Recovery of degraded coniferous Forests for environmental sustainability Restoration and climate change Mitigation: the LIFE FoResMit project

*Alessandra Lagomarsino(1), Alessandro Elio Agnelli (1), Ugo Chiavetta(2), Paolo Cantiani(2), Isabella De Meo(1), Alessandro Paletto(3), Edoardo A.C. Costantini(1)

(1) Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Centro di ricerca per l'Agrobiologia e la Pedologia (CREA-ABP), Firenze.

(2) Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Centro di ricerca per la Selvicoltura (CREA-SEL), Arezzo

(3) Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per il Monitoraggio e la Pianificazione forestale (CREA-MPF), Trento

** e mail corresponding author: alessandra.lagomarsino@entecra.it*

INTRODUCTION (Heading Trebuchet MS, 11 font size, bold)

Pine species have been extensively used for land restoration in the Mediterranean basin and in other parts of the world, since the late 19th century. The traditional strategy for reforesting degraded lands in the Mediterranean was first to introduce a fast-growing pioneer species, usually a pine species (Ceballos, 1938; Gil and Prada, 1993), assuming that this species would facilitate the introduction (either artificial or natural) of late-successional hardwoods (Barbéro et al., 1998). Indeed, the theoretical basis supporting pine utilization was its stress-tolerant and pioneer features, and their attributed role of facilitating the development of late-successional hardwoods in the long-term (Pausas et al., 2004).

Nowadays, the most of these pine stands are concluding their rule of pioneers species, colonizing the previously degraded areas and beginning the chain of ecological succession that is able to lead to an higher biodiversity and a more resilient and resistant ecosystem characterized by native broadleaved species. Nevertheless, this strategy was seldom completely applied because of the costly silvicultural post-plantation operations required and the current disturbance regime . From the National Forest Inventory, 31% of Italian pine forests in the Mediterranean zone show degradation symptoms and are damaged for a total of 462,568 ha. In most cases, pine plantations show degradation symptoms with many dead, fallen and/or damaged trees.

Forest degradation, resulting in a loss of biomass or in a reduced production, occurs through damage to residual trees and soil from poor logging practices, log poaching, fuelwood collection, overgrazing, and anthropogenic fire (FAO, 1993; Flint and Richards, 1994). Forest degradation, implying a decrease in canopy cover and regeneration , as well as forest fragmentation, will affect the annual increment of C sequestration, reducing the potential of these forests to act as a sink or transforming them into a source of GHGs. Carbon emissions from deforestation and forest degradation have been estimated to account for about 12-20% of global anthropogenic CO2 emissions (IPCC, 2007). Although deforestation is the main source, forest degradation contribute to atmospheric GHG emissions through decomposition of remaining plant material and soil carbon. These larger emission are no more balanced by the C storage capacity in woody biomass and soil, due to unstable structural conditions of the degraded stands. Deforestation and forest degradation are important contributors to global GHG emissions, but if these processes are controlled, forests can significantly contribute to climate change mitigation. Therefore, the current forest degradation needs an innovative management plan aimed to support and facilitate all the functionalities of a peri-urban forest, in a context of climate change mitigation.

Even in the cases where there are not dead, fallen or damaged trees, peri-urban pine forests in the Mediterranean area are vulnerable to forest fires. These fires can destroy vegetation cover of protective peri-urban forests and other adjacent forests and areas leading to erosion and in some cases to catastrophic debris torrent phenomena that can threaten urban infrastructures. Moreover great amounts of CO_2 can be released in atmosphere through these fires. Thinning aiming at the reestablishment of native broadleaved vegetation will make the pine dominated peri-urban forests less prone and more resistant to wildfire. Moreover through the sprout ability of broadleaves, vegetation cover of the area will be restored very soon thus protecting forest ecosystem from erosion and cities from catastrophes. As temperature and aridity rises as a consequence of global warming forest fires will appear more frequently and their intensity will be greater. In this frame broadleaved through sprouting ability can be used as a mitigating tool.

The general objective of the proposal is to define the guidelines of good silvicultural practices for the restoration of peri-urban degraded coniferous forests in Italy and Greece with native broadleaved species, improving the ecological stability and climate change mitigation potential of these ecosystems. The project aims at testing and verifying in the field the effectiveness of management options for the conversion of degraded coniferous forests in meeting climate change mitigation objectives. The project will provide data on vegetation structure, biomass increment, C accumulation in all relevant pools of vegetation and soil, and CO_2 and other greenhouse gas emissions, thus giving a complete picture of mitigation potential of management practices.

In the present work we describe the project and we report the first result regarding the soil characterization of the Italian site.

MATERIALS AND METHODS

LIFE FoResMit project is implemented in two areas of the Mediterranean basin: monte Morello (Sesto Fiorentino, Italy) and Xanthi forest (Xanthi, Greece). Within each area, nine plots have been randomly selected, with three replicates for each treatment (Fig. 1).

Figure 1. Localization of implementation sites in Italy and Greece and map with the selected plot in the Italian site.

The three treatments compared are:

1. The traditional silvicultural treatment will be based on a low thinning and it will be carried out removing trees primarily from the lower canopy, i.e. suppressed and subdominant trees, and from among the smaller diameter trees, up to 40% of the stand density (N°/ha). The aim of low thinning is to concentrate potential for growth on the larger diameter trees by removing competing smaller trees.
2. The innovative treatment will be based on a selective thinning, considering the merits of individual trees. With this "positive selection" will promote the growth and development of trees (or at least small groups of trees) characterized by the best H/D (high/diameter ratio) and a large and symmetric crown which are able to guarantee the highest stand stability and C accumulation rates in the medium- to long-term. Moreover, considering that *Pinus nigra* is a very light demanding species, all the suppressed and sub-dominant trees will be removed with the aim to avoid the increasing deadwood with time.
3. The no-treatment option (control plots).

Figure 2. Example of conventional (left) and selective (right) treatments.

Soil characterization has been performed before the silvicultural treatments implementation, to test possible differences among plots. Samples have been collected at 0-10 and 10-30 cm depth in November 2015.

The following parameters have been measured:

texture (hydrometer method); bulk density (undisturbed 100 cm^3 soil cores collected by a hammer-driven liner sampler (Eijkelkamp, The Netherlands), dried at 105°C until constant weight and the BD calculated by the ratio between the dry weight and the soil core volume), pH (soil:water 1:2.5 ratio); cation exchange capacity (Methods of Soil Analysis, MIPAF, 2000); total organic C (dry combustion, using a Thermo Flash 2000 CN soil analyzer; 20 to 40 mg soil were weighed into Ag-foil capsules and pre-treated with 10% HCl until complete removal of carbonates);

total inorganic C (CN soil analyzer, as difference between total C and total organic C); total N (Thermo Flash 2000 CN soil analyzer); inorganic N ($NH4^+$, $NO3^-$ and $NO2^-$ determined by extraction with a 2 mol L^{-1} KCl solution, according to the official methods of soil chemistry analysis n°1124.2, MIPAF, 2000).

All data were analyzed by univariate test of Analysis of Variance. Discriminant function analysis (DFA) was performed using soil physical and chemical parameters as grouping variables. Squared Mahalanobis distances between group centroids were determined. Two significant discriminatory roots were derived and the results of DFA were graphically presented in two dimensions scatterplot. Statistical analyses were performed using the Statistica 6.0 software package (Statsoft, Tulsa, USA).

RESULTS AND DISCUSSION

The Italian site of monte Morello present a loam or clay-loam texture, with average values of sand and clay of 38 and 28 %, respectively (table 1). No significant differences among the three group of plots assigned to the different treatments were observed. A higher percentage of sand was found in the first 10 cm, with respect t the deeper layer.

Table 1. Percentage of sand, clay, fine and coarse silt in the experimental site. Standard error is reported in italics.

Treatment	Depth	Sand (%)		Clay (%)		Fine silt (%)		Coarse silt (%)	
Control	0-10	41	*2*	28	*2*	28	*2*	3	*1*
Traditional	0-10	42	*2*	27	*1*	24	*3*	6	*2*
Innovative	0-10	42	*2*	28	*3*	26	*1*	4	*1*
Control	10-30	35	*2*	26	*1*	30	*1*	9	*0*
Traditional	10-30	32	*2*	32	*2*	29	*1*	7	*1*
Innovative	10-30	35	*1*	27	*2*	29	*1*	10	*1*

Soil organic matter content of the site was typical of a Mediterranean forest site, with a clear vertical distribution of total N (TN) and total organic C (TOC), showing on average a double content of both parameters in the first 10 cm than in the 10-30 cm layer (Figure 3 a and b). Plot 8 showed significantly lower TN and TOC values than plots 6 and 7. However, no significant differences among the three group of plots assigned to the different treatments were observed.

The site was rich in carbonates, although the variability was quite high. Plot 8 showed the maximum percentage of $CaCO_3$ (Figure 3 c). The site showed a moderately alkaline pH, slightly lower in the first 10 cm than in the 10-30 cm layer (Figure 3 d).No differences among plots have been found for both pH and $CaCO_3$.

Electrical conductivity (EC) and cation exchange capacity (CEC) showed large variability but no significant differences among plots (Figure 3 e and f).

Inorganic N forms showed large variability among plots and NH_4 and NO_3 were higher in the first soil layer (Figure 3 g, h and i).

From the discriminant function analysis is evident the absence of significant differences among plots and in particular among the three groups of plots assigned to the different treatments (Figure 4).

These results were preparatory to the implementation of silvicultural treatments in order to avoid biases due to different pedological conditions among plots. The lack of significant differences on soil characteristics, together with the first vegetation survey, allowed to validate the selection of test areas.

After this pedological and vegetation survey, silvicultural treatments will be implemented and monitoring actions will measure all C and N pools identified by Intergovernmental Panel on Climate Change (IPCC)-Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC-GPG) (2003) (above and belowground biomass, litter, dead-wood and soil) and their temporal variations. Net primary productivity and C accumulation in soil after thinning treatments will be assessed. Temporal changes of each pool size will be measured to obtain the C assimilation rate per year. Greenhouse gas fluxes from soil and dead-wood material will be quantified. C sequestration potential and global warming potential in the short and medium-term will be estimated. Reliable estimates of changes in C stocks, and thereby fluxes, are necessary for understanding both the global carbon cycle and national inventories of greenhouse gases (IPCC, 2000).

The main expected results of the innovative thinning treatment implementation are: i) an increase of net primary production of forest ecosystem, due to the removal of non-growing or dead trees and the higher growth rates of remained vegetation; ii) an initial increase of greenhouse gas emissions, followed by a stabilization towards a reduction after thinning treatment; iii) the reduction of heterotrophic respiration of decomposable deadwood material, with a consequent reduction of CO_2 emissions in the medium-long term.

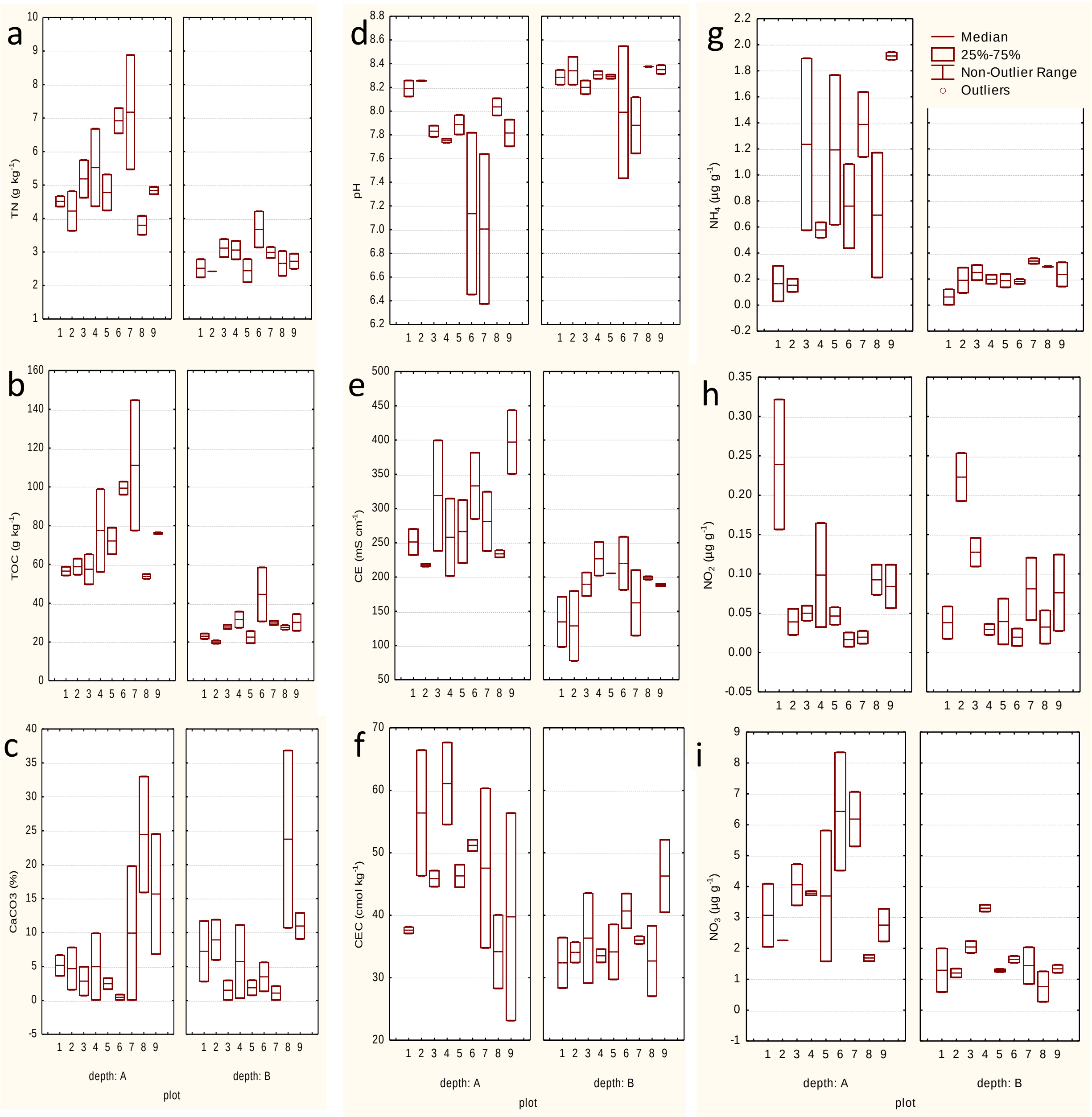

Figure 3. 2D categorized box plot of total N (TN), total organic C (TOC), carbonates ($CaCO_3$), pH, electrical conductivity (CE), cation exchange capacity (CEC), NH_4, NO_2 and NO_3 soil content.

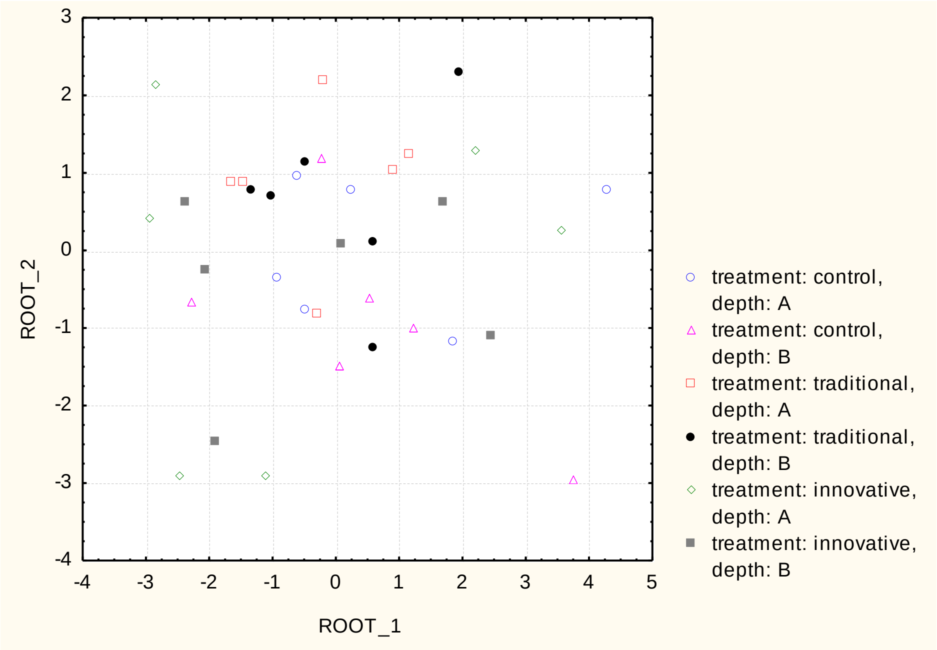

Figure 4. Scatterplot of Root1 and Root 2 derived from the Discriminant Function Analysis performed using physical and chemical soil parameters.

CONCLUSIONS

The initial physico-chemical soil characterization was fundamental to validate the selection of test areas to reduce biases due to soil heterogeneity.

After the implementation of silvicultural treatments the FoResMit project will provide data on vegetation structure, biomass increment, C accumulation in all relevant pools of vegetation and soil (above and belowground biomass, litter, dead wood and soil, IPCC 2003) and CO_2 and other greenhouse gas emissions, thus giving a complete picture of mitigation potential of management practices.

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