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Relationships between forest management practices and ecosystem services: an analysis in black pine (Pinus nigra J.F. Arnold) forests in Central Italy

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Research Framework

The study was carried out within the Project LIFE13 BIO/IT/000282 (*Innovative silvicultural treatments to enhance soil biodiversity in artificial black pine stands*) aimed to demonstrate the positive effects of innovative forest management practices on black pine forests' multifunctionality.

The aim of the research is to analyze the **relationship between silvicultural treatments and ecosystem services** provided by forests.

Silvicultural treatments

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Impact on ecosystem services

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Assessment of ecosystem services (before and after)

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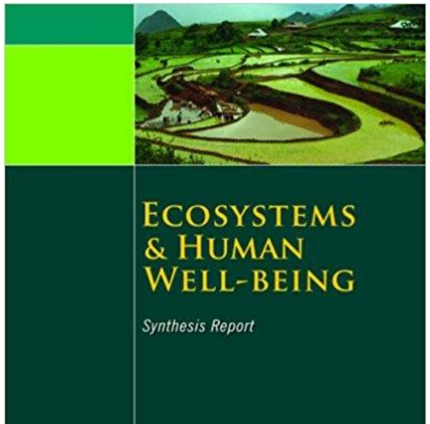
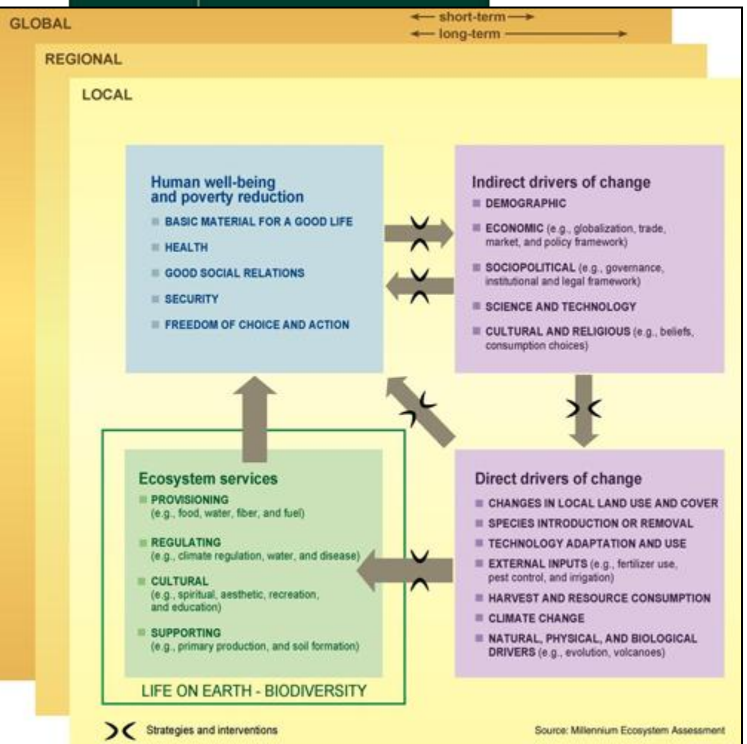
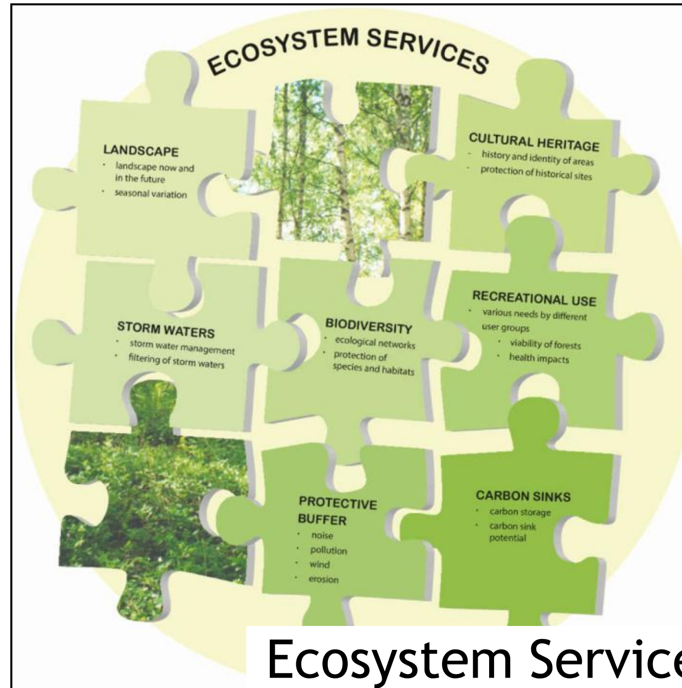
- timber and bioenergy production
- climate change mitigation
- hydrogeological protection
- biodiversity conservation

Theoretical Approach



Millennium Ecosystem Assessment (MEA) definition (2005)





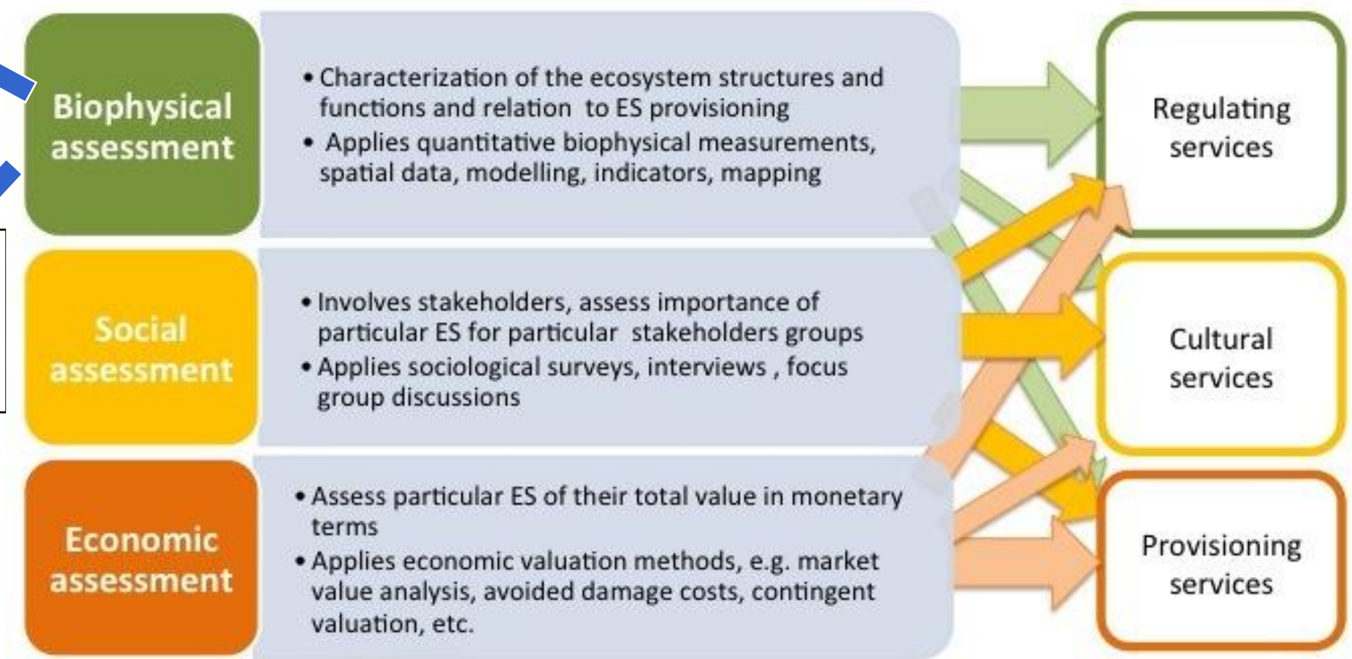
Ecosystem Services supplied by forests

How to manage the forest for wood production maintaining or improving other ecosystem services?

Approaches to assess ecosystem services

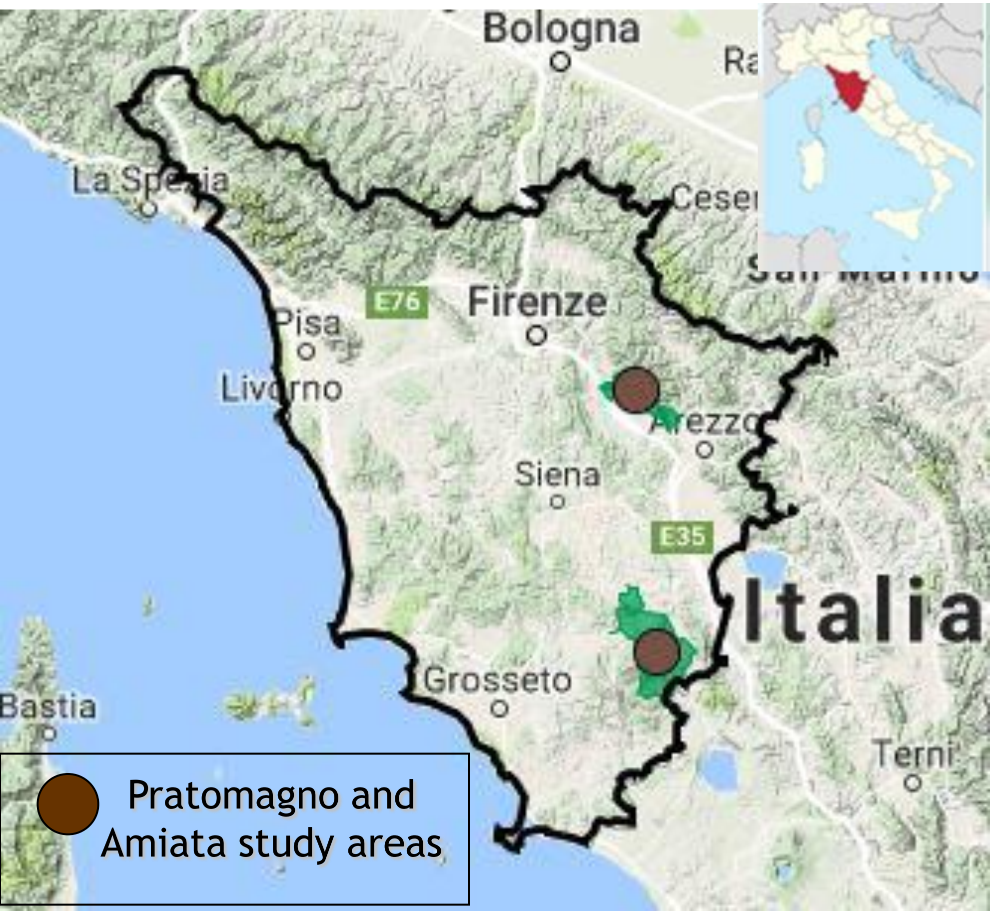
Quantitative assessment through measurement of field-based biophysical outcomes

Qualitative assessment using expert opinion of the potential flows and capacity



Source: LIFE VivaGrass

Study area

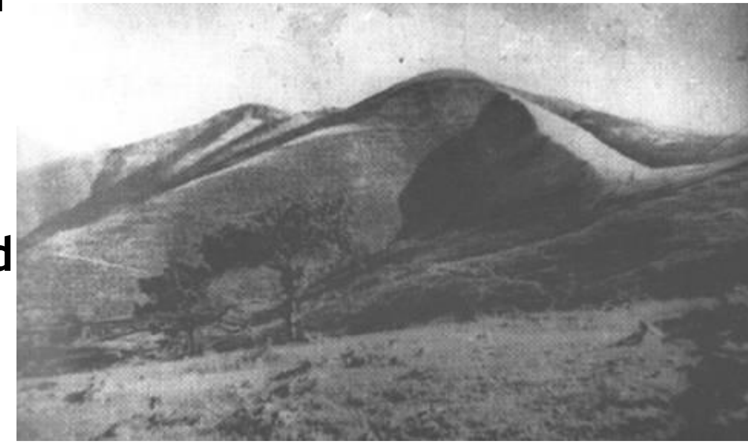


Pratomagno study area
Pratomagno (43°39′N 11°39′E) located in north-west of the Arezzo province (Tuscany region). A public property where forest area covers 95% of land area.
The main tree species are: Calabrian pine (*Pinus brutia* Ten. subsp. *brutia*), Austrian black pine (*Pinus nigra* J.F.Arnold) and some broadleaved species

Amiata study area
Amiata (42°53′N 11°37′E) located in the Siena province (Tuscany region). A public property where forest area covers 1,930 ha (87% of land area) and the main tree species are Austrian black pine (*Pinus nigra* J.F.Arnold) and Turkey oak (*Quercus cerris* L.)

Study area

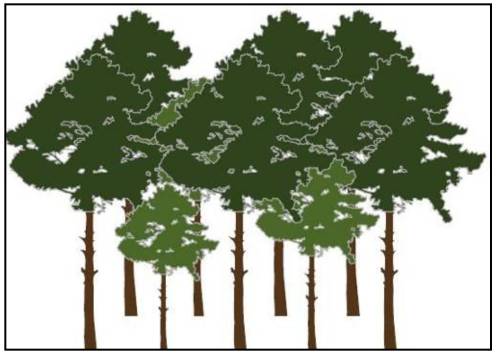
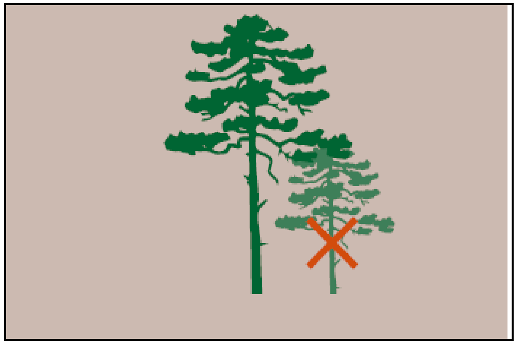
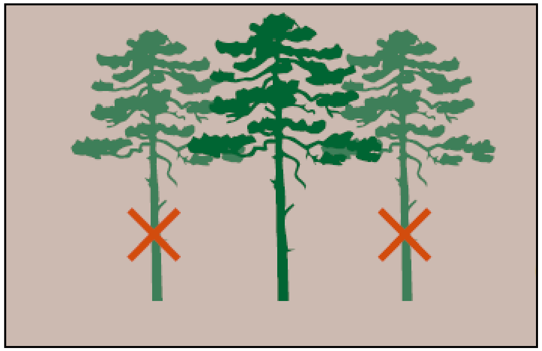
Black pine stands were established throughout the Apennines after the II World War with the purpose of re-establishing forest cover in marginal and eroded soils.
Today the key functions are the protection against soil erosion and the hydrological regulation of catchments. Pine stands are currently **characterized by a low biodiversity** level and represent the most simplified forest systems in Italy.



In Italy, black pine and Calabrian pine forests cover nearly 23% of the total area covered by conifers and in Tuscany cover 20.500 ha.

In order to guarantee the multifunctional role of these stands, it is necessary to realize silvicultural treatments aiming to guide natural evolution to more complex and stable systems and testing innovative management strategy.

Silvicultural treatments

Control	Traditional thinning	Selective thinning
		
No intervention is realized	Dominated trees are removed. No significant effect on canopy cover.	Selection of 100 candidate trees per hectare and removal of direct competitors.
		

Field measurements

In each area the data were collected in 18 sampling plots.
Each sampling plot was randomly located in a forest management unit of 1 ha of size.
The main dendrometric data were collected before and after the silvicultural treatments:

- Tree height and diameter at breast height (dbh) for all standing living trees,
- Number of stems,
- Canopy cover overstorey,
- Height and dbh for all standing dead trees.

In each study area, 3 forest management unites were managed by selective thinning (3 ha in total) and 3 forest management units were managed by traditional thinning (3 ha in total). The selective and traditional thinning were realized in 2012 in both study areas.

Mixed method between biophysical and economic approach (1/2)

Provisioning services

Timber and woodchips production

Market approach

$$V_{ps} = V_t \cdot \frac{1-(1+i)^{-n}}{i} \cdot (1+i)$$

V_{ps} annual value of provisioning services (€)
V_t = value of timber and woodchips for the rotation period (€)
n rotation period (15 years)
i annual inflation rate

Regulating services

Carbon sequestration

Carbon pools: above-ground biomass and below-ground biomass
Carbon sequestration:

$$C = [(I \cdot BEF \cdot WBD) + (I \cdot R \cdot WBD)] \cdot 0.5 \cdot 3.67$$

I = annual increment of trees volume (m^3 ha^{-1} yr^{-1})
BEF= biomass expansion factor
WBD= wood basic density, *R*= root-to-shoot ratio
0.5 (C content coefficient),
3.67 (coefficient from C to CO_2)

Forest stand stability- protection

(H:D) ratio is the indicator of single-tree mechanical stability.
H:D was calculated using data collected before and after thinning.
H:D was calculated by dividing mean tree height (m) by the mean DBH (m) of 100 dominant trees/ha

Assessment of ecosystem services

Mixed method between biophysical and economic approach (2/2)

Floristic biodiversity

Braun-Blanquet phytosociological method based on the estimation of plant cover and number of individual plants. species were identified and their abundance-dominance was assessed. Floristic biodiversity was evaluated using Shannon index

Supporting services

Standing dead trees

Change of the number of habitat trees after the two types of thinning

Value of provisioning services after thinning in the study areas

Timber and woodchips production

Results

Silvicultural treatments	Volume before thinning (m³)	Volume after thinning (m³)	Harvested timber volume (m³)	Harvested woodchips volume (m³)	V_{ps} (€ yr^{-1})
Amiata study area					
Traditional thinning	357.6	290.8	0.0	66.8	1067
Selective thinning	444.6	309.2	0.0	135.4	2163
Pratomagno study area					
Traditional thinning	722.3	582.9	104.6	34.9	4211
Selective thinning	586.6	412.9	137.5	36.5	5388

Harvested rate	% of total standing volume
Amiata study area	
Traditional thinning	18.7
Selective thinning	30.5
Pratomagno study area	
Traditional thinning	19.3
Selective thinning	29.7

Results

Value of regulating services after thinning in the study areas

Forest stand stability-protection

Change of H:D ratios of 100 dominant trees per hectare after thinning in the two study areas.

Silvicultural treatments	H:D ratio (before thinning)	H:D ratio (after thinning)	Annual variation (%)
Amiata study area			
Traditional thinning	63.15	61.93	-0.969
Selective thinning	66.32	64.62	-1.284
Pratomagno study area			
Traditional thinning	61.05	59.96	-0.889
Selective thinning	52.81	51.74	-1.012

Value of regulating services after thinning in the study areas

Carbon sequestration

Change in the carbon sequestration (Δ) after thinning in the two study areas

Silvicultural treatments	Annual increment (m^3 ha^{-1} yr^{-1})		C (tCO_{2eq} ha^{-1} yr^{-1})		Δ (tCO_{2eq} ha^{-1} yr^{-1})
	Before	After	Before	After	
Amiata study area					
Traditional thinning	1.37	1.55	1.14	1.61	0.2682
Selective thinning	0.78	1.11	1.99	2.26	0.4693
Pratomagno study area					
Traditional thinning	0.63	0.71	0.92	1.04	0.1195
Selective thinning	1.27	1.52	1.85	2.22	0.3746

Results

Value of supporting services after thinning in the study areas

Floristic biodiversity

Change of floristic Shannon Index (fH') after thinning in the two study areas

Silvicultural treatments	fH' before thinning	fH' after thinning	Variation
Amiata study area			
Traditional thinning	3.1	3.2	+0.1
Selective thinning	2.9	3.1	+0.2
Pratomagno study area			
Traditional thinning	2.1	2.2	+0.1
Selective thinning	2.2	2.5	+0.3

Value of supporting services after thinning in the study areas

Standing dead trees

Change of trees habitat after thinning in the two study areas

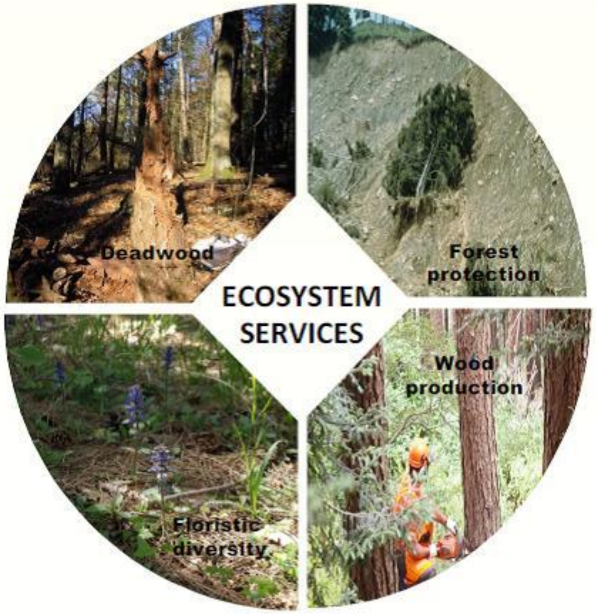
Silvicultural treatments	N° trees habitat ha^{-1} before thinning	N° trees habitat ha^{-1} after thinning
Amiata study area		
Traditional thinning	0	0
Selective thinning	1	0
Pratomagno study area		
Traditional thinning	5	2
Selective thinning	3	2

Trade-off analysis

Trade-off between ecosystem services in the two study areas

Silvicultural treatments	**Provisioning services (€ yr^{-1})**	**Regulating services**	**Supporting services**	
	Timber and woodchips production	Forest stand stability (annual variation H:D ratio)	Standing dead trees	Floristic biodiversity
			Reduction of Snag volume (%)	Shannon index (H')
Amiata study area				
Traditional thinning	1067	-0.969	**-53%**	**3,2**
Selective thinning	**2163**	**-1.284**	-55%	3,1
Pratomagno study area				
Traditional thinning	4211	-0.889	**-30%**	2,2
Selective thinning	**5388**	**-1.012**	-92%	**2,5**

In bold the silvicultural treatments more efficient to enhance the single ecosystem service



Conclusions

✓An integrated (biophysical and economic) assessment of ES can provide multi-perspective insights for forest policy makers;

✓This kind of information can be included as a part of the forest management plans;

✓Future developments might be represented by the assessment of additional ES (such as landscape, recreation…)

✓The comparison of different forest management practices and their effect on ES could be a future challenge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Thank you