Re-carbonization of soils with intensive agricultural use with the presence of pine forests and provision of fungal ecosystem services (suilus luteus and suilus granulatus).Chilean experiences

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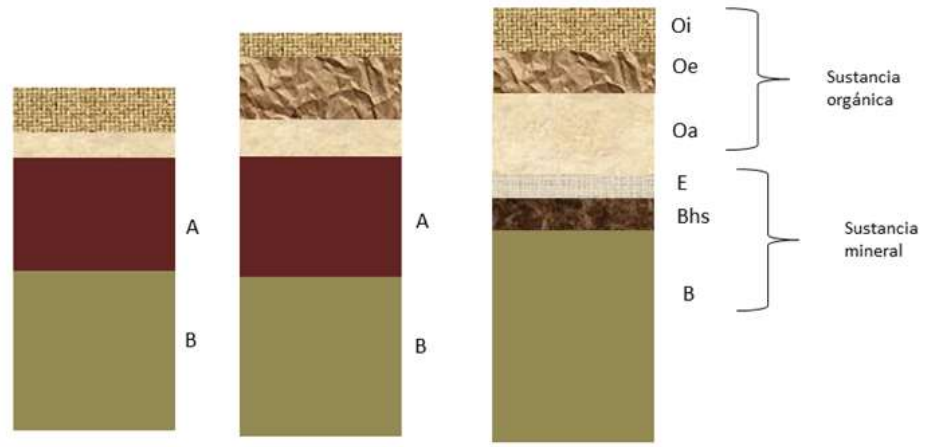
1. Management of humic covers and fungi biodiversity in forest soils

When carbonizing soils with Pinus radiata plantations, an organic horizon O is generated and the sub horizons (OF, OF, OH), organic carbon is sequestered and fixed in ranges of 22.3-44.4 ton/ha after soil site (Schlatter, J. 2001), which plays a fundamental role in the nutrition and fertility of forest soils.

Picture 1. Forest Floor



Mull	Moder	MOR	
Oi (Oe) A	Oi Oe Oa -(a)- E	Oi OeOa-(A)-E	Taxonomía de suelos
Ol (Of) Ah	Ol Of O (A)-Ae	Ol Of Oh (A)-Ae	Sistema Internacional
Muy suelta	Suelta a algo densa	Densa a muy densa	Estructura

Picture 2. Humics Form

References: handbooks of soil field recognition
Austral Chilean Austral University 2005

2.Humic forms and biological activity of the soil

The establishment and management of the forest, associated with the management of humic roots (decomposition rate C / N, CP, C / S) especially moor and moder type influence the formation of fungi (mushrooms), mainly due to an association of the condition of forest structure (canopy cover, density, distribution), climatic aspects (rainfall regime, air temperature, wind speed, cloudiness and humidity), among others. On the other hand, in bacterial covers type mull predominate bacterial strains.

C/N ratio	Humic form	Ad/ ▲AC	Biological Activity Micro organisms	Fertilidad	Tipo de Bosque
<10	Mull	>▲D	High	High	Broad leaves
<10-20	Moder	▲D= ▲AC	Medium	Medium	Mixed
>20	Moor	>AC	Low	Low	Conífers

▲ D = decomposition rate

▲ AC Accumulation Rate

Table 1. Interrelations of humic forms of forest types, biological activity and the C/N ratio

3. Pine mycorrhizae and mushroom productivity

3.1 Mycorrhizal associations

As a result, all Pinus radiata plants produced in national nurseries are inoculated with mycorrhizal fungi, with the aim that future forestry plantations develop this symbiotic relationship.

The growth and development of these fungi is dynamic and the productivity of the mushrooms is determined by a multiplicity of environmental factors, associated with the climate, the organic horizon of the soil, the humic formation, the structure and management of the Pinus radiata forest.

The main edible mushrooms produced in the country correspond to the species Suillus luteus and Suillus granulatus, constituting more than 90% of fungal exports. These fungi develop in the forests of Pinus radiata from 6 to 20 years, with yields of 300 kg / ha / year and 35 kg / day of extraction.

3.2 Suillus luteus, boletus-pine

It hat constitutes a mycorrhizal species of pines, mainly of Pinus radiata. A convex pools a little reddish brown, its surface a bit viscous. In the lower part it has fine ocher yellow tubes, which become more brown colours. It is distributed geographically from the central zone to the southern zone and bears fruit in the autumn season and in early winter

Picture 1. Suillus luteus

References: hongos.cl

3.2.1 Suillus granulatus, granulatus of pine

It is a mycorrhizal species of pines. It has a yellow brown convex pool. Its surface is dry in dry times, but it can be a bit viscous in rains. It has in the lower part thin pale yellow tubes that become more reddish as it ages. It is a cosmopolitan species found in Chile from the central zone to the southern zone. Its fructifications can be found in the autumn season and in early winter

Picture 2. Suillus granulatus, granulatus of pine

References:hongos.cl

4 Soil and water conservation practices that affect mycorrhizae and mushroom production

4.1 Fertility and soil biodiversity in forest soils

The determinants of fertility and biodiversity of forest land can be influenced by soil conservation practices.

Table 2. Management of humic covers and effects on the biodiversity of flora and fauna of forest soils through soil conservation practices

Variable/ factor of soil	Practical soil conservation practices
Provision of nutritional elements	• The objective is that the state of the soil and nutritional offer reaches an optimum level again, so that new supplies of nutrients are not necessary through: • Mineral fertilization, plantation with deep-rooted species, establishment of species rich in nutritive elements with good decomposition of its litter, tillage of the soil to remove the compacted strata with flora and fauna of the soil. • No practices to stimulate mineralization processes should be carried out.
Base saturation	• Mineral fertilization. • Green fertilizer. • Choice of the broadleaved species. • Application of soil flora and fauna strains. • Improvement of mineralization conditions through fertilization with CaO, MgO and P2O, according to litter thickness.
Humus	• Mineral fertilization. • Soil tillage work. • Choice of the species. • Application of soil flora and fauna strains. • Forest treatments and care.
Porosity	• Measures to favor the activity of soil microorganisms through soil tillage and drainage work.
Cultural care of the forest	• Creation and maintenance of an orderly development of the forest (thinning, thinning, pruning). • Avoid over-site coverage, damage to the ground (compaction) in the forest harvest, scattering of forest crop remains (bark, branches and leaves).

4.2 Experiences of sustainable forest management and mushroom production in the Maule Region, Chile

The objective of multipurpose management of the forest should consider, depending on the density and initial spatial distribution of the plantation, successive interventions of thinning and to a lesser extent pruning, to prevent the closing of glasses and maintain a luminosity percentage greater than 23%.

Dominant height (m)	Age (years)	Residual density (trees/ha)		Cultural activities	Technical Specifications
0	0	1250	0	Establishment	Use good genetic material and intensive establishment forestry. It is necessary to analyze the use of chemical products and/or fertilizers if the commercial objectives point to organic mushroom markets.
	1-2	1250	0	Weed and/or fertilization Control	The height of the weed, and undergrowth. Use fertilization when appropriate and sow fungal spores when plants do not have nursery inoculation. This is achieved by spreading leaf litter collected from pine forests in formation.
6-7	6	1250	700	Pruning 1	Pruning up to 2 to 3 meters. Select according to criteria of growth, shape, quality and luminosity of the soil. Do not exceed 35% tree height. Sort waste in the planting line, leaving the inter row clear. Encourage the formation of herbaceous (non-shrub) strata in inter-row strips, as it favors the formation and protection of mushrooms against the effects of wind.
6-7	6	700	550	Thinning	Waste or semi commercial Thinning of all unpruned trees. Sort waste not marketed in belts over the row. Schedule activity in those seasons where there is no fungus production (winter or summer). Flip those individuals that improve the luminosity of the forest (the formation of holes of light considerably increases the production of mushrooms). Avoid closing glasses.
14-18	9	500	200	Commercial thinning	Commercial thinning Turning of all the trees without raising of glass and those necessary to improve the luminosity of the forest. Sort waste not marketed in belts over the row. Schedule activity in those seasons where there is no fungus production (winter or summer). Avoid closing glasses.
24-38	16	400	100	Commercial thinning	Commercial thinning Turning of those trees that improve the brightness of the forest. Sort waste in belts over the row. Schedule activity in those seasons where there is no fungus production (winter or summer). Avoid closing cups and encourage the development of herbaceous strata, but not shrub.
28-32			400	Final Harvest	Harvest of all trees. Waste management in belts in contour lines.

5. Conclusions and recommendations to practice

- The sequestration and management of organic carbon is essential to re-carbonize soils from previous intensive agricultural use. By re-carbonizing soils using Pinus radiata roofs, especially through the organic horizon O and sub-horizons (OF, OF, OH), organic carbon is sequestered and fixed in ranges of 22 to 44 ton / ha, which plays a role fundamental in the nutrition and fertility of the forests.
- In this way, forest soils are re-carbonized, initially conforming to the fine branches, pine acicles and fungal hyphae that make up the leaf litter (forest mulch) and in turn contribute to soil biodiversity.
- The typical forest humic forms when re-carbonizing soils for forest use and with their corresponding transitions correspond to Mull, Moder and Moor. Moor-like humic forms are humidified to Moor and humic-type humic forms are humidified to mull through the interaction of forest management and intrinsic soil biodiversity.
- In these humic and modern humic roofs, ectomicorric fungi that correspond to the species Suillus luteus and Suillus granulatus develop, which develop in the forests of Pinus radiata from 6 to 20 years.

- The most important edaphic-ecological factors that influence mycorrhization and mushroom production correspond to light intensity, temperature, the percentage of soil moisture, fertility and pH.
- From the forestry point of view, the level of vegetation cover of the forest constitutes one of the determining factors in the production of mushrooms, as well as the regulation of the percentage of luminosity that reaches the ground (a minimum of 23%), the level of undergrowth and type of litter and type of forest management.
- The litter, forest mulch (10 to 15 cm high), contributes to the protection and proliferation of mushrooms, increasing the resistance to soil evaporation and dehydration of mycelia. Especially important is the depth of the litter in the protection of mycelia.
- A multiple use forest management should be contemplated in order to achieve the re-carbonization of previous intensive agricultural soils through vegetative pine covers that consider factors the density and initial spatial distribution of the plantation, successive forest management interventions (thinning and pruning), so that the closing of cups does not occur and the luminosity is favored in such a way as to induce the provision of fungal eco-systemic services (suilus luteus and suilus granulatus).

- The structure and temporal planning of silvicultural interventions are compatible with the production of edible fungi, because the initial density is not high and the successive thinnings allow a good luminosity of the undergrowth.
- Research is currently being carried out, to evaluate the effects of soil conservation practices such as selection of the species of broadleaf and shrubs (lupinus) through the application of soil and fauna strains, the improvement of mineralization and humification conditions through whitewashing (CaO) with basal applications of low doses of MgO and P2O, according to litter thickness, and promote fertilization practices that do not favor excessive stimulation of humification and mineralization processes of re-carbonization processes by budding oxidative bioturbation of soil flora and fauna.

6. Bibliographic References

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