Journal of Mediterranean Ecology **vol. 16, 2018: 27-36**

What does forest restoration mean in Italy?

Roberto Mercurio

Italian Society of Forest Restoration- SIRF-c/o Dept. Dafne Via San Camillo de Lellis, 01100 Viterbo (Italy)
Email: rmercurio@inwind.it

Keywords: Italy, forest restoration.

Abstract

The Author reviews past and new causes of forest degradation occurring in Mediterranean basin. A number of the cases examined here require rapid interventions aimed to prevent floods and so-called "natural disasters" beside to increase their yield in term of forest ecological services. With the intention of conceptualizing and proposing the most suitable meaning of forest restoration in the Italian context, the Author lists a series of forest restoration cases by partitioning these in two main categories depending upon the two approaches considered. The first category includes cases where the eco-functional approach has been considered and includes: forest burned areas, degraded afforestation with conifers (*Pinus nigra* sl), degraded or abandoned agricultural lands, degraded beech woodlands, mining areas, coastal dunes and invaded areas by alien forest species such as *Ailanthus glandulosa*. The second category includes cases where a cultural and aesthetic approach has been considered and includes chestnut orchards.

Introduction

Following the publication of the paper by Thomasius (1996), the Italian forest history can be subdivided in three main periods: 1) 3rd b.C.- 18th century: a long period characterized by destruction, reduction and fragmentation of forests due to overexploitation and overgrazing to respond to people demands; 2) 19-20th century: a short period characterized by intense afforestations with conifers on large areas for soil protection and demands of job. At the end of the 20th century, in addition to past causes of degradation (overgrazing and forest fires), there has been added the invasion of alien forest species and a wild urbanization; 3) 21st century: the increase in the public opinion that several benefits could derive by giving an ecological functionality to forest restoration of degraded sites.

The negative consequences of forest-degraded sites are represented by changes in species composition and structure, loss of biodiversity and capacity to provide ecological services.

This phenomenon has been ignored for a long time. In fact, not only the old Forest Map of Italian Kingdom (MNF 1936) but also the last Italian Forest Inventories (IFN 1985, IFNC 2005, 2015) consider the category of degraded forests in the same way as the studies on forest types. The last Forest Inventories underline the importance of the observed increase in forest surface

but overlook the quality of the woodlands, a trait strictly related to the quality of human life.

This fact could be explained by the lack of a shared definition of degraded forest/forest degradation. Lund (2009**)** reports more than 50 definitions of forest degradation, formulated for various purposes. Moreover, the definition of forest degradation FRA 2000 (FAO 2011) "Changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services" must be considered to be too general.

At the same time, biological indicators of degraded forest sites are lacking in the Mediterranean context and only recently, some new ones have been suggested (e.g. Modica et al. 2015). In any case, a shared definition and an indicator able to describe degraded forest areas represent certainly the first step toward the implementation of a forest restoration strategy.

The definition of forest restoration in Italy needs to consider the millenary presence of humans which has led to the creation of man-made peculiar forest stands (e.g. chestnut orchards, costal pinewoods, etc) with an high population density. These peculiar features require approaches different (such as the eco-functional approach and the cultural and aesthetic approach in respect to those deriving directly from a strict interpretation of the meaning of ecological restoration ("process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" *since* SER 2004).

In the Italian context, the definition of forest restoration given by the Italian Society of Forest Restoration (SIRF 2014), appears to be more appropriate. In fact, it focuses the forest restoration concept on ecosystem functioning being comprehensive of the biodiversity and ecosystem services interaction. Furthermore, forest restoration can be defined as a set of actions aimed to stimulate the recovery of the maximum potential ecological functionality by the forest ecosystem. The correct terminology concerning the different aspects of forest restoration (such as rehabilitation, reconstruction reclamation and replacement) must follow the one suggested by Stanturf (2005) and Stanturf et al. (2014 a, b) to provide an international common comprehension.

The main Italian forest restoration cases

1. The eco-functional approach

This approach concerns those degraded forest areas which are considered to be of "natural origins" despite they have been manipulated for a long time. The efforts of the restoration of these forests are focussed on speeding up the evolutionary dynamics. The aims of the new forest systems are a) to restore a "native vegetation" compatible with the site conditions; b) to provide an ecological functionality; c) to select the appropriate ecosystem services able to satisfy the social demands.

Rehabilitation of burned Aleppo and maritime pines stands

The two Mediterranean pine species (*Pinus pinaster* Ait. and *Pinus halepensis* Mill.) are able to self-regenerate very well after fires, thanks to: 1) the high quantity of seeds produced every year starting from the 5th year of age, and to 2) the presence of fire-tolerant serotinous cones. Many experiences are related to post-fire management of burned pinewoods in Italy (Saracino and Leone 2001, Leone 2001, Leone and Lovreglio 2008) and in other Mediterranean countries (Trabaut et al. 1985, Ne'eman and Perevolotsky 2000, Bonneh 2000, Pausas et al. 2004, De Las Heras et al. 2012, Moreira et al. 2013).

Several indications emerge from restoration experiences of Baldini et al. (2007) and Hofmann (2008) after fire events. In regard to this it has been pointed out that it is possible to: 1) make a salvage-logging of all the burned trees having less than 30% of live-crown before the summer following the fire to enable the establishment of Aleppo pine seeds; 2) chip all woody residual materials whenever is possible or suitable; 3) remove all burned woody material obstructing waterways to avoid formation of "green dams" following intense precipitations which could burst causing disasters in the sites downhill; 4) create wood or mixed wood-stone barriers along the contour lines to prevent soil erosion as suggested in other experiences in Mediterranean countries (Raftoyannis and Spanos 2005, Valdecantos et al. 2009, Casal and Reyes 2013, Neris et al. 2016) in steep (more than 40%) slope sites.

If the natural regeneration is abundant, then the forest system will evolve through a new pinewood; conversely good results have been obtained by introducing broadleaved species to prevent soil erosion and to increase the resilience of the forest system (Pausas et al. 2004, Manetti et al. 2007, De Las Heras et al 2007, 2012, Valdecantos et al. 2009, Vallejo et al. 2012 a, b, Pausas and Keely 2014, Granados et al. 2016).

Reconstruction of abandoned farmlands

The Miyawaki method developed for an active restoration of degraded sites has been applied in

many Asian countries (Miyawaki 1999; Miyawaki and Box 2007). The aim of this method is to restore multi-species and multi-layered forests that are very "close" to the native forests. This concept can be summarised and simplified as the principle of "consulting nature in the planting of forests". The adoption of this method has been considered for use also in Italy when the traditional techniques of afforestation have been implemented with the new knowledge about forest ecosystem functioning and forest restoration techniques (Mercurio et al. 2010, Schirone et al. 2011, Schirone and Vessella 2014, Frattaroli et al. 2017).

The experiences reported above highlight the occurrence of limitations of the original Miyawaki method when applied in Mediterranean areas due to a) high costs of manpower, b) ecological restrictions due to the dry summer period, and to c) presence of thin or eroded soils. Anyway the general criteria to use a mix of tree species belonging to the same series of vegetation dynamics appear valid as they allow: 1) a complementary use of the resources (light, water and nutrients); 2) to enhance the ecological resilience; 3) to promote the conservation of biological diversity; 4) to represent an important preventive measure to cope with climate change effects (Jacobs et al. 2015). On the other hand, an effective application of the Miyawaki method in Italy needs to reduce the number of tree species to be transplanted in aliquots: the first aliquot formed by species which occupy an early position in the successional series; the second aliquot formed by species which occupy a late successional position. Furthermore, it is necessary: a) to reduce the initial stock density; b) to mechanise the cultural operations (ploughing, harrowing, cleaning); c) to reduce the cost of manpower; d) to control the ungulates populations.

Rehabilitation of Black pine afforestation

Rehabilitation of conifer afforestation is a problem which affects many European countries (Kenk and Guehne 2001, Malcolm et al. 2001, Zerbe 2002, Hansen and Spiecker 2005, Kint et al. 2006, Dekker et al. 2007, Mercurio 2010, 2016). In Italy, the experiences on rehabilitation of silver fir (*Abies alba* Mill.) began in 1982 whereas those dealing with *Pinus nigra* sl in 2000 (Muscolo et al. 2014, 2017). The problem to solve was mainly how to spread up the evolutionary dynamics through "native broadleaves" stands, considering that most afforestations were unmanaged and the natural dynamic processes were blocked leading to 1) a higher susceptibility to forest fires, 2) attacks of insects and pests, and 3) wind damages.

The restoration of plantation forests toward semi-natural woodlands can be carried out through a number of different methods, but here we focus only on two of these systems which are representative of small-scale disturbances.

Gap cutting system.

This approach is based on the scientific assumption that the evolution of natural forests is related to openings of canopy cover (gaps). The results obtained in man-made Black pines (*Pinus nigra* sl.) stands after more than 30 years of experimental trials have been reported and summarized in some recent reviews (Muscolo et al. 2014, 2017, Mercurio and Schirone 2015, La Marca et al. 2016). The data collected to support this method indicating that gaps bigger than 400-500 m^2 are suitable for pine natural regeneration, whereas those smaller are suitable for broadleaved regeneration.

Strip-cuttings system.

In this case, the experiment started only in 2015 and was carried out in a 65-year-old Black pine (*Pinus nigra* sl) afforestation stand sited in the Abruzzi Apennines on calcareous lithosols. The excessive stand density due to the lack of thinning blocked any natural dynamics, therefore it was necessary to apply a more intense "disturbance" with respect to the gap cutting system. The disturbance consisted of opening a series of long (15 m) and wide (100 m) strips (3 per hectare removing around 45% of the stems) alternate with uncut strips. After logging operations, performed by means of three different extraction methods (i.e., horse-powered, forest-winches, and cable-crane), no significant soil damage was detected. Nevertheless, with the first two methods, the removal of grasses and mosses was observed in nearly 40 percent of the cut surface, whereas no impact occurred when the cable crane method was used (Mercurio 2015). After two years it was observed the absence of soil erosion and at the same time the appearance of the first signs of broadleaves regeneration (Mercurio 2017 personal observation).

Rehabilitation of beech woodlands

Some beech (*Fagus sylvatica* L.) woodlands are peculiar of the Apennine such as 9210* "Apennine beech forests with *Taxus* and *Ilex*" and 9220* "Apennine beech forests with *Abies alba*", representing two habitats of European priority interest according to the EU Habitats Directive (92/43/EEC). Unfortunately, the majority of these woodlands are degraded in terms of loss of a) biodiversity, c) structure (Burrascano et

al. 2013), and c) fragmentation. Causes of this situations are both past human pressure and more recently recurrence of summer dryness (Mercurio 2017 personal observation). Two significant experiences of habitat restoration and species conservation have been carried out with the EU LIFE funds.

With the main objective to conserve and reintroduce the Yew, Piovesan et al. (2002) take in consideration the beech woodlands mixed with Yew (*Taxus baccata* L.*)* and holly (*Ilex aquifolium* L.) present in the Abruzzi Region. These woodlands represent the preferred habitat of the Apennine bear (*Ursus arctos marsicanus* Altobello*)*. The authors have used the following strategies: 1) the conversion of coppice woodlands to high forest; 2) the selective thinning in the mature high forests (this strategy is essential for inducing litter mineralization and for favouring *Taxus* natural regeneration; 3) the opening of gap (300-400 m^2) with the aims of diversifying forest structure, promoting natural regeneration (in this case one gap per hectare it has been found to be the best solution in order to maintain the favourable microclimate conditions for Yew), and underplanting in marginal areas of Yew vegetation around 600 (2-year-old) seedlings per hectare. These experiments suggest that any effort of forest restoration is bound to fail if the control of ungulates is not taken into consideration.

For the project LIFE ReSilFor's (2015) developed in both Tuscany and Marche Region, the main objectives have been: a) to stop the extension of habitat loss of the "Apennine beech forests with *Abies alba*"; b) to reduce the risks of genetic segregation of the relict populations of *Abies alba*; c) to avoid disappearance of populations of *Abies alba* due to the changing of microclimate conditions by means of assisted genetic migration techniques (Miozzo et al. 2015). The general scheme of this intervention has been based on the reintroduction of native silver fir in 4 different successive steps: 1) gap (500 $m^{2)}$ opening (mainly in beech woodlands); 2) thinning on the edge areas close to the gaps; 3) plantations of grafted silver fir seedlings (with native provenances), by using a scheme where 25 -35 plants were transplanted every 3 m one from another in relation to the form, exposure and slope of the gap; 4) individual or total fencing for seedling protection from ungulates; 5) reduction of non-native silver fir populations in the "reintroduction areas" of native silver firs.

The method mentioned above has been reviewed recently by Aitken and Bemmels (2016) who suggest using seeds from multiple sources in order to increase both biodiversity and residence against climate uncertainty. However, this approach becomes unacceptable if we want to conserve the local provenance. Unfortunately, the EU LIFE funds do not enable the monitoring of the experimental sites after the end of the project, and therefore the definitive results of these experiments remain often unknown.

Reclamation of lignite mining areas

Many successful experiences have been realized in European countries on mining sites (Prach and Pyšek 2001, Prach et al. 2001, Tischew 2004, Tischew et al. 2005, Fischer and Fischer 2006, Kirmer et al. 2011). The aims of the reclamation of mining areas cannot always predict the restoration of the "native vegetation" but first the creation of areas for agricultural and forestry crops and then their re-naturalization.

One of the most representative examples of reclamation conducted in Italy it has been performed in Tuscany within a lignite mining area. The surface remodelling consisted in the realization of large flat plains connected with escarpments. In the flat areas plantations with broadleaves such as oaks (*Quercus robur* L.*, Quercus petraea* (Matt.) Liebl.), ashes (*Fraxinus angustifolia* Vahl.), cherries (*Prunus avium* L.), walnuts (*Juglans regia* L.*, Juglans nigra* L.) were established. The best growth results were obtained in plantations where the above-mentioned species were mixed with N-fixing species such as *Alnus cordata* (Loisel.) Duby*, Robinia pseudoacacia* L.*,* and *Eleagnus* sp). In the flat areas, cereals were also cultivated. In the escapements, clover (*Trifolium repens* L.) and other grasses were seeded to prevent soil erosion (Buresti 1989). Recently, in the remaining areas, a road network for bikes, horses, a lake, a golf course, and a landing strip and other infrastructures for recreational uses have been designed (Mercurio 2017 personal observation).

Rehabilitation of coastal dunes

Sand dunes systems play an important role along the Mediterranean coastlines by forming a barrier between sea and land which protects the coast from erosive forces (wind, salt, sand, sea pollution), and forms recreation areas for population beside ecosystems representing a refuge for rare and endemic living species specialized for this dune habitat. Many efforts have been done to conserve or restore these systems (Bellarosa et al. 1996, Kutiel 2001, De Lillis et al. 2004, Sabra et al. 2017). Italy has a 7911 km coastline, 3243 km of which are sandy and flat, where there are urban and industrial centres, road and touristic infrastructures.

Despite they are largely affected by specific laws and regulations of protection, they are also the most threatened ecosystems. The degradation mechanisms are mainly represented by environmental pollution, coastal erosion, urbanization, high touristic pressure (Acosta and Ercole 2015).

The restoration of the dune system began at the early of '900 in Italy with the stabilization of sand dune and creation of pinewoods as windbreak (Bosetto 1961).

In recent times the restoration initiatives consider the whole system of the coastal dunes such as wetlands behind the dunes, lagoons and coastal lakes, river estuaries, prairies of *Posidonia oceanica* and other seagrasses (Macchia et al. 2005).

The results have been summarized in many scientific reports (Onori 2009, AA.VV. 2009,Tinelli et al. 2010).

More detailed ecological restoration experiences have been carried out in specific habitat e.g.: the sand shore in Lampedusa Island (Sicily) where the sea turtle *Caretta caretta* L. lays its eggs (La Mantia et al. 2012) and the coastal dunes with *Juniperus* sp. in Sardinia (Pinna et al. 2017).

Control of invasive alien forest species: Ailanthus glandulosa

Many forest tree species have been introduced in Italy for their peculiarities: wood and fruit, pest and disease resistance, aesthetics. Unfortunately, some of them have become invasive (Scalera and Celesti Grapow 2007).

One of these, *Ailanthus glandulosa* (Tree of Heaven), was introduced in Italy at the end of the 19th century as an ornamental tree. As forest tree, it was employed in the afforestation of arid sites, road and railway escarpments and rocky soils.

Nowadays, this plant species is considered to be a major invader in many parts of the United States, in most of temperate and Mediterranean Europe and in Italy (Hulme et al. 2009, Celesti-Grapow et al. 2010, Richardson and Rejmánek 2011, Wunder et al. 2016). It has negative effects on floral diversity (Motard et al. 2011), invades natural habitat (Constan-Nava et al. 2015), urban areas and archaeological sites (Celesti-Grapowet al. 2010).

Many techniques can be used to control *Ailanthus* sp. such as mechanical remotion, prescribed burning, and use of chemicals products (Foggi et al. 2001, Burch and Zedaker 2003, Di Tommaso et al. 2006, Constan-Nava et al. 2010, Badalamenti et al. 2013).

An experience (LIFE+ Montecristo 2010) was carried out in the Montecristo Island in the National Park of Tuscan Archipelago by Vagniluca et al. (2014) comparing the use of mechanical tools and chemical products: spaying of foliage (only plants <15 m hight) of herbicides; cut and brush the trees; pierce and inject of herbicides; E-Z-Ject® lance application system.

Although the herbicides are effective and with low costs, their use does not appear suitable in protected areas for a) the risk of pollution as it is necessary to apply more treatments in order to kill the trees and b) because this practice is unsustainable with the principles of nature conservation.

Other methods have less ecological impact, despite they are more expensive and sometimes less effective such as: 1) the elimination of seed-trees by girdling (Liess 2007, Basnou and Vila 2009), 2) the manual eradication of young trees (Mercurio 2016), 3) the cutting and mulching the stump (Burch and Zedaker 2003, Constan-Nava et al. 2010).

2. The cultural and aesthetic approach

This approach can be applied to selected sites with a remnant historical and populated landscape. The aim of this approach is restoring the "historical conditions", with the same tree species composition and structure.

The rehabilitation of chestnut orchards

Chestnut (*Castanea sativa* Mill.) has been diffused in all Europe since the Roman times (Conedera et al. 2004, Conedera and Krebs 2008). Chestnut orchards are the typical man-made plantations characterizing many Italian hilly landscapes. During the Middle Ages they represented the essential source of food for mountain populations. These orchards were largely abandoned in the '50-'60 of the last century (Bounous 2014, Fratus 2015) and today they are evolving towards unpredictable forest systems bearing a very high risk of fire. Nevertheless, the remnant chestnut orchards represent a cultural landscape and also an important economic resource.

Until a few years ago, the recovery of chestnut orchards in Italy focused mainly on fruit production (Parisio et al. 2009, Bianchi et al. 2009) as in other European countries such as Switzerland (Heiniger and Conedera 2004, Conedera et al. 2004). This approach is not always sustainable from an economic and ecological point of view in consequence of: 1) a dryer climate which it threatens the ecological resilience of these chestnut orchards in the marginal areas, 2) the spread of the gall wasp (*Dryocosmus kuriphilus* Yatsumatsu) and other chestnut diseases. So the recovery of chestnut orchards has been re-oriented not

only for fruit production but also for bio-cultural, aesthetic and touristic purposes (Mercurio et al. 2015). The rehabilitation of abandoned chestnut follows the traditional procedures (Bianchi et al. 2009, Mercurio 2016): a) clearing the invasive vegetation (shrubs or trees); b) pruning the vital old chestnuts; c) cutting down the dead old chestnuts; d) removing invasive species such as black locust (*Robinia pesudoacacia* L.) or aspen (*Populus tremula* L.); d) grafting some shoots with the same local variety; e) planting new seedlings to re-establish the traditional stand density (about 100 plants per hectare); f) monitoring pest and diseases; g) maintaining some old CV of cherries (*Prunus* sp.), apples (*Malus* sp.), pears (*Pyrus* sp.) growing close to the traditional rural cabin. However, all the practices cited above require a strict control of ungulates in order to become effective.

Conclusive remarks

The forest restoration in Italy could play a significant role in enhancing the quality of the environment and subsequently the quality of human life. The development of this strategic area requires an accepted definition, supported by appropriate bio-indicators, of what is intended for "degraded forest". Therefore, the next forest inventories should take into consideration: 1) the addition of a "degraded forest" category; 2) the definition of the restoration priorities (e.g. burned sites, degraded conifer afforestation and coastal pinewoods, etc.); 3) the distinction between "natural stands" and "cultural stands". Furthermore, it would be useful and desirable to introduce in the higher education system (at Master or PhD level) a specialization in forest restoration.

References

AA., VV. 2009. SOS Dune. Stato, problemi, interventi, gestione. ISPRA Atti 2013, Roma ((Italy).

Acosta, A.T.R., Ercole, S. (Eds) 2015. Gli habitat delle coste sabbiose italiane: ecologia e problematiche di conservazione. ISPRA, Serie Rapporti, 215/2015, Roma (Italy).

Aitken, S.N., Bemmels, J.B. 2016. Time to get moving: assisted gene flow of forest trees. Evolutionary Applications 9(1): 271–290.

Badalamenti, E., La Mantia, T. 2013. Stem-injection of herbicide for control of *Ailanthus altissima* (Mill.) Swingle: a practical source of power for drilling holes in stems. iForest (early view): e1-e4 [online 2013-03-05] URL:http://www.sisef.it/ iforest/contents?id=ifor0693-006

Baldini, S., Marchi, E., Quartulli, S. 2007. Tecniche di ripristino dei boschi percorsi da incendio, possibile uso del materiale legnoso e valutazione di impatto ambientale. L'Italia Forestale e Montana 62 (1): 39-48.

Basnou, C., Vila, M. 2009. *Ailanthus altissima* (Mill.) Swingle, tree of heaven (*Simaroubaceae*, Magnoliophyta). In: "Handbook of alien species in Europe" (DAISIE ed). Springer, Dordrecht, The Netherlands, pp. 342.

Bellarosa, R., Codipietro, P., Piovesan, G., Schirone, B. 1996. Degradation, rehabilitation and sustainable management of a dunal ecosystem in central Italy. Land Degradation and Development 7: 297- 311.

Bianchi, L., Maltoni, A., Mariotti B., Paci M. 2009. La selvicoltura dei castagneti da frutto abbandonati della Toscana. ARSIA, Regione Toscana, Firenze (Italy).

Bonous, A. 2014. Il castagno. Edagricole, Bologna (Italy).

Bonneh, O. 2000. Management of planted pine forests in Israel: past, present and future. In: Ne'eman G., Trabaud L (Eds) Ecology, Biogeography and Management of *Pinus halepensis* and *P. brutia* Forest Ecosystems in the Mediterranean Basin. Backhuys Publishers, Leiden, The Netherlands, pp. 377-390.

Bosetto, G. 1961. Aspetti particolari della tecnica dei rimboschimenti delle sabbie litoranee. Atti del Congresso nazionale sui rimboschimenti, Vol. 1: 313-382, Accademia Italiana di Scienze Forestali, Firenze (Italy).

Buresti, E. 1989. Il restauro delle cave della centrale termoelettrica ENEL nel Valdarno e produzione di materiale d'impianto. In: Biondi E. (Ed.) Il bosco nell'Appennino. Centro Studi Valleremita, Fabriano, pp. 333-344.

Burrascano, S., Keeton, W.S., Sabatini, F.M., Blasi, C. 2013. Commonality and variability in the structural attributes of moist temperate old-growth forests: a global review. Forest Ecology and Management 291: 458–479.

Burch, P.L., Zedaker, S.M. 2003. Removing the invasive tree *Ailanthus altissima* and restoring natural cover. Journal of Arboriculture 29 (1): 18-24.

Casal, M., Reyes, O. 2013. Claves ecologicas para la restauracion de la vegetacion de areas quemadas en Galicia. In: Martínez-Ruiz C.; Lario Leza F.J., Fernández-Santos B. (eds). Avances en la restauración de sistemas forestales. Técnicas de implantación. SECF-AEET, Madrid, pp. 69-73.

Celesti-Grapow, L., Pretto. F., Carli E., Blasi C. 2010. Flora vascolare alloctona e invasiva delle regioni d'Italia. Casa Editrice Università La Sapienza, Roma, Italy, pp. 208.

Conedera, M., Krebs, P. 2008. History, present situation and perspective of chestnut cultivation in Europe. In:

Proceedings of the Second Iberian Chestnut Congress (ed CG Abreu, FP Peixoto and J Gomes-Laranjo), Vila Real, 20–22 June 2007, Acta Horticulturae vol. 784, pp. 23–27. Leuven: ISHS.

Conedera, M., Manetti, M.C., Giudici, F., Amorini, E. 2004. Distribution and economic potential of the Sweet Chestnut (*Castanea sativa* Mill.) in Europe. Ecologia Mediterranea 30 (2): 179-193.

Conedera, M., Krebs, P., Tinner, W., Pradella, M., Torriani, D. 2004. The cultivation of *Castanea sativa* (Mill.) in Europe, from its origin to its diffusion on a continental scale. Vegetation History and Archaeobotany 13: 161-179.

Constan-Nava, S., Bonet, A., Pastor, E., Lledo, M. 2010. Long-term control of the invasive tree *Ailanthus altissima*: insights from Mediterranean protected forests. Forest Ecology and Management 260: 1058-1064.

Constan-Nava, S., Soliveres, S., Torices, R., Serra, L. Bonet, A. 2015. Direct and indirect effects of invasion by the alien tree *Ailanthus altissima* on riparian plant communities and ecosystem multifunctionality. Biological Invasions 17(4): 1095–1108.

De Lillis, M., Costanzo, L., Bianco, P.M., Tinelli, A. 2004. Sustainability of sand dune restoration along the coast of the Tyrrhenian sea. Journal of Coastal Conservation 10: 93-100.

Dekker, M., van Breugel, M., Sterck, F.J. 2007. Effective height development of four co-occurring species in the gap-phase regeneration of Douglas fir monocultures under nature-oriented conversion. Forest Ecology and Management 238:189-198.

De Las Heras, J., Moya, D., Lopez-Serrano, F., Condes, S., 2007. Reproduction of post-fire *Pinus halepensis* Mill. stands six years after silvicultural treatments. Annals of Forest Sciences 64: 59-66.

De Las Heras, J., Moya, D., Vega, J.A., Daskalakou, E., Vallejo, R., Grigoriadis, N., Tsitsoni, T., Baeza, J., Valdecantos, A., Fernández, C., Espelta, J., Fernandes, P. 2012. Post-Fire Management of Serotinous Pine Forests Post-Fire Management and Restoration of Southern European Forests. In: Moreira F., Arianoutsou M., Corona P., De Las Heras J. (eds). Post-fire management and restoration of southern European forests. Managing Forest Ecosystems Series, Vol. 24. Springer, pp. 121-150.

DiTomaso, J.M., Brooks, M.L., Allen, E.B., Minnich, R., Rice, P.M., Kyser, G.B. 2006. Control of invasive weeds with prescribed burning. Weed Technology 20: 535-548.

FAO, 2011. Assessing forest degradation. Towards the development of globally applicable guidelines. Forest Resources Assessment Working Paper 177, Rome (Italy).

Fischer A., Fischer H. 2006. Restoration of forests. In: Van Andel J., Aronson J. (Eds). Restoration ecology: the new frontier. Blackwell Publishing, Malden, Massachusetts, pp. 124-140.

Foggi, B., Sposimo, P., Grigioni, A., Sanesi, G. 2001. Interventi per la conservazione della biodiversità. Capraia e piccole isole dell'Arcipelago Toscano. Informatore Botanico Italiano 33 (2): 109-112.

Frattaroli, A.R., Di Cecco, V., Console, C., Contu, F., Mercurio, R., Pirone, G. 2017. Beech woods restoration in the Gran Sasso and Monti della Laga National Park (Central Apennine - Italy). Plant Sociology 54 (Suppl. 1):11-18.

Fratus, T. 2015. L'Italia è un bosco. Laterza Roma-Bari (Italy).

Granados, M. E., Vilagrosa, A., Chirino, E., Vallejo, V. R., 2016. Reforestation with resprouter species to increase diversity and resilience in Mediterranean pine forests**.** Forest Ecology and Management 362: 231-240.

Hansen, J., Spiecker, H. 2005. Conversion of Norway spruce (*Picea abies* [L] Karst.) forests in Europe. In: Stanturf J.A., Madsen P (Eds) Restoration of boreal and temperate forests. CRC Press, Boca Raton, pp. 339-347.

Heiniger, U., Conedera, M. 2004. Chestnut Forests and Chestnut Cultivation in Switzerland. Vegetation History and Archaeobotany 13: 175–178.

Kirmer, A., Baasch, A., Tischew, S. 2011. A reflection of ecological restoration of surface-mined land based on German experiences. In: Řehounková, K., Řehounek, J., Prach, K. (Hrsg.) Near-natural restoration vs. technical reclamation of mining sites in the Czech Republic, 94-108. University of South Bohemia in České Budějovice.

Hofmann, A. 2008. Ricostituzione per via artificiale. In: Baldini S. (Ed.) Tecniche di ripristino dei boschi percorsi da incendio, A.G.R.A, Roma, Italy, pp. 87-107.

Hulme, P., Roy, D., Cunha, T., Larsson, T.-B., 2009. A pan-European inventory of alien species: rationale implementation and implications for managing biological invasions. In: DAISIE Handbook of Alien Species in Europe. Springer, Dordrecht, Netherlands.

Jacobs D. F., Oliet J.A., Aronson J., Bolte A., Bullock J.M., Donoso P.J., Landhausser, S.M., Madsen, P., Peng, S., Rey-Benayas, J.M., Weber, J.C. 2015. Restoring forests: What constitutes success in the twenty-first century? New Forests 46: 601–614.

Kenk, G., Guehne, S. 2001. Management of transformation in central Europe. Forest Ecology and Management 151: 107-119.

Kint, V., Geudens, G., Mohren, G.M.J., Lust, N. 2006. Silvicultural interpretation of natural vegetation dynamics in ageing Scots pine stands for their conversion into mixed broadleaved stands. Forest Ecology and Management 223: 363-370.

Kutiel, P. 2001. Conservation and management of the Medi-

terranean coastal sand dunes in Israel. Journal of Coastal Conservation 7 (2): 183-192.

Leone, V. 2001. Interventi selvicolturali per il recupero di soprassuoli boschivi percorsi da incendio. L'Italia Forestale e Montana. 56 (6): 430-440.

Leone, V., Lovreglio, R. 2008. La ricostituzione delle formazioni boschive percorse In: Baldini S. (Ed.) Tecniche di ripristino dei boschi percorsi da incendio, A.G.R.A, Roma, Italy, pp. 33-60.

La Mantia, T., Messana, G., Billeci, V., Dimarca, A., Del Signore, M.B., Lenza, M., Livreri Console, S., Maraventano, G., Nicolini, G., Prazzi, E., Quatrini, P., Sanguedolce, F., Sorrentino, G., Pasta, S., 2012. Combining bioengineering and plant conservation on a Mediterranean islet. iForest (early view): e1-e10 [online 2012-12- 17] URL: http://www.sisef.it/iforest/contents?id=ifor0638-005

La Marca, O., Mercurio, R., Nocentini, L. 2016. Management and restoration on Italian afforestations under global change. Reforesta 2:50-59.

Liess, N. 2007. Der Baum des Himmels? *Ailanthus altissima* (Mill.) Swingle. Monitoring und Evaluierung von Kontrollmethoden im Nationalpark Donau-Auen (Osterreich). Fachbereich Landschaftsnutzung und Naturschutz. Fachhochschule Eberswalde, Germany

Lund, H.G. 2009.What Is a Degraded Forest. Forest Information Services. Gainesville, VA, USA. http://home.comcast.net/~gyde/2009forestdegrade.doc.

Macchia, U., Pranzini, E., Tomei, P.E. 2005. Le dune costiere in Italia. La natura ed il paesaggio. Felici, San Giuliano Terme (Pisa) Italy.

Malcolm, D.C., Mason, W.L., Clarke, G.C. 2001. The transformation of conifer forests in Britain: regeneration, gap size and silvicultural systems. Forest Ecology and Management 151 (1-3): 7-23.

Manetti, M.C., Cutini, A., Gugliotta, O.I., Hayny, M., Amorini, E. 2007. Sviluppo della componente arborea e arbustiva e tecniche di recupero in una pineta percorsa dal fuoco, Castel Fusano, Roma. Forest@, 4 (1): 131-141.

Moreira; A., Ferreira; A., Abrantes N., Catry F.; Fernandes, P.; Roxo, L., Keizer J.J.; Silva, J. 2013 Occurrence of native and exotic invasive trees in burned pine and eucalypt plantations: implications for post-fire forest conversion. Ecological Engineering 58: 296-302.

Mercurio, R. (Eds) 2010. Restauro della foresta mediterranea. Clueb, Bologna, Italy.

Mercurio, R**.** (Eds.) 2015. Linee guida per la rinaturalizzazione dei rimboschimenti di conifere in Abruzzo e per l'utilizzo di biomasse. Linea Grafica editrice, L'Aquila, Italy.

Mercurio, R. 2016. Otto lezioni sul restauro forestale. Youcanprint Self-Publishing http://www.youcanprint.it/natura/natura-ecosistemi-e-habitat-foreste-e-foreste-pluviali/otto-lezioni-sul-restauro-forestale-9788892635562.html

Mercurio, R., Schirone, B. 2015. Black Pine Afforestations in Abruzzo (Central Italy): Perspectives and Management. Journal of Environmental Science and Engineering A 4: 494-500.

Mercurio, R., Contu, F., Scarfò, F. 2010. New approaches concerning forest restoration in a protected area of central Italy: An introduction. Scandinavian Journal of Forest Research 25 (Suppl.1): 1-6.

Mercurio, R., Nocentini, L., Picchio, R. 2015. Castagneti da frutto abbandonati: quali le opportunità di recupero? Sherwood 213: 31-37.

Miozzo, M., Ducci, F., Montini, P. 2015. Ricostituzione di boschi a dominanza di Faggio con *Abies alba* nell'Appennino Tosco - Marchigiano | Guida al Progetto LIFE08NAT/000371/ReSilFor Edited by D.R.E.AM. Italia.

Miyawaki, A. 1999. Creative Ecology: Restoration of Native Forests by Native Trees. Plant Biotechnology 16: 15-25.

Miyawaki, A. Box, E.O. 2007.The Healing Power of Forests: The Philosophy Behind Restoring Earth's Balance with Native Trees. Kosei Publishing Co. Japan.

Modica, G., Merlino, A., Solano, F., Mercurio, R. 2015. An index for the assessment of degraded Mediterranean forest ecosystems. Forest Systems 24 (3): 1-13.

Motard, E., Muratet, A., Clair-Maczulajtys, D., Machon, N. 2011. Does the invasive species *Ailanthus altissima* threaten floristic diversity of temperate peri-urban forests? Comptes Rendus Biologies. 334: 872–879.

Muscolo, A., Bagnato, S., Sidari, M., Mercurio, R. 2014. A review of the roles of forest canopy gaps. Journal of Forestry Research 25 (4): 725-736.

Muscolo, A., Settineri, G., Bagnato, S., Mercurio, R, Sidari, M. 2017. Use of canopy gap openings to restore coniferous stands in Mediterranean environment. iForest (early view). – doi: 10.3832/ifor1983-009 [online 2017-02-23]

Ne'eman, G., Perevolotsky, A. 2000. The management of burned forests in Israel. In: Ne'eman G., Trabaud L (Eds) Ecology, Biogeography and Management of *Pinus halepensis* and *P. brutia* Forest Ecosystems in the Mediterranean Basin. Backhuys Publishers, Leiden, The Netherlands, pp. 321-333.

Neris, J., Santamarta, J.C., Doerr, S.H., Prieto, F., Agulló-Pérez, J., García-Villegas, P. 2016. Post-fire soil hydrology, water erosion and restoration strategies in Andosols: a review of evidence from the Canary Islands (Spain). iForest (early view): e1-e10. – doi: 10.3832/ifor1605-008 [online 2016-03-17].

Onori, L. 2009. Il ripristino degli ecosistemi marino-costieri e la difesa delle coste sabbiose nelle Aree protette. ISPRA Rapporti N. 100/2009, pp. 674. [online] URL: http://

www.isprambiente. gov.it/files/pubblicazioni/rapporti/rapporto-100-2009-cap-1-11.pdf-http://www.isprambiente.gov.it/files/pubblicazioni/rapporti/ra pporto-100-2009-cap-12-14.pdf

Parisio, M., Falchero, G., Ricchiardone, K., Turchetti, T. 2009. Esperienze di recupero di castagneti da frutto nella Valle di Susa (Torino). Atti del 5° Convegno Nazionale sul Castagno Cuneo, Italy, pp.83-88.

Pausas, J.G., Blade, C., Valdecantos, A., Seva, J.P., David Fuentes, D., Alloza, J.A., Vilagrosa, A., Bautista, S., Cortina, J., Vallejo, R. 2004. Pines and oaks in the restoration of Mediterranean landscapes of Spain, new perspectives for an old practice: a review. Plant Ecology 171 (1-2): 209-220.

Pausas, J.G., Keeley, J.E. 2014. Evolutionary ecology of resprouting and seeding in fire-prone Ecosystems. New Phytologist 204: 55-65.

Pinna, M.S, Bacchetta, G., Orrù, M., Cogoni, D., Sanna, A., Fenu, G. 2017. Results of the Providune project: restoration of the "Coastal dunes with *Juniperus* spp." priority habitat in Sardinia. Plant Sociology 54 (1): 73-84.

Piovesan, G., Schirone, B., Hermanin, L., Lopuzone, G. 2002. Considerazioni ecologico selvicolturali sulla ricomposizione e riabilitazione delle tassete: il caso della faggeta di Morino. In: Schirone, B., Bellarosa, R., Piovesan, G. (eds) "Il tasso un albero da conoscere e conservare". Cogecstre, Penne (PE), Italy pp. 114-137.

Prach, K. Pyšek, P. 2001. Using spontaneous succession for restoration of human-disturbed habitats: Experience from Central Europe. Ecological Engineering 17: 55-62.

Prach, K., Bartha, S., Joyce, C.B., Pyšek, P., van Diggelen, R., Wiegleb, G. 2001. The role of spontaneous succession in ecosystem restoration: A perspective. Applied Vegetation Science 4: 111- 114.

Raftoyannis, Y., Spanos, I. 2005. Evaluation of log and branch barriers as post-fire rehabilitation treatments in a Mediterranean pine forest in Greece. International Journal of Wildland Fire 14 (2): 183-188.

Richardson, D.M., Rejmánek, M., 2011. Trees and shrubs as invasive alien species – a global review. Diversity Distribution 17 788–809.

Sabra, J., Imad, R, Miri, H., Yehia, Y., Al-Zein, M.S. 2017. Restoration against all odds: the case of coastal sand dunes in Ouzai. Plant Sociology 54 (1): 61-71.

Saracino, A., Leone, V. 2001. Strategie di sopravvivenza al fuoco e meccanismi di recupero post-incendio in ambiente mediterraneo: il caso delle pinete di pino d'Aleppo. Monti e Boschi 52 (2): 38-46.

Scalera, R., Celesti Grapow, L. 2007. Alien species. In: Blasi C., Boitani L., La Posta S., Manes F., Marchetti M. (eds) Biodiversity in Italy. Palombi, Roma, Italy pp. 128-130.

Schirone, B., Vessella, F. 2014. Adapting the Miyawaki method in Mediterranean forest reforestation practices. In: Bozzano, M., Jalonen, R., Thomas, E., Boshier, D., Gallo, L., Cavers, S., Bordács, S., Smith, P., Loo, J., (eds). Genetic considerations in ecosystem restoration using native tree species. State of the World's Forest Genetic Resources – Thematic Study. Rome, FAO and Biodiversity International, pp. 140-143.

Schirone, B., Salis, A., Vessella, F. 2011. Effectiveness of the Miyawaki method in Mediterranean forest restoration programs. Landscape Ecological Engineering 7: 81-92.

Stanturf, J.A. 2005. What is forest restoration? In: Stantuf J.A., Madsen P. (eds), Restoration of Boreal and Temperate Forests, CRC Press, Boca Raton, pp. 3-11.

Stanturf, J.A., Palik, B.J., Dumroese, R.K. 2014a. Contemporary forest restoration: A review emphasizing function. Forest Ecology and Management 331: 292-323.

Stanturf, J.A., Palik, B.J., Williams, M.I., Dumroese, R.K., Madsen, P. 2014b. Forest restoration paradigms. Journal of Sustainable Forestry 33 (Suppl 1), S161-S194.

Thomasius, H. 1996. Geschichte, Anliegen und Wege des Waldumbaus in Sachsen. In: Waldumbau. Schriftenreihe Sächs. Landesanst. f. Forsten, H. 6, 11-52.

Tischew, S. (Ed.) 2004. Renaturierung nach dem Braunkohleabbau. B.G. Teubner Verlag, Stuttgart Leipzig Wiesbaden (Germany).

Tischew, S., Kirmer, A., Lorenz, A. 2005. Alternative restoration strategies in former lignite mining areas of eastern Germany. Biodiversity Structure and Function – Vol. II - Alternative Restoration Strategies in Former Lignite Mining Areas of Eastern Germany - S. Tischew, A. Kirmer, A. Lorenz ©Encyclopedia of Life Support Systems (EOLSS) [www.eolss.com]

Tinelli, A., Tinelli, P., Maffei, L. 2010. I sistemi dunali. In: Mercurio R. (Ed.) Restauro della foresta mediterranea, Cleub, Bologna, Italy, pp. 291-306.

Trabaud, L., Michelis, C., Grosman, J. 1985. Recovery of burnt *Pinus halepensis* mill. forests. II. Pine reconstruction after wildfire. Forest Ecology and Management 13 (3-4): 167-179.

Vagniluca, S. Quilghini, G., Giunti, M. 2014. The Tree-of-heaven on Montecristo and the efforts leading to its eradication (L'Ailanto a Montecristo e gli interventi che conducono alla eradicazione). In: Quaderni del Parco, documenti tecnici volume 2 Progetto LIFE+ Montecristo 2010, Eradicazione di componenti florofaunistiche aliene invasive e tutela di specie e habitat nell'Arcipelago Toscano". Parco Nazionale Arcipelago Toscano, Portoferraio (2014). http://www.montecristo2010.it/stealthV3_pubblica/0840566ARG4637055061.pdf, pp 26- 33 (accessed 3 march 2017)

Valdecantos, A., Baeza, M.J., Vallejo, V.R. 2009. Vegetation management for promoting ecosystem resilience

in Fire-Prone Mediterranean shrublands. Restoration Ecology 17 (3): 414-421.

Vallejo, V.R., Allen, E.B., Aronson, J., Pausas, J.G., Cortina, J., Gutiérrez, J.R. 2012a. Restoration of Mediterranean-type woodlands and shrublands. In: van Andel J., Aronson J. (Eds), Restoration Ecology: The New Frontier. Blackwell Publishing Ltd., pp. 130–144.

Vallejo, V.R., Smanis, A., Chirino, E., Fuentes, D., Valdecantos, A., Vilagrosa, A. 2012b. Perspectives in dryland restoration: approaches for climate change adaptation. New Forest 43: 561–579.

Wunder, J., Knusel, S., Gurtner, D., Conedera, M. 2016. The spread of tree of heaven in Switzerland in Krumm, F.Vítková, L. (Eds). Introduced tree species in European forests: opportunities and challenges. European Forest Institute, pp -374- 386.

Zerbe, S. 2002. Restoration of natural broad-leaved woodland in Central Europe on sites with coniferous forest plantations. Forest Ecology and Management 167 (1-3): 27-42.

Web sites

Forest Map of Italian Kingdom 1936. http://193.205.194.133/ (accessed 4 august 2017)

http://www.liferesilfor.eu/index.php?option=com_jdownloads&Itemid=58&task=viewcategory&catid=10&lang=it (accessed 4 august 2017)

http://www.sian.it/inventarioforestale/jsp/dati_introa.jsp?menu=3 (accessed 4 august 2017)

http://www.ser.org/SER (accessed 4 august 2017)

http://www.sirf.it/ (accessed 4 august 2017)