Progressive fragmentation of a traditional Mediterranean landscape by hazelnut plantations: The impact of CAP over time in the Langhe region (NW Italy)

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Abstract

Land use change is strongly modifying the traditional landscape of hilly productive Mediterranean sites. An example of this situation is the *Langhe* region (Piemonte, NW Italy), where woody plantations such as vineyards and orchards have been cultivated on hillslopes for centuries. In this paper we assess the landscape changes occurred in the *Diano* study area (2651 ha) in the 1954-2000 period and we ascertain land use transition paths and rates in this rural ecosystem. Land use mapping obtained from object-oriented analysis of aerial photographs was used to quantify land use changes between 1954 and 2000. To examine the spatio-temporal patterns of land use change over time, a set of spatial statistics that capture different dimensions of landscape change was identified. An increase of landscape heterogeneity from 1954 to the present was observed due to the expansion of orchards and the fragmentation of field crops. A significant portion (55%) of current orchards surface is represented by former field crops, 24% by vineyards and 15% by forests. The strong expansion of hazelnut orchards concurred to the fragmentation of the traditional rural landscape dominated by vineyards, field crops and forests. Hazelnut orchards expansion was mainly located in places where the cultivation of grapes was less remunerative. A further expansion of hazelnut in the area should be planned, discussed and carefully monitored through change detection studies in order to avoid potential unsustainable use of the land.

Key words

Historical aerial photograms; land use change; *Corylus avellana* L.; landscape metrics; spatial pattern

1. Introduction

Rural landscapes in Mediterranean Europe have been managed and modified by people for centuries. These human dominated landscapes experienced both intensification and extensification of agricultural practices that are strong drivers of land use and land cover changes (Turner and Gardner, 1990). In most productive sites agricultural activities (e.g. intensive cultivation and forest logging) and urban sprawl increased (Stoate et al., 2001). In more marginal areas traditional rural practices declined or ceased causing the abandonment of agricultural lands (Bonet, 2004; Sluiter and de Jong, 2007) and favouring a subsequent reforestation process (Sitzia et al., 2010). Rural European areas have recently undergone several important socio-economic changes that influenced their landscape dynamics. From the beginning of the twentieth century urban areas development increased to the detriment of rural ones (Antrop, 2004) causing a progressive abandonment of such regions. In addition to the rural-urban migration phenomenon, between the second half of the nineteenth century and the first decades of the following one, about 40 millions of European workers moved to more industrialized countries (Hatton and Williamson, 1994). In the second half of the twentieth century, as a consequence of post-war dynamics, a local growth of industrial districts was observed (Fauri, 1996; Becattini and Coltorti, 2006). An opposite process was recently observed in Europe, where a decrease in industrial employees was caused by global economical changes such as the outstanding development of late-industrializing countries (Amsden, 1991) and the restoration of some abandoned marginal rural areas (Pinto-Correia, 2000). The restoration of rural areas was also favoured and often sustained by institutional financial support (Meeus et al., 1990; Vos and Meekes, 1999).

Land use change drivers such as urbanization, globalization and population growth are translated by policy-makers into land use regulations at regional, national or supra-national scale (Van Rompaey et al., 2001), but environmental conditions such as vegetation, soil, topography and climate act as local constraints for the landscape pattern. The establishment in Europe of a common agricultural policy (EU-CAP) is thus considered a fundamental factor influencing rural landscape change (Rabbinge and Van Latesteijn, 1992; Tanrivermis, 2003). Up to 1992 EU-CAP was a production-oriented subsidy policy aimed to guarantee self-sufficiency in basic foodstuffs (Martinez-Casasnovas et al., 2010). Through the 1992 EU-CAP reform EU supported the farmers relative to set-aside land on their farm (Van Rompaey et al., 2001). The EU-CAP reform in 2003 introduced an agricultural policy that supported the long-term livelihood of rural areas focusing the attention on conservation agriculture and sustainable farming (European Commission, 2004; Martinez-Casasnovas et al., 2010). The effects of the EU-CAP subsidies in Europe have been diverse depending on local rural policies and due to the varied environmental conditions of the rural landscape.

There are several methods and tools for land use change assessment or change detection. Among them the analysis of historical geographical sources is a preferred tool to reconstruct traditional land mosaic (McClure and Griffiths, 2002, Cullotta and Barbera, 2011). The most common historical geographical data sources are aerial images (Schiefer and Gilbert, 2007) and cadastral maps (Vuorela et al., 2002), but also old satellite images acquired for military purposes are used (Scardozzi, 2008). These geographical data sources can be employed separately or combined, according to their availability for a certain study area. In change detection studies the adoption of aerial images is preferred as they allow a direct interpretation of landscape elements, rather than historical maps where land is represented by symbols (Morgan et al., 2010).

In this paper we study land use change in a hilly region of southern Piemonte (north-western Italy). The choice of our study area is motivated by the following considerations: (i) the landscape is a traditional complex mosaic of forests, vineyards, orchards and other cultivated fields; (ii) the land use changes in the area are particularly strong; (iii) we had the opportunity to use the camera calibration certificates to perform a rigorous photogrammetric processing of the historical images; (iv) the entire *Langhe* region is famous for the quality of its wine and food and is candidate to be included in the UNESCO World Heritage List.

The goals of our study are: (i) to quantify and analyze the landscape changes occurred in the area between 1954 and 2000; (ii) to determine the location of land cover change and the type of change;

(iii) to determine transition paths and transition rates of the land use categories in this ecosystem. Finally, the potential effects of European and local agricultural policies on the rural landscape of *Langhe* region are discussed in relation to the sustainability of the modern farming systems.

2. Materials and methods

2.1. Study area

Land cover changes and landscape structure has been studied in a 2651 ha area (Fig. 1) located in the southern part of Piemonte region, north-western Italy (44°40' N, 07°59' E). The elevation ranges from 190 to 634 m a.s.l. and the climate belongs to type Cfa in areas lower than 500 m a.s.l., having humid summer and dry winter seasons and to type Cfb with milder conditions at upper elevations, in terms of Köppen-Geiger's classification (Peel et al., 2007). Annual precipitation ranges from 800 to 1100 mm with a main minimum in July and a secondary one in winter and with a peak in autumn. Total annual rainfall averages 730.4 mm and mean annual temperature averages 11.9 °C (Rodello climatic station, 415 m a.s.l.). Lithological substrate is made up of siltstone and marlstone on hillsides and alluvial deposits in valley bottoms and soils are mainly represented by Entisols and Inceptisols (ARPA, 2012).

The study area (*Diano*) is part of *Langhe* hilly region which is characterized by strong agricultural character and is widely renowned for its high quality wine production like Barolo and Barbaresco (Delmastro, 2005). The entire *Langhe* region is currently candidate to be included within the UNESCO World Heritage List (UNESCO, 2012). The study site falls within the municipalities of Diano d'Alba (52%), Alba, Grinzane Cavour, Serralunga d'Alba, Rodello, Benevello and Montelupo Albese. We used the demographic data of Diano d'Alba and the agricultural statistics of the entire Cuneo Province in order to describe the demographic trends experienced by the analyzed land surface. The population density declined in the first part of the studied period (1951-1971) from 2612 to 2216 respectively, but consistently increased in the last decades from 2216 in 1971 to 2980 in 2001.

2.2. Image analysis

Historical aerial photographs were retrieved in the archive of Italian National Research Council (CNR-IRPI, Torino), where historical and recent aerial images concerning hydrogeological phenomena are stored (IRPI, 2012). During the archive consultation a small block of four photograms has been recovered. These aerial photographs belong to the Gruppo Aeronautico Italiano (GAI) flight that represents the first available flight covering almost all Italian territory after the Second World War. Older aerial images for Italian territory are available from the beginning of the twentieth century. Both USAAF (Today USAF) and RAF employed images for photointerpretation purposes in order to plan bombing or army raids (Kaye, 1957). These images were also processed and merged with the aim of making three-dimensional terrain models of the theatre of operations (Reed, 1946). On the other side Luftwaffe and Regia Aeronautica performed several flights for intelligence purposes and to monitor Allied campaign in southern Italy (Ceraudo, 2005). GAI flight was carried out in 1954-55 with a flight height ranging from 10000 m a.s.l. in mountain regions to 5000 m a.s.l. in the plains, and having a medium scale of 1:33000 (Campana and Francovich, 2003; Acosta et al., 2005; Beni Culturali, 2011).

We had the extraordinary opportunity to find the camera calibration certificates of the investigated flight at the Italian Military Geographic Institute (IGMI) historical archive allowing us to perform a rigorous image orientation. Each photogram was scanned in TIF format to 600 dpi resolution, and its orientation was obtained through the Automatic Aerial Triangulation approach (Mikhail et al., 2001) and the employment of the above-mentioned certificates assuring an overall accuracy of 2.22 meters. The oriented images were then orthorectified and mosaicked at 1-m resolution. Because the calibration certificates for GAI flight are usually rare, we assessed their role in the process by computing a second orientation employing only the focal length value. Through a comparison of the obtained residuals we observed a quality loss of an order of magnitude when the process is carried out without calibration data (Table 1). The whole image processing was accomplished using Z-Map software. A recent, RGB, orthoimage (Terraitaly - IT2000™, Blom C.G.R. S.p.A) having a nominal scale of 1:10000 and a ground resolution of 1-m, was employed in the change detection analysis.

2.3. Image classification

Automated segmentation with eCognition (scale parameter = 100, shape factor = 0.5) with manual correction was used to delineate polygons on the test area. The segmented images were on-screen classified into six categories of land cover (Table 2). The two resulting maps (1954 and 2000) were then enhanced in a GIS environment in order to reduce the effect of different input image quality and achieve a minimum mapping unit (MMU) of 100 m^2. At the end of the above-mentioned phase an additional topological check was performed by merging adjacent polygons of the same land cover category (Fig. 2).

2.4. Landscape analysis

Landscape changes in the studied period (1954-2000) were assessed through change detection approach and a comparison of landscape metrics over time. The change detection analysis on the two land cover maps was performed by using the “Change detection” free extension in ArcView environment (Chandrasekhar, 1999). This GIS extension allowed computing a transition matrix reporting the transition between each pair of land cover categories as extent or proportion of area per unit time.

To analyze changes in landscape pattern, we used Fragstats software (McGarigal and Marks, 1995) to calculate several key landscape metrics for the studied period, applying an 8-cell neighbourhood definition. We selected representative metrics for landscape configuration and composition, including patch size and density, edge, contagion, connectivity, and diversity (Cushman et al., 2008). Since many metrics are closely related at the landscape level and describe similar aspects of landscape structure (Riitters et al., 1995; Cain et al., 1997; Neel et al., 2004), ten landscape-level metrics were selected excluding those that were highly correlated (r > 0.8) (Tischendorf, 2001). Landscape structure was also analyzed at the class level by computing 13 metrics for the 6 land cover classes, for the two time periods.

3. Results

3.1. Landscape structure

An accuracy assessment was performed on each land use map resulting in the K statistic (Landis and Koch, 1977) ranging from 0.86 (90.2% overall accuracy) for the 1954 image to 0.87 (90% overall accuracy) for the 2000 image. Our analyses on landscape structure showed that important changes have been occurred at *Diano* study site during the 1954-2000 period. A general increase in landscape heterogeneity from 1954 to the present was observed. The metrics computed for the landscape as a whole (Table 3) showed an increase in patch density (PD) and a decrease of patch area (AREA_MN, LPI). A reduction of shape complexity (Shape Index, Contiguity Index) was confirmed by a reduction of Edge Density (ED). Patches aggregation (CONTAG) decreased and a decline in the isolation of patches of the same category (ENN_MN) was also observed. Patch richness (six categories) remained unchanged during the observed period, but diversity (Simpson's Diversity Index) slightly increased.

3.2. Landscape change

The change detection approach highlighted remarkable changes in study area land use. 'Fields' and 'Orchards' land cover categories experienced the strongest variations (Fig. 3). The total surface of 'Orchards' increased of 24.6%, instead the 'Fields' category strongly (-26.9%) decreased. A slighter increasing tendency (3.6%) was observed for the 'Urban' class too. A relatively little change was observed for both the 'Forests' and 'Vineyard' categories that experienced an increase and a reduction respectively. Based on transitions occurring in the period from 1954 to 2000 (Table 4), five main transformations can be highlighted:

Fields → Orchards (375 ha), Fields → Vineyards (269 ha), Vineyards → Orchards (165 ha), Fields → Forests (161 ha), Forests → Orchards (105 ha).

The establishment of new settlements took place at the expenses of fields, forests and vineyards mainly. The noteworthy variation experienced by the 'Orchards' category pushed us to deepen our analysis on class level transitions. Only 3% of the total surface of 'Orchards' category remained unchanged, while 55% of them were former fields, 24% vineyards, 15% forests and 3% other categories.

4. Discussion

4.1 Landscape changes

Land use change study requires careful approaches able to deal with the heterogeneity of the involved tools (e.g. resolution) and the variability of the landscape processes (e.g. spatial and temporal scale). Such an investigation should be carried out by employing trustworthy data sources in order to correctly reconstruct historical landscape patterns (Burgi and Russell, 2001). For this reason, we adopted a rigorous photogrammetric approach that involved camera calibration certificate assuring accurate orthorectification results (Rocchini et al., 2012). In particular was possible to obtain an orientation quality for the GAI flight images higher than those from previous studies (Peroni et al., 2000; Gennaretti et al., 2011). The adopted image processing approach together with the obtained high classification accuracy assured a reliable land use change analysis.

Among the six land use categories, 'Orchards' increased from 1954 to 2000, replacing mainly other agricultural areas ('Fields' and 'Vineyards') and 'Forests'. During the same period, 'Fields' drastically decreased and were replaced mainly by 'Orchards', 'Vineyards' and 'Forests'. The strong expansion of 'Orchards', together with the increase of 'Urban' areas (Chiabrando et al., 2009, 2011) transformed a traditional landscape that was dominated by vineyards, crops and forests in a more fragmented land mosaic represented by a higher evenness between the land use categories. Moreover, a decrease of patch shape complexity was observed at landscape level (Contiguity and Landscape Shape indices) and this was probably due to the regular boundaries of the new hazelnut plantations. Particularly interesting is the overall dynamic of forests and vineyards that remained almost constant in terms of total surface but experienced a substantial change. In the case of forests, the natural reforestation process confined to the more marginal areas contrasted the expansion of orchards. The reforestation pattern observed at *Diano* study sites is in agreement with other Italian and European (Falcucci et al., 2007; Sitzia et al., 2010; Cocca et al. 2012) mountainous and hilly areas, but the productive nature of the site greatly limited the trees encroachment. The nonmarginal character of the investigated area is also witnessed by a remarkable increase of inhabitants observed in the last decades. This trend is in contrast with many other sites in Italy and other EU countries (Pinto-Correia, 1993; Peroni et al., 2000; Conti and Fagarazzi, 2004; Zomeni et al., 2008). As opposite to forests, the vineyards expanded in the most accessible and productive sites, thus limiting the orchards expansion too. However a reduction of vineyards surfaces in marginal and less accessible sites in favour of orchards was observed and confirmed by other studies in the Mediterranean region (e.g. Marull et al., 2010; Corti et al., 2011). On the contrary, there are other Mediterranean-climate ecoregions where a strong expansion of vineyards was favoured by wine market booming (Merenlender, 2000; Fairbanks et al. 2004) or agricultural policies (Cots-Folch et al., 2006).

4.2 Transition from vineyards to hazelnut orchards

The land use category defined as ‘Orchards’ in the present paper was almost entirely represented by hazelnut (*Corylus avellana* L.) orchards. A wider classification that included all the orchards was used in this paper in order to reduce misclassification errors (Franco, 1997). The domestication of hazelnut in Mediterranean areas probably started during the Greeks and Romans periods (Trotter, 1921; Boccacci and Botta, 2009), but became important for the *Langhe* region at the end of 1800 (Comunità Montana Alta Langa, 2009). At that time the appearance of downy mildew (*Plasmopara viticola* [Berk. & Curt] Berl. & de Toni), of grape phylloxera (*Daktulosphaira vitifoliae* Fitch) and other grapevine parasites increased the uncertainty of winemakers that started to cultivate the hazelnut (Valentini and Me, 2002). A similar dynamic has been observed also in the metropolitan region of Barcelona, Spain (Marull et al., 2010). During the Second World War the hazelnut oil was used as a surrogate for olive oil, but only in the late 80s its cultivation became really important and expanded in Piedmont region. The hazelnut cultivated surface increased by 20% in the last decade of the study period, and the highest increment peak was observed during the 1990 – 1995 period (Valentini and Me, 2002). Moreover, during the 1981 – 2000 period the surface expansion triggered an increase of hazelnut production from 9.171 tons to 11.959 tons and of its price from 1.66 €/Kg to 1.96 €/Kg. A shift of vineyard cultivation toward hazelnut is detectable from the historical statistics on cultivated surfaces of the Cuneo province (ISTAT 1971-2001). In a twenty year time span (1980 - 2000) hazelnut orchards have nearly doubled their surfaces, while vineyards have shown a remarkable decrease (Fig. 4). These historical statistics confirmed the results observed at *Diano* site through change detection analysis.

4.3 Agricultural policies concerning hazelnut cultivation

The strong increase of hazelnut surfaces occurred in Piedmont at the beginning of the 90s, reflected an increasing interest of landowners towards hazelnut and its economical potential (Valentini and Me, 2002). Even if we did not directly measure the effects of local and European agricultural policies on the hazelnut cultivation, it is interesting to mention those events that influenced its diffusion in Piedmont region. The European Union supported young farmers through a regulation devoted to improve the efficiency of agricultural structures (EC 2328/91) and encouraged the adoption of agronomic practices with a positive impact on the environment, through the agri-environment regulation (EU 2078/92). Probably the most important policy measure regarding hazelnut in Piedmont is a decree of the Italian Ministry of Agricultural and Forestry Policies (DM n. 2/12/93) that recognized its Protected Geographical Indication (PGI) under the appellation "Nocciola Piemonte". In 1996 the European Union registered the "Piedmont hazelnut" as a Protected Geographical Indication (PGI) through a regulation on the registration of geographical indications and designations of origin (EC 1107/96). The two latter regulations supported and acknowledged the quality of the hazelnut fruit, but other measures favoured the hazelnut expansion too. A direct Community aid to farmers producing hazelnuts was granted since the 2003 (EC 1782/03) and more recently (2007) the hazelnut variety cultivated in the *Langhe* region was registered within the Community Plant Variety Office (CPVO) with a new name ("Tonda gentile Trilobata") for a more efficient preservation. All these European regulations were locally acknowledged by the PSR 2007-2013 (Action 214) rural development plan (Regione Piemonte, 2009). The success of hazelnut orchard in the *Langhe* region was favoured by the increasing demand for quality products related to the sweet factory market (Garrone and Vacchetti, 1994; Cova and Pace, 2006) that together with the EU food-labelling (PGI) policy facilitated the "Nocciola Piemonte" to survive against stronger producer countries such as Turkey (Reis and Yomralioglu, 2006). In fact, according to FAO database (FAOSTAT, 2010), hazelnut plantations in Turkey increased their surface by 40% during the 1961 – 2000 time span. A smaller increase (23%) of hazelnut surface in Italy and a stable situation in Spain have been observed in the same period.

4.4 Management issue

Hazelnut cultivation in the Langhe region expanded at the expenses of other orchards, fallow lands, grasslands and generally in places where the cultivation of grapes was less remunerative (Valentini and Me, 2002). Particularly important is the decline of crops in hilly regions such as *Langhe* that resulted less productive than those located in flat areas (Comunità Montana Alta Langa 2009). The rapid expansion of hazelnut plantations is radically transforming the rural landscape of *Langhe* region and its further expansion could result in a use of not suitable areas for its cultivation. This phenomenon has been recently observed in Turkey, where the hazelnut production exceeds the demand mainly due to a lack in land use policy (Reis and Yomralioglu, 2006; Aydinoglu, 2010). Medium-term consequence for this may include the abandonment of no more profitable hazelnut orchards and consequent land degradation. These potential problems could be averted if the effective quality of *Langhe* hazelnut production will continue to be achieved and adequately protected. This paper highlights the potential of change detection investigations as a support for national and international bodies in evaluating rural policies for valuable agriculture (London Economics, 2008) and their effects on landscape, production and society (Westhoek et al., 2006; Martinez-Casasnovas et al., 2010; Van Berkel and Verburg, 2011). Future researches should extend the study area to give an accurate estimation of rural landscape dynamics filling the research gap regarding remote detection of hazelnut cultivations expansion in the Mediterranean area (Franco, 1997; Reis and Yomralioglu, 2006). Moreover, socio-economic factors should be integrated in the analysis of the drivers of land use change in order to achieve a more coherent and complete study of the process under study (e.g. De Aranzabal et al., 2008; Tzanopoulos et al., in press).

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Tables

Table 1 Comparison of root mean square errors obtained through the orthorectification of the 1954 aerial photographs with calibration certificate or with focal length only.

	ResX *(m)*	*ResY* *(m)*	*ResZ* *(m)*	*|ResX|* *(m)*	*|ResY |* *(m)*	*|Res Z|* *(m)*
Calibration certificate						
Mean	-0.11	-0.95	-1.29	2.45	1.80	1.51
RMS	3.12	2.07	1.48	1.65	1.25	1.22
Focal length						
Mean	1.36	4.27	14.86	8.42	16.73	18.78
RMS	13.51	19.95	15.86	10.10	9.63	9.88

Table 2 Description of the land use/land cover (LUCL) categories adopted in the aerial images classification at *Diano* site.

LULC class	Abbreviation	Description
Forests	FO	Forest patches or single trees, excluding arboriculture plantations
Fields	FI	Cultivated or uncultivated grasslands and polygons not univocally identified
Vineyards	VI	Surfaces cultivated with vine
Urban	UR	Human infrastructures and buildings
Orchards	OR	Arboriculture and hazelnut orchards
Waters	WA	Water bodies (lakes and rivers)

Table 3 Metrics on landscape level (McGarigal and Marks 1995) computed for the *Diano* study site at two periods (1954-2000 land use maps).

Metrics (abbreviation)	Component measured	Units	Land Use maps (2651.59 ha)	
			1954	2000
Patch Density (PD)	Density	n/100 ha	213.26	344.86
Patch Area Mean (AREA_MN)	Area	ha	0.47	0.29
Largest Patch Index (LPI)	Area	%	4.25	3.68
Edge Density (ED)	Edge	m/ha	486.95	411.43
Landscape Shape Index (LSI)	Edge	-	63.78	54.05
Shape Index Mean (SHAPE_MN)	Shape	-	1.99	1.52
Contiguity Index Mean (CONTIG_MN)	Shape	-	0.66	0.41
Euclidean N.N. Distance (ENN_MN)	Isolation	m	7.06	4.39
Contagion Index (CONTAG)	Contagion	%	60.08	53.55
Simpson's Diversity Index (SIDI)	Diversity	-	0.69	0.77

Table 4 Transition matrix showing land cover changes (ha) from 1954 to 2000. Values are expressed in hectares and in percent (in parentheses) relative to the total area of the class in 1954.

Land uses in 1954	Land uses in 2000						
	Forests	Fields	Vineyards	Urban	Orchards	Water	Total area (ha)
Forests	388.21 (60%)	58.77 (9%)	56.07 (9%)	41.93 (6%)	105.17 (16%)	0.89 (<1%)	651.04 (25%)
Fields	160.81 (15%)	221.19 (20%)	268.69 (24%)	72.50 (7%)	375.24 (34%)	0.77 (<1%)	1099.20 (41%)
Vineyards	78.69 (11%)	83.34 (11%)	370.93 (50%)	36.59 (5%)	165.09 (22%)	0.18 (<1%)	734.82 (28%)
Urban	12.16 (11%)	19.03 (17%)	13.85 (12%)	54.62 (48%)	14.19 (12%)	0.16 (<1%)	114.00 (4%)
Orchards	6.16 (18%)	1.25 (4%)	3.66 (10%)	1.56 (4%)	22.31 (64%)	0.00 (<1%)	34.92 (1%)
Water	7.20 (41%)	2.97 (17%)	0.05 (<1%)	1.74 (10%)	4.16 (24%)	1.49 (8%)	17.60 (1%)
Total area (ha)	653.23 (25%)	386.54 (15%)	713.23 (27%)	208.93 (8%)	686.16 (26%)	3.49 (<1%)	2651.59 (100%)

Table 5 Total land surface area occupied by hazelnut orchards in Italy. Data are given as a whole and divided by region (ISTAT, 2012). Statistical records are also reported for Turkey (Turkish Statistical Institute, 2009).

Italian Regions	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Data source
Piemonte	8042	8042	8042	8043	9211	9519	9718	10531	11671	12366	12388	12142	12133	ISTAT

Campania	24805	24841	25417	25064	23496	22872	22831	22834	22828	22819	22849	12616	22787	ISTAT
Lazio	18930	18878	18949	18999	19033	18996	18974	18985	18929	18914	18968	18969	19008	ISTAT
Sicilia	15878	15730	15368	15368	15431	15146	15090	15080	16482	14930	16075	14350	14740	ISTAT
Others	2140	2134	2058	2071	2094	2080	2244	2245	2394	2011	1749	1521	1814	ISTAT
Italy	69795	69625	69834	69545	69265	68613	68857	69675	72304	71040	72029	59598	70482	ISTAT
Turkey	530700	549500	550000	560000	600000	621200	621200	621200	621200	621200	-	-	-	TSI

Figure captions

Figure 1 Location of the 2651 ha study area (white dot) within Piedmont region (upper image) and its topography (lower image) with main rivers and settlements.

Figure 2 Land use classifications of 1954 (upper map) and 2000 (lower map) orthoimages.

Figure 3 Land uses expressed as proportion of the total study site surface in 1954 (black bars) and 2000 (grey bars) at *Diano* site.

Figure 4 Agricultural statistics of Cuneo (Piedmont, Italy) province in the 1971-2001 period.

References

Acosta, A., Carranza, M.L., Giancola, M., 2005. Landscape Change and Ecosystem Classification in a Municipal District of a Small City (Isernia, Central Italy). Environmental Monitoring and Assessment 108, 323 - 335.

Aydinoglu, A.C., 2010. Examining environmental condition on the growth areas of Turkish hazelnut (Corylus colurna L.). African Journal of Biotechnology 9, 6492-6502.

Amsden, A.H., 1991. Diffusion of Development: The Late-Industrializing Model and Greater East Asia. The American Economic Review 81, 282 - 286.

Antrop, M., 2004. Landscape change and the urbanization process in Europe. Landscape and Urban Planning 67, 9 – 26.

ARPA, 2012. Geologia e processi di dissesto. <http://webgis.arpa.piemonte.it/elenco_servizi/index.html>

Becattini, G., Coltorti, F., 2006. Areas of large enterprise and industrial districts in the development of post-war Italy: A preliminary survey. European Planning Studies 14, 1105 -1138.

Beni Culturali, 2011. National Aerial Photographic Archive - The Collection. <http://www.iccd.beniculturali.it/index.php?en/165/le-collezioni>

Boccacci, P., Botta, R., 2009. Investigating the origin of hazelnut (Corylus avellana L.) cultivars using chloroplast microsatellites. Genetic Resources and Crop Evolution 56, 851 - 859.

Bonet, A., 2004. Secondary succession of semi-arid Mediterranean old-fields in south-eastern Spain: Insights for conservation and restoration of degraded lands. Journal of Arid Environments 56, 213 - 233.

Burgi, M., Russell, E.W.B., 2001. Integrative methods to study landscape changes. Land Use Policy 18, 9-16.

Cain, D., Riitters, K., Orvis, K., 1997. A multi-scale analysis of landscape statistics. Landscape Ecology 12, 199 - 212.

Campana, S., Francovich, R., 2003. Landscape archaeology in Tuscany: Cultural Resource Management, remotely sensed techniques, GIS based data integration and interpretation, in: Forte, M., Williams, P. R. (Ed.), The Reconstruction of Archaeological Landscapes through Digital Technologies. Archaeopress, Oxford, pp. 15 - 28.

Ceraudo, G., 2005. 105 Years of Archaeological Aerial Photography in Italy (1899 - 2004), in: Bourgeois, J., Meganck, M. (Ed.), Aerial Photography and Archaeology 2003. A Century of Information. Academia Press, Ghent University pp. 73 - 86.

Chandrasekhar, T., 1999. Change Detection Extension for ArcView. ESRI, Redlands.

Chiabrando, R., Fabrizio, E., Garnero, G., 2009. The territorial and landscape impacts of photovoltaic systems: Definition of impacts and assessment of the glare risk. Renewable and Sustainable Energy Reviews 13, 2441-2451.

Chiabrando, R., Fabrizio, E., Garnero, G., 2011. On the applicability of the visual impact assessment OAISPP tool to photovoltaic plants. Renewable and Sustainable Energy Reviews 15, 845-850.

Cocca, G., Sturaro, E., Gallo, L., Ramanzin, M., 2012. Is the abandonment of traditional livestock farming systems the main driver of mountain landscape change in Alpine areas? Land Use Policy 29, 878 - 886.

Comunità Montana Alta Langa, 2009. La coltivazione del nocciolo in Alta Langa. Linee guida per una corilicoltura sostenibile. Comunità Montana Alta Langa, Bra, p. 66.

Conti, G., Fagarazzi, L., 2004. Sustainable mountain development and the key issue of abandonment of marginal rural areas. Planum - The Journal of Urbanism 11, 1 - 20.

Corti, G., Cavallo, E., Cocco, S., Biddoccu, M., Brecciaroli, G., Agnelli, A., 2011. Evaluation of Erosion Intensity and Some of Its Consequences in Vineyards from Two Hilly Environments Under a Mediterranean Type of Climate, Italy, in: Godone, D., Stanchi, S. (Ed.), Soil Erosion Issues in Agriculture. InTech, Rijeka, pp. 113 – 160.

Cots-Folch, R., Martinez-Casasnovas, J.A., Ramos, M.C., 2006. Land terracing for new vineyard plantations in the northeastern Spanish Mediterranean region: Landscape effects of the EU council regulation policy for vineyards' restructuring. Agriculture Ecosystems and Environment 115, 88–96.

Cova, B., Pace, S., 2006. Brand community of convenience products: new forms of customer empowerment – the case "my Nutella The Community". European Journal of Marketing 40, 1087 - 1105.

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). Landscape and Urban Planning 100, 98-108.

Cushman, S.A., McGarigal, K., Neel, M.C., 2008. Parsimony in landscape metrics: Strength, universality, and consistency. Ecological Indicators 8, 691-703.

De Aranzabal, I., Schmitz, M.F., Aguilera, P., Pineda, F.D., 2008. Modelling of landscape changes derived from the dynamics of socio-ecological systems: A case of study in a semiarid Mediterranean landscape. Ecological Indicators 8, 672-685.

Delmastro, M., 2005. An investigation into the quality of wine: Evidence from piedmont. Journal of Wine Research 16, 1-17.

European Commission, 2004. The Common Agricultural Policy explained. European Commission Directorate General for Agriculture, Brussels.

Falcucci, A., Maiorano, L., Boitani, L., 2007. Changes in land-use/land-cover patterns in Italy and their implications for biodiversity conservation. Landscape Ecology 22, 617 – 631.

Fauri, F., 1996. The Role of Fiat in the Development of the Italian Car Industry in the 1950's. The Business History Review 70, 167 - 206.

Fairbanks, D.H.K., Hughes, C.J., Turpie, J.K., 2004. Potential impact of viticulture expansion on habitat types in the Cape Floristic Region, South Africa. Biodiversity and Conservation 13, 1075–1100.

FAOSTAT, 2010. <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>

Franco, S., 1997. Use of remote sensing to evaluate the spatial distribution of hazelnut cultivation: Results of a study performed in an Italian production area. Acta Horticulturae 445, 381 - 388.

Garrone, W., Vacchetti, M., 1994. Hazelnut quality in relation with the requirements of confectionary industry, in: Me, G., Radicati, L. (Ed.), III International Congress on Hazelnut, Wageningen pp. 641 - 647.

Gennaretti, F., Ripa, M.N., Gobattoni, F., Boccia, L., Pelorosso, R., 2011. A methodology proposal for land cover change analysis using historical aerial photos. Journal of Geography and Regional Planning 4, 542 - 556.

Hatton, T.J., Williamson, J.G., 1994. What drove the mass migrations from Europe in the late nineteenth century? Population and Development Review 20, 1 - 27.

IRPI, 2012. Aerial photo archive. <http://www.irpi.to.cnr.it/index_en.php?page=aerofototeca_en.>

Kaye, C.A., 1957. Military Geology in the United States Sector of the European Theater of Operations During World War II. Geological Society of America Bulletin 68, 47 - 54.

Landis, J.R., Koch, G.G. 1977. The measurement of observer agreement for categorical data. Biometrics 33, 159-174.London Economics, 2008. Evaluation of the CAP policy on protected designations of origin (PDO) and protected geographical indications (PGI). European Commission - Agriculture and Rural Development, p. 275.

Martinez-Casasnovas, J.A., Ramos, M.C., Cots-Folch, R., 2010. Influence of the EU CAP on terrain morphology and vineyard cultivation in the Priorat region of NE Spain. Land Use Policy 27, 11 - 21.

Marull, J., Pinob, J., Tello, E., Cordobilla, M.J., 2010. Social metabolism, landscape change and land-use planning in the Barcelona Metropolitan Region. Land Use Policy 27, 497 – 510.

McClure, J.T., Griffiths, G.H., 2002. Historic Landscape Reconstruction and Visualisation, West Oxfordshire, England. Transactions in GIS 18, 289 - 352.

McGarigal, K., Marks, B.J., 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure, Portland.

Meeus, J.H.A., Wijermans, M.P., Vroom, M.J., 1990. Agricultural landscapes in Europe and their transformation. Landscape Urban Planning 18, 289 - 352.

Merenlender, A.M. 2000. Mapping vineyard expansion provides information on agriculture and the environment. California Agriculture 54, 7–12.

Mikhail, M.E., Bethel, J.S., Mc Glone, J.C., 2001. Introduction to Modern Photogrammetry. John Wiley and Sons, New York, p. 479.

Morgan, J.L., Gergel, S.E., Coops, N.C., 2010. Aerial photography: a rapidly evolving tool for ecological management. BioScience 60, 47 - 59.

Neel, M., McGarigal, K., Cushman, S., 2004. Behavior of class-level landscape metrics across gradients of class aggregation and area. Landscape Ecology 19, 435 - 455.

Peel, M.C., Finlayson, B.L., McMahon, T.A., 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences 11, 1633 - 1644.

Peroni, P., Ferri, F., Avena, G.C., 2000. Temporal and spatial changes in a mountainous area of central Italy. Journal of Vegetation Science 11, 505 - 514.

Pinto-Correia, T., 2000. Future development in Portuguese rural areas: how to manage agricultural support for landscape conservation? Landscape and Urban Planning 50, 95 - 106.

Pinto-Correia, T., 1993. Land abandonment: changes in the land use patterns around the Mediterranean Basin. International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) Zaragoza, pp. 97 – 112.

Rabbinge, R., Van Latesteijn, H.C., 1992. Long-term options for land use in the European community. Agricultural Systems 40, 195 - 210.

Reed, H.P., 1946. The Development of the Terrain Model in the War. Geographical Review 36, 632 - 652.

Regione Piemonte, 2009. Programma di sviluppo rurale PSR 2007-2013. Regione Piemonte, Torino, p. 656.

Reis, S., Yomralioglu, T., 2006. Detection of current and potential hazelnut plantation areas in Trabzon, North East Turkey using GIS and RS. Journal of Environmental Biology 27, 653 - 659.

Riitters, K., O'Neill, R., Hunsaker, C., Wickham, J., Yankee, D., Timmins, S., Jones, K., Jackson, B., 1995. A factor analysis of landscape pattern and structure metrics. Landscape Ecology 10, 23 - 39.

Rocchini, D., Metz, M., Frigeri, M., Delucchi, L., Marcantonio, M., Neteler, M., 2012. Robust rectification of aerial photographs in an open source environment. Computer & Geosciences 39, 145 - 151.

Scardozzi, G., 2008. Old high resolution satellite images for landscape archaeology: case studies from Turkey and Iraq, in: Michel, U., Civco, D. L., Ehlers, M., Kaufmann, H. J. (Ed.), Remote Sensing for Environmental Monitoring, GIS Applications, and Geology VIII.

Schiefer, E., Gilbert, R., 2007. Reconstructing morphometric change in a proglacial landscape using historical aerial photography and automated DEM generation. Geomorphology 88, 167 - 178.

Sitzia, T., Semenzato, P., Trentanovi, G., 2010. Natural reforestation is changing spatial patterns of rural mountain and hill landscapes: A global overview. Forest Ecology and Management 259, 1354 - 1362.

Sluiter, R., de Jong, S.M., 2007. Spatial patterns of Mediterranean land abandonment and related land cover transitions. Landscape Ecology 22, 559 - 576.

Stoate, C., Boatman, N.D., Borralho, R.J., Carvalho, C.R., Snoo, G.R.d., Eden, P., 2001. Ecological impacts of arable intensification in Europe. Journal of Environmental Management 63, 337-365.

Tanrivermis, H., 2003. Agricultural land use change and sustainable use of land resources in the Mediterranean region of Turkey. Journal of Arid Environments 54, 553 - 564.

Tischendorf, L., 2001. Can landscape indices predict ecological processes consistently? Landscape Ecology 16, 235 - 254.

Trotter, A., 1921. Contributo alla storia colturale del nocciuolo nella Campania, Congresso di Arboricoltura Meridionale, Napoli (Italy), pp. 3 - 19.

Turner, M.G., Gardner, R.H., 1990. Quantitative Methods in Landscape Ecology. Springer, New York.

Tzanopoulos, J., Jones, P.J., Mortimer, S.R., in press. The implications of the 2003 Common Agricultural Policy reforms for land-use and landscape quality in England. Landscape and Urban Planning.

UNESCO, 2012. Wine Grape landscapes: Langhe, Roero, Monferrato and Valtellina. <http://whc.unesco.org/en/tentativelists/5001/>

Valentini, N., Me, G., 2002. Attualità e problematiche della coltura del nocciolo in Italia: la situazione piemontese, Atti del 2° Convegno Nazionale sul Nocciolo, Giffoni Valle Piana (SA), pp. 133 - 140.

Van Berkel, D.B., Verburg, P.H., 2011. Sensitising rural policy: Assessing spatial variation in rural development options for Europe. Land Use Policy 28, 447 - 459.

Van Rompaey, A.J.J., Govers, G., Van Hecke, E., Jacobs, K., 2001. The impacts of land use policy on the soil erosion risk: a case study in central Belgium. Agriculture, Ecosystems and Environment 83, 83 – 94.

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

Vuorela, N., Alho, P., Kalliola, R., 2002. Systematic Assessment of Maps as Source Information in Landscape-change Research. Landscape Research 27, 141 - 166.

Westhoek, H.J., van den Berg, M., Bakkes, J. A., 2006. Scenario development to explore the future of Europe's rural areas. Agriculture, Ecosystems & Environment 114, 7 - 20.

Zomeni, M., Tzanopoulos, J., Pantis, J. D., 2008. Historical analysis of landscape change using remote sensing techniques: An explanatory tool for agricultural transformation in Greek rural areas. Landscape and Urban Planning 86, 38- 46.