Effects of thinning on soil carbon storage in *Pinus laricio* forest

Muscolo Adele, **Settineri G., Mallamaci C., Attinà E., Sidari M.**

Università degli Studi Mediterranea di Reggio Calabria

THEME 2

INTRODUCTION

Forests act as a natural storage for carbon at the global scale, contributing approximately 80% of terrestrial aboveground, and 40% of terrestrial below-ground carbon storage. The relatively rapid change in the status of forests– from a steady state of minimal CO2 emission/sequestration to major CO2 emitter – during this time period may offer a cautionary tale of how quickly the source/sink status of large-scale forest C stocks can change. Our understanding of how forest management influences standing C stocks, however, is limited because many forest C studies have focused on quantifying trends in unmanaged forests. Among silvicultural practices, thinning, reducing tree density and altering microclimate and organic matter budget can affect soil carbon (C) storage and soil ecosystem functioning. In Italy, thinning of pine forests is the most effective silvicultural treatment to enhance the ecological value of these stands; however, changes in soil C, soil microbial biomass and activity after thinning in pine forests are not well elucidated yet.

OBJECTIVES

Our objectives were to understand how thinning affects the dynamics of total carbon in forest ecosystems as well as each of its component pools. We estimated carbon stocks in *Pinus laricio* stands, evaluating carbon pool dynamics in forest subject to different thinning intensities (0, 30 and 60%) and clear cut over two contrasting seasons (winter and summer), to verify if the environmental conditions affect in short term soil carbon pool. Our aim was to identify the silvicultural practice that increased carbon storage in pinus forest. Our hypothesis-driven research was that increasing thinning intensities physico-chemical, microbiological and biochemical properties of soil related to soil quality and fertility decreased, while improving stand stability, quality, diameter and growth volume of the remaining stand.

Fig. 1: Pinus laricio forest

MAIN RESULTS

Results showed that soil carbon content and C/N ratio were significantly higher in T60 than in T0, T30 and CC. Under T60, the soils had the highest enzymatic activities, MBC, and colonies of fungi and bacteria (Tables 1, 2). 60% thinning having lower density of trees compared to control and higher ones compared to CC and T30, determined regimes of light, temperature and humidity at soil level that increased the amount and diversity of herbaceous vegetation, promoting an increase in overall soil microbial biomass, and in bacteria responsible for the production of enzymes involved in carbon transformation. Humification indices confirmed that humification process prevailed in T60 with consequent carbon storage (Table 3). Additionally, dendro-auxometric parameters evidenced that pinus accretion and wood density changed with the treatments. H/D ratio in 60% thinning was lower than in 30% thinning and control suggesting that the positive effect of 60% thinning on the mechanical stability of the trees is related to their ability to accumulate large amounts of carbon in their wood (data not shown). This study shows that T60 is a sustainable forest management practice able to improve in parallel soil quality and C storage already after few years of treatments.

Tab. 1: Chemical and biochemical soil analysis: organic matter (OM%), C/N ratio, fluorescein diacetate (FDA, µg fluorescein released g-1 dry soil), protease (PROT, µg tyrosine g-1dry soil/2h), catalase (CAT, % O2/3min/g dry soil), dehydrogenase (DHA, µg TTF g-1 h-1), microbial biomass C (MBC, mg C g-1dry soil) under Pinus laricio plantation differently managed: thinning 0%, T0l; thinning 30%,T30; thinning 60%, T60 and clear cut, CC.

Season		OM	C/N	FDA	PROT	CAT	DHA	MBC
	T30	18.35 ^{b*}	16.5^{b}	58.52^{b}	80.35^{b}	1.69^{b}	7.36^{b}	7574^{b}
	T60	24.21^{a}	19.5^{a}	71.92^{a}	90.90^{a}	1.88^{a}	11.15^{a}	7997^{a}
Summer	CC	16.86^{c}	15.8^{b}	53.18^{c}	76.07^{c}	1.13^{c}	6.23^{c}	6810^{c}
	T0	7.68^{d}	12^{c}	45.86^{d}	68.22^{d}	0.74^{d}	5.89^{d}	6378^{d}
	T30	14.49^{b}	12^{b}	53.25^{b}	59.86^{b}	1.32^{b}	3.77^{b}	6800^{b}
Winter	T60	15.54^{a}	13^{a}	61.80^{a}	63.01^{a}	1.41^{a}	4.40^{a}	7550^{a}
	CC	13.48^{c}	9^{d}	50.10^{c}	56.81^{c}	1.03^{c}	2.24^{c}	6352^{c}
	T0	12.32^{d}	11^{c}	42.85^{d}	52.79^{d}	0.94^{d}	1.93^{d}	6027^{d}
Replicates		5	5	5	5	5	5	5
Factors		P-value	P-value	P-value	P-value	P-value	P-value	P-value
Results of ANOVA								
Season		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Treatment		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Interaction		<0.05	=0.1	<0.05	<0.05	<0.05	<0.05	<0.05

*Different letters in the same column indicate, within each season, significant differences (Tukey's test, p ≤0.05).

Tab. 2: Effect of 0% thinning, T0; 30% thinning, T30; 60% thinning, T60 and clear cut, CC on total organic carbon (TOC), total extractable carbon (TEC), humic acid (HA), fulvic acid (FA), humic acid plus fulvic acid carbon CHA+FA, humic acid/fulvic acid (HA/FA), humification index (HI), humification rate (HR), humification degree (DR).

Season		TOC %	TEC %	C_{HA+FA} %	HA/FA	HI	HR %	DR %
	T30	10.66^{b*}	8.4^{b}	6.77^{b}	1.42^{a}	0.24^{c}	63.5^{b}	80.5^{b}
Summer	T60	14.07^{a}	12.6^{a}	10.83^{a}	1.17^{c}	0.16^{d}	77.0^{a}	85.9^{a}
	CC	9.80^{c}	7.6^{c}	5.56^{c}	1.43^{a}	0.37^{a}	56.7^{c}	73.1^{c}
	T0	4.46^{d}	3.3^{d}	2.61^{d}	1.25^{b}	0.26^{b}	58.5^{c}	79.1^{b}
	T30	8.42^{b}	6.6^{b}	4.95 ^{b}	1.96^{a}	0.33^{b}	58.8^{c}	75.2^{c}
Winter	T60	9.03^{a}	7.8^{a}	6.85^{a}	1.22^{d}	0.14^{d}	75.3^{a}	87.5^{a}
	CC	7.83^{c}	6.2^{c}	5.0 ^{b}	1.67^{b}	0.24^{c}	63.3^{b}	80.7^{b}
	T0	7.16^{d}	5.3d	3.85^{c}	1.58^{c}	0.38^{a}	53.5^{d}	72.1^{c}
Replicates		5	5	5	5	5	5	5
Factors		P-value	P-value	P-value	P-value	P-value	P-value	P-value
Results of ANOVA								
Season		<0.05	<0.05	<0.05	<0.05	<0.05	=0.4	=0.4
Treatment		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Interaction		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Tab. 3 Colonies of fungi and bacteria (CFU g^{-1} dry soil) in soil under *Pinus laricio* plantation differently managed: 0% thinning, T0; 30% thinning, T30; 60% thinning, T60 and clear cut, CC.

Season	Treatment	Fungi	Bacteria	Total count
	T30	2x10^{4} a*	1.8x10^{5} b	2.0 x10^{5} b
	T60	6.7x10^{3} d	2.2x10^{5} a	2.3 x10^{5} a
Summer	CC	1.3x10^{4} b	1.6x10^{5} c	1.8 x10^{5} c
	T0	1.0x10^{4} c	9.7x10^{4} d	1.1 x10^{5} d
	T30	3.3x10^{3} b	5.3x10^{4} b	5.63 x10^{4} b
Winter	T60	1.7x10^{3} c	6.3x10^{4} a	6.47 x10^{4} a
	CC	3.3x10^{3} b	5.3x10^{4} b	5.63 x10^{4} b
	T0	6.7x10^{3} a	2.3x10^{4} c	2.97 x10^{4} c
Replicates		5	5	5
Factors				
Results of ANOVA				
Season		<0.05	<0.05	<0.05
Treatment		<0.05	<0.05	<0.05
Interaction		<0.05	<0.05	<0.05

*Different letters in the same column indicate, within each season, significant differences (Tukey's test, *p* ≤0.05)

Fig. 2: Pinus laricio forest

CONCLUSION

In short we found that 60% thinning was the silvicultural practice to adopt for increasing carbon storage in plant and soil. Our study provides scientific information for predicting the consequences of current management practices for future forest productivity, and understanding how ecological processes interact with human interventions to influence soil carbon storage. The results of our research are important for land managers policymakers, carbon accountants, and scientists working on a variety of forest-related issues.