Sustainable forest management in radiata pine plantations: a case study in Sardinia (Italy)

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Radiata pine plantations in Sardinia

- At the beginning of the eighties of the last century, the surface of **radiata pine plantations** in Italy was about 25,000 hectares, of which almost **half in Sardinia**.
- Main objective of plantations in Sardinia was to **supply raw material to the pulp and paper industry** developing on the central-eastern coast in Arbatax.
- Development of **local timber economies** and **environmental aspects** (landscape, biodiversity, carbon sequestration, water quality, soil erosion, pest and climate change risks) represent today new challenges for forest managers.
- The Forest Agency of Sardinia is looking to the future, associating to the purely productive approach of forestry also the **enhancement of the most significant functions**.

Research question

How to achieve a sustainable forest management of radiata pine plantations of an area in inner Sardinia, by integrating biological and ecological aspects with socio-economic constraints and opportunities?

Research aim

- To explore effects on forest stand structure by silvicultural treatments (thinning and regeneration felling) which promote natural regeneration under continuous forest cover conditions.
- To identify forest species which can play a significant role in the natural regeneration process for the replacement of monospecific plantations in the future.
- To assess the economic sustainability of the performed silvicultural treatments by calculating effective harvesting costs and timber value.

Materials and Methods

Systematic thinning

Selective thinning

Regeneration felling

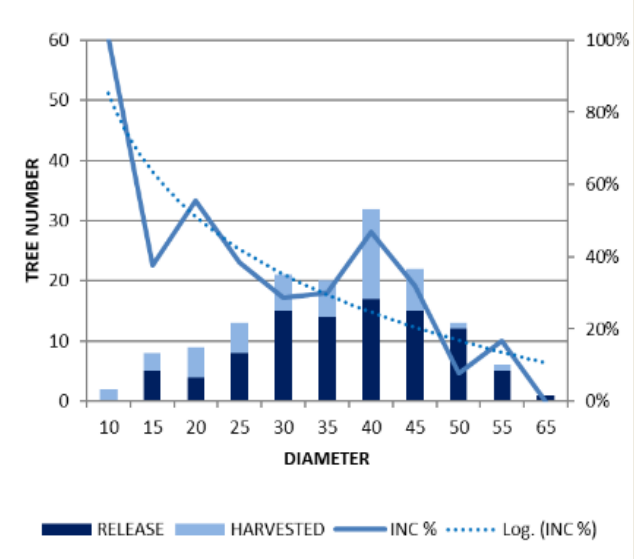
- Monte Idòlo forest complex (Arzana NU), 880 m asl, 45 yrs old plantations
- 2 thinning types, 1 regeneration felling on each 3000 m^2 testing areas
- Point-centered quarter method for analysis of natural regeneration
- Forest mechanization: chainsaw for felling, tractor + winch for extraction, processor for cross-cutting

Results – Natural regeneration

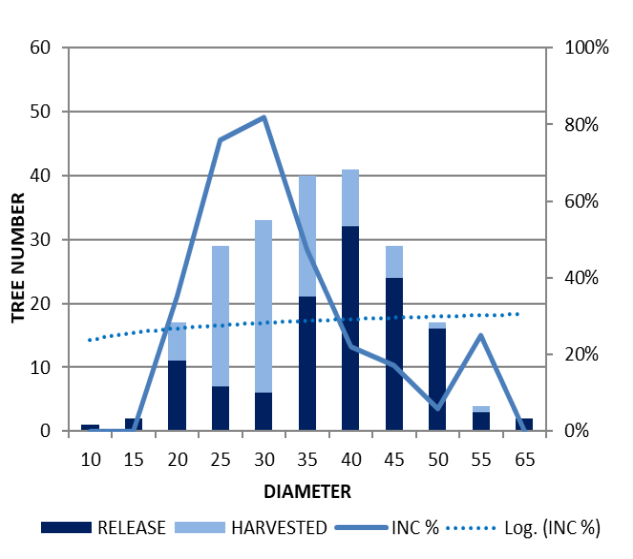
Species	Rel. Density	Rel. Cover	Abs. Density
Quercus ilex (T)	62.50	50.00	3351.94
Pinus radiata (T)	21.25	25.00	1139.66
Prunus avium (T)	10.0	15.00	536.31
Prunus spinosa (S)	45.0	32.61	203.44

Number of plants per hectare (Abs. Density) and % (Rel. Density and Cover) for trees (T) and shrubs (S).

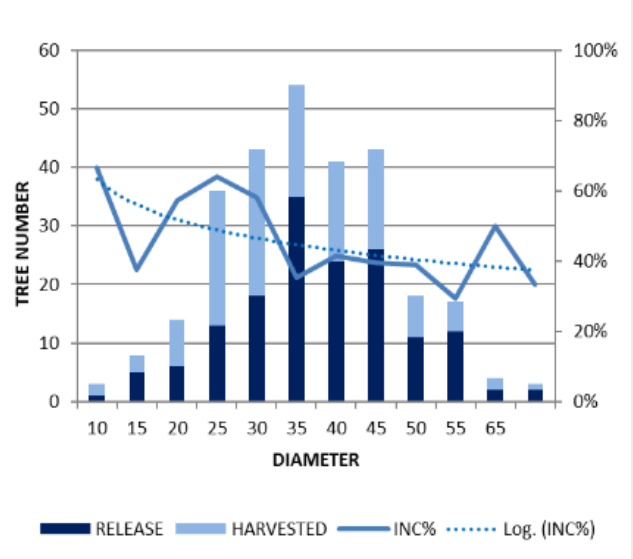
Results – Stand structure change by management



Systematic thinning

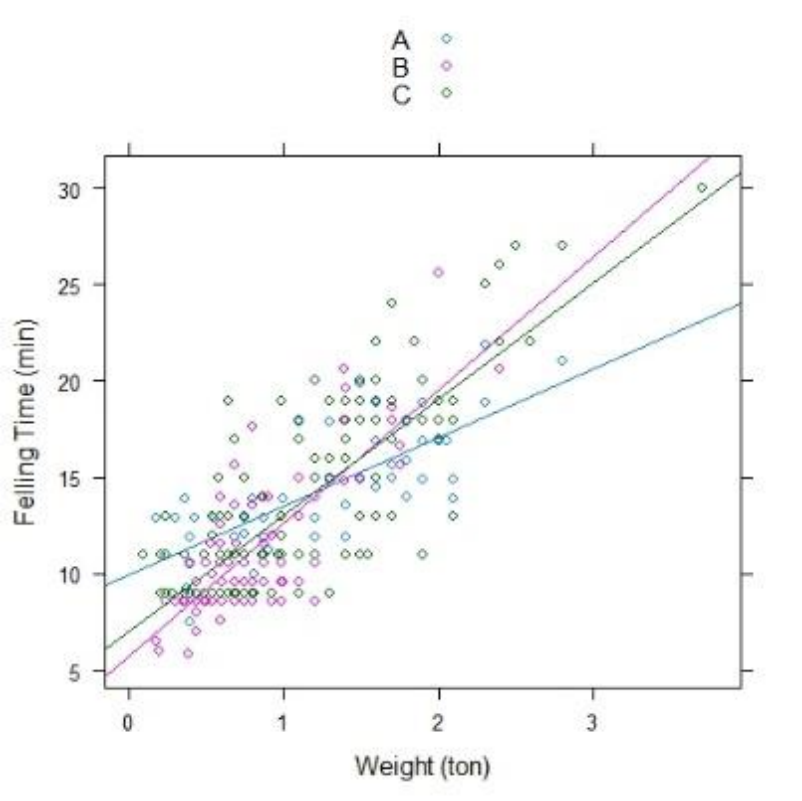


Selective thinning



Regeneration felling

Results – Harvesting operations



Felling
A-Systematic
B-Selective
C-Regeneration felling

Operation	Equation	F (df)	p-value
FELLING	A) Time = 9.95 + 3.55*Weight B) Time = 5.70 + 6.92*Weight C) Time = 6.99 + 6.03*Weight	ANCOVA F (1, 257) = 450.32	p < .001
CROSS-CUTTING	Time = 2.37 + 1.73*Weight	F (1, 261) = 386	p < .001, R^2=0.595
EXTRACTION	Time = -5.33 + 0.077*Distance + =0.30*Load + C*Type	F (4, 161) = 103.4	p < .001, R^2=0.714

Assortments	F (df)	p-value
Multiple regression to predict VOLUME of saw timber from tree DIAMETER*, HEIGHT*, SHAPE, stand POSITION**, TYPE of management	ANCOVA F (8, 261) = 1179	p < .001, R^2=0.972
*statistically significant variables **dominant position		p < .001

Results – Economic aspects

- Timber assortments: sawtimber, firewood and woodchips
- Maximum economic benefit is obtained from regeneration felling
- Thinning operations reduce the revenues by about 36% for the systematic and 61% for the selection type
- Management intervention has a positive outcome in economic terms

70,40 €/t

36,50 €/t

26 €/t

Management	Yield t/ha	Costs €/ha	Value €/ha	Revenue €/ha
Systematic thinning	220.6	7,131	14,118	6,987
Selective thinning	235.2	10,039	14,282	4,243
Regeneration felling	405.7	14,809	25,809	11,000

Main findings

- Holm oak (*Quercus ilex*) represents the principal component of the forest vegetation in the area. Forest management improves requirements for natural regeneration.
- One or more cycles of naturally regenerated radiata pine formations (mixed with the outcoming regeneration of native species) seem an affordable and sustainable goal for forest management.
- Selective crown thinning focuses on quality of the remaining trees but increases the forest operation costs by about 30%.
- Regeneration felling focuses on quickly improving the process of establishing a new generation of trees, taking advantage from the ability of radiata pine to regenerate naturally in the area. Mainly due to the greater wood mass extracted, value of timber is higher (about 23,000 €/ha) and consequently the economic gain is higher.

Conclusions

Advantages in managing radiata pine plantations in Sardinia as Continuous Cover Forestry systems with the long-term objective to change forest composition and structure:

- **Environment** - use of natural regeneration and establishment of native tree species, increase of biodiversity, more abundance of deadwood (felling operations), soil protection (forest cover).
- **Economy** - the three management options (thinnings and regeneration felling) performed a positive economic gain, which accounts for the convenience of forest operations in plantations.
- **Social and cultural** - mitigation of poor perception of clearfelling which originated public debate, positive perception deriving from forest formations, local value chain of timber products and positive impact on employment, rising recognition of landscape and cultural values of conifer plantations in the area.