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Black Pine Afforestations in Abruzzo (Central Italy): Perspectives and Management

Roberto Mercurio and Bartolomeo Schirone

Agriculture, Forestry, Nature and Energy Department (DAFNE), University of Tuscia, Viterbo 01100, Italy

Abstract: In Italy, the hydro-geological protection of the Apennine territories is a well-known issue. For this reason, at the end of the 19th century, a new reforestation technique was proposed by the Inspector of Forest Service, Pietro Montanari to cope with difficult soil conditions of the mountain areas. This new approach was the first application of the so-called "gradoni" (small terraces) method of soil preparation. Each "gradone" was 100-120 cm wide and made with a slight counter slope (ca 10-15 degrees) to promote the accumulation of water and organic matter. Along each "gradone", bare root black pine seedlings (*Pinus nigra* Arn.) were planted at a distance of 1 m from each other with a density of more than 3,000/ha. Nowadays, 19,158 hectares of black pine forests are growing in the Apennine of the Abruzzi region, largely resulting from those reforestation projects realized since the beginning of the 20th century. A case study of Monte Plaia (42°00'12" N 13°53'39" E), that illustrates the situation after 70-110 years in consequence of lacking of silvicultural treatment and the application of aforest restoration method is presented.

Key words: Black pine afforestation, forest restoration, Italy.

1. Introduction

Black pine (*Pinus nigra* Arn. subsp. *nigra* var. *italica* Hochst) is an endemic species in some small sites in Abruzzo [1, 2], but since the 19th century, many afforestations were established with *Pinus nigra* Arn. s. l. in order to protect the soil from erosion and prevent landslides and floods.

The Inspector of Forest Service, Pietro Montanari, cope with the difficult soil conditions of the mountain areas, proposed a new reforestation technique. This new approach was the first application of the so-called "gradoni" (small terraces) method of soil preparation [3]. Each "gradone" was 100-120 cm wide and made with a slight counter slope (ca 10-15 degrees) to promote the accumulation of water and organic matter. The vertical distance among the "gradoni" was of a few meters depending on the slope. Along each "gradone", bare root black pine seedlings (*Pinus nigra* Arn. s. l.) were planted at a distance of 1 m from each other with a density of more than 3,000/ha.

Corresponding author: Roberto Mercurio, Ph.D., main research fields: forest restoration and silviculture. E-mail: presidente@sirf.it/rmercurio@unirc.it.

Black pine proved to be particularly suitable for reforesting slopes with shallow soils and harsh climatic conditions (prolonged summer drought) thanks to the efficient use of soil water and the root system extension of the black pine [4].

At present, according to the Forest National Inventory [5], in the Abruzzi region, the surface of black pine stands covers 19,158 hectares. Afforestations are present from 600 m up to 1,500-1,600 m, more frequently between 800 m and 1,200 m [6], considered the best vegetation belt for this species.

The lack of silvicultural practices causes negative effects on stand stability, favoring biotic damages, loss of biomass, accumulation of deadwood and risk of fires. Recently, windstorms and recurring drought fostered by climate change have provoked local disasters.

The unmanaged afforestations show blocked natural dynamic processes, while the density has been reduced for natural or artificial causes (as thinnings). It's easy to assist to a recruitment of native broadleaves under canopy cover.

Given the current attention toward sustainable forestry, the long-term objective is to restore a complex structure, the species diversity and the function of a native forest ecosystem through the gradual conversion of these conifer monocultures into native broad-leaved or mixed coniferous [7, 8].

The issue of restoration has been set in Italy since afforestations have been performed with pines, as they are considered transitional species. In fact, the black pine afforestations significantly changed the microclimate and the soil environment, making it suitable for more demanding species [9].

The restoration (or rehabilitation, conversion-transformation into mixed broadleaved or conifer-broadleaved forests) of man-made conifer stands represents one of the main objectives of forest policy in many countries [10-19].

Such objectives fall within broader ones than those provided by the United Nations Framework Convention on Climate Change (UNFCCC), the Conservation on the Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD).

This paper aims to provide some considerations on such issues with respect to one case study. In particular, the following questions have been addressed:

(1) What changes are taking place in the unmanaged afforestations?

(2) What should be the most appropriate silvicultural tool to restore more stable stands?

2. Material

The study was carried out in 50 years and 90 years old black pine (*Pinus nigra* Arn. s. l.) afforestation at Monte Plaia (Introdacqua, L'Aquila) 42°00′12" N 13°53'39" E (Table 1).

Table 1 Monte Plaia, study site.

Altitude (m.a.s.l.)	840
Aspect	W
Slope (inclination (°))	17-25
Mean ann. T. (°C)	11.8
Mean ann. P. (mm)	746
Vegetation type	*Cyclamino hederifolii-Quercetum ilicis*
Bedrock	Limestone
Soil type	Lithic hapludoll

3. Method

3.1 Framework of the Silvicultural Approach

Here is a proposed silvicultural approach that mimics natural disturbances that may restore forests in a more suitable and natural way, optimizing harvest and yield and preserving biodiversity and ecosystem functioning [20].

In temperate forests, gap opening is the major process determining regeneration development [21] and a vast body of literature exists on the effects of canopy gaps on tree recruitment patterns [19, 22, 23].

The gap-cutting system or gap-cutting silviculture [24] and gap-based approach [25] attempt to mimic the natural gap size and frequency in gap-disturbed forests through judicious use of well-planned partial cutting [26].

This approach has been applied in many forest types over the world: in boreal forests [25-29]. In temperate forests [30-33]; in several tropical rain forests [34, 35]; in the coniferous forest of the Pacific Northwest USA [36, 37]; in long-leaf pine ecosystems of south-eastern USA [38-40] and in Australian eucalyptus natural forests [24, 41].

In particular, gap cutting is designed to allow the establishment of new regeneration, which is not present [42].

It assumes that frequent small-scale disturbances produce:

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

3.2 Field Survey

The dendrometric parameters provide the starting

information for the description of the whole stand before the cuttings (Table 2).

Advanced regeneration was detected inside each gap by two orthogonal transects (N-S/E-W) across a 1 m wide gap. In each sub plot of 1 m^2, the number of tree species born by seed, their total height and age were determined. The Regeneration Index (RI) [43], density × mean height in cm, was used to compare regeneration conditions among the gaps, considering good regeneration a value > 100.

On June 2000, an experimental gap cutting system was applied according to the following scheme (Table 3).

Natural regeneration established after the cuttings was surveyed in thirteen circular sub-plots of 3.14 m^2 (100 cm radius) inside each gap. One sub-plot was positioned in the centre of each gap and the others were located at one-third of the radius starting from the centre to the gap edge along the cardinal directions. All seedlings inside each sub-plot were identified by species and total height was measured. Census of seedlings in each sub-plot was carried out in the summer 2002 and 2007. During the surveys of 2015, natural regeneration census was expressed in grade of cover and mean height distinguishing pines from broadleaves in orthogonal transects, 3 m wide, across the gaps.

4. Results and Discussion

4.1 Observations at Stand Level

Common characteristic of these > 70 year old stands are: high stocking and crown cover, decrease in the vitality and annual increment, growth in dead wood and frequent insects outbreaks.

The high density is shown by the low value of Hart-Becking spacing factor (18%-21%), respect to the optimal value of 25% for black pine [44].

4.2 Advanced Regeneration

Under pine canopy cover, seedling recruitment is difficult firstly because of low level of solar radiation, and secondly, of a dense stratum of grasses (*Brachypodium* sp.), mosses and needles. They become impenetrable for the rootlets of seeds that can germinate.

The ecological requirement of the different tree species, especially respect to solar radiation, explains the results obtained (Tables 4 and 5).

The low solar radiation level in seedlings of a light-demanding species like black pine, limits their growth and they frequently die, this is worsen by the concurrence of water availability by grasses [44].

While the seedlings of more shade-tolerant species as holm oak (*Quercus ilex*), hop-hornbeam (*Ostrya*

Table 2 Monte Plaia, dendrometric parameters.

	Stems ($N \cdot ha^{-1}$)	Mean DBH (cm)	Mean height (m)	Top height (m)	Slenderness H/D	Hart-Becking spacing factor S%	Basal area ($m^2 \cdot ha^{-1}$)	Volume ($m^3 \cdot ha^{-1}$)	Standing dead trees (%)
Stand 90 years old	791*	28.3	14.5	17.75	52	21	49.73	367.3	2
Stand 50 years old	1,795	20.1	11.50	14.00	57	18	57.53	331.5	8

* Thinned stand.

Table 3 Monte Plaia, gap cutting system.

Gap no.	Age years	Gap diameter (measured between stems edges), D/tree height, H	Gap size (m^2)
1	50	1	154
2	50	0.75	85
3	90	1	260
4	90	0.75	132

Table 4 Monte Plaia, advanced regeneration inside the gap.

	Mean height (m)	Mean age years	Density n./m^2	RI
Gap 50 years old	0.13	2.3	0.44	5.7
Gap 90 years old	0.45	4.5	0.9	40.5

Table 5 Monte Plaia, advanced regeneration: tree species distribution inside the gap.

Species	Gap 50 years old	Gap 90 years old
	%	%
Quercus pubescens	30	20
Quercu silex	10	10
Pinus nigra	5	10
Fraxinus ornus	5	5
Ostrya carpinifolia	5	3
Acer campestre	1	-

carpinifolia), manna-ash (*Fraxinus ornus*), maples (*Acer* sp.), pubescent oak (*Quercus pubescens*) remain viable for some years. Similar observations have been done in the Middle Balkan Range, Bulgaria in mature Black pine (*Pinus nigra* Arn.) plantations [45]. The advanced regeneration was dominated by broadleaves as shown in many other afforestations in the Apennines [46, 47] and in the Karst Region of Trieste, north-eastern Italy [48].

In this area, hop-hornbeam is not as frequent as it is in other similar afforestations in calcareous soils in central Italy [46, 49]. In fact, this species can grow and survive in very low light level.

The density and R.I. of advanced regeneration was low (Table 4), both for seedlings and saplings as founded in a 85-103 years old afforestation at 1,000-1,600 m.a.s.l. along the calcareous western slopes of Monte Genzana (Abruzzo, Italy) [47].

4.3 Natural Regeneration after Gap Cutting

As shown in previous studies [50-52] since the early years after cuttings the natural regeneration had established.

Nowadays, after 15 years, the experience can be considered closed because all the gaps are well regenerated (Table 6). Results indicate that the re-arranged vegetation type is represented in multi-layer structures by holm oak (*Quercus ilex*) (30% in grade of cover) followed by other broadleaves as hop-hornbeam (*Ostryacar pinifolia*), 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 [53, 54].

This suggests that these experienced gap size are unsuitable for regeneration mainly for the light demanding species like pines as shown in other studies [10, 55]. Moreover, the observed mortality and suffering in regeneration of black pine, could be due to shortage of lightbut alsoto the unsuitable ecological sites (low altitude of vegetation at western aspects) worsened by the effect of climate change (drought stress), responsible of the decline of black pine in many areas [56-59]. The capacity of the “gradoni” to improve the soil water availability is not sufficient to contrast the effect of climate change anymore.

5. Conclusions

5.1 Implications for Sustainable Forest Management

Gap cutting system configures a silvicultural treatment with low environmental and aesthetic impact, which derives from the possibility of diluting the cuttings over time and space.

The conditions, procedures and temporal sequences are summarized in Table 7. This accounts for a total regeneration cycle between 16 years and 30 years, after which the stand will be managed with conventional

Table 6 Monte Plaia, natural regeneration, pooled data.

Mean gap size (m^2)	D/H	Broadleaves		Pines		Total grade of cover (%)
		Grade of cover (%)	Mean height (m)	Grade of cover (%)	Mean height (m)	
207	1:1	50	2.1	50	0.92	90
108	1:0.75	65	2.8	35	0.90	85

Table 7 Gap cutting system, conditions, procedures and temporal sequences.

Stand conditions	Indicative age of the stand at the first cut (years)	Gap size (m^2)	Indicative surface % at the first intervention	Slope inclination (%)	Turnover time* years	Indicative volume removed at first cut per ha (m^3)
High stand density without advanced regeneration, thick layer of needles and mosses	> 65	> 250	25 (30)	< 50	8-10	70-80

* mean time between successive interventions.

thinning, depending on management goals. In fact, thinnings may be performed earlier, if the regeneration inside a gap will be too dense.

As the Monte Plaia area has many tourists, it would be inadvisable to leave standing dead trees mainly near the most frequented paths. In order to reduce the risk of accidents for tourists and fires, it could be better to create some "islets" far from the touristic sites.

5.2 How the Changing Landscape Can before Seen in Consequence of Forest Restoration

The final result will be that of a mixed-species stand, with a group structure. This stand will be young and diversified, hence, much more resilient to any biotic and abiotic damage agents.

As suggested by Fule et al. [60], an open structure of native broadleaves, in this case a mesophylous holm oak vegetation, will be dotted by big pines with wide crown of high aesthetic value.

References

[1] Bruschi, P., Di Santo, D., Grossoni, P., and Tani, C. 2006. "Indagini Tassonomiche Sul Pino Nero (*Pinus nigra* Arn. Pinaceae) Della Majella." *Informatore Botanico Italiano* 38 (2): 357-362.

[2] Pirone, G., Frattaroli, A. R., and Ciaschetti, G. 2010. "Le Serie Di Vegetazione Della Regione Abruzzo." In *La Vegetazione D'Italia*, edited by Blasi C. Roma: Palombi Partner S.r.l..

[3] Ciancio, O., Mercurio, R., and Nocentini, S. 1989. "Los Gradoni Y Las Plazoletas, Sistema Allegretti, Plantacion Hendidura." In *Forestacion En Paises Mediterraneos Tecnicas*, edited by Molina G. L., Navarro, M., Montero Burgos, J. L., and Herranz, G. L. Madrid: ICONA.

[4] Del-Favero, R. 2010. *I Boschi Delle Regioni Dell Italia Centrale*. Padova: Cleup.

[5] INFC. 2007. "Le Stime Di Superficie 2005. Seconda Parte." In *Inventario Nazionale Delle Foreste Dei Serbatoi Forestali Di Carbonio*, edited by Tabacchi, G., De-Natale, F., Di-Cosmo, L., Floris, A., Gagliano, C., and Gasparini, P. et al. Trento: MiPAF, Corpo Forestale Dello Stato, Ispettorato Generale, CRA-ISAFA.

[6] Gambi, G. 1983. "Black Pine, A Tree for the Mountain Environment Restoration." *Annali Istituto Sperimentale Per La Selvicolturais* 14: 3-45.

[7] Vallauri, D. R., Aroson, J., and Barbero, M. 2002. "An Analysis of Forest Restoration 120 Years after Reforestation on Badlands in the South-western Alps." *Restoration Ecology* 10: 16-26.

[8] Mercurio, R. 2010. *Restauro Della Foresta Mediterranea*. Bologna: Clueb.

[9] Tonon, G., Panzacchi, P., Grassi, G., Minotta, G., Cantoni, L., and Bagnaresi, U. 2005. "Spatial Dynamics of Late Successional Species under *Pinus nigra* Stands in the Northern Apennines (Italy)." *Annals of Forest Science* 62 (7): 669-679.

[10] Malcolm, D. C., Mason, W. L., and 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.

[11] Kenk, G., and Guehne, S. 2001. "Management of Transformation in Central Europe". *Forest Ecology and Management* 151: 107-119.

[12] Diaci, J. 2002. "Regeneration Dynamics in a Norway Spruce Plantation on a Silver Fir-Beech Forest Site in the

Slovenian Alps." *Forest Ecology and Management* 161: 27-38.

[13] 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.

[14] Spiecker, H., Hansen, J., Klimo, E., Skovsgaard, J. P., Sterba, H., and Von Teuffel, K. 2004. *Norway Spruce Conversion*, *Options and Consequences*. EFI Research report.

[15] Hansen, J., and Spiecker, H. 2005. "Conversion of Norway Spruce (*Piceaabies* (L.) Karst) Forests in Europe." In *Restoration of Boreal and Temperate Forests*, edited by Stanturf, J. A., and Madsen, P. Boca Raton: CRC Press.

[16] Kint, V., Geudens, G., Mohren, G. M. J., and 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.

[17] Wang, G., and Liu, F. 2011. "The Influence of Gap Creation on the Regeneration of Pinustabuliformis Planted Forest and Its Role in the Near-Natural Cultivation Strategy for Planted Forest Management." *Forest Ecology and Management* 262: 413-423.

[18] Harmer, R., Kiewitt, A., and Morgan, G. 2012. "Effects of Overstorey Retention on Ash Regeneration and Bramble Growth during Conversion of a Pine Plantation to Native Broadleaved Woodland." *European Journal of Forest Research* 131 (6): 1833-1843.

[19] Muscolo, A., Bagnato, S., Sidari, M., and Mercurio, R., 2014. "A Review of the Roles of Forest Canopy Gaps." *Journal of Forestry Research* 25 (4): 725-736.

[20] Lindenmayer, D. B., and Franklin, J. F. 2002. *Conserving Forest Biodiversity*: *A Comprehensive Multiscaled Approach*. Washington, DC: Island Press.

[21] Runkle, J. R. 1982. "Patterns of Disturbance in Some Old-Growth Mesic Forests of Eastern North-America." *Ecology* 63: 1533-1546.

[22] Harcombe, P. A., Bill, C. J., Fulton, M., Glitzenstein, J. S., Marks, P. L., and Elsik, I. S. 2002. "Stand Dynamics over 18 Years in a Southern Mixed Hardwood Forest, Texas, USA." *Journal of Ecology* 90: 947-957.

[23] Kwit, C., and Platt, W. J. 2003. "Disturbance History Influences Regeneration of Non-pioneer Understory Trees." *Ecology* 84: 2575-2581.

[24] Van Der Meer, P. J., Dignan, P., and Savenh, A. G. 1999. "Effect of Gap Size on Seedling Establishment, Growth and Survival at Three Years in Mountain Ash (Eucalyptus Regnans F. Muell) Forest in Victoria, Australia." *Forest Ecology and Management* 117: 33-42.

[25] Coates, K. D., and Burton, P. J. 1997. "A Gap-Based Approach for Development of Silvicultural Systems to Address Ecosystem Management Objectives." *Forest Ecology and Management* 99: 337-354.

[26] Mc-Carthy, J. 2001. "Gap Dynamics of Forest Trees: A Review with Particular Attention to Boreal Forests." *Environmental Reviews* 9: 1-59.

[27] Coates, K. D. 2002. "Tree Recruitment in Gaps of Various Size, Clear-Cut and Undisturbed Mixed Forest of Interior British Columbia, Canada." *Forest Ecology and Management* 155: 387-398.

[28] Raymond, P., Munson, A. D., Ruel, J. C., and Coates, K. D. 2006. "Spatial Patterns of Soil, Microclimate, Light, Regeneration, and Growth within Silvicultural Gaps of Mixed Tolerant Hardwood-White Pine Stands." *Canadian Journal of Forest Research* 36: 639-651.

[29] Poznanovic, S. K., Poznanovic, A. J., Webster, C. R., and Bump, J. K. 2014. "Spatial Patterning of under Represented Tree Species in Canopy Gaps 9 Years after Group Selection Cutting." *Forest Ecology and Management* 331: 1-11.

[30] Diaci, J., Pisek, R., and Boncina, A., 2005. "Regeneration in Experimental Gaps of Subalpine Piceaabies Forest in the Slovenian Alps." *European Journal of Forest Research* 124: 29-36.

[31] Albanesi, E., Gugliotta, O. I., Mercurio, I., and Mercurio, R. 2008. "Effects of Gap Size and within-Gap Position on Seedlings Establishment in Silver Fir Stands". *Forest* 1: 55-59.

[32] Cater, M., Rozenbergar, D., and Diaci, J. 2014. "Gap Size and Position Influence Variable Response of Fagus Sylvatica L. and Abies Alba Mill." *Forest Ecology and Management* 325: 128-135.

[33] Vilhar, U., Rozenbergar, D., Simoncic, P., and Diaci, J. 2015. "Variation in Irradiance, Soil Features and Regeneration Patterns in Experimental Forest Canopy Gaps." *Annals of Forest Science* 72: 253-266.

[34] Kuusipalo, J., Hadenggana, S., Adjers, G., and Sagala, P. S. 1997. "Effect of Gap Liberation on the Performance and Growth of Dipterocarp Trees in a Logged-Over Rainforest." *Forest Ecology and Management* 92: 209-219.

[35] Dupuy, J. M., and Chazdon, R. L. 2008. "Interacting Effects of Canopy Gap, Understory Vegetation and Leaf Litter on Tree Seedling Recruitment and Composition in Tropical Secondary Forests." *Forest Ecology and Management* 255: 3716-3725.

[36] Gray, A. N., and Spies, T. A. 1996. "Gap Size, within-Gap Position and Canopy Structure Effects on Conifer Seedling Establishment." *Journal of Ecology* 84: 635-645.

[37] Gray, A. N., Spies, T. A., and Pabst, R. J. 2012. "Canopy Gaps Affect Long-Term Patterns of Tree Growth and

Mortality in Mature and Old-Growth Forests in the Pacific Northwest." *Forest Ecology and Management* 281: 111-120.

[38] Palik, B. J., and Pederson, N. 1996. "Overstory Mortality and Canopy Disturbances in Longleaf Pine Ecosystems." *Canadian Journal of Forest Research* 26: 2035-2047.

[39] Gagnon, J. L, Jokela, E. J., Moser, W. K., and Huber, D. A. 2003. "Dynamics of Artificial Regeneration in Gaps within a Longleaf Pine Flatwoods Ecosystem." *Forest Ecology and Management* 172: 133-144.

[40] Gagnon, J. L., Jokela, E. J., Moser, W. K., and Huber, D. A. 2004. "Characteristics of Gaps and Natural Regeneration in Mature Longleaf Pine Flatwoods Ecosystems." *Forest Ecology and Management* 187: 373-380.

[41] Van Der Meer, P. J., and Dignan, P. 2007. "Regeneration after 8 Years in Artificial Canopy Gaps in Mountain Ash (Eucalyptus Regnans F. Muell) Forest in South-Eastern Australia." *Forest Ecology and Management* 244: 102-111.

[42] Schliemann, S., and Bockheim, J. 2011. "Methods for Studying Treefall Gaps: A review." *Forest Ecology and Management* 261: 1143-1151.

[43] Magini, E. 1967. "Ricerche Sui Fattori Della Rinnovazione Naturale Dell'Abete Bianco Sull'Appennino." *L'Italia Forestale Montana* 22 (6): 261-270.

[44] Hermanin, L. 1980. Aspetti Della Rinnovazione Naturale Del Pino Nero in Una Zona Dell'Appennino Abruzzese." *Annali Accademia Italiana Di Scienze Forestali* 29: 32-62.

[45] Zlatanov, T., Velichkov, I., Lexer, M. J., and Dubravac, T. 2010. "Regeneration Dynamics in Aging Black Pine (*Pinusnigra* Arn.) Plantations on the South Slopes of the Middle Balkan Range in Bulgaria." *New Forests* 40 (3): 289-303.

[46] Bellezza, P., Corona, P., Ferrari, B., and Plutino, M. 2005. "Analisi Del Processo Di Rinnovazione in Una Pineta Di Pino Nero Presso Rieti." *Linea Ecologica* 2: 42-50.

[47] Portoghesi, L., Consalvo, M., Angelini, A., Ferrari, B., Barbati, A., and Castaldi, C. et al. 2013. "Multifunctional Management of Mountain Reforestations: Thoughts and Perspectives from a Case Study in Central Italy." *L'Italia Forestale Montana* 68 (6): 305-315.

[48] Pignatti Wikus, E. 2003. "Pinete Del Carso Triestino Loro Rinaturalizzazione." *Linea Ecologica* 35 (1): 3-11.

[49] Maetzke, F. 2002. "I Rimboschimenti Di Monte Morello: Analisi Indirizzi Di Un Progetto Aperto Per La Loro Rinaturalizzazione." *L'Italia Forestale Montana* 57 (2): 125-138.

[50] Gugliotta, O. I., and Mercurio, R. 2003. "Prime Osservazioni Su Tagli a Buche in Pinete Di Pino Nero in Abruzzo." *Monti Boschi* 54 (1): 18-21.

[51] Mercurio, R., Mallamaci, C., Muscolo, A., and Sidari, M. 2009. "Effetti Della Dimensione Delle Buche Sulla Rinnovazione Naturale in Rimboschimenti Di Pino Nero." *Forest* 6: 312-319.

[52] Muscolo, A., Mallamaci, C., Sidari, M., and Mercurio, R. 2011. "Effects of Gap Size and Soil Chemical Properties on the Natural Regeneration in Black Pine (Pinusnigra Arn.) Stands". *Tree and Forestry Science and Biotechnology* 5 (1): 65-71.

[53] Ciaschetti, G., Di-Martino, L., Frattaroli, A. R., and Pirone, G. 2004. "La Vegetazione a Leccio (*Quercusilex* L.) in Abruzzo (Italia Centrale)." *Fitosociologia* 41 (1): 77-86.

[54] Pirone, G., Corbetta, F., Frattaroli, A. R., and Tammaro, F., 1997. "La Copertura Vegetale." *Ricerche Sulla Valle Peligna* (*Italia Centrale*, *Abruzzo*) 23: 81-119.

[55] Bagnato, S., Mercurio, R., and Scarfo, F. 2012. "Conifer Afforestations in Italy: An Opportunity for Wood Energy and Forest Restoration." *L'Italia Forestale Montana* 67 (2): 167-172.

[56] Tíscar Oliver, P. A. 2007. "Dinamica De Regeneracion De Pinusnigrasubsp. Salzmannii Al Sur De Su Area De Distribucion: Etapas, Procesos Factoresimplicados." *Investigacion Agraria*: *Sistemas Recursos Forestales* 16 (2): 124-135.

[57] Tíscar Oliver P. A., and Linares J. C. 2011. "Structure and Regeneration Patterns of *Pinusnigra* Sub Sp. *Salzmannii* Natural Forests: A Basic Knowledge for Adaptive Management in a Changing Climate." *Forests* 2: 1013-1030.

[58] Herrero, A., Rigling, A., and Zamora, R. 2013. "Varying Climate Sensitivity at the Dry Distribution Edge of *Pinussylvestris* and *Pinus nigra*." *Forest Ecology and Management* 308: 50-61.

[59] Sanchez-Salguero, R., Camarero, J. J., Dobbertin, M., Fernandez-Cancio, A., Vila-Cabrera, A., and Manzanedo, R. D. et al. 2013. "Contrasting Vulnerability and Resilience to Drought-Induced Decline of Densely Planted vs. Natural Rear-Edge Pinusnigra Forests." *Forest Ecology and Management* 310: 956-967.

[60] Fule, P. Z., Ribas, M., Gutierrez, E., Vallejo, R., and Kaye, M. W. 2008. "Forest Structure and Fire History in an Old *Pinus nigra* Forest, Eastern Spain." *Forest Ecology and Management* 255: 1234-1242.