RENATURALIZATION INTERVENTIONS WITHIN A REGIONAL FOREST COMPLEX LOCATED IN A COSTAL PINE FOREST IN THE SOUTH OF ITALY

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Abstract – The spontaneous vegetation of the Alimini district (south Italy) is represented by plant communities that vary in relation to geology and distance from the coastline: garrigue, scrub, scrub forest and Holm Oak forest, reforestation of Pinus halepensis and Pinus pinea. In the definition of the thinning treatment to be proposed, the identification of the chosen trees for the cutting was done not only based on their vegetational, morphological and phytosanitary features of the single plant, but, primarily keeping in mind the influence exerted by each arboreal element, in terms of biospace, to the underlying layers. Silvicultural interventions have also been defined to contrast the drought phenomenon, desertification and fires, through the planting of broadleaved trees, providing more species, both indigenous primary (arboreal) and secondary (shrub-like).

Introduction

The spontaneous vegetation of the Alimini district, which includes the aim of the study areas, is represented by plant communities that vary in relation to geology and distance from the coastline. Proceeding from the sea towards the inland, the vegetation landscape changes continuously, due to natural facts, or caused by anthropozoogenic actions. In fact, you can find natural origin entities (garrigue, scrub, scrub forest and Holm Oak forest) to reforestation of Aleppo Pine (*Pinus halepensis* Miller) and Stone Pine (*Pinus pinea* L.). The vegetation of natural origin is attributable to what remains of the Great forest of Lecce, which in the Fourteenth Century stretched for 75 km along the Adriatic Coast of Salento proceeding from North to South, between the locality Fontanelle (Brindisi) and the northern outskirts of Otranto, pushing itself inside and including also pastures and swamps (MAINARDI, 1989). In the following centuries the ancient forest was affected by a series of vicissitudes that reduces its surface and consistency. The "Frassanito" forest complex is currently consisting of Mediterranean conifer forests, deriving from planting, mainly composed of Aleppo pine, or Stone pine. The reforestation activities in the area behind the dunes, for about one km and for an average depth of about 700 m towards the hinterland, began in 1930 on land mainly consisting of xeric grasslands, created by the Ripartimental Inspectorate of Forests of the State Forestry Corps (CFS), with funding from the Ministry of Agriculture and Forests and the Fund for the South. The studies carried out show that once, very probably, the Alimini district was characterized by the presence of extensive scrub-forests, mainly of Kermes Oaks (*Quercus coccifera* L.), alternating with Holm Oak forests (*Quercus ilex* L.), limited to microenvironments marked by stationary conditions, mostly of a pedogealogical nature, which satisfied the temperament and needs of the Holm Oak and its companion species.

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The remarkable diffusion of the Kermes Oak, typical of mesomediterranean plain, is due to the high elasticity of adaptation of the ontogenetic cycle of the species to the bioclimatic one (BIANCO, 1960). The silvicultural interventions outlined in the study are aimed at bringing the artificial population, represented by an adult high forest mainly of Stone Pine with the presence of Aleppo Pine, towards more natural and resilient structural settings, simultaneously reducing the amount of necromass in the woods. Analysing the distribution of the number of trees in the diameter classes, it's clear that this is a pine forest of the same age mainly of Stone Pine with presence of Aleppo Pine (Table 1).

Table 1 – Distribution of the number of trees per hectare by diameter classes.

Diametric classes	**Total population**	
cm	*no./ha*	*%*
10	11	1.5
15	85	11.9
20	144	20.1
25	148	20.7
30	90	20.7
35	46	12.6
40	30	6.4
45	22	3.1
50	16	2.2
55	6	0.8
TOTAL	**716**	**100.0**

In order to normalize the distribution curve, it is necessary to perform moderate cutting operations from below, mainly affecting the smaller diameter classes, 10-15 and 20 cm, represented by arboreal elements denominated dry and with no future. The various forms of cultivation for the improvement and conservation of the few Mediterranean forest realities must therefore be differentiated in relation to the aims to be pursued, avoiding all sorts of generalization (GUALDI, 1998). So, in the definition of the thinning treatment to be proposed, the identification of the chosen trees for the cutting was done not only based on their vegetational, morphological and phytosanitary features of the single plant, but, primarily keeping in mind the influence exerted by each arboreal element, in terms of biospace, to the underlying layers.

As a consequence, the thinning treatment proposed in favor of the arboreal layer elements fell back almost exclusively on dominated elements and on a few intermediates affected by pathogen or mechanical trauma due to the strong action of sea winds. As regards the intensity and frequency of the interventions in question, a moderate intensity intervention was planned. Silvicultural interventions have also been defined to contrast the drought phenomenon, desertification and fires, through the planting of broadleaved trees, providing more species, both indigenous primary (arboreal) and secondary (shrub-like), suitable for the environmental and climatic conditions of the intervention area (Regional area of the Salento Peninsula). The intervention will affect the areas of the pine forest characterized by an incipient or almost completely absent undergrowth, foreseeing the planting of 150 elements per hectare. The chosen species for thickening are evergreen, xerophilous and reproductive, therefore able

to better withstand fires, represented both by arboreal species of sclerophyll, with a percentage of about 70 %, and by shrub species, for the remaining 30 %. The aim of this intervention was to obtain: balanced and adequate distribution of the used species, regular lighting of the plants, easy management of the forest. Considering the purposes of the thickening interventions that were proposed, mainly based on environment, landscape and contrast to the propagation of fires, it was planned an irregular arrangement of the plants, by groups, using native species, coming from propagation material originated from seed woods of Puglia Region, in the following percentage: Holm oak 70 %, Strawberry tree 15 %, Mastic tree 15 %.

Materials and Methods

The pine forest under consideration is located in "Frassanito," Otranto (LE), not far from the coastline and about 8 km from the town of Otranto, within the Alimini SCI area (Site of Community Importance). IT for an extension of about 30.00 ha.

Thermo-pluviometric data collected by the Bari Hydrographic Office at the Otranto station were analyzed as a priority. The examination and further processing of the data resulted in the following reflections:

- the value of the average annual temperature is 16.5 °C
- the coldest month in the study area is January, at 9.6 °C
- the hottest month turned out to be August, with average monthly temperature values of 24.8 °C
- rainfall, measured by the amount of fallen rain, expressed in mm, is characterized by fairly high values; the annual average is, 845.90 mm, concentrated in the autumn-winter period
- the drought period runs from late April to mid-September
- the pluviometric cycle is characterized by a rainfall falling between the equinoctial and solstitial types, with an absolute maximum in November and a relative maximum in March, the latter resulting from disturbances in the Balkans that last until late spring. Particularly pronounced is the action exerted by winds from the northern and eastern quadrants (the Tramontana from the north and the Levante from the east).

The vegetation type was then assessed by surveying the actual vegetation, the species and cover (%) of the tree layer, the main species and cover (%) of the shrub layer, and finally, the main species of the herbaceous layer.

From the physiognomic point of view, the actual vegetation of the considered geographical (bearing in mind what is reported in the map of the actual vegetation of FENAROLI (1970), as it falls into the area of the evergreen sclerophylls of the Basal Plain, with sub-littoral Mediterranean vegetation) is represented (by what has been directly observed in the field by the writers) by a "predominantly Stone Pine forest, with the presence of Aleppo Pines of artificial origin about 65 years of age, characterized by the spontaneous diffusion within it of an incipient undergrowth with established patches of evergreen sclerophylls (Figure 1).

In the areas closest to the coastline, Aleppo Pines almost entirely replace the Stone Pines, and the undergrowth appears to be highly developed (Figure 2).

Figure 1 – Example of sample plot area in the pine forest of Stone Pine in Frassanito locality (Otranto – Le).

Figure 2 – Contact area between predominantly Stone Pine and Aleppo Pine Forest in Frassanito locality (Otranto - Le).

In order to identify the vegetation stage that potentially distinguishes the area under consideration, it was necessary to consider EMBERGER's climograph and modify it according to QUEZEL's (1976) methodology through the schematic localization of the bioclimatic area of spread of certain species and plant combinations of the Mediterranean forest. This is verified by ascertaining that the forest in question falls in the temperate variant of the "Upper Thermomediterranean" humid stage (altitudinally speaking), characterized, potentially by the Thermomediterranean forest, being generally "sclerophyllous," consisting mainly of evergreen quercus species, especially the Holm Oak and Kermes Oak.

The above is confirmed by the fact that within the pine forest, there is an established diffusion of arboreal and shrubby elements of evergreens sclerophylls such as the Kermes Oak, Holm Oak, Mastic tree (*Pistacia lentiscus* L.), Myrtle (*Myrtus communis* L.), Buckthorn (*Rhamnus alaternus* L.), Green Olive tree (*Phillyrea latifoglia* L.), Strawberry Tree (*Arbutus unedo* L.), etc. The same species, together with Heather (*Erica arborea* L.), characterize a patch of scrub forest located between the pine forest and the first dune cordon.

In order to determine the estimated woody mass of the intercropped stand resulting from the thinning intervention within the identified typologies, a total number of 10 sample plot areas were defined and reported on the ground with one for every 3 hectares or so of wooded area, in implementation of Apulia Region Reg. No. 10/2009 "forest cuts" and subsequent amendments and additions. These circular-shaped areas have a diameter of 35.69 meters and each an area of 1000 m².

The delineation of the areas was carried out using metric tape, and horizontal yellow strokes were affixed to the stems of trees vegetating in their immediate vicinity to make it easeir to find the test areas. Progressive numbers from 1 to 10 were also painted on the stem of a plant present in the centerline of the test area.

Next, all tree elements growing in each area with stem diameters greater than 7.5 cm (diametric class 10 cm) were numbered at 1.30 m above the ground.

Field operations were concluded with the selection of the elements to be subjected to cutting. For each of the tree elements in the group, data were recorded for the following dendrometric parameters:

Stem:

- no. 2 orthogonal diameters, measured at 1.30 m from the ground, through the use of an aluminum PONCET dendrometer mount;
- dendrometric heights of no. 3 tree elements of the total stand, with diameters close to or equal to the mean diameter, no. 3 tree elements of the intercalated stand, with diameters close to or equal to the mean diameter. The heights were measured using the BLUME LEISS hypsometer.

The data collected in the forest were later processed by default.

For each element surveyed in the test areas, the dendrometric parameter values deemed most significant were determined

Stem:

- average diameter (dg), at 1.30 m above the ground, obtained from the average of the two measured diameters;
- basal area (G).

Furthermore, after the tree elements were grouped withing each type into diameter classes of 5 cm width (always measured at 1.30 m from the ground), the values referring to

the area of a hectare, the number of trees (Nha), basal area (Gha), and volume (Vha), as well as those of the average height of each diametric class, were determined for both the total stand and the interplant stand to be exported by phytosanitary cutting.

Results

The identified vegetation type is mainly characterized by three vegetation layers detailed below:

- arboreal layer, predominantly Stone Pine with the presence of Aleppo Pine, covering of 90-100 % of the total;
- shrub layer, absent or incipient, with a maximum cover of 10 %;
- herbaceous layer with 2 % coverage.

Stone Pine elements, constituting a large part of the tree layer, have upper heights of between 14 and 20 meters, with fairly regular stem forms, growing in good condition.

Numerous dry tree elements are still standing, broken by wind action, or lying on the ground. Tree and shrub elements are absent or incipient. The species present are Prickly asparagus, Wild madder, Mastic tree, and Myrtle.

The herbaceous layer, less than 0.30 m in height, consists exclusively of sporadic elements of Mediterranean sedges.

Near the coastline, the tree layer is represented almost exclusively by Aleppo pines with the sporadic presence of Stone pines. The arboreal stand is sparser, covering 70 % of the total area. The arboreal and shrub layers appear to be established, and in some places, highly developed, covering 70 %. The herbaceous layer, which is sparsely present, has an estimated cover of 5 %.

Analysis of the distribution of the number of trees in the diametrical classes shows that this is an even-aged pine forest with a predominance of Stone Pines with the presence of Aleppo Pines. In order to normalize the distribution curve, it is necessary to carry out moderate cutting interventions from below, mainly targeting the smaller diametric classes of 10-15 and 20cm, represented by dominated, dry, and unbecoming tree elements. In defining the thinning model to be proposed, it was realized that, in this specific case, interventions must be applied with a high degree of elasticity in the sense that the identification of the trees selected for cutting is to be done not only on the basis of the vegetational, morphological, and phytosanitary characteristics of the individual plants, but, primarily, examining the influence exerted by each tree element in terms of biospace on the underlying strata. As a result, the proposed thinning in favor of the elements of the tree layer almost exclusively involved dominated elements and some plants affected by pathogens or mechanical trauma caused by wind action. Regarding the intensity and frequency of the interventions under consideration, it should be noted that, in this case, a moderate intensity intervention was budgeted.

These are silvicultural interventions aimed at bringing the considered stand, represented by a mature group of predominantly domestic pines with the presence of Aleppo pines, towards more natural and resilient compositional structural arrangement, while at the same time, reducing the amount of necromass in the forest.

In the tables below is respectively reported the estimated wood mass of Stone Pine (Table 2) and Aleppo Pine (Table 3) from the thinning intervention, divided by diametric classes.

Table 2 – Estimated wood mass of Stone Pines from the thinning intervention, divided by diametric classes.

Diametric classes	**Trees**	**Basal area**	**Average heigh**	**Dendrometric volume**	**Specific weight of timber**	**Quantity of retractable timber**	**Quantity of retractable timber/ha**
cm	*no.*	m^2	*m*	m^3	kg/m^3	*q*	*q/ha*
10	210	2.022	17.43	21.146	900	190.31	6.34
15	2340	47.613	17.43	497.936	900	4 481.43	149.38
20	2580	81.165	17.43	848.823	900	7 639.41	254.65
25	1710	55.545	17.43	580.244	900	5 228.01	174.27
30	360	27.084	17.43	283.491	900	2 549.20	84.97
35	90	8.844	17.43	92.491	900	832.41	27.75
40	30	4.155	17.43	43.453	900	391.08	13.03
					TOTAL	**21 311.86**	**710.39**

Table 3 – Estimated wood mass of Aleppo Pines from the thinning intervention, divided by diametric classes.

Diametric classes	**Trees**	**Basal area**	**Average heigh**	**Dendrometric volume**	**Specific weight of timber**	**Quantity of retractable timber**	**Quantity of retractable timber/ha**
cm	*no.*	m^2	*m*	m^3	kg/m^3	*q*	*q/ha*
10	60	0.498	17.43	5.208	650	33.85	1.12
15	210	3.957	17.43	41.382	650	268.98	8.96
20	390	12.384	17.43	129.511	650	841.82	28.06
25	180	8.976	17.43	93.871	650	610.16	20.33
30	150	10.473	17.43	109.526	650	711.92	23.73
40	90	8.427	17.43	88.129	650	572.84	19.09
					TOTAL	**3 040.00**	**101.32**

To improve the structure and stability of the tree layer and the structure of the entire community of plants - including arborescent and shrubby ones - whose main dendrometric parameters are illustrated in the table below (Table 4), a moderate thinning from below has been proposed. This thinning would lead to the results expressed by the values relating to the same parameters considered for the total population, referring to the interlayer tree stands (Table 5) and main (Table 6).

Table 4 – Total population.

Aleppo Pine		
Number of trees	No./ha	120
Basal area	m^2/ha	9.8177
Volume	m^3/ha	115.40
Stone Pine		
Elements	No./ha	596
Basal area	m^2/ha	37.1664
Volume	m^3/ha	436.85
Total: Aleppo Pine + Stone Pine		
Elements	***No./ha***	***716***
Basal area	***m^2/ha***	***46.9841***
Volume	***m^3/ha***	***552.25***

Table 5 – Intercropping tree stand (to be cut with the proposed improvement intervention).

Aleppo Pine		
Number of trees	No./ha	36
Basal area	m^2/ha	1.4905
Volume	m^3/ha	15.59
Stone Pine		
Elements	No./ha	226
Basal area	m^2/ha	7.5476
Volume	m^3/ha	78.93
Total: Aleppo Pine + Stone Pine		
Elements	***No./ha***	***262***
Basal area	***m^2/ha***	***9.0381***
Volume	***m^3/ha***	***94.52***

Table 6 – Main tree stand (after cutting).

Aleppo Pine		
Number of trees	No./ha	84
Basal area	m^2/ha	8.3272
Volume	m^3/ha	99.81
Stone Pine		
Elements	No./ha	370
Basal area	m^2/ha	99.6188
Volume	m^3/ha	357.92
Total: Aleppo Pine + Stone Pine		
Elements	***No./ha***	***454***
Basal area	***m^2/ha***	***37.946***
Volume	***m^3/ha***	***457.73***

Discussion

Examination of the dendrometric data collected and processed shows that there is a need to take action with appropriate silvicultural interventions aimed at bringing the stand under consideration, represented by a mature forest with a predominance of Stone Pine with the presence of Aleppo Pine, towards more natural and resilient compositional structural arrangements while simultaneously reducing the amount of necromasses present in the forest. The intervention is to be carried out on a total area of **300 000 square meters** and will affect the entire forest area. The thinning intervention is to be implemented through the following processing steps:

1) Selective thinning to be carried out on mature forest of resinous trees of variable age, having a diameter (at 1.30 m from the ground) of 10-20 cm, by cutting at the base. The work includes limbing, collection and transport or accumulation of the resulting material (brushwood) in a suitable place to be carried out on an area of **30.00 ha.**
2) Setting up, concentrating, and hauling the woody material that can be used with the logging intervention, amounting to **2 835.60 m^3**. In addition, the intervention includes land clearing, collection, and transport of the woody material from the stand (in the forest) to the truck road.
3) Wood chipping of brushwood and logs (less than 10 cm in diameter) in resinous forest subject to thinning, for the purpose of fire prevention, including the distribution of residual chipped plants around the area of intervention, an estimated quantity of chipping material equal to **7 138 q**, of which 4 870 q derived from cutting operations, and the remaining 2 268 q derived from dry material on the ground.
4) The actual harvestable and marketable timber is **19 482.00 q**.

In addition to the thinning intervention, silvicultural interventions against the phenomena of drought, desertification, and fires have also been envisaged via the planting of broadleaf trees, providing more native species, both main (tree) and secondary (shrub), adapted to the environmental and climatic conditions of the intervention area (Regional area of the Salento Peninsula), aimed at increasing resilience to fires and climate change. Forest propagation materials to be used must be accompanied by certifications of origin and phytosanitary certifications. The native species to be used must come from seed forests in the Apulia Region. Moreover, bearing in mind the limitations established by Article 10 of Regional Law No. 4 of 29/03/2017 "Management of Xylella fastidiosa bacteriosis in the territory of the Apulia Region", the intervention will affect only those areas of the pine forest characterized by incipient or almost completely absent undergrowth. The planned number of plants, on a total area of about 170 000 square meters, amounts to 2550 elements, about 150 plants per hectare, in view of the density of the area affected by the intervention. The species of choice for replanting shall be evergreens, xerophilous, and polliniferous, thus more able to resist fire. The planned 2550 elements are represented by both sclerophyllous tree species in the proportion of about 70 %, and shrub species for the remaining 30 %. With regard to the planting layout, it was defined on the basis of various criteria, including the area of intervention, its slopes, the nature of the soil and its variability within the areas under intervention, the species to be planted, the ease replanting, and the area of gaps present within the forested areas. The intervention aimed to achieve a balanced spatial distribution appropriate to the species to be used, regular lighting of the seedlings, and ease of forest

management. In view of the purposes of the proposed replanting interventions, which are mainly environmental, landscaping, and combating the spread of fires, an irregular planting arrangement in groups was planned. To replant the Pine forest, bearing in mind the pedoclimatic characteristics of the station, both the use of sclerophyll tree species, in the percentage of about 70 %, and the use of shrub species for the remaining 30 %, to be comprised of 70 % Holm Oak, 15 % Strawberry Tree, and 15 % Mastic tree were planned for the realization of the renourishments within the Pine Forest.

Conclusion

The results show that the assumed phytosanitary cutting in the typology under consideration would affect 36.59 % of the number of trees, 19.24 % of the basal area, and 17.11 % of the volume present before the intervention. It should be emphasized that this is a cut that will mainly affect standing dead trees, as well as withered, dominated, and some intermediate trees that are unable to grow, or otherwise hindered in their normal development by the underlying tree and shrub elements. The analysis of the distribution of the number of trees in the diametrical classes shows that that this is a coetaneous pine forest with a predominance of Stone Pines with the presence of Aleppo Pines that has lacked appropriate silvicultural interventions that should have been carried out over time. Therefore, to normalize the distribution curve, it is necessary to carry out moderate cutting interventions from below, concentrating on the smaller diametric classes of 10-15 and 20 cm, represented by dominated, dry, and unbecoming tree elements. High flexibility was kept in the definition of the thinning model to be proposed, considering not only the vegetational, morphological, and phytosanitary characteristics of individual plants but also the influence exerted by each tree element in terms of biospace on the underlying strata. Following these principles, the proposed thinning mainly affected the dominated tree layer elements and some intermediate ones affected by pathogens or mechanical trauma due to wind action. Regarding the intensity and frequency of the interventions under consideration, the intervention is of moderate intensity. Ultimately, the choice was made to carry out silvicultural interventions aimed at bringing the considered stand, represented by a mature forest of predominantly Stone Pines with the presence of Aleppo Pines, toward more natural and resilient compositional structural arrangements while simultaneously reducing the amount of necromass present in the forest.

In addition to the thinning intervention, silvicultural interventions against the phenomena of drought, desertification, and fires have also been envisaged via the planting of broadleaf trees, providing more native species, both main (tree) and secondary (shrub), adapted to the environmental and climatic conditions of the intervention area, aimed at increasing resilience to fires and climate change.

The intervention will affect only those areas of the pine forest characterized by incipient or almost completely absent undergrowth. The planned number of plants, on a total area of about 170 000 square meters, is 2550 elements, about 150 plants per hectare.

The species of choice for replanting shall be evergreens, xerophilous, and polliniferous, thus more able to resist fire. The planned 2550 elements are represented by both sclerophyllous tree species in the proportion of about 70 %, and shrub species for the remaining 30 %.

The intervention aimed to achieve a balanced spatial distribution appropriate to the species to be used, regular lighting of the seedlings, and ease of forest management.

In view of the purposes of the proposed replanting interventions, which are mainly environmental, landscaping, and combating the spread of fires, an irregular planting arrangement in groups was planned.

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