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SURFACE MORPHOLOGY AND THINNING GRADE EFFECT ON SOILS OF A CALABRIAN PINE PLANTATION IN THE SILA MOUNTAIN (Calabria, Italy)

Summary: COSTANTINI E.A.C., *Surface morphology and thinning grade effects on soils of a Calabrian Pine plantation in the Sila Mountain (Calabria, Italy)* (IT ISSN 0391-9838, 1993).

Important reafforestation programmes of the Sila mountain with the main purpose of soil conservation and hydrogeological control started in 1955. Interactions with the soil and surface morphology have been studied in a plantation of *Pinus nigra* var. *calabrica* Schneid., where a field trial was carried out to establish the optimum thinning grade from an economic point of view. The experimental area is sited near Camigliatello Silano, at 1247 m above sea level, on soils derived from granite and granitic saprolite.

Soil profiles were dug and completely analysed in eight selected sites. At each plot, colour, organic matter, depth and texture of all the soil horizons, as well as slope and exposure were measured.

Pedological investigation results indicate that soil varies considerably between different plots according to the degree of its evolution, thus three main types of soil have been identified. Quite a rapid development of the umbric horizon, somehow depending on slope, exposure and thinning grade, has been recognised. In this sense the negative effects of a slope gradient exceeding 25% and southern facing exposures come out clearly, whereas thinning doesn't seem to affect soil conservation, even when somewhat heavy thinning grades are utilised.

KEY WORDS: Pine plantation thinning, Surface morphology, Soil conservation, Calabria (Italy).

Riassunto: COSTANTINI E.A.C., *Effetto della morfologia delle superfici e dell'intensità del diradamento sui suoli di un rimboschimento con pino calabro in Sila* (IT ISSN 0391-9838, 1993).

L'opera di rimboschimento della Sila è stata intrapresa nel 1955 con lo scopo principale della conservazione dei suoli e della difesa idrogeologica. In un rimboschimento sperimentale con *Pinus nigra* var. *calabrica* Schneid., realizzato per stabilire il grado di diradamento ottimale da un punto di vista economico, sono state studiate le relazioni tra i suoli e la morfologia delle superfici. L'area sperimentale è situata nei pressi di Camigliatello Silano, a 1247 m sul livello del mare, su suoli evoluti da saprolite di granito e gneiss.

Nell'area sperimentale sono stati scavati, descritti e analizzati, otto profili; in ogni parcella, inoltre, sono stati misurati la pendenza e l'esposizione, nonché il contenuto in sostanza organica, il colore, la profondità e la tessitura dei suoli.

I risultati dell'indagine pedologica indicano anzitutto una variabilità del tipo di suolo tra le parcelle, secondo il grado di evoluzione, che ha portato all'individuazione di tre principali tipi di suolo. È stato rilevato, inoltre, un tasso di sviluppo dell'orizzonte umbrico piuttosto rapido, ma in qualche modo dipendente dalla pendenza, dall'esposizione e dall'intensità del diradamento. In tal senso è emerso l'effetto negativo delle pendenze superiori al 25% e delle esposizioni a mezzogiorno, mentre il diradamento come tale non sembrerebbe pregiudicare la conservazione del suolo, anche quando vengono adottate intensità di diradamento piuttosto elevate.

TERMINI CHIAVE: Diradamenti in rimboschimento di pino, Morfologia della superficie, Conservazione del suolo, Calabria.

INTRODUCTION

Important reafforestation programmes of the Sila mountain with the main purpose of soil conservation and hydrogeological control started in 1955. Only few studies on the effectiveness of these plantations for environmental conservation have been undertaken. Among these we can mention the researches carried out by the Istituto Sperimentale per lo Studio e la Difesa del Suolo, of the Italian Ministry of Agriculture and Forestry, in some small watersheds planted with *Eucaliptus occidentalis* Endl. near Crotone (AVOLIO & *alii*, 1980). More recently, an experimental basin has been set up by the Istituto di Ecologia e di Idrologia Forestale of the National Research Council (C.N.R.) in a pine forest of the Sila, with the aim to collect long-term hydrological and hydrometric measurements (IOVINO & PUGLISI, 1990).

In the last few years, as a consequence of the very good performance of the plantations and of the lack of silvicultural treatments, thinning has become urgent. Nevertheless, this operation has to be graded in function of the economic results and of the consequences on soil conservation, both varying according to environmental characteristics.

The present report deals with the effects of surface morphology and thinning grade on the soil characteristics in a plot trial planted with *Pinus nigra* var. *calabrica* Schneid.,

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Author wishes to acknowledge dr. P.G. Arcara and dr. E. Gregori of the Biology section of the Istituto Sperimentale per lo Studio e la Difesa del Suolo of Florence for the helpful suggestions about the biological characters of the examined soils, and mr. M. Maletta and mr. Brandi of the Catanzaro and of the Chemistry sections of the same Institute for the active collaboration. Author also wishes to thank Dr. S. Avolio of the Istituto Sperimentale per le Foreste di Cosenza for his kind hospitality.

carried out by the Istituto Sperimentale per le Foreste of Cosenza in order to establish the optimum thinning grade from an economical point of view (Avolio & Ciancio, 1979). The pedological study was devoted to the achievement of a preliminary knowledge about the effects of pine plantation, thinning grade and surface morphology, on soil development and conservation.

ENVIRONMENT

The experimental area is located in Varco S. Mauro, near Camigliatello Silano, at 1247 m above sea level, on soils formed in granite and gneiss saprolite (fig. 1). The main topographical and climatic data of Camigliatello Silano are shown in table 1. The climate is sub-mountain mediterranean, characterised by heavy autumn and winter rainstorms and a somewhat summer aridity. Despite elevation, the mean temperature is fairly high, especially in summer, so that the climate induces quite a rapid weathering of saprolitic rock and favours soil development. Before the trial area was planted in the period 1958-60, soils were subjected to very strong erosion, caused by repeated cultivations of potato and rye and by excessive grazing. Data concerning the soils of the area in that time are not available. However, the Foresters' observations, the examination of both the aerial and surface photographs taken before the plantation, and a recent survey of the soils of the area subjected to the mentioned agricultural land use (Alliata & *alii*, in press) indicate they probably were Dystric Xerorthents and Xerochrepts (Soil Taxonomy), that means soils very similar to the saprolite, pale coloured and with little organic matter content.

MATERIALS AND METHODS

The experimental design of the trial was a «randomised blocks», with five thinning grade treatments: control, light, moderate, heavy and very heavy thinning (corresponding respectively to 0%, 15%, 23%, 29%, 39% of tree standing volume reduction) and five blocks (replications). Pines of block 3 have been completely destroyed by fire occurred in the first half of the eighties, so it has been excluded from the investigation. The plot size was 900 m^2 (30 x 30 m), the total experimental area 18,000 m^2. The first thinning was done in 1975, the second one in 1984-1985 and the soil survey in 1987-1989. The soil survey of the experimental area included a series of observations performed in each plot by means of a hand auger, with analysis of soil texture and organic matter, and the complete description and analysis of eight soil profiles. Maximum slope and exposure were also measured in each plot. The «chi-square» non parametric tests of the SAS-STAT module (SAS institute, 1987) was utilised for the statistical analysis of data because of the qualitative response variable (the soil type); furthermore, the «Fisher's exact» test was performed because of the little amount of data.

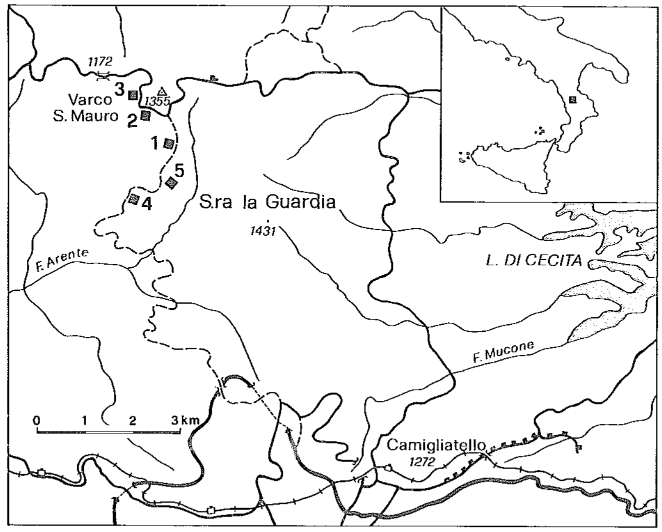

Fig. 1 - Experimental plots location.

RESULTS AND DISCUSSION

The soils of the experimental area

Results indicated the occurrence of a soil variability between plots, according to there main types of soils, which have been classified following the Soil Taxonomy (1985, 1990) such as: Pachic Haplumbrepts (type 1), Typic Xerumbrepts (type 2), Dystric Xerorthents (type 3). Soil evolution, regarding in particular the dark coloured surface umbric horizon, mostly depended on the organic matter balance of the forest ecosystem, which in turn depended on the organic matter coming from the trees onto the soil and through the roots into the soil, and on the organisms activity. Whereas soil conservation depended on the rate of the surface erosion. In this sense, type 1 soils were more evolved and preserved, while type 2 and 3 soils were less evolved and more or less eroded.

In tables 2, 3 and 4, description and analytical data regarding the characteristic profile of the three soil types are reported. The main characteristics of type 1 soils were:
— an umbric horizon deeper than 50 cm; a cambic horizon whose base reaches depths of 100 cm or more from the surface; a udic moisture regime.

Type 2 soils were characterised by:
— an umbric horizon less than 50 cm deep; a cambic horizon developed up to 60-80 cm from the surface; a xeric moisture regime.

Type 3 soils were characterised as follows:
— the presence of an ochric surface horizon; the absence of a clearly definable cambic horizon; a strong xeric moisture regime.

As far as the consequence of pine plantation is concerned, it could be observed that most soils of the plots have evolved in quite rapidly. In fact, in the case of the Pachic Haplubrepts, the organic matter accumulation and the consequent development of a well expressed umbric horizon, reaching depths of 60-80 cm, have taken place in about 27 years.

TABLE 1 - Main topographical and climatic data of the site Camignatello Silano.

Elevation:	1291 m
Latitude:	39° 83′ N
Longitude:	4° E
Annual rainfall:	1639 mm
Useful rainfall:	938 mm
Summer rainfall:	85 mm
Days of rain:	113
Mean temperature:	9° C
Coldest month:	January 0.8 °C
Warmest month:	August 18.1 °C
Potential evapotranspiration (Thornthwaite):	595 mm

As a plantation of pines sometimes implies the induction of podzolization phenomena that can affect soil fertility and hamper the introduction of broadleaf species, iron and aluminium forms in a profile were analysed (tab. 3). In this case, the analytical data showed only some evidences of podzolization without any diagnostic value according to Soil Taxonomy, and probably not yet affecting the soil fertility and the introduction of the broad-leaf.

Pedoclimatic and hydrological differences of soils

Pedoclimatic and hydrological characteristics of the three soils have been estimated utilising the data measured at Camigliatello Silano site and processing the data following the Billaux method (BILLAUX, 1978). Results are reported in table 5. The Available Water Capacity (A.W.C.) ranged from 242 to 59 mm, so the annual evapotranspiration deficit varied from 96 to 195 mm and the soil moisture control sections were dry for a period of 43-101 days per year. The soil moisture regime ranged from udic (type 1 soil) to xeric (type 2 and 3), according to the A.W.C. of the three profiles. As a consequence of the different hydrological regimes, the mean annual runoff could be estimated in a range of 439-538 mm. Therefore, a higher runoff of some 1000 $m^3.ha^{-1}.year^{-1}$ could be estimated for the more eroded and less developed soils (type 3, Dystric Xerorthents), compared with the preserved and evolved Pachic Haplumbrepts (type 1 soil).

Interactions between soil, surface morphology and thinning grade

The results of the soil survey have been compared with exposure, slope steepness and thinning grade of the experimental plots (tab. 6). First of all, a good relationship between soil type and exposure resulted. In fact, the most eroded and less developed soils (type 3) were preferentially located on southern facing slopes (135-225°) whereas

TABLE 2 - Description of the type 1 soil characteristic profile (following the *Soil Survey Manual,* 1985 and the *Keys to Soil Taxonomy,* 1990).

Profile 06

Location - Varco S. Mauro, Block 1, treat. A
Date - 3.10.1987
Stoniness - none
Exposure - 250° (OSO)
Slope - 23%

Classification: U.S.D.A.: Pachic Haplumbrept, coarse-loamy, mixed, mesic. F.A.O.: Orthi-Umbric Cambisol, 2b.

*Description**

Horiz.	Depth in cm	Colour	Texture	Rock fragm.	Consist.	Struct.	Roots	Pores	Biol. act.	Boundary
Oi	1.5-0									
Oe	0-1.5									
A1	1.5-11	7.5YR3/2	L	f, 5%	vf	gr; m, 3	2, r	m, f, 2	3	cl, sm.
A2	11-45/85	7.5YR3/2	L	f, 3%	f	sb; m, 3	3, r	m, f, 2	1	cl, ir.
Bw	45/85-105	9YR5/6	SL	f, 6%	f	sb; m, 1	2, r	vf, f, 2	1	gr, ir.
BC	105-140	10YR6/6	SL	f, 10%	f	sb; m, c, 1	1, r	vf, f, 3	1	gr, ir.
C	140-160+	10YR6/6	LS	me, co, 80%	r	massive	1, r	vf, f, 1	1	

* Colour of the moist soil; texture: SL = sandy loam, LS = loamy sand, L = loam, rock fragments: f = fine, m = medium, co = coarse; consistence: vf = very friable, f = friable, r = firm; structure: gr = granular, sb = subangular blocky, f = fine, m = medium, c = coarse, 1 = weak, 2 = moderate, 3 = strong; pores: vf = fine, m = medium; roots, pores and biological activity: 1 = few, 2 = common, 3 = many; boundary: cl = clear, gr = gradual, sm = smooth, ir = irregular.

Table 3 - Description of the type 2 soil characteristic profile (following the *Soil Survey Manual,* 1985 and the *Keys to Soil Taxonomy,* 1990).

Profile 08

Location - Varco S. Mauro, Block 2, treat. B
Date - 3.10.1987
Stoniness - few
Exposure - 302° (ONO)
Slope - 49%

Classification: U.S.D.A.: Typic Xerumbrept, coarse-loamy, mixed, mesic. F.A.O.: Orthi-Umbric Cambisol, 2c.

Description

Horiz.	Depth in cm	Colour	Texture	Rock fragm.	Consist.	Struct.	Roots	Pores	Biol. act.	Boundary
Oi	4-0									
Oe	0-3									
A1	3-18	7.5YR3/3	L	f, me, 3%	f	gr; m, 3	3, r	m, f, 3	3	gr, sm.
A2	18-35	7.5YR3/3	L	f, me, 5%	f	sb; m, 3	3, r	m, f, 3	3	cl, ir.
AB	35-52	7.5YR3/4	L	f, me, 5%	f	sb; m, 2	3, r	m, f, 3	3	cl, ir.
Bw	52-70	7.5YR4.5/4	SL	f, me, 10%	vf	sb; m, f, 1	2, r	vf, f, m, 3	2	cl, sm.
BC	70-80/103	8YR5/7	L	f, me, 20%	f	sb; m, 1	2, r	vf, f, 3	1	cl, ir.
C	80/103-170+	10YR7/7	LS	me, co, 90%	r	massive	1, r	vf, f, 2	1	

Table 4 - Description of the type 3 soil characteristic profile (following the *Soil Survey Manual,* 1985 and the *Keys to Soil Taxonomy,* 1990).

Profile 07

Location - Varco S. Mauro, Block 2, treat. C
Date - 3.10.1987
Stoniness - none
Exposure - 140° (SSE)
Slope - 47%

Classification: U.S.D.A.: Dystric Xerorthent, loamy-skeletal, mixed, mesic. F.A.O.: Orthi-Dystric Regosol, 2c.

Description

Horiz.	Depth in cm	Colour	Texture	Rock fragm.	Consist.	Struct.	Roots	Pores	Biol. act.	Boundary
Oi	2-0									
Oe	0-2									
A1	2-4	10YR4/3	SL	f, 5%	f	gr; m, f, 2	3, r	m, f, 3	3	cl, sm.
AB	4-29	8YR4/4	SL	f, me, 7%	vf	sb; m, f, 2	3, r	m, f, 3	3	cl, ir.
CB	29-63	7.5YR5/6	SL	f, me, 70%	vf	sb; m, 1	2, r	vf, f, 2	1	gr, ir.
C	63-100+	7.5YR5.5/6	SL	me, co, 95%	r	massive	1, r	vf, f, 1	1	

more developed and less eroded soils (types 1 and 2) were grouped in the other exposures. The «chi square» test provided in this case a value of 8.148, with $P<0.001$; the «Fisher's exact» test gave a P of 0.0081.

As regards the effect of slope steepness, the preserved soils (type 1) occurred with higher frequency on slopes with a gradient less than 25%, while the more or less eroded soils (types 2 and 3) were confined to slopes as steep as 25% or more. The contingency table relevant to this case produced a «chi square» value of 7.179, with $P< 0.001$, and the «Fisher's exact» test gave a P of 0.0147.

Finally, the T and B (control and moderate) thinning grades have been found to be associated with less developed soils (types 2 and 3), whilst A, C and D grades resulted frequently associated with the most evolved ones (type 1). In this case the association was revealed by «chi square» value of 7.179, with $P< 0.001$, and by «Fisher's exact» test of 0.0147.

TABLE 5 - Main pedoclimatic and hydrological data of the three soil types.

	Soil type		
	1	2	3
A.W.C. (mm)	242	124	59
Deficit (mm)	96	145	195
Moisture index (Thornt.)	74	81	90
Aridity index (Thornt.)	16	24	33
Runoff (mm)	439	488	538
Control section *(following the Billaux's methodology):*			
Moist (d)	275	226	192
Partly moist (d)	47	55	72
Dry (d)	43	84	101
Soil classification (Soil Taxonomy):	Pachic Haplumbrept	Typic Xerumbrept	Dystric Xerochrept

Analytical Data	Profile 06			
Horizon	A1	A2	B	BC
Depth (cm)	11	45/85	105	140
Texture (%)				
coarse sand	26.9	26.6	43.2	39.5
fine sand	9.3	10.0	11.0	11.9
v. fine sand	6.5	6.7	10.1	14.1
coarse silt	18.6	16.7	12.7	13.9
fine silt	24.7	27.6	15.6	13.4
total sand	42.7	43.3	64.3	65.3
total silt	43.3	44.3	28.3	27.3
clay	14.0	12.4	7.4	7.2
pH (H_2O)	5.9	5.6	5.7	5.8
pH (KCl)	4.2	4.0	3.9	3.7
C (%)	5.83	3.89	0.87	0.44
O.M. (%)	10.06	6.72	1.50	0.76
N (%)	3.27	2.33	0.41	0.17
C/N	17.8	16.7	21.2	25.9
Ex. bases (cmol (+) kg^{-1})				
Ca	5.8	2.6	1.5	2.1
Mg	1.9	0.9	0.4	0.7
Na	0.4	0.5	0.4	0.4
K	1.3	1.3	0.4	0.1
Sum of bases (cmol (+) kg^{-1})	9.4	5.3	2.7	3.3
Ex. acidity (cmol (+) kg^{-1})	17.5	32.5	12.5	10.0
C.E.C. (cmol (+) kg^{-1})	26.9	37.7	15.1	13.3
Base sat. (%)	35.0	13.8	17.2	25.0

Analytical Data	Profile 07			
Horizon	A1	AB	CB	C
Depth (cm)	4	29	63	100 +
Texture (%)				
coarse sand	42.8	42.8	43.3	32.0
fine sand	11.4	11.4	9.7	17.5
v. fine sand	9.0	8.6	10.4	12.5
coarse silt	15.8	7.1	17.0	23.1
fine silt	13.4	19.7	12.4	10.1
total sand	63.2	62.8	63.4	62.0
total silt	29.2	26.8	29.4	33.2
clay	7.6	10.4	7.2	4.8
pH (H_2O)	5.8	5.8	5.9	6.3
pH (KCl)	4.0	3.7	3.4	3.2
C (%)	3.12	1.29	0.36	0.36
O.M. (%)	5.39	2.23	0.63	0.63
N (%)	1.26	0.65	0.31	0.04
C/N	24.8	19.8	11.6	90.0
Ex. bases (cmol (+) kg^{-1})				
Ca	5.5	2.4	4.8	6.1
Mg	1.3	0.7	2.2	2.8
Na	0.4	0.4	0.7	0.5
K	0.9	0.5	0.5	0.2
Sum of bases (cmol (+) kg^{-1})	8.1	4.0	8.2	9.6
Ex. acidity (cmol (+) kg^{-1})	7.5	10.0	5.0	2.5
C.E.C. (cmol (+) kg^{-1})	15.6	13.9	13.2	12.0
Base sat. (%)	52.1	28.3	62.2	79.2

Analytical Data	Profile 08					
Horizon	A1	A2	AB	BW	BC	C
Depth (cm)	18	35	52	70	80/103	170 +
Texture (%)						
coarse sand	25.6	22.3	23.5	31.2	24.7	62.0
fine sand	10.9	11.6	14.4	11.0	11.2	13.3
v. fine sand	9.7	9.2	7.1	10.0	12.8	10.3
coarse silt	16.6	16.0	14.8	20.6	23.5	6.6
fine silt	21.6	24.2	26.8	18.6	20.1	5.2
total sand	46.2	43.1	45.0	52.2	48.7	85.6
total silt	38.2	40.2	41.6	39.2	43.6	11.8
clay	15.6	16.7	13.4	8.6	7.7	2.6
pH (H_2O)	5.9	6.1	6.2	5.8	6.2	6.2
pH (KCl)	4.2	3.9	4.0	3.8	3.0	3.2
C (%)	4.38	2.90	2.55	1.26	0.39	0.23
O.M. (%)	7.56	5.0	4.40	2.18	0.67	0.39
N (%)	2.11	1.80	1.54	0.62	0.12	0.10
C/N	20.3	16.1	16.6	20.3	32.5	23.0
Fe (dith.) (%)	1.27	1.54	1.55	1.17	1.50	0.27
Fe (pyroph.) (%)	0.19	0.31	0.34	0.19	0.06	0.05
Al (dith.) (%)	0.40	0.55	0.56	0.34	0.20	0.06
Al (pyroph.) (%)	0.34	0.44	0.44	0.25	0.08	0.05
Ex. bases (cmol (+) kg^{-1})						
Ca	5.7	4.3	2.4	2.2	7.5	0.7
Mg	1.8	1.2	0.9	0.7	3.1	0.3
Na	0.5	0.6	0.4	0.4	0.6	0.4
K	1.2	0.9	0.7	0.5	0.2	0.1
Sum of bases (cmol (+) kg^{-1})	9.2	7.0	4.4	3.8	11.4	1.5
Ex. acidity (cmol (+) kg^{-1})	5.0	22.5	22.5	2.5	5.0	7.5
C.E.C. (cmol (+) kg^{-1})	14.2	29.5	26.9	4.1	16.4	9.0
Base sat. (%)	64.7	23.7	16.4	39.2	69.5	16.8

TABLE 6 - Slope, exposure and soil type of the experimental plots in relation to the silvicultural treatments.

	Blocks (replications)											
	1ª			2ª			4ª			5ª		
	Slope (%)	Expos. (°)	Soil type	Slope (%)	Expos. (°)	Soil type	Slope (%)	Expos. (°)	Soil type	Slope (%)	Expos. (°)	Soil type
Treatments (thinning grades)												
T (Control)	17	200	3	39	140	2	10	270	2	25	200	3
A (Light)	23	240	1	49	320	2	10	230	1	18	180	1
B (Moderate)	16	230	2	53	320	2	20	210	3	25	180	3
C (Heavy)	23	220	1	47	140	3	20	260	2	21	190	1
D (Very heavy)	28	230	2	21	205	1	27	260	2	23	180	1

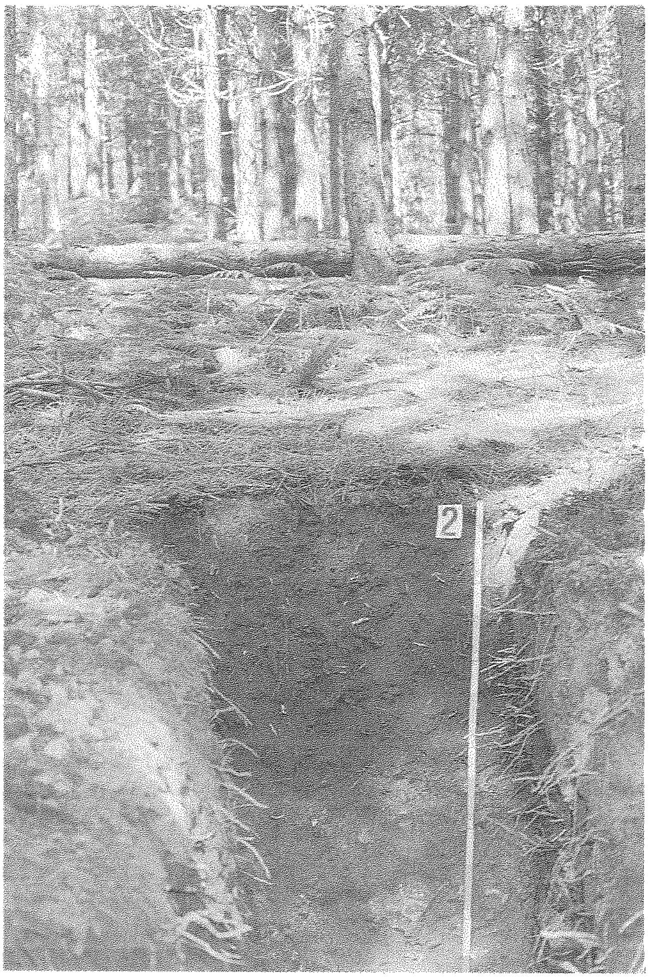

FIG. 2 - Soil of the experimental area with a well developed humbric horizon (Pachic Haplumbrept).

CONCLUSIONS

The survey of the experimental area brought to light the fact that in most cases the soils of the plots developed a well expressed umbric horizon, without remarkable evidences of podzolization, so that the soil conservation effectiveness of this reafforestation programme with calabrian pine is confirmed.

This good effect on soil development and conservation, however, appeared to vary according to slope steepness and exposure and, to some extent, thinning grade. In this sense, the present recognitive study, based only on soil characteristics, indicated a negative effect on soil development and conservation of southern facing exposures, as well as of slopes equal to 25% or higher.

As regards the effect of silvicultural treatment, the thinning operations resulted to have no negative influence on soil development and conservation, also when the light and even the heavy and very heavy grades had been adopted. In fact, in this environment, the thinnings favoured and increase in the microbiological activity, in terms of biomass of the A1 horizon (measured with the fumigation technique, ARCARA & GREGORI, personal communication), probably due to the increased lighting of the soil surface. However, the silvicultural investigations of the research project will be able to better explain the comprehensive effect of the thinnings.

REFERENCES

ALLIATA V., BIDINI D., BIGI L., CALZOLARI C., COSTANTINI E.A.C., DAZZI C., DIMASE A.C., FAVI E., GIORDANO A., IOVINO F., LULLI L., MACCIONI L., MAIANI S., MELIS R., MADRAU S., PRETI D., RAIMONDI S., ROSSI R., RUSTICI L. & VINCI A. (in press) - *Suoli e superfici nel bacino del Trionto*. C.N.R., Roma.

AVOLIO S. & CIANCIO O. (1979) - *Prove di diradamento e tavole di cubatura per pinete artificiali di pino laricio*. Ann. Ist. Sper. Selvicoltura, *10*, 25-78.

AVOLIO S., CIANCIO O., GRINOVERO C., IOVINO F., MIRABELLA A., RAGLIONE M., SFALANGA M. & TORRI D. (1980) - *Effetti del tipo di bosco sull'entità dell'erosione in unità idrologiche della Calabria - modelli erosivi*. Ann. Ist. Sper. Selvicoltura, *11*, 47-131.

BILLAUX P. (1978) - *Estimation du régime hydrique des sols au moyen des données climatiques*. Cahiers O.R.S.T.O.M., Ser. Pédologie, *16* (3).

F.A.O. - UNESCO (1988) - *Soil map of the word*, revised legend, Roma.

IOVINO F. & PUGLISI S. (1990) - *Hydrological researches in a forest basin*. Excursion guide-book of the symposium on geomorphology of active tectonics areas, ed. M. Sorriso-Valvo, C.N.R.-IRPI, Geodata n° 39, Rende (Cs) Italy.

SAS (1987) - *SAS/STAT Guide for personal computer*. SAS Institute Inc., Cary, NC, USA, Version 6 Edition.

SOIL SURVEY STAFF (1990) - *Keys to Soil Taxonomy*, SMSS Technical Monograph 19.

U.S. SOIL CONSERVATION SERVICE (1985) - *Soil Survey Manual*.