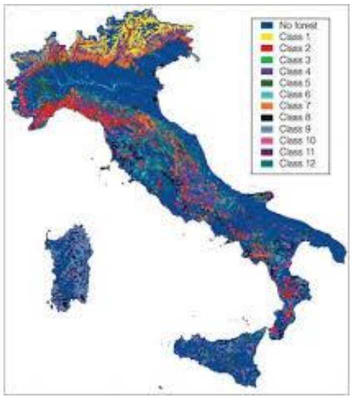

Management and restoration of Italian afforestations under global change

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Abstract

As a consequence of past deforestation, degraded areas in Italy have been subjected to afforestation since the beginning of the XXI century. These afforestations have been done mainly with conifers (*Pinus nigra*, *Pinus pinaster*, *Pinus halepensis*, *Pinus pinea*), and with the aim to 1) protect the soil and to 2) prevent floods. Exotic forest tree species have been used for the afforestation of selected sites of the Apennine. In the case of Douglas fir, it is possible to state that after ninety years the results are very good in terms of both ecological adaptability and high growth-rate.
Nowadays, the lack of silvicultural treatments, the ageing processes, insect and fungi outbreaks have led pine afforestations to a condition of an unsteady biological equilibrium in many sites. Moreover, this condition seems to be due to additional factors related to climate change such as wind storms and dryness. The restoration of these pine afforestations is therefore one of the main aims of the present Italian forest management policy which aims to increase their level of resilience. In particular, the priority of the researchers has been given to the most fragile stands where three possible objectives of restoration measures should be considered:

1. To rehabilitate conifer stands by introducing native broadleaves when these stands are in a very degraded condition, and when the local wood energy chain needs to be started;
2. To conserve the conifer stands in the cases where the cultural, aesthetic and recreational functions, are the prevailing obtainable ecosystem services;
3. To foster the mixed stands, with the conifers of the old cycle and native broadleaves, which could increase resilience to the extreme events.

In regards of Douglas-fir stands, new silvicultural models have been developed which aim to a) conserve these stands and to b) combine a higher growth rate with a much improved mechanical tree stability.

Keywords

Afforestation; Exotic forest tree species; Forest restoration

Contents

1 Italian forest policy

Afforestation has been historically the main tool of the Italian forest and mountain policy (Lazzarini 2002). Afforestation activity starts with the first Italian Forest Act of 1877 and continues with Forest Act of 1923 until the 1970s. The legislator's objectives have been the soil protection and an attempt to find a solution to unemployment in mountain areas. The main problem with soil erosion was due to the serious state of degradation of the lands and woodlands which characterized the end of the 19th century with the consequence recurrence of flood events. During the 1970s, afforestation objectives have focused more on wood production which, thanks to State funding, gave rise to great interventions, especially in the southern and insular Italy.

By the 1980s, nearly 1,100,000 hectares had been afforested. Conifers were the most used species because they gave assurances of rapid initial establishment and development to allow a prompt and effective soil cover and greater adaptability to soil heterogeneity. In descending order, the interested species were the following: Black pine *(Pinus nigra* sl), Maritime pine (*Pinus pinaster* Ait.), Aleppo Pine (*Pinus halepensis* Mill.), Umbrella pine (*Pinus pinea* L.). Furthermore, even some other exotic forest species (Douglas fir, Radiata pine, Cedars) have produced good results as shown by a series of experimental trials (Ciancio et al. 1984, 1997).

Other particular aspects have distinguished the Italian forestry system. First of all, during the 1930s poplar plantations that supply paper and panels industries, have been subjected to a considerable development in the Po Valley with a maximum in the late 1960s. Currently, the area has been reduced to approximately 80,000 hectares. The best result obtained by these practices was the selection of poplar hybrids that are now known worldwide (I 214, Luisa Avanzo, etc.). Secondly, between the 1950s and the 1980s, about 72,000 hectares of eucalyptus were established in the south of Italy (*Eucalyptus globulus* Labill. ssp. *bicostata*, *E*. *globulus* Labill. ssp. *globulus*, *E*. *occidentalis* Endl, *E. x trabutii* M. Vilm., *E. camaldulensis* Dehnh., *E. viminalis* Labill). Approximately 54,000 of them were used for soil protection and wood production. Thirdly, from 1994 to 1999, about 100,000 hectares of pure or mixed broadleaves were established in Italy (with EU funds in the implementation of policies on set-aside). In particular, in the 75% of afforestations were used high quality wood tree species (common walnut, wild cherry, maples and ashes, etc.), whereas in the 22% were used hybrid poplars. Negligible were the interventions with conifers (Colletti 2001).

If one compares the past with the present situation, it is possible to realize that there has been a turning point in the way that afforestation measures are considered. The changes regard: a) a passage from State- to private-interventions, b) a change in plant species adoption from coniferous to broadleaved species; and c) a change from afforestation on large bare lands to small farmlands.

2 Conifer afforestation

The general results obtained with conifer afforestations have been positive during the early years in regard of seedling establishment and development. In particular, the operators have noticed occurrence of remarkable effects from both a) soil-conservation and b) socio-economic point of view. On the other hand, when considering wood production these afforestations have resulted to be largely unproductive for several reasons such as: 1) the adoption of not-adequate cultivation techniques, 2) the lack of planning and lack of financial resources; 3) the onset of timber market crisis in recent decades.

Mainly in the pinewoods, the absence of thinning produced a high level of stand-density. In addition other negative factors were active in these afforestations such as: 1) a structural fragility; 2) the arrest of dynamic processes; 3) a high susceptibility to damages from winds and storms; 4) the spread of insects and pathogens. Part of these afforested stands are 80-130 years old, and for this reason they have reached a stage of biological maturity characterized by a fragile biological- and mechanical-stability.

On the contrary, Douglas fir afforestations have been successful firstly because they have been established on better sites and secondly because they have been thinned regularly due to financial return.

The restoration interventions and the consequent type of management to be adopted for conifer afforestations depends upon a) the ecosystem service selected and b) their degree of bio-structural evolution.

In regard of the ecosystem services to perform there could be two cases:

1) *Soil protection*.

By taking into consideration the characteristics of the sites where these afforestations were established, it is possible to state that they are generally susceptible to be restored.

2) *Wood production.*

When these afforestations have regarded unadapted sites it is possible to foresee that they will be unable to provide future satisfying production increments. For this reason these type of afforestations could be subjected to restoration. Instead, when these afforestations were made on successful sites, they could be conserved and actively managed.

In regards of the degree of bio-structural development there could be two different cases but it is possible to predict the afforestation intervention for both:

1) Sites characterized by dynamic processes of evolution.
2) Sites characterized by absence of dynamic process of evolution.

The above elements are important to choose the future choice of forest restoration strategies.

3 Management options

Where conifer afforestations have been encroached by broadleaves under canopy cover, a gradual transformation into mixed broadleaf stands with a component of the old conifers is predictable. These will be generally stands of high naturalistic and aesthetic, even if they have a low economic value.

Conversely, in cases where conifer afforestations are characterized by a high tree density, there could be an intrinsic structural fragility (high slenderness ratios h/d, etc) which makes it extremely difficult (if not impossible!) to maintain these stands under such conditions by taking into account their susceptibility to fires, wind damages, and insect outbreaks as well.

When afforestations are in good conditions (as it seems to be the case of those located in deep and flat soils), the assumption could be made that the best strategy could be to conserve these stands. A significant example are the Douglas-fir plantations that in some Italian regions have reached important surfaces extensions (15-20,000 hectares the total Italian surface area).

According to recent investigations conducted by La Marca (2016), these stands gave a production of 700-750 m^3 ha^{-1} after 45 years with an annual mean increments (main crop) of about 15 m^3 ha^{-1} yr^{-1}. In some Douglas fir stands, natural regeneration has also been observed (La Marca and Pozzi 2016). This last aspect highlights the occurrence of a high resilience to biotic and abiotic stressors, and this element is very important to ensure the conservation of these species. Despite the current economic crisis of timber which affects the majority of European countries, there are signs that induce to foresee an increasing demand of woody products for the coming future.

4 Forest restoration

The restoration (or rehabilitation, into mixed broadleaved or conifer-broadleaved forests) of conifer man-made stands represents one of the main objectives of forest policy in many countries. (Malcolm et al. 2001; Kenk and Guehne 2001; Mc Alpine and Drake 2003; Spiecker et al. 2004; Hansen and Spiecker 2005; Kint et al. 2006; Dekker et al. 2007; Wang and Liu 2011; Harmer et al. 2012; Muscolo et al. 2014). The problem of restoration has arisen in Italy since reforestation with pines had been performed**.** After a first transitional phase, the preparatory species are is replaced with definitive ones. For the Black pine stands, which are the most consistent in the Apennines, restoration is one of the main objectives of their management (La Marca 1998, 1999; Mercurio 2010, 2015).

The objectives of forest restoration are the following:

- To steer the stands toward greater compositional and structural complexity;
- To reactivate the natural dynamics, i.e. the mechanisms of self-regulation;
- To enhance the forest system resistance and resilience to environmental stresses;
- To increase soil fertility; and
- To obtain biomass for energy uses.

The choice of the intervention depends on stand features (tree composition, density, age, phytosanitary state, degree of natural encroachment of broad-leaves, soil evolution, longevity), on the sites features (altitude, exposure, geo-pedology and climate) and on the objective of the restoration.

4.1 Gradual removing cuts

Gradual removing cuts can be applied to two storied stands (an upper-storey of conifers that dominate an under-storey of encroached broadleaves) and consists in the removing the upper storey of conifers. This intervention is performed ignoring the rotation age, but evaluating the phytosanitary, structural and dynamics conditions. Gradual removing cuts may be applied by thinnings, strip-cutting, or small clear-cutting (<10,000 m^2) of different configuration.

De Mas (1993) reports experiences carried out in the Venetian Pre-Alps, in a 50 years old Black pine afforestation with phytosanitary problems but characterized by regeneration of a good under-canopy cover of broadleaves. In these experiments two theses were compared:

a) the total elimination of Black pine of old cycle and the consequent broadleaves release
b) b) the elimination of the 80% of the old pines, by releasing 100-150 pines per hectare (biological heritage) and broadleaves.

The best results were obtained with the complete pine-removal which facilitates the growth of broadleaves such as manna ash (*Fraxinus ornus*) and hornbeam (*Ostrya carpinifolia*). Based on these initial experiences**,** a lower environmental impact intervention was proposed. In this case, by starting from regeneration nuclei, alternate strip-cuttings 10 m wide were carried out, with a slight inclination downwards to obtain a 'herringbone' pattern with pine strips of the same width.

In Black pine afforestations located in Casentino Mountain (Tuscany) Bianchi and Paci (2003) a cultural model was applied based on a progressive reduction of pine cover. In the first phase two or three interventions, aimed to obtain a two-storey structure, with 50-70 large trees on the upper storey and broadleaves in the lower storey. In these cases, the pine trees could be kept up to their natural mortality, or cut down in order to speeding up the transformation into the new stand dominated by broadleaves (linden, ash, mountain elm and maple).

Another example was undertaken in 70-years old afforestations of Black pine in the Chianti district (Tuscany), where there was extensive broadleaved regeneration (oak, maple, chestnut) in the dominated storey. This intervention consisted of small clear cuts of 3,000-10,000 m^2 of the pine stand and the coppicing of the broadleaves present under the canopy cover (Nocentini 2008).

4.2 Strip- cuttings system

Experiences of strip-cuts were performed in a 65 years old afforestation of Black pine on calcareous lithosols, in the Abruzzi Apennines (Pizzoli, AQ). The lack of thinning operations had resulted in excessive density of the stand followed by an arrest of its natural dynamics. In fact, in the lower storey, the advanced regeneration of both a) trees and b) shrubs species was almost absent because of shortages of light and formation of dense carpets of grasses, mosses and needles. The cuts were done using a series of 15 m long and 100 m wide strips (3 per hectare to remove the 45% of the pinewood) alternate with uncut strips. After logging operations, performed with three different extraction methods (i.e., horse-powered, forest-winches, and cable-crane) no significant soil damages were observed. Nevertheless, in the first two cases, occurrence of grasses and mosses removal in nearly 40 percent of the cut surface was observed, whereas no impact occurred when the cable crane method was used (Mercurio 2015).

4.3 Gap-cutting system

The gap-cutting system (gap-cutting silviculture -*sensu* Van der Meer et al. 1999- and gap-based approach -*sensu* Coates and Burton 1997) attempts to mimic the natural gap size and frequency observable in gap-disturbed forests where a judicious use of well-planned partial cutting is applied (Mc Carthy 2001).

This approach has been used in a number of forests types around the world (Coates and Burton 1997; Coates 2002; Mc Carthy 2001; Diaci et al. 2005; Raymomd et al. 2006; Cater et al. 2014; Ponzanovic et al. 2014; Vilhar et al. 2015). In particular**,** gap cutting is designed to allow the establishment of new regeneration, where this is not present (Schliemann and Bockheim 2011).

The application of this type of intervention assumes that frequent small-scale disturbances produce:

- a fine-grained stand texture,
- a multi-aged age structure,
- high variability of tree sizes in a small area,
- continuous (at stand scale) regeneration process,
- small spatial-temporal variation in biomass accumulation.

4.4 Variant with natural regeneration

The first trial was performed in the Abruzzi Apennines (Introdacqua, AQ) Black pine afforestations in the spring of 2000. Four gaps were opened: 2 in a 50 years old stand, (85-154 m^2) and 2 in 90-years old stand (132-260 m^2) by removing soil organic layer, herbs, and mosses during logging operations. After 15 years of monitoring (Gugliotta and Mercurio 2003; Mercurio et al. 2009; Muscolo et al. 2011; Mercurio and Spinelli 2012; Mercurio and Schirone 2015), the results show that all the gaps are well regenerated. An initial prevalence of Black pine regeneration was followed by a regressive phase. The last field surveys indicate that the re-arranged vegetation type is represented in multi-layer structures by holm oak (*Quercus ilex*) (30% of the canopy cover) followed by other broadleaves such as hop-hornbeam (*Ostrya carpinifolia*), pubescent oak (*Quercus pubescens*) and manna-ash (*Fraxinus ornus*), sometimes with maples and cherries mixed with Black pines. These species are the main component of the native vegetation type. The optimal size of the gap was, in these cases, higher than 250 m^2.

Other experiments on 50-years old Black pine afforestations began in 2003 in the Calabrian Apennine (Capistrano, VV). The results obtained after 10 years (Gugliotta et al. 2006; Muscolo et al. 2007; Bagnato et al. 2012; Mercurio e Spinelli 2012; Muscolo et al. 2014) revealed that in the large gaps (1,520 m^2) Black pine regeneration prevails. In the medium gaps (855 m^2), and especially in the small gaps (380 m^2), the late successional species (silver fir and beech) prevail, whereas the Black pine regeneration presents a subordinate role. These results suggest that, if the aim of restoration are the native woodlands, the gaps of 300-400 m^2 are the most appropriate.

4.5 Variant with natural regeneration

With the intent of creating dissemination spots within the stand and in presence of favorable environmental conditions, broadleaved species have been planted in opened gaps. For example, Turkey oak (*Quercus cerris* L.) and sessile oak (*Quercus petraea* -Matt.- Liebl.) were planted in a Black pine afforestation 40 years old Black pine afforestation site in the Calabrian Apennine (Bagnato et al. 2013). In the Tuscan pre-Apennine (Pratomagno), sessile oak (*Quercus petraea* -Matt.- Liebl.) was planted in gaps created in 30-50 years old Black pine afforestations (Cantiani et al. 2003; Plutino et al 2009).

4.6 Variation with sowing of native conifers

The Poletto Method was developed in the Calabrian Apennine (Azienda Agricola La Foresta at Serra San Bruno, VV) in man-made Black pine stands. This method consists of applying selective thinnings every 10 years when 20% of the standing trees are removed. After the last thinning, when trees were about 60 years old, and crown cover was partially open, a series of tilled strips about 80 cm wide were made every 3.5 m. In September, silver fir (*Abies alba*) cones were collected in the surrounding stands, disjointed and the collected seeds were immediately seeded in the strips. After a few years when the silver fir seedlings are well established, the old pine stand is removed in two times. Subsequent treatments consist: 1) cleaning between the strips (manly bramble, bracken) with brush cutter; 2) cleaning from silver fir regeneration (Bagnato et al. 2013).

5 Broadleaves plantations

The results obtained with poplar plantations are very positive and the reason relays on the fact that they have been limited to the very best sites in alluvial plains. In fact, these plantations represent one of the most important wood resources for Italian industries.

In the case of eucalyptus plantations, the results are not exactly as expected, primarily because of the selection of harsh soil conditions and secondly for the shortage of water supplies. In these cases, the replacement with other species (i.e. pines) or restoration should be considered.

In the case of broadleaved plantations aimed for high-quality wood production, the results are often negative. The failure is due to a number of factors such as: inexperience (use of nursery materials of poor quality, inappropriate soil preparation, poor knowledge of auto-ecology of the species), economic speculations that extended the plantations even in unsuitable areas (degraded soils, sites subject to water stress), and the lack of adequate cultivation techniques. However, there are also examples of successful plantations. Where these plantations have failed, the total or partial replacement with the other tree species should be considered (once the cycle ends); in alternative, return to crop cultivations should be considered.

6 Restoration perspectives under climate change

Climate change projections indicate that remarkable changes in the regional climate might occur in the next few decades. A substantial warming and a significant decrease of precipitation might affect the region in the period 2021-2050 (IPCC 2014). The worsening of environmental stresses added to the abandonment of forest practices going on during the last decades could increase beyond any catastrophic perspective the recurrence of forest fires, wind storm, insect and pathogen attacks, and the ungulate population explosion. In order to mitigate these consequences many afforestations, which are in non-optimal soil/climate conditions, should be restored to strengthen their resilience.

7 Conclusions

All forest restoration initiatives taking place in Mediterranean areas should be programmed by considering the occurrence of small-scale anthropological and environmental disturbances. The experiences of new management/restoration approaches carried out in Italy in many mountain areas, indicate that, in presence of global change (climate, economic and social), any intervention should take in consideration the adoption of different cultural techniques in relation to different ecological and structural situations but also in relation to the degree of social acceptance of the proposed measures. Moreover, while the climate change effects remain a long-term perspective with a high margin of uncertainties, at local scale there are other factors which could affect immediately the success or the failure of forest management or restoration initiatives. One of those initiatives is the high pressure of ungulates. Finally, it is necessary that new European and national forest rules regarding forest restoration should be implemented.

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