Mediterranean Forest Research Agenda 2030
Webinar series – 3 November 2022

Forest management addressing trade-offs and synergies between multiple ecosystem services

Davide Travaglini
University of Florence

INTRODUCTION

The demand for ES is growing, but how to manage ecosystems for multiple services is still an open question

ES are not independent of each other and the relationships between them may be highly non-linear

Attempts to optimize a single service often lead to reductions or losses of other services → “traded-off”

Forests continue to be managed through conventional means with single or few objectives → unable to address the current challenges

Maximizing production of a service (or set of services) may lead to a less resilient and more vulnerable system, not only from the ecological but also from a socio-economic perspective

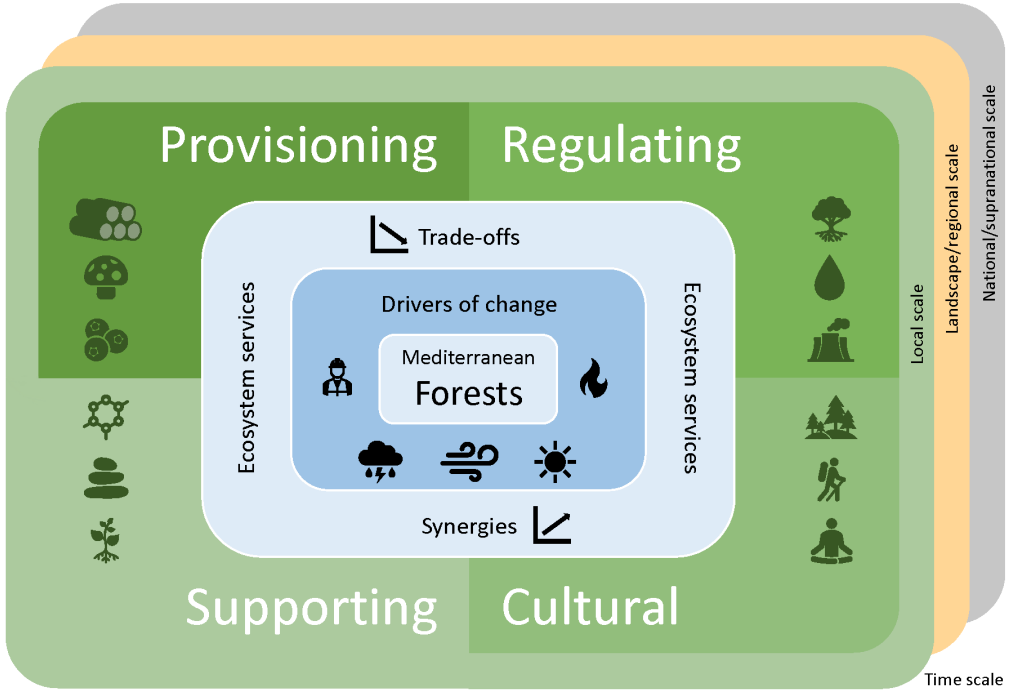
Mediterranean forests

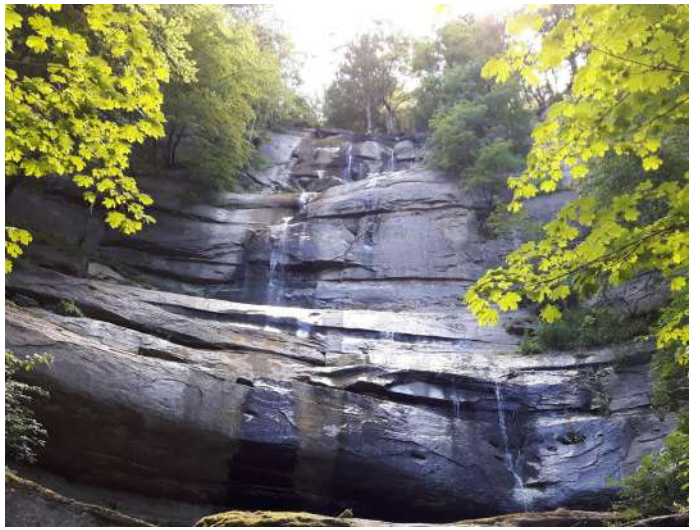
Part of a landscape mosaic that reflects interactions between variable climatic and geomorphological conditions, regional landforms and human influence

Multiple goods and benefits, which are crucial for the socio-economic development of rural areas, as well as for the well-being of the urban populations

Silviculture and forest planning approaches, with few exceptions, have been mostly wood based

The ability to provide multiple ES will be increasingly affected by environmental and social changes



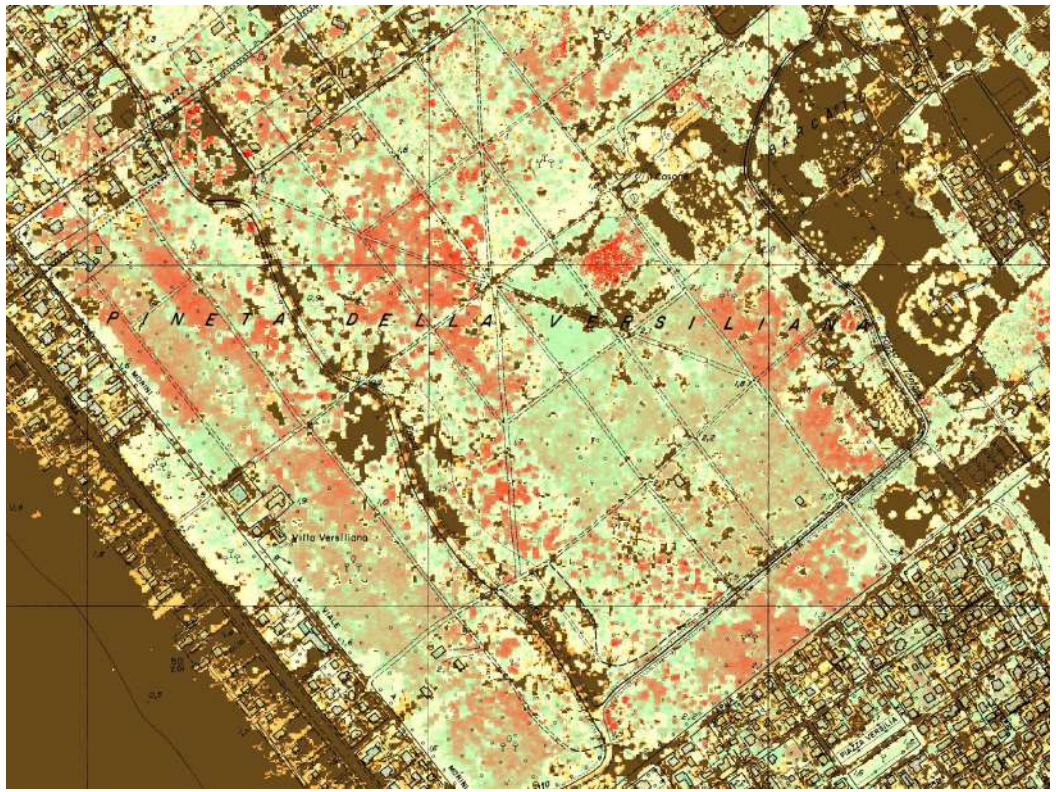


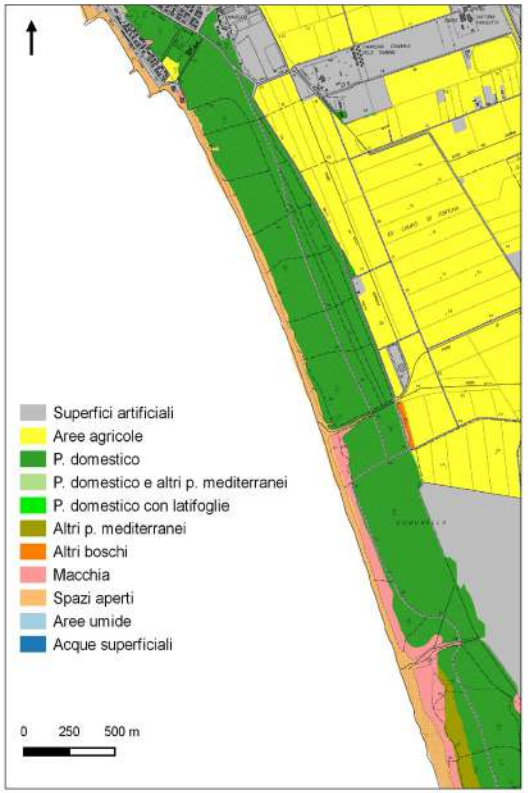
2010-2020 Mediterranean Forest Research Agenda – key challenges

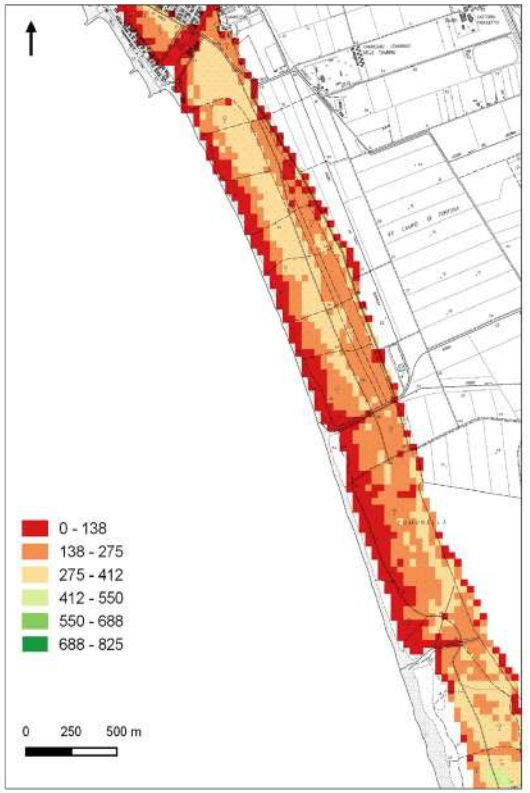
a) Develop tools and methods to predict the effects of forest management on ES and related resources

b) Design new forest management models that address the multifunctionality in an integrated stand-to-landscape scale

c) Develop user-friendly forest landscape DSS to capture the preferences of key stakeholders, and be able to optimize forest management to ensure the provision of ES







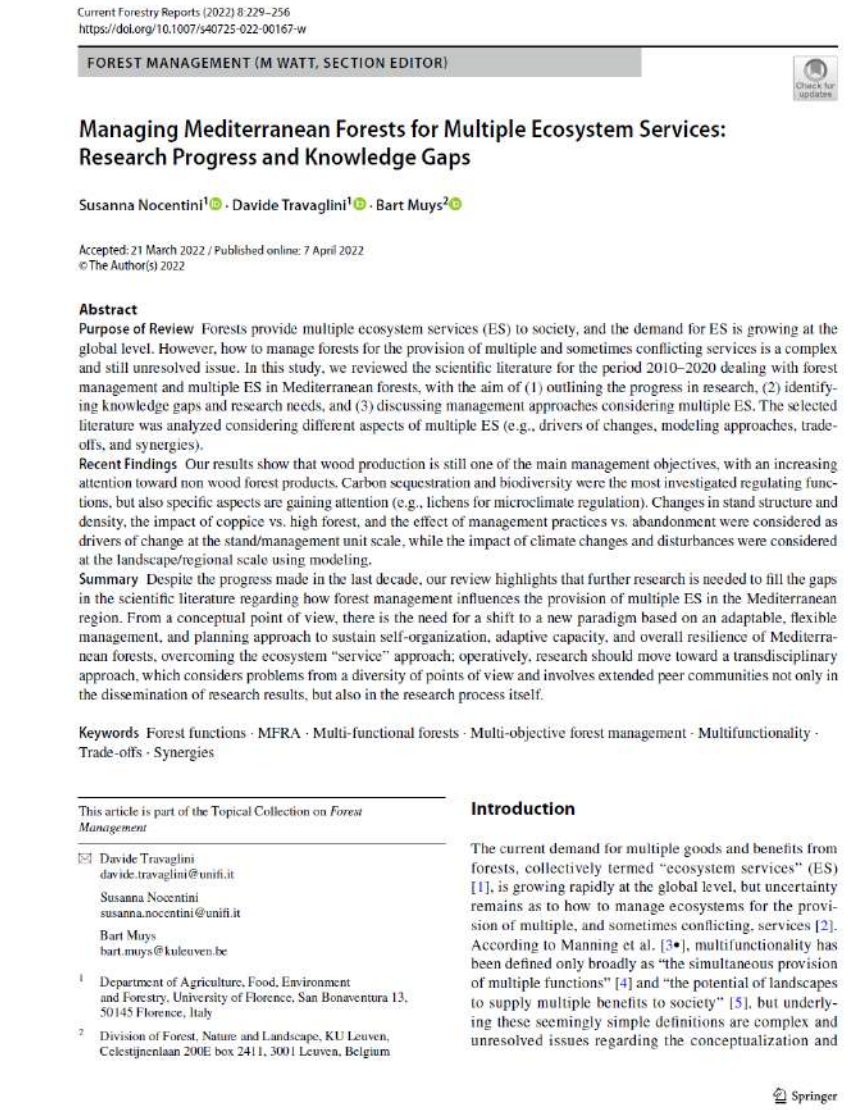
OBJECTIVES

We reviewed the scientific literature specifically dealing with forest management and multiple ES in Mediterranean forests, with the aim of:

1) Outlining the progress in research in the last 10 years

2) Identifying knowledge gaps and research needs

3) Discuss management approaches considering multiple ES



Current Forestry Reports (2022) 8:229–256
https://doi.org/10.1007/s40725-022-00167-w

FOREST MANAGEMENT (M WATT, SECTION EDITOR)

Managing Mediterranean Forests for Multiple Ecosystem Services: Research Progress and Knowledge Gaps

Susanna Nocentini[1] · Davide Travaglini[1] · Bart Muys[2]

Accepted: 21 March 2022 / Published online: 7 April 2022

Abstract

Purpose of Review Forests provide multiple ecosystem services (ES) to society, and the demand for ES is growing at the global level. However, how to manage forests for the provision of multiple and sometimes conflicting services is a complex and still unresolved issue. In this study, we reviewed the scientific literature for the period 2010–2020 dealing with forest management and multiple ES in Mediterranean forests, with the aim of (1) outlining the progress in research, (2) identifying knowledge gaps and research needs, and (3) discussing management approaches considering multiple ES. The selected literature was analyzed considering different aspects of multiple ES (e.g., drivers of changes, modeling approaches, trade-offs, and synergies).

Recent Findings Our results show that wood production is still one of the main management objectives, with an increasing attention toward non wood forest products. Carbon sequestration and biodiversity were the most investigated regulating functions, but also specific aspects are gaining attention (e.g., lichens for microclimate regulation). Changes in stand structure and density, the impact of coppice vs. high forest, and the effect of management practices vs. abandonment were considered as drivers of change at the stand/management unit scale, while the impact of climate changes and disturbances were considered at the landscape/regional scale using modeling.

Summary Despite the progress made in the last decade, our review highlights that further research is needed to fill the gaps in the scientific literature regarding how forest management influences the provision of multiple ES in the Mediterranean region. From a conceptual point of view, there is the need for a shift to a new paradigm based on an adaptable, flexible management, and planning approach to sustain self-organization, adaptive capacity, and overall resilience of Mediterranean forests, overcoming the ecosystem "service" approach; operatively, research should move toward a transdisciplinary approach, which considers problems from a diversity of points of view and involves extended peer communities not only in the dissemination of research results, but also in the research process itself.

Keywords Forest functions · MFRA · Multi-functional forests · Multi-objective forest management · Multifunctionality · Trade-offs · Synergies

This article is part of the Topical Collection on *Forest Management*

✉ Davide Travaglini
davide.travaglini@unifi.it

Susanna Nocentini
susanna.nocentini@unifi.it

Bart Muys
bart.muys@kuleuven.be

[1] Department of Agriculture, Food, Environment and Forestry, University of Florence, San Bonaventura 13, 50145 Florence, Italy

[2] Division of Forest, Nature and Landscape, KU Leuven, Celestijnenlaan 200E box 2411, 3001 Leuven, Belgium

Introduction

The current demand for multiple goods and benefits from forests, collectively termed "ecosystem services" (ES) [1], is growing rapidly at the global level, but uncertainty remains as to how to manage ecosystems for the provision of multiple, and sometimes conflicting, services [2]. According to Manning et al. [3•], multifunctionality has been defined only broadly as "the simultaneous provision of multiple functions" [4] and "the potential of landscapes to supply multiple benefits to society" [5], but underlying these seemingly simple definitions are complex and unresolved issues regarding the conceptualization and

MATERIALS AND METHODS

Scopus and WoS databases (period 2010–2020)

Criteria used to select documents:

1. The research must be related to forests in the Mediterranean basin
2. The research must be related to the forest management context
3. At least one ES and the relationships with forest management must be considered

Snowball approach (final set of 56 documents):

- Scale/scope of research
- Considered ES and indicators
- Drivers of change in ES provisioning
- Modeling approaches
- Forest types
- Interactions between ES and trade-offs and synergies

RESULTS

Growing research interest towards the impact of forest management on the provision of multiple ES

- Research papers: 82% of the selected documents
- Literature reviews and general discussions: 18% of the selected documents
- Papers from northwestern countries: 91% of the selected documents
- Papers from south and south-eastern countries: 9% of the selected documents

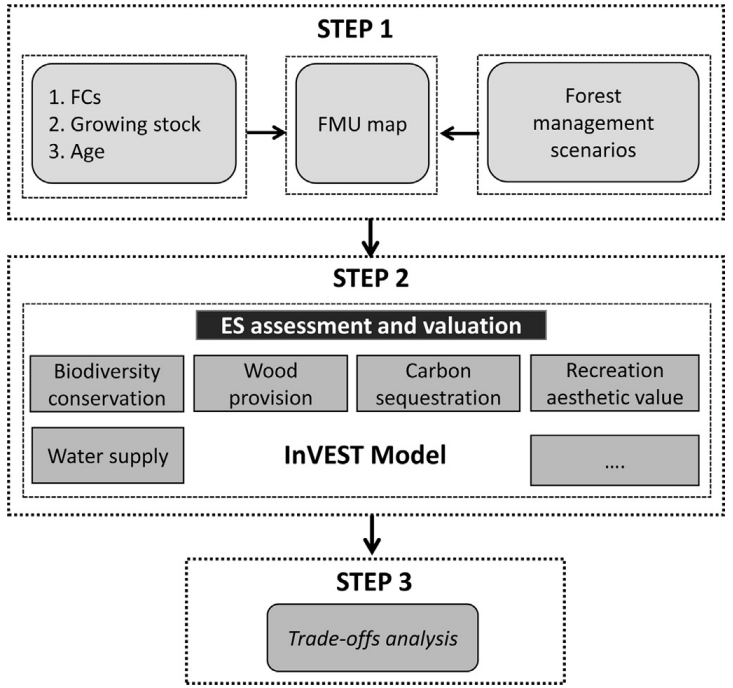
Scale of application

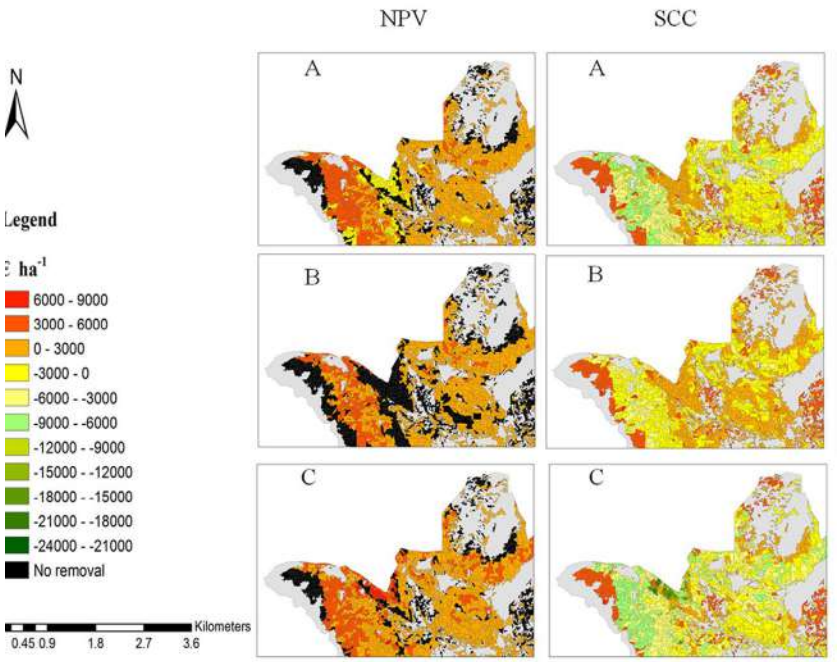
Stand / management unit level (32% of the selected documents):

- Experimental field data
- Inventory data
- Retrospective studies based on archives

Landscape / Regional scale (43% of the selected documents):

- Stakeholder perception
- Expert opinion
- Modeling





Ecosystem Services

Most of the publications mentioned one, two, or three ES (77%)

Rarely more than three ES have been considered (23%)

Twenty different ES were considered

P – Provisioning (8 ES)

- Wood production
- Increasing attention on NWFP

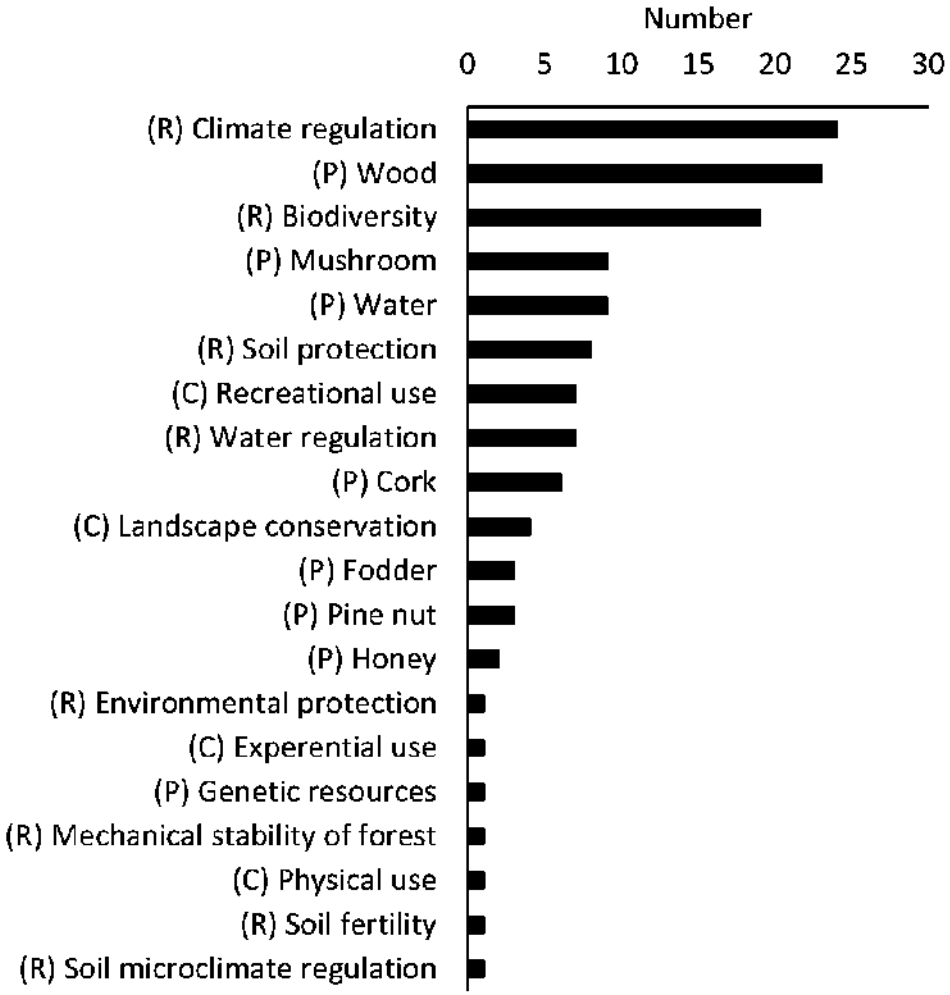
New terms have been coined
(e.g., mycosilviculture, hydrology-oriented silviculture)

R – Regulating (8 ES)

- Climate regulation and biodiversity
- Increasing attention on specific aspects
  (e.g., lichen communities for microclimate regulation)

C – Cultural (4 ES)

- Less investigated



Indicators

ES		Indicator	Unit
PROVISIONING	Cork	Cork supply	kg
			kg ha^{-1}
		Annual increment cork mass	kg ha^{-1} yr^{-1}
	Edible mushroom	Mushroom production in one year	kg ha^{-1} yr^{-1}
		Mushroom production	kg ha^{-1}
	Fodder	Annual fodder production	Annual FU
		Forage for goats and forage for cattle	kcal m^{-2}
		Grazing	FU
	Genetic resources	Seed dispersal	ha
	Honey	Annual honey production	kg ha^{-1} yr^{-1}
		Index based on flower counts in the plots	Score (0-10)
	Pine nut	Annual cone production	kg ha^{-1} yr^{-1}
			kg $tree^{-1}$ $year^{-1}$
	Water	Deep drainage into the water table	l m^{-2} yr^{-1}
		Annual water	m^3 ha^{-1} yr^{-1}
		Water recharge	mm yr^{-1}
		Water quality based on nitrate yield	kg ha^{-1} yr^{-1}
	Wood	Wood production per year	t ha^{-1} yr^{-1}
			m^3 ha^{-1} yr^{-1}
		Wood production	m^3 ha^{-1}
			t ha^{-1}
		Capacity to fulfil different functions	Score (0-10)
		Timber yield	m^3
		Annual increment	m^3 ha^{-1} yr^{-1}

ES		Indicator	Unit
REGULATING	Biodiversity	Grassland habitat cover	%
		Tree microhabitats	n ha^{-1}
		Habitat for biodiversity (deadwood)	m^3 ha^{-1} yr^{-1}
		Habitat conservation	Score (0-10)
		Density of geophyte, density of flowers	n m^{-2}
		Density of fleshy fruits	kcal m^{-2}
		Tree species diversity	-
			N
		Floristic diversity	-
		Reptiles	N
		Reptile (species richness)	N
		Bird (species richness)	N
		Bird species (density)	n ha^{-1}
		Vertebrate (species distribution)	Ha
		Photosynth. perform. by macrolichens	-
		Stand structure diversity indices	-
		Ecosystem diversity (pattern analysis)	-
	Climate regulation	C in above ground biomass	Kg
			kg ha^{-1}
			Mg ha^{-1}
			t_{CO2eq}
		C in above and below ground biomass	t ha^{-1} yr^{-1}
			kg ha^{-1}
		C in above ground and below ground biomass, dead organic matter, and soil organic carbon	Mg ha^{-1}
		C in above and below ground biomass from annual increment of tree volume	t_{CO2eq} $ha^{-1}yr^{-1}$
		Gross primary production and soil respiration	kg $C{\cdot}m^{-2}{\cdot}year^{-1}$
		Vegetation C and soil organic C	kg $C{\cdot}m^{-2}$

(the full list is available in the review)

Drivers of Change

The majority of the studies considered forest management as the only driver of change (72%)

The remaining studies considered no more than three drivers

Forest management was combined with climate change (20%) and to a lesser extent with fire (4%)

Few studies (4%) combined climate change and biodiversity with management or socio-economic variables

Stand / management unit scale

- Stand structure and density
- Coppice vs. high forest
- Traditional management vs abandonment

Landscape/ regional scale

- Impact of climate and disturbances such as fire

Modeling Approaches

Model name	Country	Scenario map	Scale	Time period (years)	Forest type	Ecosystem services			Drivers of change	Trade-offs and synergies
						Provisioning	Regulating	Cultural		
GOTILWA	Spain	No	MU	200	Pine, Evergreen oak	Wood production	Climate regulation Water use efficiency	Fire risk	Forest management Climate Change Soil	Trade-offs analysis
PICUS	Spain	No	L	120	Pine	Cone production Wood production	Climate regulation	n.c.	Forest management Climate change	No
SUBER	Portugal	No	L	90	Oak	Cork production	Climate regulation	n.c.	Forest management Climate Change	No
SADfLOR	Portugal	No	R	50	Oak	Cork production Wood production	Climate regulation	n.c.	Forest management	Trade-offs analysis
SORTIE-ND	Spain	No	L	99	Pine	Wood production Edible mushrooms production Water provisioning	Biodiversity Climate regulation Erosion control	n.c.	Forest management Climate change	Trade-offs and synergies analysis
LURE	France	Yes	L	200	Silver fir	Genetic resources	Biodiversity	n.c.	Forest management	No
-	Portugal	Yes	N	40	Different forest types	Water provisioning (water quality)	Erosion control	n.c.	Forest management	No
MIMOSE	Italy	Yes	R	20	Different forest types	Wood production	Climate regulation	n.c.	Forest management	Trade-offs analysis
TOOFES	Italy	Yes	MU	50-210	Silver fir	Wood production	Biodiversity Climate regulation	Recreational use	Forest management	Trade-offs analysis
-	Italy	Yes	MU	n.c.	Oak	Cork production Fodder production Water provisioning	Climate regulation	n.c.	Forest management	No
-	Spain	Yes	R	Different time period depending on ESs	Different forest types	Edible mushrooms production Water provisioning Wood production	Climate regulation Erosion control Flood protection Soil fertility Water regulation	Experiential use Landscape conservation Physical use Recreational use	Socioeconomic variables Climatic variables Biodiversity variables	Trade-offs and synergies analysis
EEFMD	Spain	Yes	R	90	Oak Pine	Water provisioning	Climate regulation	n.c.	Forest management Land abandonment	Trade-offs analysis
-	Tunisia	Yes	L	n.c.	Oak	Cork production Fodder production	Climate regulation Erosion control	n.c.	Forest management	No

(the full list is available in the review)

Forest Types

Cork oak woodlands (20% of the selected documents)

Pine stands (29% of the documents)

Oak forests (11% of the documents)

Broadleaved and coniferous forests (32% of the documents)

DISCUSSION

What have we learned from research in the last ten years?

Process-oriented research based on field experiments and research protocols is still at the beginning

Research based on spatially explicit data and modeling is showing substantial progress → growing ability in data processing and increasing availability of remote sensing data

Approaches based on one or few ES

- More flexibility in accounting for drivers of change
- Only partial view of the multifunctional role of forest ecosystems

Approaches based on a wide range of ES

- Rely on heterogeneous data
- Data combination more complex and less robust
- Uncertainty assessment

Selection of ES indicators is frequently problematic

- Some indicators are not considered because of the lack of information
- Some indicators used to assess a specific ES could be related with more than one ES
- Information regarding marketed services of forest ecosystems is still scarce

Forest management is one of the major drivers of change in multiple ES provision

- Spatial models provide ES maps that have many potential uses for decision-makers and planners
- Modeling complex forest dynamics is still a challenge for future research

Climate change is a growing global threat impacting on ES and human well-being

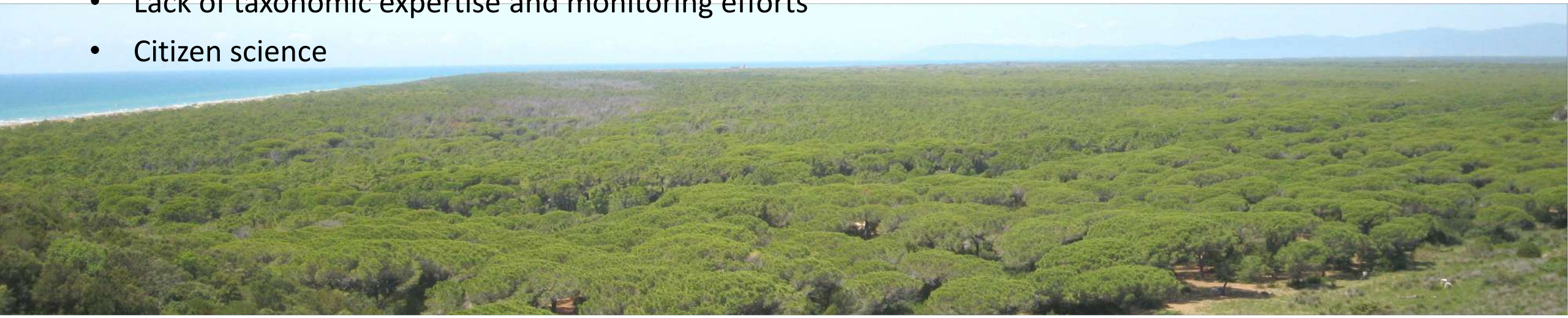
- A limited number of studies considered climate change as a driver in multiple ES provision

The impact of land abandonment on ES supply is still not fully understood

- The added effects of climate change and land abandonment can increase the risk of fire

Biodiversity loss is one of the biggest threats to Mediterranean ecosystems and their ES provision

- Clever forest management techniques in synergy with water, fire, livestock, bioeconomy management
- Lack of taxonomic expertise and monitoring efforts
- Citizen science



Synergy | Trade-off

References in brackets () = one ecosystem service is not directly investigated as such but appears in the discussion/conclusions. References in blue = modelling approaches, in black = field data and experimental trials, in red = literature reviews. Drivers: * thinning intensity/type/stand density; ** regeneration method; *** evenaged/uneven aged; + traditional management; + + traditional management vs abandonment; + + + coppice/high forest; °long rotations

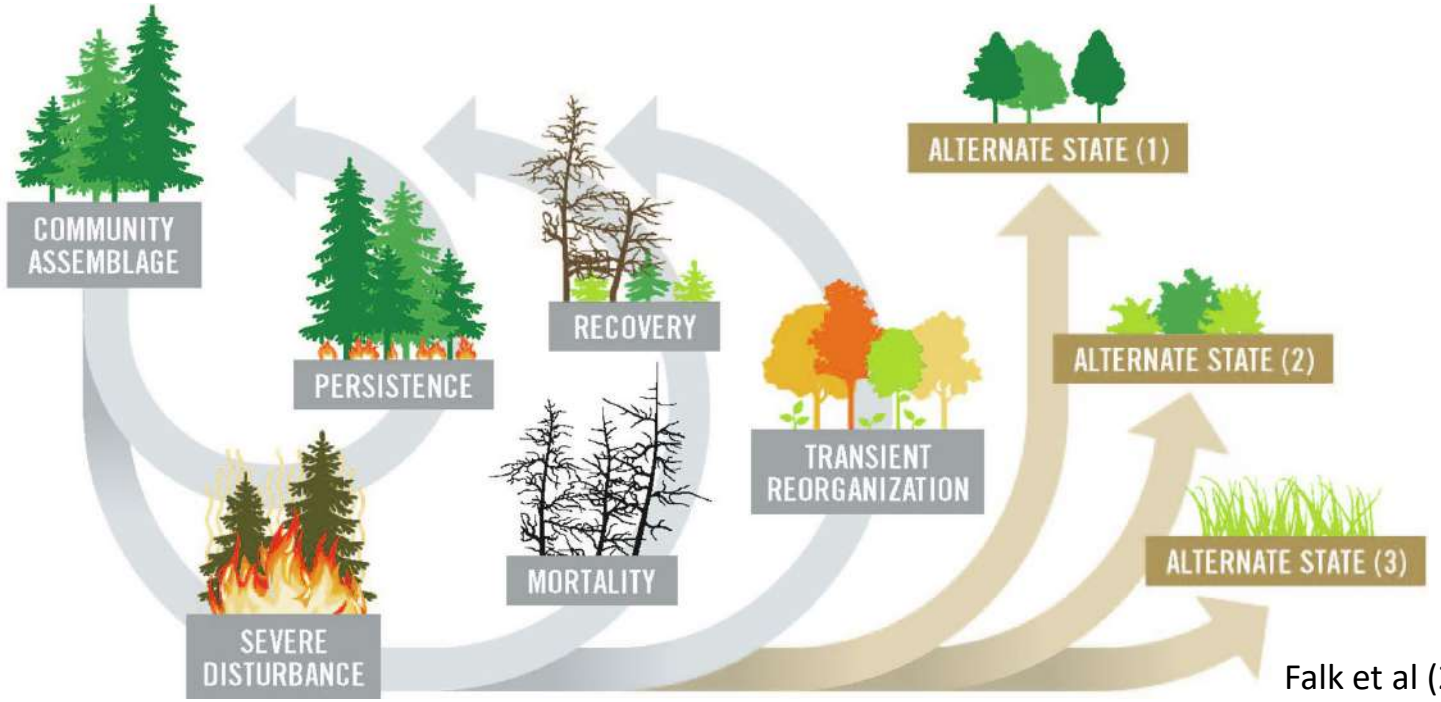
ES Syn → Trad ↓	Wood production	Cork production	Pine nuts	Edible mushrooms	Honey	Fresh water (Blue water)	Fodder	Carbon sequestration	Biodiversity	Water holding capacity	Provisioning services generic	Cultural services generic	Regulating services generic
Wood production	-			([63])* [88]+				[69]*	[69]* [71]** *** [70]				
Cork production	[77]*	-						[68]*	[25]+				
Pine nuts	[75]		-					[75]					
Edible mushrooms				-						[82]			
Honey	[81]°				-								
Fresh water (Blue water)		[68]*				-							
Fodder		[68]*					-						
Carbon sequestration	[75] [76]+++ [77]* [87]*** +++	[25]++				[83]++		-	[69]* [86]* +++ [88]+				
Biodiversity									-	[84]°			
Water holding capacity										-			
Provisioning services generic											-	[82]	
Cultural services generic											[82]	-	
Regulating services generic											[82]		-

How should we manage Mediterranean forests for the provisions of multiple ES?

"Think globally, act locally"

Global level

- Forest resilience and adaptive capacity in face of an uncertain future both in the environmental and socio-economic condition
- Consider stakeholder perceptions and expectations as drivers



Falk et al (2022)

Local level

- Two main constraints: water limitation and fire risk (climate change and land use changes)
- Need for forest management approaches that can promote
  - Synergy between fire prevention and water management both at the stand and landscape scale, especially where land abandonment is favouring a densification of forest stands
  - Synergies with biodiversity conservation and circular bioeconomy

Overall, management should increase heterogeneity and adaptability of simplified and often maladapted forest systems in the face of changing conditions

Thinning

- Potentially beneficial in terms of reducing the risk of fire hazard
- Increasing the ground water supply

But may as well lead to a certain loss of forest microclimate

- ✓ Optimal density for these combined benefits depends on the site, composition, and structure of each specific situation
- ✓ Research must focus on more in-depth knowledge of the ecohydrology of Mediterranean forests and their response to drought to ensure the best application of these management practices



CONCLUSIONS

Research is still mostly conceived following an ES-oriented approach

- Managing forests to create the structure and composition that best meet the desired output for humans
- Reduced ability of forest ecosystems to adapt to future unexpected changes

Consider Mediterranean forests as complex adaptive systems

- This implies an adaptable, flexible management and planning approach that sustains self-organization, adaptive capacity, and overall resilience of Mediterranean forests
- Promote functionally diverse forests and landscapes, which can act as insurance for the maintenance of key ecosystem functions such as, e.g., water conservation and regulation, carbon storage, resilience against disturbances (fire, drought), and ecosystem productivity



- Maintain traditional Mediterranean forest landscapes, not only for their cultural and historical importance, but also because they can contribute to keeping more options open for adaptation to future changes
- Human presence and involvement in Mediterranean forest landscapes is a safeguard against the negative consequences of rural abandonment
- Both research and policymakers should contribute to finding sustainable solutions for maintaining economically and environmentally viable livelihoods in these environments
- Research on managing Mediterranean forests for multiple functions and benefits requires moving toward a transdisciplinary approach, where extended peer communities are involved

Forest management addressing trade-offs and synergies between multiple ecosystem services