual impact assessment of rural buildings by geographic information systems. Biosyst. Eng. 88 (2), 255–263.

Hervieux, B., 2008. Les Orphelins de L'exode Rural. Éditions de l'Aube, La Tour d'Aigues.

Iosifescu-Enescu, I., Hugentobler, M., Hurni, L., 2010. Web cartography with open standards: a solution to cartographic challenges of environmental management. Environ. Model. Softw. 25, 988–999.

Jenny, B., Hurni, L., 2011. Studying cartographic heritage: analysis and visualization of geometric distortions. Comput. Graph. 35, 402–411.

Jeong, J.S., Garcìa-Moruno, L., Hernàndez-Blanco, J., 2012. Integrating buildings into a rural landscape using a multi-criteria spatial decision analysis in GIS-enabled web environment. Biosyst. Eng. 112, 82–92.

Lambin, E.F., Geist, H.J., Lepers, E., 2003. Dynamics of land-use and land-cover change in tropical regions. Annu. Rev. Environ. Resour. 28, 205–241.

Laxton, P., 1976. The geodetic and topographical evaluation of English county maps, 1740–1840. Cartogr. J. 13, 37–54.

Leyk, S., Boesch, R., Weibel, R., 2006. Saliency and semantic processing: extracting forest cover from historical topographic maps. Pattern Recognit. 39, 953–968.

Locke, W.W., Wyckoff, W.K., 1993. A method for assessing the planimetric accuracy of historical maps: the case of the Colorado-Green River system. Prof. Geogr. 45 (4), 416–424.

Neubert, M., Walz, U., 2002. Auswertung historischer kartenwerke fürein landschaftsmonitoring. In: Strobl, J., Blaschke, T., Griesebner, G. (Eds.), Angewandte Geographische Informationsverarbeitung XIV, Beiträge zum AGIT-Symposium Salzburg 2002, Heidelberg. , pp. 396–402.

Olbrich, G., Quick, M., Schweikart, J., 2002. Desktop Mapping: Grundlangen und Praxis in Kartographie und GIS-Anwendungen, 3rd ed. Springer Verlag, Berlin, Heidelberg, New York, pp. 30.

Pelorosso, R., Leone, A., Boccia, L., 2009. Land cover and land use change in the Italian central Apennines: a comparison of assessment methods. Appl. Geogr. 29, 35–48.

Picuno, P., 2012. Vernacular farm buildings in landscape planning: a typological analysis in a southern Italian region. J. Agr. Eng. XLIII (e20), 130–137.

Picuno, P., Tortora, A., Capobianco, R.L., 2011. Analysis of plasticulture landscapes in Southern Italy through remote sensing and solid modelling techniques. Landsc. Urban Plan. 100, 45–56.

Pôças, I., Cunha, M., Pereira, L.S., 2011. Remote sensing based indicators of changes in a mountain rural landscape of Northeast Portugal. Appl. Geogr. 31, 871–880.

San-Antonio-Gómez, C., Velilla, C., Manzano-Agugliaro, F., 2014. Urban and landscape changes through historical maps: the Real Sitio of Aranjuez (1775–2005), a case study. Comput. Environ. Urban Syst. 44, 47–58.

Schneeberger, N., Bürgi, M., Kienast, P.D.F., 2007. Rates of landscape change at the northern fringe of the Swiss Alps: historical and recent tendencies. Landsc. Urban Plan. 80, 127–136.

Statuto, D., Tortora, A., Picuno, P., 2013. Analysis of the evolution of landscape and land use in a GIS approach. In: Proceedings of the First International Symposium on Agricultural Engineering – ISAE 2013, Session VI, 4–6 October, 2013, Belgrade, Serbia, pp. 25–33.

Tassinari, P., Torreggiani, D., Paolinelli, G., Benni, S., 2007. Rural buildings and their integration in landscape management. Agr. Eng. Int. CIGR J. 9, Manuscript LW 07 020.

Tortora, A., Capobianco, R.L., Picuno, P., 2006. Historical cartography and GIS for the analysis of carbon balance in rural environment: a study case in Southern Italy. Agr. Eng. Int. CIGR EJ. VIII.

Tucci, M., Giordano, A., 2011. Positional accuracy, positional uncertainty, and feature change detection in historical maps: results of an experiment. Comput. Environ. Urban Syst. 35, 452–463.

Van Delden, H., Stuczynski, T., Ciaian, P., Paracchinie, M.L., Hurkensa, J., Lopatka, A., Shi, Y., Prieto, O.G., Calvo, S., van Vliet, J., Vanhout, R., 2010. Integrated assessment of agricultural policies with dynamic land use change modelling. Ecol. Model. 221, 2153–2166.

Verburg, P.H., van de Steeg, J., Veldkamp, A., Willemen, L., 2009. From land cover change to land function dynamics: a major challenge to improve land characterization. J. Environ. Manage. 90, 1327–1335.

Vos, W., Meekes, H., 1999. Trends in European cultural landscape development: perspectives for a sustainable future. Landsc. Urban Plan. 46, 3–14.

Willemen, L., Hein, L., Verburg, P.H., 2010. Evaluating the impact of regional development policies on future landscape services. Ecol. Econ. 69, 2244–2254.

Yeh, C.T., Huang, S.L., 2009. Investigating spatiotemporal patterns of landscape diversity in response to urbanization. Landsc. Urban Plan. 93, 151–162.