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Olive agroforestry systems in Sicily: Cultivated typologies and secondary succession processes after abandonment

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Abstract

The first part of this study provides an overview on Sicilian olive systems. Subsequently, the study describes the different typologies of cultivated agroforestry systems present in South-Eastern Sicily employing olive trees in association with other Mediterranean tree species, in particular for the production of firewood, coal and animal food (downy or pubescent oak, holm oak, cork oak), but also in association with forage or grazing species (oat, barley, vetch, etc.) or cereals. The study shows that Sicilian agroforestry systems are much more diversified than it was known so far. In the second part, the study describes the spontaneous colonization processes by plants, observed in abandoned olive agroforestry systems and leading to the formation of more complex ecosystems (renaturation). Most of the previously described agroforestry systems are at present subject to abandonment. Our analysis of secondary succession dynamics shows how woody species, and above all those species which are part of the cultivated system, rapidly colonize abandoned areas, so that a maquis-wood is formed within few decades.

Keywords: *Agrosilvicultural systems, Hyblaean Plateau, landscape, Olea europaea, terraces*

Introduction

Over the last recent years, numerous research papers have highlighted the presence and widespread diffusion of agroforestry systems in Europe and in the USA (Gordon & Newmann 1997; Eichhorn et al. 2006). In Italy, the diversity of agroforestry systems has been shown by some local studies (Bertolotto et al. 1995; Cullotta et al. 1999; La Mantia 2005a).

Agrosilvicultural systems are characterized by a wide variety of management typologies and of polyfunctional outputs, combining productive services and environmental protection issues. In industrialised countries of the temperate region, over the last decades problems have risen on how to manage agricultural and silvicultural systems, above all as regards the productive surplus of certain crop plants, the considerable input of energy required, the massive employment of chemical substances, and the continuous need of biomass for industrial use. Moreover, the importance of tree cover for contrasting environmental degradation (erosion by wind and water, greenhouse effect, water and air pollution) has been recognized. In this context, agrosilviculture with its technical and biological flexibility and its multiproductive approach can be regarded as a valid alternative, in particular where the environmental and economic conditions do not allow other solutions (Paris & Cannata 1991; Le Houerou 1993). Agrosilvicultural systems may also play an important role for food safety issues, as it has been underlined during the ''Italian Official Celebrations World Food Day 2005''.

In Sicily, geomorphological conditions and the presence of low-productive soils and very steep, non-wooded surfaces have led to the development of combined land use systems. The typical Sicilian agroforestry systems are linked to traditional tree crops characterized by an intermediate activity between agricultural and extensive silvicultural techniques (Cullotta et al. 1999). Combined systems where fruit trees play a key role, such as carob tree (*Ceratonia siliqua* L.), almond (*Prunus dulcis* (Mill.) Webb), hazelnut (*Corylus avellana* L.), ash tree (*Fraxinus* spp.), but above all olive trees (*Olea europaea* L.) are of paramount importance. Olive trees are often found in the hilly zones of Sicily in association with spontaneous herb and shrub species which are regularly grazed after fruit harvesting

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(autumn) and, to a lesser extent, during summer (Cullotta et al. 1999). Another important system is that including *Quercus* ssp. woods (*ilex* L., *suber* L., *congesta* C. Presl, *dalechampii* Ten., *amplifolia* Guss., *gussonei* (Borzi) Brullo, *cerris* L.), which are frequently overgrazed and show considerable similarities to the Iberian "*Dehesas*" (Vicente & Ales 2006). Even if olive agroforestry systems are an important component of the Sicilian agriculture, no accurate classification and description of them has been drawn up so far. So, the first aim of this manuscript is to classify and describe the named Sicilian agroforestry systems.

The second focus of this study is on spontaneous colonization processes by plants taking place in abandoned agroforestry systems, which may lead to the formation of more complex ecosystems (renaturation). In Sicily, large surfaces characterized by agroforestry systems have been abandoned over the last decades, even if this process is not visible from the agricultural statistics (cf. Table I) for a simple reason: many olive orchards, and above all the olive agroforestry systems, are located in non-mechanizable mountain areas. The abandonment of these areas has been replaced and outnumbered by the cultivation of olives in the plains, frequently with a low degree of environmental suitability, due to special financial contributions.

In the first place, the abandonment processes have affected low-profit areas. Low profits are mainly caused by the low income of farmers, but also by an excessive parcelling due to succession and by the depopulation process of rural areas. There are no studies available on renaturation dynamics in Sicilian olive agroforestry systems, but from studies on abandoned olive groves in Italy (Blasi et al. 1997), it can be assumed that the cessation of human cultivating activity leads to significant modifications of the floristic composition and of the structure of these systems within few decades. However, the study of secondary succession processes in agroforestry systems should lead to results different from secondary succession processes in other old fields (such as abandoned monocultures of olive, vine, grain, etc.) for the simple reason that dispersal centers for woody species colonization are located within the old field, instead of being located on its border or at a certain distance from it. In fact, other studies have shown that colonization processes by perennial herbs and woody plant species are mainly influenced by the quantity of mother plants which are present in vicinity of the old field (Mc Donnell & Stiles 1983; Debussche & Lepart 1992; Speranza et al. 1995). A recent study on vine fallows has highlighted that old fields surrounded by wood or maquis communities are subject to a more rapid renaturation process than those surrounded only by grasslands or cropland (Rühl 2007). With nearby dispersal centers, abandoned vine crops are colonized by dense maquis communities (Rühl et al. 2006; La Mantia et al. 2008) 3–5 decades after the abandonment, and also olive groves after less than 5 decades can host woods (Blasi et al. 1997). Therefore, as regards renaturation in agroforestry systems our study focuses on the question whether the presence of woody species dispersal centers (olive, *Quercus* ssp., etc.) can accelerate secondary succession processes, and on the issue whether formerly cultivated trees survive in a way to be part of the older stages of succession.

Materials and methods

For the classification and characterization of Sicilian agroforestry systems, we have initially subdivided all surfaces ascribed to olive orchards into classes of homogeneous environmental conditions. This classification is in accordance with the one made by the AA.VV. (1996), which coincides by the majority with a classification of olive agrarian systems based on: soil characters, varieties, tree density (nr/ha), techniques of pruning and tree shaping (Caruso et al. 2007).

As a second step, we have carried out a more detailed analysis on the olive agroforestry systems present on the Hyblaean Plateau, which makes up large part of South-Eastern Sicily, extending between 36°40′ and 37°20′ N and between 14°30′ and 15°20′ E (Figure 1). The Hyblaean landscape is characterized by large tablelands interrupted by deep ravines generated by water erosion (Grande 1996). A large part of the Hyblaean Plateau is made up of calcareous submarine rocks, but in its Northern and Southern part there are also volcanic rocks: in fact, the highest point *Mount Lauro* (986 m a.s.l.), is a volcanic mountain. The most common soils are Lithosols, Eutric Regosols, Eutric Cambisols, and

Table I. Land surface (ha) of Sicily covered by the main crop plants in 1982, 1990 and 2000.

	1982 (ha)	1990 (ha)	2000 (ha)	Change from 1982 to 1990 (%)	Change from 1990 to 2000 (%)
Olive	118.596	120.883	138.308	+2.287	+17.425
Other tree crops	377.188	357.651	257.152	−19.537	−100.499
Grain crops	881.335	801.575	647.857	−79.760	−153.718

Source: National Institute for Statistics.

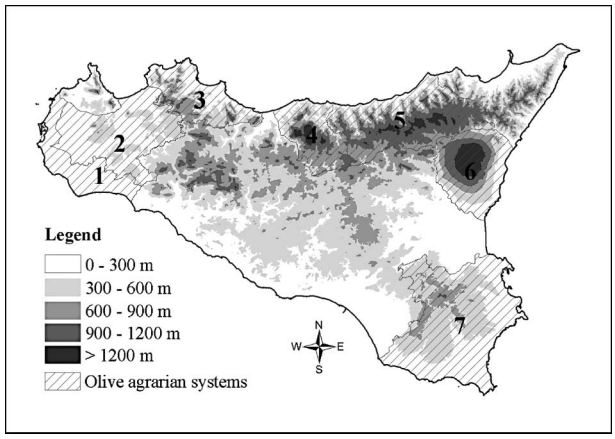

Figure 1. The most important olive systems present in Sicily and the location of the studied area: 1, Western coastal plane; 2, Hills of Trapani; 3, Palermo mountains and Palermo coastal planes; 4, Northern Mountain Chain (Madonie mountains); 5, Northern Mountain Chain (Nebrodi Mountains); 6, Mount Etna; 7, Hyblaean Plateau.

Chromic Luvisols. The climate of the Hyblaean Plateau is typically Mediterranean, with average annual rainfall between 600 and 800 mm, prevalently concentrated between October and January. In summer, there is a drought period of 4 months. The average annual temperatures range between 14° and 18°C.

The cultural landscape of the Hyblaean Plateau is one of the most anciently colonized and transformed landscapes of Sicily (Di Pasquale & Garfì 1988; Ruggiero & Scrofani 1996; Tiralongo 1998). Since the first colonizations, there have been agricultural and pasturing activities. Moreover, the aspect of the landscape is closely linked to its richness in stones and rocky outcrops, used by the farmers to build dry-stone walls.

Up to the first decades of the twentieth century, the feudal land use system based on cattle raising and crop cultivation, which had taken its origin in the 12th century under Norman domination, remained unmodified. At this point in time, the landscape was at its peak of anthropogenic pressure. All usable surfaces were cultivated and the woods were intensely used. Large grazed surfaces were agroforestry systems, characterized by a contemporary cultivation of olive, almond, and carob trees. In the following decades, however, this pressure decreased with the emigration flow of Sicilians to Extra-European countries. Today, still large surfaces are cultivated by grain and olive crops, and the grazing pressure is high.

For our analysis of cultivated and abandoned olive agroforestry systems present in South-Eastern Sicily, the Hyblaean Plateau was checked for the presence of olive crops cultivated in association with Mediterranean tree and herbaceous species of agricultural relevance, such as *Triticum durum, Avena sativa, Vicia sativa, Vicia faba,* and *Vitis vinifera*. Then, within the spotted areas sample plots were chosen.

In the cultivated systems, the *relevés* were focussed on the description of the respective cultivation typology from a productive, as well as from an ecological–environmental point of view. Apart from interviews with the local farmers, determined parameters were taken, based on a methodological approach already used in other studies of agroforestry systems in Italy (Bertolotto et al. 1995). More specifically, the parameters considered were the following: (1) principal and associated crop species, (2) extension and geographic position, (3) altitude and inclination, (4) structural classification (agrosilvicultural, silvopastoral, or agrosilvopastoral), (5) horizontal structure of the woody component and density (nr. of individuals/ha), (6) services of the woody and the herbaceous components (productive, protective, naturalistic), (7) the type and intensity of grazing, where available.

For the abandoned sites, on the other hand, the age of abandonment was identified, and whether the area has been subject to disturbances since its abandonment. This was done through interviews with the respective land owner and an analysis of land-use change by aerial photos (photos were used from (a) year 1955 (b/w) from *Istituto Geografico Militare* of Florence; (b) year 1968 (b/w) from *Istituto Geografico Militare* of Florence; (c) year 1987 (colour) from *A.T.A. Regione Siciliana, Compagnia Generale Riprese Aeree* of Parma)). In total, seven former olive agroforestry systems were selected, and in each of them was made a representative *relevé* of 20 × 10 m, which was chosen randomly within the abandoned area (cf. Rühl et al. 2005). All selected sites are characterized by Mesomediterranean Low Subhumid bioclimatic conditions (cf. Rivas-Martínez 1994; Rivas-Martínez & Loidi Arregui 1999) and by soil associations of Lithosols and Eutric Cambisols (Fierotti 1988).

In each *relevé,* the present woody species were recorded and all woody individuals were counted by dividing them into seedlings, saplings, and adults. All the individuals being not older than 1 year have been defined as seedlings, while all young individuals being not taller than 10 cm were considered as saplings. Moreover, since it was assumed that the dry-stone walls favor microsites for woody colonization (cf. Rühl 2007), woody individuals growing within 20 cm from walls were separately marked within the relevé sheet in order to study the influence of dry-stone walls on renaturation processes.

Results

The Sicilian olive agroforestry systems

In Sicily, olive tree is the main crop on large surfaces. The presence of very old trees (called ''Saracen olives'') indicates that olive tree has been a

widespread crop plant already in ancient times. It was surely cultivated already in Greek and Roman times (Cannella 2007), and the presence of names of some varieties with Arab roots proves its frequent use at the end of the first millennium ''*Zaituna*'' is a name of a local variety and the Arabic word for olive (Caruso et al. 2007).

The high environmental heterogeneity of the island has determined the development of very heterogeneous olive-cultivating systems, and, thus, of olive agroforestry systems. Often, a system is linked to particular environmental conditions and is characterized by a variety of olive (Caruso et al. 2007). On a general level, it is possible to link these systems to geographical areas which are homogeneous from a morphological and an environmental point of view (Regione Siciliana 1996) (Table II; Figure 1).

Today, large parts of these agroforestry systems have been abandoned, above all the ones located in the Palermo Mountains and in the Madonie Mountains, while others have been subject to intensification.

The olive agroforestry systems of South-Eastern Sicily

Description of the typologies. In total, six different cultivated olive agroforestry systems have been spotted in the Hyblaean Plateau (Table III and Photo 1); two of them were found abandoned.

Olive with horticultural crops. This typology is very common, but it covers small surfaces, as it is often linked to family self-sufficient production. In many cases, these olive groves are located on terraced slopes and, in relation to the width of the terrace, olive trees are grown in rows or in a more or less regular spacing. As a consequence, the density of olive trees per ha is very heterogeneous. The herbaceous component, which is often made up of nitrogen-fixing species, is grown in a discontinuous way in relation to the need of the farmer's family. Other than nitrogen-fixing species (broad bean, pea and chick-pea), a large variety of the most common horticultural crops (potato, tomato, onion, garlic) are also cultivated here. In another variety of this typology, officinal species are grown, such as *Salvia officinalis*, *Thymus* spp., and *Origanum* spp. In this case, however, the production is not focussed on family self-sufficiency, but on organic products. The prevailing function is productive but there is also a protective function, since the continuous maintenance of dry-stone walls prevents erosive processes.

Olive with Prunus amygdalus (almond). This typology was mainly spotted in the Eastern part of the Hyblaean Plateau. It is cultivated on slopes with low inclination values and, thus, it covers large, regular parcels. As it is typical for the Hyblaean landscape, these are delimited by dry-stone walls. The woody component is characterized by dense trees (mainly with 100 trees ha^{-1}), mainly made up of almonds and less of olives, which are present with 15 to 25 trees ha^{-1} on average. Usually, the trees are set in a more or less regular spacing, with a casual distribution of olive trees within the rows of almond. The dense cultivation of trees is possible due to the low quantities of water needed by almond (de Herralde et al. 2003; Romero et al. 2004) and by its deciduous character, which allows full development of olive trees.

The main aim of this system is fruit production, while no grazing activity is involved. In some cases, a couple of other tree species can be associated, such as carob tree (*Ceratonia siliqua)* and pear (*Pyrus communis*). Due to the low inclinations characterizing these systems their soil protective value is low.

Olive with Vitis vinifera (vine). The associated cultivation of olive and vine has always been a very characteristic combination in Sicily and, in particular, on the Hyblaean Plateau. In general, these systems are grown as small parcels of 0.2–0.3 ha within other land use systems or in association with the typology ''Olive with forage and grain species''. The density of olive trees per ha is very heterogeneous and depends on the spatial organization of the vine rows. In fact, the olives are planted in rows alternating with rows of vine, or in a casual distribution with smaller density. Olive tree density is always <50 individuals ha^{-1}.

Olive trees are grown with very large crowns and this modifies the microclimatic conditions because they block the wind and reduce evaporation from the soil surface. In addition, they also protect vine plants from winter frost and reduce weeds, insects, and pathogens (Altieri & Nicholls 2002).

Usually, these systems can be found as part of larger agricultural or zootechnical farms, where they are not part of the major productive cycles, but fulfil the needs of the farmer's family. In this sense, this typology is very much linked to the agricultural traditions of the territory.

Olive with forage and grain species. This typology is the most common and is mainly found in the municipalities of Buscemi, Giarratana, and Palazzolo Acreide. Olive trees are present in low densities (15 trees ha^{-1}) and are more or less casually distributed within the forage crop. Apart from olive trees, in some cases also downy oak, almond and carob trees can be found as part of the tree component.

Table II. The most important olive systems in Sicily.

System*	Province	Characteristics, cultivars**
''Western coastal plane'' and part of ''Hills of Trapani''	Trapani, Palermo, Agrigento	Fields without inclination. Altitudes < 600 a.s.l. This area is characterized by the cultivation of the table variety (''*Nocellara Belice*'') pruned so that the trees take a shape of a truncated cone. Another variety is ''*Biancolila*''. A third very common cultivar is ''*Cerasuola*'' (cherry type fruit) whose tree is recognized for the very high vigour. In most cases, these are very intensely cultivated systems (AA. VV., 2001).
''Palermo Mountains and Palermo coastal planes''	Palermo	Mixed systems on calcareous mountains or in alluvial plains along the coast. In the past, these systems were referred to agrosilvicultural systems characterized by the presence of grazing sheep migrating towards the top, even though the altitudinal variation was limited. During winter, the sheep were conducted to the lower-lying plains. The systems located in marginal areas have been abandoned while those situated in more accessible areas have been intensified. In general, the varieties present in the area are ''*Cerasuola*'' and ''*Ogliarola Messinese*''. In the mountains of Palermo the particular technique of roots grafting has been used (La Mantia 2005b).
''Northern Mountain Chain (Madonie Mountains)''	Palermo	The morphological characteristics are similar to the previous category. Contrary to the classification made by Regione Siciliana (1996) also the systems present in the valley of the river Pollina must be included in this section. These systems are characterized by a special oliviculture, since there is a double-owning mechanism: some farmers own only the land, while others own only the olive plants which had been grafted by their ancestors in the past. The most frequent varieties are ''*Crastu*'', ''*Ogliarola Messinese*'' and, to a lesser extent, ''*Biancolilla*''.
''Northern Mountain Chain (Nebrodi Mountains)''	Messina	These systems are present in coastal hilly/plain areas and in mountain areas. The most frequent geological substrate is flysch. Probably, this is the area with the highest level of diversity among varieties; among these varieties the most common are ''*Santagatese*'', ''*Ogliarola Messinese*'', ''*Minuta*'', ''*Nocellara messinese*'' and ''*Verdello*''.
''Hyblaean Plateau''	Ragusa, Catania, Siracusa	For environmental characteristics see Material and Methods of this study. Probably, this area hosts the highest diversity of olive Agroforestry Systems of Sicily. The most frequent varieties are *Moresca* and *Tonda iblea*.
Volcanic ''Mount Etna''	Catania	The only common variety is ''*Nocellara etnea*'', present in the sub-mountainous layer of Mt. Etna. It is used also in the plains as windbreaker in citrus orchards.

The provinces are listed in order of economic importance of olive grove. * From AA. VV. 1996. ** From Caruso et al. 2007.

The herbaceous component serves as fresh forage as well as to make hay, so that cattle feeding are guaranteed all over the year. Sowing is done in late summer (September), followed by grazing which lasts up to the successive spring (April–May) then it completes its cycle and is reaped. The most widely used forage species are Oats (*Avena fatua*), Barley (*Hordeum vulgare*), Common vetch (*Vicia sativa*), and sporadically Fenugreek (*Trigonella foenum-graecum*) and *Field beans* (*Vicia faba minor*), which are used as species to be ploughed in to enrich soil with nitrogen.

Those systems which are not cut every year, but which are periodically cut for 5–6 years and those systems which are not grazed, but where *Triticum* sp. pl. is grown for the production of grain of wheat are also included in this typology.

The systems belonging to this typology provide a very important soil-protective service, since they guarantee a plant cover for long time periods or even for the whole year and they also stabilize soils on steep slopes. Moreover, besides ensuring fruit production for men (almond) and animals (carob), trees also provides a shelter against the sun for grazing animals.

Olive on volcanic substrate with Quercus suber *and* Quercus pubescens *s.l.* For the structural and functional similarities, the systems belonging to this typology can be compared to the Iberian *Dehesas*,

Table III. The typologies of olive agroforestry systems which have been spotted on the Hyblaean Plateau, six of them are cultivated and two abandoned.

Typology	Cultivation status	Structural classification	Distribution
Olive with horticultural crops	Cultivated	Agrosilvicultural	Very common
Olive with *Prunus amygdalus* (almond)	Cultivated	Agrosilvicultural	Local
Olive with *Vitis vinifera* (vine)	Cultivated	Agrosilvicultural	Very common
Olive with species of grain of forage	Cultivated	Agrosilvicultural	Widespread
Olive on volcanic substrate with *Quercus suber* and *Q. pubescens s.l.*	Cultivated + abandoned	Silvopastoral	Local
Olive on limestone substrate with *Quercus pubescens s.l.* and *Q. Ilex*	Cultivated + abandoned	Agrosilvopastoral	Very common

even if they do not share the same tree species. Due to their unique management and structural characteristics mainly linked to the edaphic-climatic conditions in which they are grown, like in the *dehesas* trees are an integrating part of the system.

In Sicily, *Quercus pubescens* s.l. and *Quercus suber* coexist and form, often also together with *Quercus ilex*, the dominant tree layer of wood associations of *Quercion ilicis* and *Erico-Quercion ilicis* (Brullo et al. 2009). On volcanic substrates of the Hyblaean Plateau, *Quercus suber* and *Quercus pubescens* s.l. are found together as dominant trees in the Pisano wood (municipality of Buccheri; Di Pasquale & Garfì 1998; Cirino et al. 1999).

This typology has been found on very stone-rich, volcanic substrates. Tree density is quite low (40–50 individuals ha^{-1}), and the herbaceous component is discontinuous and characterized to low biomass quantity, due to the transhumance grazing activity carried out in these areas from November to May. Grazing animals are mainly bovines, pigs and horses, which are brought up on the pastures and fed with a typically herbaceous diet (*Dactylis* sp., *Vulpia* sp., *Trifolium* sp.), but also with the products of woody species (*Quercus suber*, *Olea europaea* var. *sylvestris*, *Quercus pubescens* s.l., *Prunus spinosa*) (Garfì 1992–93).

Apart from trees, shrubs are also present in these systems. Due to grazing, these are typical species of disturbed environments, such as *Calicotome* spp., *Pyrus* spp., *Prunus* spp., *Pistacia terebinthus*, and *Crataegus* spp., and their growth and density is strongly limited. Also due to grazing, there is evident compression of soil and the formation of paths.

The productivity of pastures under tree and shrub cover is strongly limited by the quantity of light which can pass through the crowns. In fact, the woody component is the major alimentary source in the system under investigation. Another productive characteristic of these systems is cork collection from *Quercus suber* and the products deriving from pasturing.

Olive on limestone substrate with Quercus pubescens s.l. and Quercus ilex. The systems belonging to this typology are among the most complex; in these systems the different components (oaks, olives, domestic animals, other crops such as pears or cereals) fulfil their productive and environmental-protective functions in different time periods and separate spaces. They are located on terraces as well as in the plains; in this case they are delimited by dry-stone walls which have been built to clear the fields from stones. It is probably for the characteristics of the stone-rich limestone substrate where spontaneously growing *Olea europaea* var. *sylvestris* individuals have often been used as a rootstock for grafting. This explains the strongly irregular spacing and the varying density of the cultivated olives, which is also conditioned by the presence of rocks and the applied agricultural techniques.

The density of the oaks present in this cultivated system is quite low, because olive trees do not support the presence of evergreen associated trees in dense spacing. Nowadays, holm oak and downy oak are present as short shoots emerging from the older stumps, which are cut more or less periodically. In past times, when wood was the only source of energy, the shoots were grown up to the necessary length and, thus, managed by a turn. As this use of wood has lost its importance today, the density of the remaining stumps has been reduced through the continuous cutting of new shoots. Nonetheless, in marginal positions old standard of uncut downy oak can be present. Apart from the use of their wood, oaks also provided shelter and acorns to grazing animals.

Secondary succession processes after abandonment

A few years after the cessation of the various human activities (agricultural, silvicultural, pastoral), abandoned agroforestry systems are already subject to rapid renaturation processes. This process is characterized by a fast colonization by woody species.

On limestone, the most frequently observed species in areas that have been abandoned maximum 15 years ago are those species which were formerly cultivated in the agrosilvopastoral system, with *Quercus pubescens* s.l. being more frequent than *Quercus ilex* (Table IV). In addition to the formerly cultivated oaks other woody species originating from

''outside'' the old fields are also spreading. The most common ones are the bird-dispersed *Pyrus amygdaliformis* Vill. and *Prunus spinosa* L.

Also on volcanic substrate, the formerly cultivated oaks are the most frequently represented woody species among colonizing woody individuals. After abandonment, the bird- and mammal-dispersed *Quercus pubescens* s.l. successfully spreads within the old fields, and also the acidophilous *Quercus suber* is quite successful. Other than oaks, some shrubs, which are often linked to grazed environments, spread within the abandoned areas. These are mainly *Calicotome* spp., *Prunus spinosa* and *Rosa* spp., which were often present already before abandonment, but in lower number.

It is important to underline that seedlings or saplings of *Olea europaea* were almost never found within the abandoned areas. Even if also this species is bird-dispersed and, thus, could show good dispersal performance, young individuals are found only rarely due to the light demand of this species.

The number of woody individuals present on volcanic substrates is lower than the number of individuals found on limestone substrates. In order to understand these colonization dynamics, it is important to consider the age structure of the counted woody individuals and the former cultivation techniques. The most frequent species on limestone, *Quercus pubescens* s.l., does not show a high number of adult individuals in comparison with the volcanic areas, within the first decade of abandonment (Figure 2) (Photo 2). However, the number of seedlings and saplings is higher than on volcanic substrate. This difference is not due the difference in substrate, however, but to the cultivation technique that was used in the studied limestone systems, but not in the volcanic ones: the presence of dry-stone walls, built as terrace walls on slopes or as delimiting lines in the plains, considerably affects the presence of colonizing woody individuals after abandonment (Figure 3). This fact is due to a number of reasons. First of all, the bases of the dry-stone walls favour microsites for woody individuals' survival and growth, since they are characterized by an elevated water availability (Barbera & La Mantia 1998; Rühl, unpublished data). This is mainly due to water vapour condensation on the wall's stones and to the shade created by walls. Secondly, the bases of the dry-stone walls may have been subject to lower cultivation intensity than the rest of the field, since farmers may not plough directly next to the wall and, thus, a special species pool can already develop in cultivation times.

For the still very intense land use in South-Eastern Sicily, it is almost impossible to find any olive agroforestry systems which had been abandoned many decades ago and which had not been transformed into a more intensely used agrarian system. The only area which was found to be abandoned for many decades belongs to the typology ''Olive on volcanic substrate with *Quercus suber* and *Quercus pubescens* s.l.''. Even if it extends over several hectares, since it is the only example of its kind, only a short qualitative description of the ongoing processes should be given here. The slope has probably been used for Agroforestry for centuries. The present olives are actually individuals of *Olea europaea* var. *sylvestris*, which have been grafted at a height of ca. 2 m. Probably for this reason, their spatial distribution is casual within a coppice of holm oak and downy oak, which in the past have been cut in an established turn. Since the last cut was made about 50 years ago, today the wood has transformed into a high forest, which is oppressing the formerly cultivated olive trees that are dying for the lack of light. The still surviving olive individuals are not as productive as they were in the cultivated system. In fact, the harvesting of olives was abandoned about 10 years ago. Up to about 50 years ago, cereal crops and pears were cultivated under and between the oak and olive trees, in alternation with grazing of bovines, pigs and goats. Grazing by bovines is the only activity which is still performed today, but its intensity is quite low, so that renaturation processes can be observed. In fact, the coppice is transforming into a high forest not only due to the growth of the formerly cut stumps, but also because of the natural dispersal of the oaks' acorns. In dependence of the grazing intensity, a more or less dense understorey, mainly made up of *Calicotome* spp is also present.

Discussion and conclusions

Olive trees characterize numerous Mediterranean landscapes (Barbera et al. 2005), and they are recognized as a typical Agroforestry species. Nonetheless, as it was noted by Eichhorn et al. (2006) ''The olives form a consistent component of the landscape'' there are no specific studies on olive agroforestry systems.

This study has shown that olive agroforestry systems do still exist in South-Eastern Sicily, but that they are mainly present where difficult environmental conditions (terraced slopes, stone-rich substrates, etc.) have inhibited the transformation into intensive olive groves, and where the agricultural system is characterized by small farms and the active participation of senior farmers ($>$ 60 years old). The most common agroforestry systems in the Hyblaean Plateau are those which can be structurally classified as ''agrosilvopastoral'' or ''silvopastoral'' systems (sensu Nair 1993), and which associate oaks (*Quercus pubescens* s.l., *Quercus ilex*, *Quercus suber*) or grass to olives.

Table IV. Number of colonizing woody species individuals in the sample plots in abandoned areas of the typology "Olive on limestone substrate with *Quercus pubescens* s.l. and *Quercus ilex*)" (L) and "Olive on volcanic substrate with *Quercus suber* and *Quercus pubescens* s.l." (V).

	1	2	3	4	5	6	7	*tot. L*	*tot. V*
Years of abandonment	*4*	*5*	*10*	*12*	*5*	*8*	*10*		
Geological substrate	*L*	*L*	*L*	*L*	*V*	*V*	*V*		
Asparagus spp.				12		7	4	*12*	*11*
Calicotome spp.			2			22	17	*2*	*39*
*Ceratonia siliqua*_2			1	1				*2*	*0*
Cistus spp.		2		4				*6*	*0*
Crataegus spp._3	2	3			5	2	2	*5*	*9*
Hedera helix L.	1	4						*5*	*0*
*Olea europaea*_2	2	2		1				*5*	*0*
Osyris alba L.	1	2		1				*4*	*0*
Pistacia terebinthus L.	1	2			1	4	3	*3*	*8*
Prunus spinosa L._1			1	4				*5*	*0*
*Prunus spinosa*_3		3	6		3	6	2	*9*	*11*
Pyrus amygdaliformis Vill._3	5	3	2	25	2			*35*	*2*
*Quercus ilex*_1	4			4				*8*	*0*
*Quercus ilex*_2	5	14	2	1				*22*	*0*
*Quercus ilex*_3	3	11		1				*15*	*0*
Quercus pubescens Willd._1	13	19	12	4	16	12	6	*48*	*34*
*Quercus pubescens*_2	25	16	6	12	2	3	2	*59*	*7*
*Quercus pubescens*_3	7	8	5	1	4	6	3	*21*	*13*
*Quercus suber*_1					2	2	4	*0*	*8*
*Quercus suber*_2					1	3	2	*0*	*6*
*Quercus suber*_3					1	5	2	*0*	*8*
Rhamnus alaternus L.		5	3					*8*	*0*
Rosa spp.			2	2	16			*4*	*16*
Rubus spp.		2	2		3			*4*	*3*
Ruscus aculeatus L.			2					*2*	*0*
Smilax aspera L.	1	2						*3*	*0*
Total of tree individuals	*59*	*73*	*32*	*28*	*29*	*37*	*21*	*192*	*87*
Total of shrub individuals	*11*	*25*	*14*	*45*	*27*	*35*	*26*	*95*	*88*
Total of individuals	*70*	*98*	*46*	*73*	*56*	*72*	*47*	*287*	*175*

Formerly cultivated plant individuals are not included. Species denomination includes also information about the age of the individuals: 1 = seedling, 2 = sapling, 3 = adult.

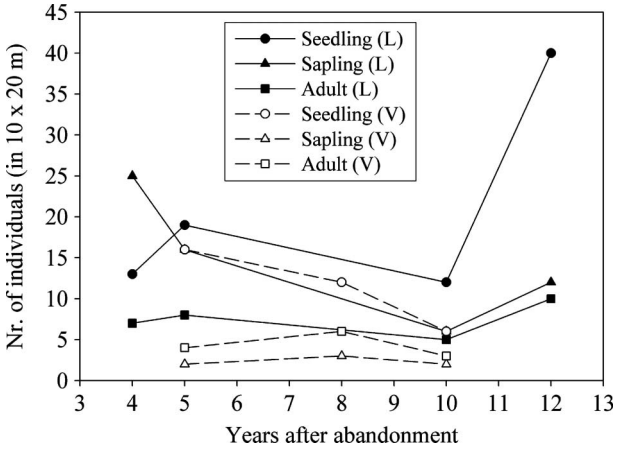

Figure 2. Number of colonizing individuals of *Quercus pubescens* s.l. in abandoned areas growing on limestone (L) and volcanic (V) substrate.

In the latter case, the association of pastures with trees shows many advantages. A study, which has been carried out on a silvipastoral system in Oregon (Carlson et al. 1994), including *Pseudotsuga menziesii*, *Trifolium subterraneum*, and *Festuca arundinacea*, has highlighted the relationship between plants, soil and water availability. It has also stressed that not only grazing can reduce the water stress of the tree individuals by reducing the total transpiration of the system, but also that nitrogen-fixing plants can increase the nitrogen availability for other plants (Carlson et al. 1994). There are many studies attributing advantages to such integrated systems through nitrogen fixation (Nair et al. 1999; Nygren et al. 2000) and through the modifications of the chemical, physical and biological soil properties because of the activity of the micro- and meso- fauna around the roots (Belsky et al. 1993; Tornquist et at. 1999; Wedderburn & Carter 1999). Moreover, according to Harvey et al. (1998), scattered trees in pastures can contribute to the conservation of biodiversity and, in addition, they provide various products and services, such as shading, energy, wood, and fruits.

Finally we must emphasize that the agroforestry systems, although not very compatible with the needs of modern agriculture and in particular with

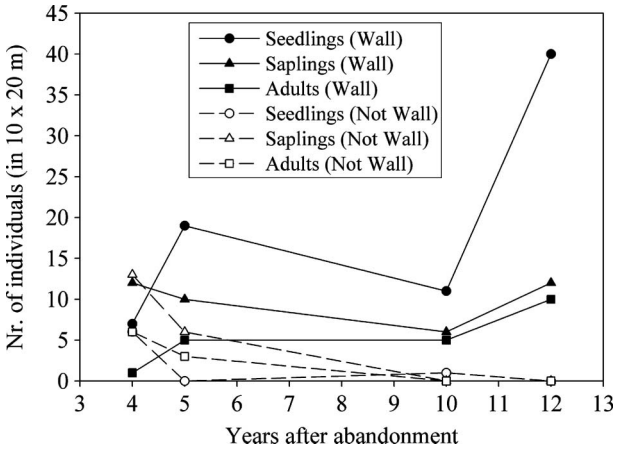

Figure 3. Number of colonizing individuals of *Quercus pubescens* s.l. in abandoned areas growing on limestone close to dry-stone walls (wall) and in the open fields (not wall).

mechanization, have acquired an important role in the light of new environmental requirements (La Mantia 1997; Lo Verde et al. 2002).

Our study found that when Sicilian olive agroforestry systems are abandoned and not disturbed by wildfires or grazing, they are subject to rapid processes of secondary succession, similar to Sicilian vine old fields (Rühl & Pasta 2008). The abandonment of traditional olive grove cultivation leads to a reduction of diversity at landscape level, with a contemporaneous increase of the semi-natural systems which once competed with agrarian systems (shrublands, woods) (Agnoletti & Paci 1999). In fact, with progressive succession processes grasslands are transformed into shrublands and then into woodland, or even directly from grasslands into woodlands. The rapidity of these transformation processes very much depends on the previous cultivation techniques, including olive tree density, temporary use as pasture, etc. On this regard, the presence of dry-stone walls (also as part of terraces) is a very important factor which favours succession rapidity, because they offer favoring conditions in terms of fertility and water availability (Rühl 2007; La Mantia et al. 2008; Rühl & Pasta 2008). Another factor which influences succession pace is the presence or absence of grazing activities after abandonment. In average, within 30–40 years an olive grove transforms into maquis and then into wood (Blasi et al. 2000; Petrocelli et al. 2003; Barbera et al. 2005). This is valid for conditions where a maquis or wood is present nearby the abandoned olive orchard, so that the woody individuals which colonize the old fields originate from these woods or from the shrublands (ecotones) between the wood and the formerly cultivated surface (Barbera et al. 2005), but also from some isolated tree individual within the old field. Olive orchards are almost always located in ecological conditions where semi-natural systems of variable degree of naturalness are also present. With the words of Blasi et al. (1997): ''olive is a cultivation which maintains the dynamic connection with the natural potential vegetation''. Where oaks are present as an integrated part in the cultivated systems, as it is the case in some of the systems studied here, the availability of dispersal centers of trees is even more pronounced, and the transformation into maquis and woods is even more rapidly performed due to avian dispersal. With this rapid colonization by tree individuals, there is no intermediate succession stage in terms of closed shrub communities, since tree species dominate the post-abandonment vegetation from the beginning. One of the advantages of fast renaturation processes is a reduced erosion rate on slopes.

The formerly cultivated individuals of olive survive for 4 to 5 decades, but then are oppressed by the oaks due to their need for light (see Barbera et al. 2005). However, in case of a disturbance, such as fire, olive trees can resprout quickly and thus become part of the vegetation for other decades. As it was already pointed out, in the abandoned systems observed seedlings and saplings of olive were rarely found, so that this species does not play a role for the renaturation of olive agroforestry systems. This is in contrast to renaturation dynamics of other types of systems, as for example the afforestions by allochthonous species (*Pinus* and *Eucalyptus*) in which seeds originating from nearby cultivated olive orchards are the only element of renaturation (La Mantia & Pasta 2001).

But the rapidity of renaturation not only depends on the abundance of dispersal centers, but also on other environmental factors, such as water availability for the colonizing species. In this context, the presence of safe sites for the germination and survival of woody individuals is a fundamental factor. The role of a safe site is often provided – in the studied cases – by dry-stone walls. Another determining factor for the rapidity and dynamics of renaturation are disturbances prior to and, above all, after abandonment. Based on the intensity and/or frequency of grazing and/or wildfires, renaturation dynamics are modified.

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