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ASSESSMENT OF ECOSYSTEM SERVICE VERIFICATION ACCORDING TO FSC STANDARDS IN THE MEDITERRANEAN COUNTRIES

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Abbreviations and acronyms

CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
CITES	Convention on International Trade in Endangered Species
CoC	Chain of Custody
ES	Ecosystem Services
ESCD	Ecosystem Service Certification Document
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FIAT	Forest Integrity Assessment Tool
FM	Forest Management
FMU	Forest Management Unit
ForCES	Forest Certification for Ecosystem Services
FSC	Forest Stewardship Council
GEF	Global Environment Facility
ha	Hectares
IGI	International Generic Indicators
IPBES	Intergovernmental Panel on Biodiversity and Ecosystem Services
MBI	Market Based Instrument
MEA	Millennium Ecosystem Assessment
NTFP	Non-Timber Forest Products
NWFP	Non-Wood Forest Products
PAN	Protected Areas Network
PES	Payment for Ecosystem Services
PEFC	Programme for the Endorsement of Forest Certification
SLIMF	Small and Low Intensity Managed Forest
SDG	Sustainable Development Goals
SFM	Sustainable Forest Management
TEEB	The Economics of Ecosystems and Biodiversity
ToC	Theory of Change
WWF	World Wildlife Fund

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Summary

Conserving and valuing nature resources, including forest ones is a pressing global development issue. Forest sustainability standards and certifications, like those promoted by the Forest Stewardship Council (FSC), foster responsible forest management. After the publication of the Millennium Ecosystem Assessment and under the increasing concerns due to the global climate and biodiversity crises, the ecosystem services (ES) concept has gained momentum within the research and policy arena. Within this, the FSC system has expanded its scope to encompass the intangible benefits associated with forest management. Although many ES are difficult to assess, quantify and certify due to their complexity, intangibility and (often) public good nature, appropriate market-based instruments, like voluntary certifications, can help internalize them. The integration of certification and ES verification within the FSC system represents an ongoing effort to address the complexities of quantifying and certifying the ES associated with forest management, thus creating opportunities to remunerate forest owners/managers providing them. The objective of this study is to investigate the state of the art of ES verification according to FSC. The FSC ES procedure within the Mediterranean region, i.e., in the five countries currently hosting forests that have been verified according to this procedure: Croatia, France, Italy, Spain and Portugal. This includes, among others, analyzing the types of verified ES, the number of certificates issued, the indicators and methodologies employed to assess positive impacts of forest management on ES over time. An assessment framework was developed for this. FSC certificate holder database was used to extract information from publicly available audit reports. Each public report from every certificate holder was analyzed to extract the information and feed the assessment framework. Both quantitative and qualitative analysis methodologies were used to analyze data collected and draw conclusions about ES verification in the Mediterranean region. Our study reveals that the Mediterranean region is witnessing a growing interest in ES verification within the FSC framework, albeit with significant variations among countries. Italy emerges as a pioneer, covering all five ES categories, emphasizing the importance of considering the broader ecosystem context in forest management decisions. However, the scope of ES verification remains limited in some countries, suggesting a potential lack of awareness, readiness among forest owners, or competing timber-focused priorities. Biodiversity and Carbon sequestration appear to be the most popular and desired ES, likely driven by specific policy initiatives and market opportunities. We also identified a significant diversity of methodologies employed in ES assessment within the FSC framework. Key findings include varying interest levels, diverse ES categories, and methodologies, with Italy leading in comprehensive verification. Economic implications remain underexplored, emphasizing the need for standardized assessments. We recommend periodic studies, close collaboration between stakeholders, and better procedural and methodological consistency. This research underscores the dynamic nature of ES verification and its potential to contribute to sustainability goals while identifying areas for further development.

1. Introduction

In the last decades, the conservation and valuing of nature - including forest resources - have emerged as prominent and urgent issues within the global development policy arena. Multiple policy tools have been developed to support sustainable forest management. Besides initiatives by governments and other international and national public bodies, voluntary initiatives have been launched by the private sector and civil society. Among these, sustainability standards and certification systems play a relevant role and have been largely adopted as market-based voluntary tools for sustainability in different fields and sectors, including forestry (Meijaard *et al*., 2014; Savilaakso and Guariguata, 2017).

Set up in 1993, the Forest Stewardship Council (FSC) was the first independent certification scheme developed for the forest sector, aiming to promote responsible forest management and ensure traceability of forest products along the supply chain (chain of custody) (Meijaard *et al*., 2014). While originally developed as a marketing tool for traditional forest products – mainly wood and wood-based ones – the FSC system has been increasingly paying attention to other, intangible, benefits associated with forest management. This occurred in the wake of the rising visibility and importance of ecosystem services (ES), which started gaining momentum within the international policies after the publication of the Millennium Ecosystem Assessment (MEA).

ES are crucial for human well-being and environmental sustainability and are defined as the benefits that ecosystems provide to people, thus contributing to different dimensions of human health and well-being (MEA, 2005). Although different ES classification systems exist, ES are often distinguished into three main categories (though naming might vary depending on the classification system), i.e. *provisioning services* such as biomass, building materials and drinking water; *regulating services* such as the regulation of soil quality, pest and disease control, regulation of baseline flows and extreme events; and *cultural services* i.e., physical and experiential interactions with natural abiotic components of the environment, including spiritual, symbolic and other interactions, such as recreational activities in nature, landscape beauty and environmental education (Young and Potschin-Young, 2018).

Due to their nature, ES, including many forest-based ES, are difficult to quantify both in biophysical and monetary terms, and mainly consist of externalities (Helbling, 2010). As such, many of them are not traded/exchanged on markets, which makes their management even more challenging (Meijaard *et al.*, 2014). To internalize ES within markets different kinds of tools have been proposed, with a special relevance gained, within literature and policies, by market-based instruments (MBI) (Pirard and Lapeyre, 2014). MBI include different tools, among which are voluntary price signals, i.e. "*schemes whereby producers send a signal to consumers that environmental impacts are positive (in relative terms) and consequently gain a premium on the market price*" (Pirard and Lapeyre, 2014): voluntary certification and labeling schemes fall within this group.

Forest certification serves as a voluntary market-based instrument that differs from traditional policies and laws, such as command-and-control (Jaung *et al.,* 2016c). Certification encompasses an external validation by a third party to confirm compliance with predefined standards for a procedure or item (Nussbaum and Simula, 2005). The issuance of an affirmative verification certificate can be associated with adhering to labeling requirements or products originating from certified procedures. The effective influence of a certification scheme on ES provision and its assistance in enabling consumers to identify sustainable products align with multiple objectives outlined in the United Nations' Sustainable Development Goals (SDG) (Jaung *et al.*, 2019). To ascertain the potential certification eligibility of specific ES, a comprehensive assessment is required, involving an evaluation of the inherent values of these services, the metrics employed to quantify them, and an analysis of both the demand and supply dynamics (Meijaard *et al.*, 2011).

Building on the idea that forest certification could be helpful to improve the conservation and valuing of ES (Paluš *et al.*, 2021) FSC started investigating potentialities to revise and enlarge its certification mechanisms and standards to include ES verification. Forest Certification for Ecosystem Services (ForCES) was a pilot ES certification project, funded by the Global Environment Facility (GEF) and the Ministry for Foreign Affairs of Finland and promoted by FSC, that helped to visualize real life situations of forest ES certification (Savilaakso and Guariguata, 2017). ES certification has emerged as a mechanism to promote the sustainable management of ecosystems while also enabling economic incentives for conservation efforts.

Besides fine-tuning technical aspects of certification and auditing, initiatives promoted within the ForCES project allowed the emergence of criticisms, bottlenecks and other specific issues that formed the basis for further discussion and standard setting processes. For example, the authorities from the pilot countries involved within ForCES raised questions about the ownership of ES (Savilaakso and Guariguata, 2017). At the same time, studies revealed possible ES to target and stakeholders' preferences about them. For example, a study by Jaung *et al.* (2016a) collecting opinions from different stakeholders revealed that existing certification schemes were mainly adaptable for the verification of ES like biodiversity conservation, carbon storage and the provision of non-timber forest, followed by the watershed protection services which had medium adaptability. On the other hand, Jaung *et al.* (2016b) found that agricultural products and ecotourism were much less suitable for certification. Other studies came to different conclusions, for example emphasizing that the only ES with a considerable market development potential was carbon fixation and storage (Meijaard *et al.*, 2014). Moreover, forest owners tend to prefer the forest ES certification which would come in bundles of benefits and costs (Jaung *et al.,* 2016c). Expanding into international markets would grant the opportunity to connect with a significant pool of potential customers, potentially leading to higher sales of approved forest-based ES services. The extent of market growth is greatly influenced by legal structures and specific physical characteristics of forest-based ES (Jaung *et al.,* 2016c).

The FSC has focused primarily on management of natural and planted forests to produce timber and fibers. The FSC Principles and Criteria, however, have relevance for the certification of other ES too. The FSC has also established 'Small and Low Intensity Managed Forest' standards (SLIMFs) to ease the certification process for smallholders and communities whose harvest scale or frequency puts less burden on the ecosystem (Meijaard *et al.*, 2011).

The FSC ES procedure (see section 2.1) stands as the inaugural approach enabling forest managers to delineate a range of services (including biodiversity, water, soil, carbon, and recreational services) they are maintaining or restoring. Moreover, organizations that are willing to engage in a payment for ecosystem services (PES) backed by the FSC trademarks find assurance due to FSC's esteemed global reputation. In a broader context, ES have captured growing corporate interest, encompassing both carbon-related and biodiversity perspectives. Recognizing the multifaceted benefits achievable solely through a high-quality project, companies are acknowledging that tree planting alone falls short in asserting effective restoration of forest ecosystems (Mansourian and Vallauri, 2020).

1.1 Background

Above-reported considerations about the importance of valuing forest-based ES are relevant for Mediterranean forests that are characterized by peculiar ecological as well as socio-economic features that are presented below.

1.1.1 The Mediterranean region

Mediterranean forest ecosystems are characterized by inherent multi-functionality – contributed by the richness in forest biodiversity, signifying their capacity to offer a diverse array of valuable goods and services to society. The multifunctional nature of Mediterranean forests demands integrated and adaptive management strategies that balance the often-conflicting demand of these diverse functions. The complexity of managing Mediterranean forests for these multiple functions gives rise to substantial challenges (Nocentini *et al.*, 2022). Box 1 provides an overview of the state of Mediterranean forests, including their conservation status and threats challenging their management.

Box 1: FAO and Plan Bleu: State of Mediterranean Forests 2018

The Mediterranean is a biodiversity hotspot. Despite the abundance of natural and cultural resources in the Mediterranean region, they continue to exist in a delicate state and are susceptible to various threats, mainly as a result of anthropogenic pressure and climate change. Mediterranean forests are multifunctional, providing, apart from wood products, a diverse range of Non Wood Forest Products (NWFP) like cork, mushrooms, truffles, pine seeds and honey and ES, which help raise the local economy. These actually account for sixty-five percent of the total economic value. To put into action, the policies that encourage the recognition of the total economic value, PES are highly efficient.

According to the data presented in the FAO's Global Forest Resources Assessment, the forests within the Mediterranean region held a carbon stock of 5,066 billion tons in 2015, which corresponds to 1.7 percent of the world's forest carbon. Among the countries, France, Turkey, Italy, and Spain collectively accounted for 67.6 percent of the total forest carbon stock within the Mediterranean region.

Integrating the diverse benefits of Mediterranean forests is key for their sustainability. Effective management and policies are needed to address undervaluation and uncertainties. Collaborative efforts among Mediterranean countries are crucial to recognize and manage these forests' ecological, social, and economic importance. A coordinated regional strategy is required, building on existing commitments and engagement. Harmonization and collective action will enhance the regional agenda.

Although Mediterranean forests can supply multiple valuable goods and services to society, prevailing silvicultural and forest planning methodologies have predominantly centered around wood-based production, with only limited exceptions (Palahi *et al.,* 2008). Wood production stands out as a key goal in managing Mediterranean forests; however, over the past few years, there has been a noticeable change in attention towards examining how forest management influences various dimensions of forest ecosystems (Nocentini *et al.*, 2022). Numerous Mediterranean forests offer a range of products beyond just timber, including non-wood forest products like mushrooms (Karavani *et al.,* 2018; Olano *et al.*, 2020), medicinal plants, and aromatic herbs (Lamrani-Alaoui and Hassikou, 2018). These resources frequently hold economic significance that surpasses the value of the wood products extracted from these forests. Apart from providing goods and services with a well-defined market - such as most of the provisioning services - Mediterranean forests also provide a vast range of ES that are public goods and externalities, which do not have a market nor a clearly defined economic dimension (Masiero *et al.*, 2016).

Over an extended duration marked by human-driven alterations, there has been a substantial decrease in the extent of forested regions within the Mediterranean area (Blondel, 2006). However, while in Northern Mediterranean forests are experiencing expansion mainly attributed to the abandonment of marginal areas and agricultural practices, in the Southern Mediterranean anthropogenic pressures combined with ecological conditions have led to an uneven distribution of forested areas and in some cases, such as in Algeria, also to their decrease over decades (Masiero *et al.*, 2016). Specifically, 73% of the total forested area lies within the northern region, with a significant portion of 58% concentrated in the northwest. In comparison, the eastern and southern Mediterranean regions account for only 16% and 11% of the forested area, respectively (FAO and Plan Bleu, 2013).

There are multiple contributing factors to the depletion of forest resources in the Mediterranean. Within the Southern Mediterranean countries (Algeria, Egypt, Libya, Morocco, Tunisia), the ecosystems inherently possess fragility and susceptibility to the prevailing environmental and climatic conditions. Consequently, they are confronted with an elevated vulnerability due to the escalating human pressures they face as well as due to the effects of climate change. These pressures encompass activities such as land clearance and cultivation in marginal zones, coupled with the overexploitation of firewood and overgrazing. Furthermore, instances of illegal harvesting have been reported in countries including Morocco, Turkey (Gunes and Elvan, 2005), Albania, and Bosnia and Herzegovina (Bouriaud, 2005), particularly in the Northeastern part of the Mediterranean. Interestingly, this concern does not appear to be significant within the Northwestern Mediterranean context (Masiero *et al.*, 2016).

Over the last decade, there has been an increasing focus in research on understanding how forest management influences the supply of various ES in Mediterranean forests (Aznar-Sánchez *et al.*, 2018; Nocentini *et al.*, 2022; Kefalas *et al.*, 2023).

Wood production is an important aspect of Mediterranean forests, but there is increasing recognition of the need to manage these forests for multiple ES. Through a comparative analysis of scenarios involving carbon sequestration and timber harvesting, research findings by Enríquez-de-Salamanca (2021) have shed light on a crucial insight within Mediterranean forests. This study revealed that the most effective approach to enhancing profitability in this context is by prioritizing the maximization of carbon sequestration.

Masiero *et al.* (2016) assessed the value of different goods and services like timber, firewood, NWFP, and carbon sequestration. Timber and firewood held the highest value at 64% and 24% respectively, while NWFP and carbon sequestration had 9% and 2%. Yet, caution is needed due to limited NWFP data, leading to potential underestimation of its value (FAO and Plan Bleu, 2018).

1.2 Objectives

In this section research objectives are presented, dividing them into main (or general) and specific objectives.

1.2.1 Main Objective

Analyzing the state of art of the ES verification against FSC standards in the Mediterranean countries.

1.2.2 Specific Objectives

- To describe the current state of FSC ES certification/verification in Mediterranean countries.
- To analyze which ES are targeted.
- To analyze methodologies used to verify positive forest management impacts in terms of ES.
- To analyze economic implications of the ES verification.
- To inform potential future developments in the field of ES verification in Mediterranean countries.

1.3 Structure of the thesis

Chapter 1 sets out the introduction for the study and the background (section 1.1) on the Mediterranean region. The research objectives are then stated in the section 1.2.

Chapter 2 introduces the relevant literature in the study. In section 2.1, the literature about the five ES within the scope of ES verification according to FSC standards and Procedure is generally summarized. Special attention is paid to FSC ES Procedure in section 2.3.

Chapter 3 describes the research methodology. After a brief description of the study area in the first section, the next section describes the data collection method. Furthermore, data analysis and elaboration methods are explained.

Details of the results are presented in Chapter 4, then the discussions of the empirical findings, as well as the limitations of the study and the suggestions for future research are presented in Chapter 5.

Finally, the conclusions drawn from the research results and their analysis are found in Chapter 6.

2. Theoretical background

This chapter sets the theoretical background of the research deepening key concepts and aspects that are of paramount importance for the thesis.

2.1 Ecosystem services

Extensive research has been conducted in the field of ES since the term emerged. ES can be defined as the conditions and processes through which natural ecosystems and the associated species sustain and fulfil human life (Daily, 1997). These are the benefits obtained by people from the biodiversity itself. The prominence of the ES concept can be attributed to the MEA in 2005; The Economics of Ecosystems and Biodiversity (TEEB) Synthesis Report (Sukhdev *et al*., 2010); and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) (Ingram *et al*., 2012).

The MEA provided the scientific groundwork for promoting the protection and sustainable utilization of ecosystems and their benefits for human well-being. The ES gained through biodiversity includes provisioning services like fuel, water; regulating services like regulation of climate, waste; cultural services like recreation, aesthetic; and supporting services such as formation of soil, nutrient cycling (MEA, 2005). The Common International Classification of Ecosystem Services (CICES) has categorized ES into three services: Provisioning, Regulating and Cultural services (Haines-Young and Potschin, 2012).

The topic of ES became even more important in the last years, as several studies showed that multiple drivers are putting ES services at risk at the global scale (Millennium Ecosystem Assessment, 2005; Schröter *et al*., 2005). This has led to an increase of studies on how to secure the provision of ES that human populations rely on (Nicholson *et al*., 2009).

Among multiple existing ES, a group of five is deepened below: these are the five ES groups which are addressed by the FSC procedure for ES (see 2.2 and 2.3.1 below for more details).

2.1.1 Biodiversity

The Convention on Biological Diversity (CBD) defines biodiversity as: '*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*' (Mace *et al*., 2012).

Biodiversity is a fundamental component of ecosystems ensuring ecological functions and supporting the supply of ES, thus contributing to our planet's functionality and supporting human well-being. Biodiversity plays a critical role in maintaining ecological balance, providing resources, and enhancing resilience against environmental changes. However, in recent years, the rapid loss of biodiversity has raised concerns about the stability of ecosystems and the services they provide (Skogen *et al*., 2018; Liu *et al*., 2023; May, 2023).

Biodiversity's role within ecosystem assessments varies widely. Sometimes, the terms "biodiversity" and "ecosystem services" are used interchangeably, suggesting their close relationship. This implies that effective management of ES ensures biodiversity preservation and vice versa. Biodiversity is regarded as an intrinsic ES, with the preservation of wild species - especially those of conservation significance - becoming a primary objective in ecosystem management. Furthermore, biodiversity fulfills diverse roles in delivering ES: serving as a regulator of ecosystem processes, functioning as an independent service, and holding intrinsic value as a valuable asset (Mace *et al*., 2012). However, it is crucial to acknowledge that the concepts of ES approaches and biodiversity conservation aren't synonymous areas of thinking or application, and their compatibility with each other might not be constant (Naidoo *et al*., 2008).

Various strategies aimed at conserving biodiversity have been put into action, ranging from initiatives at the local and regional levels to worldwide inter-governmental policies like the Convention on Biological Diversity (CBD) and the Convention on International Trade in Endangered Species (CITES) (Ingram *et. al*., 2012) among others. There are also other frameworks at the regional scale, e.g., at the European level the “EU Biodiversity Strategy” (European Commission, 2011), and even at the national level, e.g. the Italian National Biodiversity Strategy (*Strategia Nazionale per la Biodiversità*) (Andreella *et al*., 2010). The Protected Areas Network (PAN) plays a crucial role in tackling global biodiversity conservation challenges (Bruner *et al*., 2001). This includes a broad range of protected areas, subjected to different degrees of protection: according to Protected Planet, (2023); protected areas and other effective area-based conservation measures cover about 17% of the total terrestrial lands and inland waters.

However, protected areas do not represent the only approach for biodiversity conservation that may also occur within managed areas as well as by using market mechanisms to value the services it provides. There has been a trend of biodiversity offsets and compensatory mitigation programmes to help regulate reduce developmental impacts on biodiversity (Madsen *et al*., 2010). Globally, there are 7 voluntary offsets projects and 205 compensatory mitigation projects till date (Forest Trends, 2023).

2.1.2 Carbon

Carbon sequestration involves capturing and storing atmospheric Carbon dioxide (CO_2) over the long term, aiming to mitigate global warming and prevent the adverse effects of climate change (Dhanwantri *et al*., 2014). It is essentially the accumulation of Carbon dioxide removed from the atmosphere and stored within an ecosystem over a specific period (Sierra *et al*., 2021).

As Carbon-based beings, humans rely entirely on a Carbon-based biosphere for their sustenance. Given the pivotal role of the Carbon cycle in human-environment interactions, it is unsurprising that the Carbon cycle directly impacts many of the ES outlined by the MEA and indirectly influences all of them.

The global Carbon cycle directly plays a role in numerous ES and indirectly influences them all. It forms the foundation for supporting services, such as nutrient cycling, soil creation, and biological primary production. Terrestrial Carbon compound production in biomass is essential for provisioning services, which supply food, fiber, and bioenergy through agriculture and forestry. Similarly, aquatic Carbon compound production sustains all fisheries. The Earth's natural cycles, encompassing Carbon, water, and nutrients, collectively support cultural services (including aesthetic, spiritual, educational, and recreational aspects) as well as regulating services like flood control, disease management, and water purification (Raupach, 2011). The global Carbon cycle comprises the interconnected reservoirs of Carbon within the Earth's system, along with the Carbon movements that link these reservoirs. Primary Carbon reservoirs are found on land (including biomass and soils), in the ocean, in the form of atmospheric carbon dioxide, and within fossil fuel deposits (Sabine *et al*., 2004).

Ecosystems help control the levels of Carbon in the atmosphere by the way living things interact with it. This means that ecosystems also play a role in maintaining Earth's climate because temperature and the amount of Carbon in the air are linked over long periods of time (Chapin *et al*., 2002). When living organisms help turn carbon dioxide into long-lasting, non-active materials, it's called "biosequestration" (Graber *et al*., 2008). Biosequestration is a process that temporarily takes Carbon out of its active cycle. More broadly, carbon sequestration is about capturing substances that contain Carbon, especially carbon dioxide, and storing them in a different place where they will stay for a longer time (IPCC, 2007).

So, when there's a rise in the amount of Carbon stored in a specific part of an ecosystem, it can be described as sequestration because the Carbon is kept in that particular reservoir and kept apart from the rest of the ecosystem (Powlson *et al*., 2011). The goods and services that ecosystems offer to society and sustain nature's functions are intimately linked to the flow of Carbon within ecosystems. Thus, as Carbon sequestration influences the movement of Carbon into and within ecosystems, it could emerge as a crucial element of ES. (Graber *et al*., 2008). ES benefit greatly from Carbon storage in both the oceans and terrestrial ecosystems, signifying their paramount significance (Raupach, 2011).

A substantial portion of the Earth's terrestrial Carbon sink is believed to be situated in the northern hemisphere, notably within forests that are in the process of recovering from previous disruptions (Stephens *et al*., 2007; Raupach, 2011). From 1990 to 2007, the entire terrestrial Carbon sink can be attributed to the Carbon absorption of well-established forests worldwide (Pan *et al*., 2011). Consequently, forests play a pivotal role as Carbon storage systems on land. Forests encompass approximately 30% of the Earth's ice-free land area, and roughly 55% of this land is actively managed for purposes such as timber production and the extraction of various ES (FAO, 2010). Forest management, when done thoughtfully, has the potential to boost Carbon sequestration (Fahey *et al*., 2010). Effective forest management can enlarge Carbon reservoirs by elevating production rates, decreasing the rate of decomposition losses, minimizing the export of materials from the forest stand, and prolonging the time between disturbances or management interventions (Birdsey *et al*., 2007).

Forests have a significant impact on the terrestrial Carbon cycle and are vital for our endeavors to regulate atmospheric Carbon levels. Consequently, forestry plays a crucial role in both voluntary Carbon markets and government initiatives aimed at addressing climate change. As a result, Carbon sequestration within forests is receiving significant focus as an ES. Global inventory data reveal the distribution of Carbon sources and sinks, underscoring the role of temperate and boreal forests as present-day Carbon sinks, as well as the substantial fluxes (both sources and sinks) associated with tropical forests. Currently, forests absorb approximately 27% of the yearly carbon dioxide emissions stemming from fossil fuels and offer a substantial reduction in carbon dioxide emissions (Le Quéré *et al*., 2009). In addition to various other ES, forests contribute to the sequestration of carbon dioxide on top (Shvidenko *et al*., 2007).

Carbon in organic form within forests is stored in the biomass of both living and dead trees, within the forest floor, and in the mineral soil. Among various vegetation types, forests stand out as having a biomass Carbon pool that is notably similar in size to that of the soil Carbon pool. The largest Carbon pool is primarily observed in tropical forests, where deforestation dynamics play a prominent role, and where the available data on carbon stocks may be incomplete or lacking in some instances (Dixon *et al*., 1994; Bonan, 2008).

2.1.3 Soil

Soil is a key component of ecosystems and influences many ecosystem processes across landscapes. It is the cornerstone of terrestrial ecosystems, promoting plant development and providing habitat for a variety of organisms. (Barrios, 2007; Brevik *et al*., 2015). Furthermore, soil provides and regulates ES, and due to its paramount role as the primary foundation for plants, raw materials, and food production, it holds significant value in human life as well (Adhikari and Hartemink, 2016; Brevik *et al*., 2016).

Soils and their functions play a critical role in ensuring the effective provision of various ES. The value of these soil-based ES is determined by both their capacity to provide essential resources and how we manage and utilize them. In the ES community, soils are often described as "natural capital stocks" to assess and quantify their contributions to ES (e.g., Robinson *et al*., 2009; Robinson *et al*., 2013; Hewitt *et al*., 2015). The ability of soils to supply ES is primarily influenced by their functions, with each specific soil function contributing to the overall provision of ES (Bouma, 2014).

The European Commission introduced a soil protection strategy in 2006, representing a substantial initiative that raised awareness about soil functions among the general public and brought it to the forefront of the political agenda. It defined seven crucial soil functions, namely: (i) production of food and biomass, (ii) storage, filtering and transformation of compounds, (iii) habitats for living creatures and gene pools, (iv) the physical and cultural environment, (v) source of raw materials, (vi) carbon pool, and (vii) archive of geological and archaeological heritage (Greiner *et al*., 2017).

Soil conservation activities are intrinsically tied to the safeguarding of ES, as they exert a direct impact on the well-being and operational efficiency of ecosystems. Practices like agroforestry and precision agriculture, for instance, actively contribute to the preservation of vital aspects of soil health, including its structure, nutrient cycling, and carbon sequestration – all of which constitute integral elements of ES (Gebbers and Adamchuk, 2010). These approaches play a crucial role in ensuring the sustained provision of services such as water purification and climate regulation by mitigating soil erosion and preventing degradation (Montgomery, 2007).

2.1.4 Water

Water is an essential resource for human life. To address declines and deterioration of water resources, several initiatives have been adopted worldwide (Seijger *et al.*, 2021). The EU, for example, has adopted the Water Framework Directive to protect its water resources, regulating individual pollutants and setting regulatory standards (European Commission, 2023). Other initiatives include direct investments for more sustainable land use practices to improve ES provision (Ouyang *et al.*, 2016). Bennett and Ruef (2016) estimated that, in 2015, nearly $25 billion were spent in green infrastructures for the conservation of watershed services globally.

A healthy landscape contributes to the provision of various water-related ES, and this is directly linked to the conservation of forest ecosystems. According to Bennett *et al.* (2017), these are some of the services provided by watersheds, and the roles that forests play in their supply:

a) Water for consumptive and non-consumptive human use: forests can ensure clean water for drinking, agriculture (irrigation), hydropower generation, navigation, aquaculture and other uses.
b) Aquatic productivity: aquatic habitats and species, which are an important source of food and medicine and may have important ecological value.
c) Flow regulation and storm and flood buffering: the absorption power of forests, wetlands, grasslands, and mangroves helps recharging groundwater supplies, reducing flood risk, and maintaining stream flows during dry period.
d) Filtration of nutrients and contaminants: ecosystems, including forests and wetlands, filter pollutants, improving water quality by restricting sediments and pollutants to reach water resources.
e) Erosion control and soil fertility: forests and grasslands help stabilize soils, preventing erosion and landslides; natural areas also host critical nutrient cycling, maintaining soil health and productivity.

The Mediterranean region is particularly vulnerable to the decline of water-linked ES due to global changes (Schröter *et al.*, 2005; Schneider *et al.*, 2013). These risks highlight the need for sustainable management of water resources in the Mediterranean, including the development of effective policies and instruments to maintain ES provision, such as water prizing mechanisms (García-Ruiz *et al.*, 2011).

Forest management in one of the factors contributing to the provision of water-liked ES. Water supply can increase or decrease in forested landscapes through time depending on the practices adopted and management history (Perry *et al.*, 1999; Ford *et al.*, 2011). Furthermore, forestry activities such as cultivation and site preparation, fertilization, and harvesting, impact water quality

(Zanchi *et al.*, 2021; Shah *et al.*, 2022). The adoption of single-species or mixed standards can also influence water dynamics (Barrientos and Iroumé, 2018). Therefore, it is important to acknowledge the effect of forest management on ES provision, identifying and promoting the best practices for maintaining them.

Forest certification might play a significant role in securing the provision of water-related ES. Forest certification can support ES provision by promoting water-friendly practices in certified forests, such as special management regimes for riparian zones, and measures for soil conservation and prevention of erosion, which affect water quality (Stupak *et al.*, 2011; McDermott *et al.*, 2018; Gutierrez Garzon *et al.*, 2020). For example, Dias *et al.* (2015) found that forest certification has a positive effect on the ecological condition of stream ecosystems in a Mediterranean area, since certified sites presented more continuous, dense, and diverse riparian vegetation when compared to non-certified sites.

Forest certification can also work as a channel for reinforcing compliance with water regulations (Keskitalo and Pettersson, 2012). Furthermore, ES users could benefit from certification frameworks when certification schemes disclosure the impact, verified by a third party, that environmentally sound forest management practices have on ES provision (e.g., water quality, flood regulation) (Jaung *et al.*, 2016d; Jaung *et al.*, 2018; Paluš *et al.*, 2021).

Nevertheless, management targets and decisions should also consider the potential trade-offs between ES. For example, while the increase of forest cover can lead to a higher carbon sequestration and improved water quality, it can also have negative consequences on the water supply, due to the increased water demand by trees (Brogna *et al.*, 2017; Filoso *et al.*, 2017; Hoek van Dijke *et al.*, 2022). This is an even greater concern in the Mediterranean, which experiences long periods of drought (Ovando *et al.*, 2019). Therefore, there are constraints in developing frameworks for improving ES provision across multiple domains.

2.1.5 Recreation

Recreation is one of the many nonmaterial contributions of nature to people (Díaz *et al*., 2018). Forests are a key element of recreation provision, which are commonly associated with attractive landscapes (Abraham *et al*., 2010). The capacity of ecosystems to provide this service is influenced by socio-economic characteristics. With projections for forest areas to increase in Europe, demand and opportunities for recreation activities linked to this land cover (e.g., hiking, cycling, hunting, camping) are likely to increase as well (Metzger *et al*., 2006).

Contact with forest ecosystems can contribute significantly to human well-being (Doimo *et al*., 2020). Therefore, recreation represents a high value for people, which can be translated into monetary terms. However, there is not a formal market established for this ES, which could be a factor contributing to the vulnerability of natural ecosystems (Caboun *et al*., 2014; Matthew *et al*., 2022).

Previous studies have shown that forest disturbance affects recreation values of forests. For instance, impacts of invasive species can lead to a loss in the capacity of forests for providing non-market ES, such as outdoor recreation (Holmes *et al*., 2009). Furthermore, forest disturbances such as drought, fires, and bark beetle can deeply damage forest ecosystems and limit their capacity of providing recreation services, as well as others such as climate regulation (Sánchez *et al*., 2021).

Forest management is another factor affecting the potential of forests to provide recreation (Edwards *et al*., 2012). In Northern Europe, people preferred forest stands with higher tree size and advanced stand development. Moreover, large clear cuts and forestry operations were little appreciated (Gundersen and Frivold, 2008). Therefore, there is a potential trade-off between wood provision and recreation (Eggers *et al*., 2018).

In this context, a significant concern nowadays would be how to properly manage and conserve forests to maintain their capacity to provide recreation services. In fact, specific management practices can be applied to potentialize recreation values of forests (Horal *et al*., 2021). Therefore, it is important to develop policies and instruments that incorporate recreation values in natural resources management for conserving forests, as well as identify best management practices and their impacts on recreation provision.

2.2 Forest certification according to FSC standards

FSC certification aims to promote sustainable forest management (SFM), primarily encompassing social and ecological concerns (Pezdevšek Malovrh *et al.*, 2019). Certified organizations (certificate holders) perceive certification as playing a more prominent role in guaranteeing specific ES which pertains to the availability of woody biomass and water resources (Paluš *et al.*, 2021). Compared to the non-certified forests, FSC-certified forests are associated with better forest services' management, e.g., watershed conditions (Dias *et al.*, 2015). Due to standard implementation and checking, certification also implies improvements in the certified organization/company managing certified forests.

The FSC-certified forest area has been expanding since 2010, resulting also in improvements in the organizations/companies in charge of managing certified forests. A significant portion of the FSC certified forest area is situated in Europe and North America (FSC, 2023a).

According to Jaung *et al*. (2016a), several studies has emphasized the connection between FSC forest certification, and the services provided by ecosystem such as non-timber forest products soil protection, and ecotourism. However, the differences arise among the various studies due to the use of different criteria, scales, economic contexts, and expectations. Because of these differences it is complicated to compare the results of different studies and at the same time to expand the FSC system to encompass forest ES.

A number of studies identify the linkage of FSC forest certification to biodiversity conservation, non-timber forestry products (NTFPs), water quality or quantity management, soil protection, and ecotourism. Among these, discrepancies emerge due to the use or consideration of different criteria (e.g., compliance to standards vs. on-the-ground impacts), different spatial scales (e.g., standards applicable internationally vs. at the national level), different economic contexts (developing vs. developed countries), and different expectations (e.g., those of biologists vs. sociologists). These discrepancies not only make it difficult to compare results from one study to the next; they are also indicative of a degree of complexity in expanding the FSC system to forest ES.

2.2.1 Ecosystem service verification and certification

ES certification is the process of verifying and certifying the positive impacts of responsible forest management on ES. FSC provides certification programs for forest managers of all types (i.e., private and public, large and small, etc.) to qualify for ES claims (FSC, 2022a). Only forests or woodlands that are covered by FSC forest management certification are eligible for ES impact verification using the FSC ES procedure (FSC, 2022b). Certification of the management of forests and their services is one possible approach to ensure that standards in PES systems are maintained, and that payments are made for the delivery of the services (Meijaard *et al*., 2011). The FSC ES Procedure allows forest owners and managers to identify, measure, and third-party verify the positive impacts of responsible forest management on five categories of ES, including carbon sequestration and storage, biodiversity conservation, watershed services, soil conservation, and recreational services (ETIFOR, 2022b). The utilization and efficacy of voluntary market-based tools, such as certification, can have a beneficial impact on the forest ES provision (Paluš *et al*., 2021).

2.3 Theoretical approach

FSC introduced the Ecosystem Services Procedure in 2018 to incentivize ecosystem protection through certification. This procedure includes tools for demonstrating impacts on ES. It complements FSC's existing safeguard model (FSC certification) with a quality model (to quantify the ES) for emerging markets (Ningsih *et al.*, 2020). FSC-certified forest managers can use this to showcase impacts and make verified ES Claims. This effort aligns with FSC's strategy to enhance forest value and brand. FSC Ecosystem Services Procedure is the first tool from FSC for enabling FSC certificate holders to display how their forest management actions impacts ES (Ningsih *et al.*, 2020).

2.3.1 FSC Ecosystem Services Procedure

FSC has made a huge commitment for the verification of ES by developing and publishing the Ecosystem Services Procedure (Paluš *et al.*, 2021). The document 'Ecosystem Services Procedure: Impact Demonstration and Market Tools' (FSC-PRO-30-006 V1-0 EN; FSC, 2018) is the procedure that pioneered ES introduction into forest management certification. This procedure provides a framework for verifying impacts and approving FSC ES claims that can be used by forest managers to access ES markets and/or other benefits. It specified the standards for FSC-certified forest managers to demonstrate the impact of their actions on the maintenance, restoration, or improvement of ES in a credible manner.

The procedure refers to five ES (Table 1) and FSC-accredited certification bodies assess adherence with the procedure while conducting a forest management evaluation (Figure 1). ES claims that have been verified or validated are recorded in the Ecosystem Services Certification Document (ESCD), which is published in the FSC public certificate database, thus ensuring information disclosure and transparency. Verifiable impacts create ES claims, which can be exploited for marketing (FSC-PRO-30-006 V1- 2 EN). It is only applicable to FSC-certified forests (Vallauri *et al.*, 2022).

Table 1: Five categories of ecosystem services verifiable according to the FSC ecosystem service procedure (FSC, 2018) (FSC-GUI-30-006 V1-2 EN)

ES1		**Biodiversity conservation**
ES2		**Carbon sequestration and storage**
ES3		**Watershed services**
ES4		**Soil conservation**
ES5		**Recreational services**

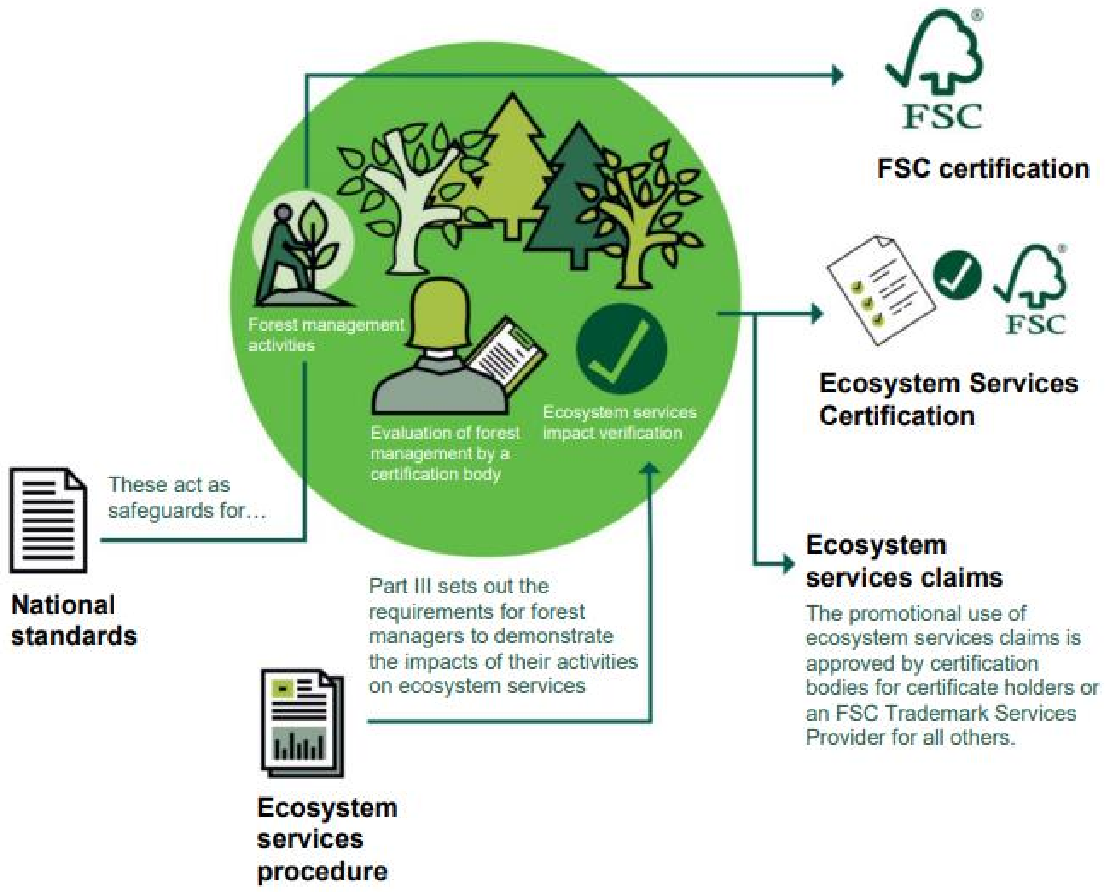

Figure 1: The fit of the Ecosystem Services Procedure within the existing FSC assurance system (FSC, 2021)

The FSC ES Procedure consists of five parts for the development of FSC ES claims. The first part gives the information about the general requirements that the organization needs to comply for this procedure. The second part reports the additional management requirements for impacts related to each of the five ES within the scope of the procedure. Part three outlines the procedures that the organization must implement to demonstrate the impact of its management efforts on ES. This includes the seven steps required to demonstrate the ES impacts. Part four defines the trademark and chain of custody requirements for FSC ES claims. The fifth part covers the extra requirements that certifying bodies must meet when evaluating organizations that use this approach.

2.3.2 Seven steps for the demonstration of the ecosystem service impacts

In this section the seven steps for the verification of positive forest management impacts on ES (Figure 2) are described.

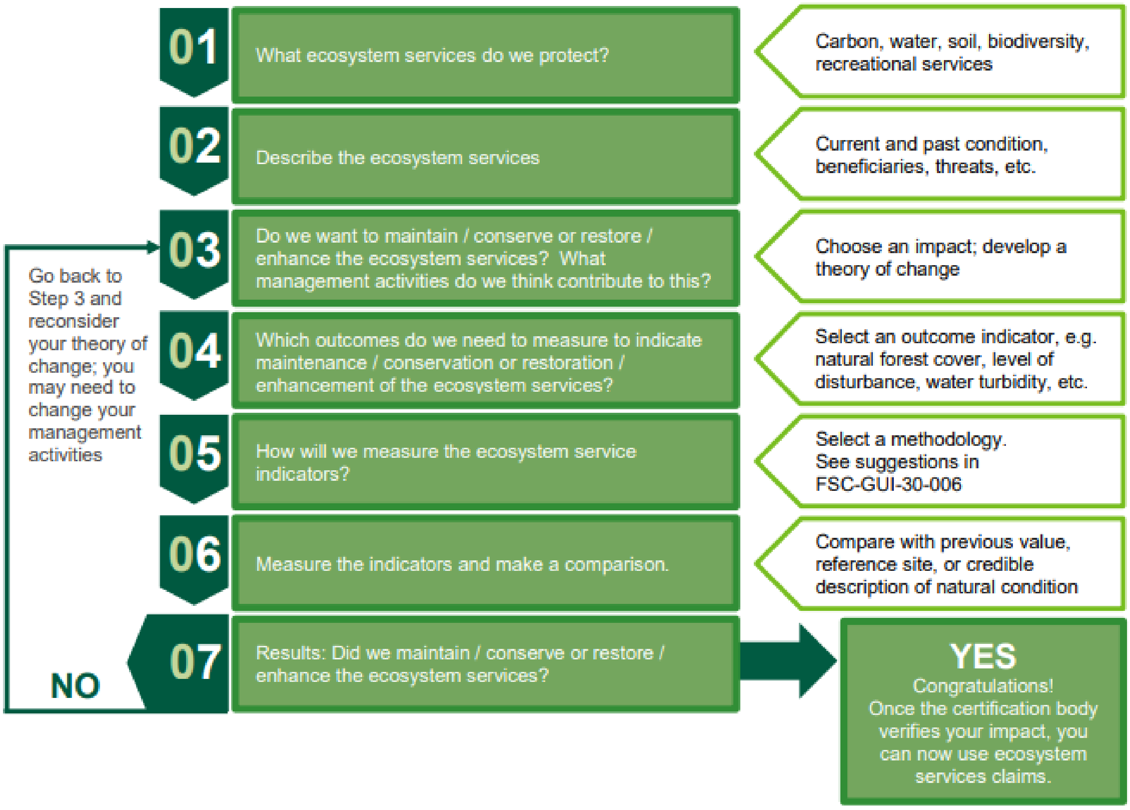

Figure 2: The seven steps required to demonstrate ecosystem services impacts according to the FSC Procedure (FSC, 2021)

<u>Step 1: Declaration of the ecosystem service(s)</u>

In the initial step of the process, the organization is required to clearly state the specific ES (one to five among the ES addressed by the Procedure) that are subject to proposed impacts. The ES should be among the five proposed by FSC. It should also briefly detail its legal rights to manage, utilize, and receive benefits for these services. The organization must outline its management goals for the chosen ES, which may include objectives from its management plan.

Step 2: Description of the ecosystem service(s)

For each declared ES, the organization should describe the present and the past conditions of the ES (e.g., total carbon stock, habitat conservation status, total length of hike trails etc.) and identify both internal and external factors within the management area that contribute to the ES. The individuals or groups benefiting from the ES should also be identified in this step.

Step 3: Theory of change: Linking management activities to impacts

In this step, the organization needs to propose one or multiple impacts for every identified ES, as specified in Annex B to the Procedure. For each of these selected impacts, the organization is required to develop a theory of change (ToC) that outlines the connection between the management activities that contribute to it and the proposed impacts.

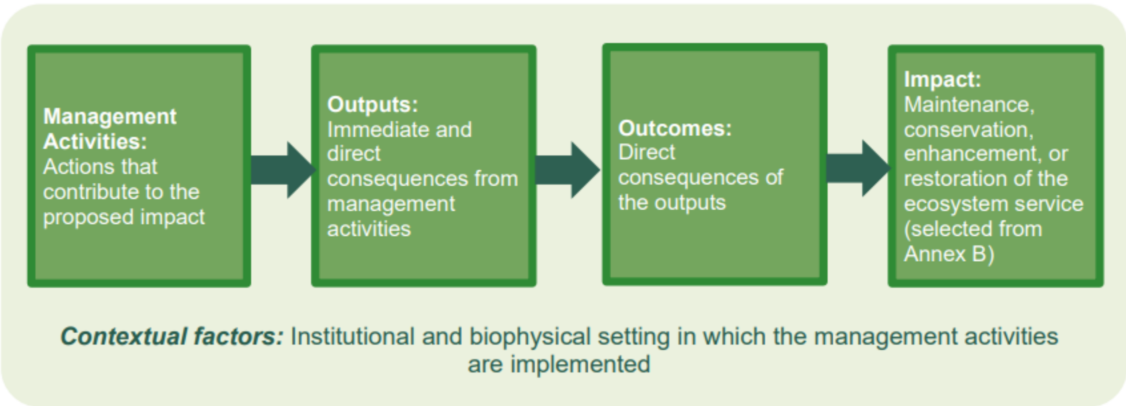

Figure 3: Basic structure of a theory of change (FSC, 2021)

The ToC plays a crucial role in achieving proposed impacts. When developing a ToC, the organization needs to specify the management activities contributing to these impacts, including those for mitigating threats. Additionally, the resulting outputs from these activities and the subsequent outcomes they lead to must be specified. Any new management activities contributing to the impact should also be acknowledged alongside any contextual factors influencing the outcomes. A ToC shall be developed according to a structure and rationale similar to the one reported in Figure 4.

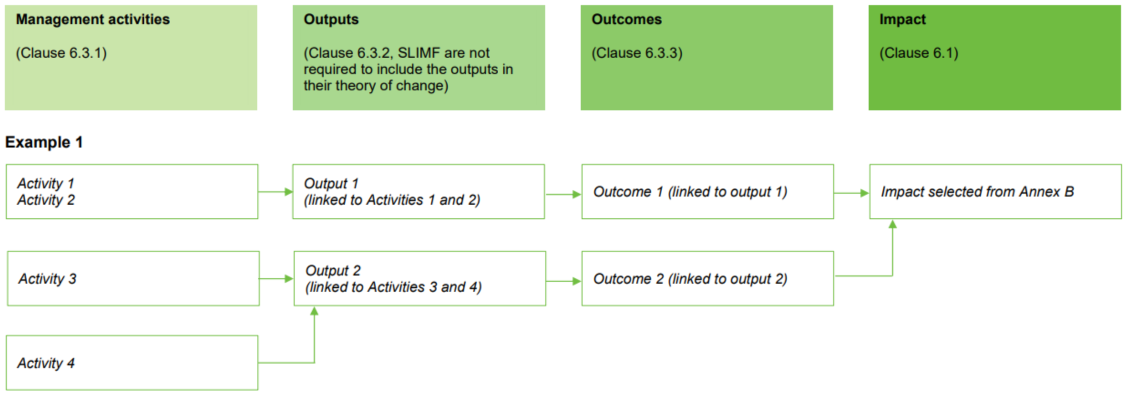

Figure 4: Structure and rationale of a ToC (FSC, 2021)

Step 4: Selection of outcome indicators

For each impact proposed, there shall be one or more indicators selected. These outcome indicators must be consistent with outcomes expected from the ToC and will be selected from Annex B of the Procedure or based on evidence of relevance to the outcomes. The organization must set a verifiable target that represents a desired future value for each outcome indicator selected. Also, the choice for the verifiable target must be justified.

Step 5: Methods

This step reports the methods used to measure the outcome indicators. The organization can either choose any methodology from the document FSC-GUI-30-006 Guidance for Demonstrating Ecosystem Services Impacts or use another methodology following the criteria given. These selected methodologies are to be described in clear terms to allow for evaluation. In this step, the organization shall also describe methods and sources used for the collection and analysis of data.

Step 6: Measurement and comparison of the value of outcome indicator(s)

This step entails measuring the current value of each of the selected outcome indicators. These values are then to be compared with the specified value according to the specifications given in Annex B to the Procedure (Comparison column). This must be done at least every five years unless the methodology requires more frequent measurements.

Step 7: Statement of results

The organization must provide evidence that the present value of the selected outcome indicators fulfils the necessary result provided in the column 'necessary result' of the Annex B to the Procedure for each proposed impact. They must also describe the likelihood of achieving the proposed verifiable targets in the future contributes by the results.

When the outcomes of the assessment demonstrate positive enhancements, restoration, or maintenance of targeted ES, the certification body checks and validates the impact, thereby enabling the organization to substantiate its claims regarding ES. However, in instances where positive results are not evident, the organization is required to revisit step 3 and re-evaluate their ToC. This entails a reassessment of their assumptions and strategies. Should it be determined that the desired positive impacts have not been achieved, the organization might need to revise its approach to management activities. This process aims to enable the organization to align its practices more effectively with the desired outcomes and eventually attain the positive impacts sought through ES verification.

The ESCD is the report an organization must develop when verifying an ES, to show the information in detail on how the management activities are done and what are the current status of the ES and their impacts. This report ensures a transparent disclosure of key information and data associated to the verification and certification process as it is published on the online FSC public certificate database.

3. Research methodology

This section presents the methodological approach adopted to pursue the objectives set as part of this study. It includes the study area (3.1), the methods and sources used for data collection (3.2) for data analysis and elaboration (3.3).

3.1 Study area

The study area for this research corresponds to Mediterranean countries – defined consistently with FAO and Plan Bleu (2018)[1] - that have valid FSC forest management (FM) certificates including ES verification within their scope. Among the 1,500 FSC certificate holders worldwide, covering about 160 million ha (FSC, 2023), 49 include verified ES impacts. These certificates occur in 24 different countries worldwide (Figure 5a) of which five – i.e. Croatia, France, Italy, Portugal and Spain – are Mediterranean countries (Figure 5b).

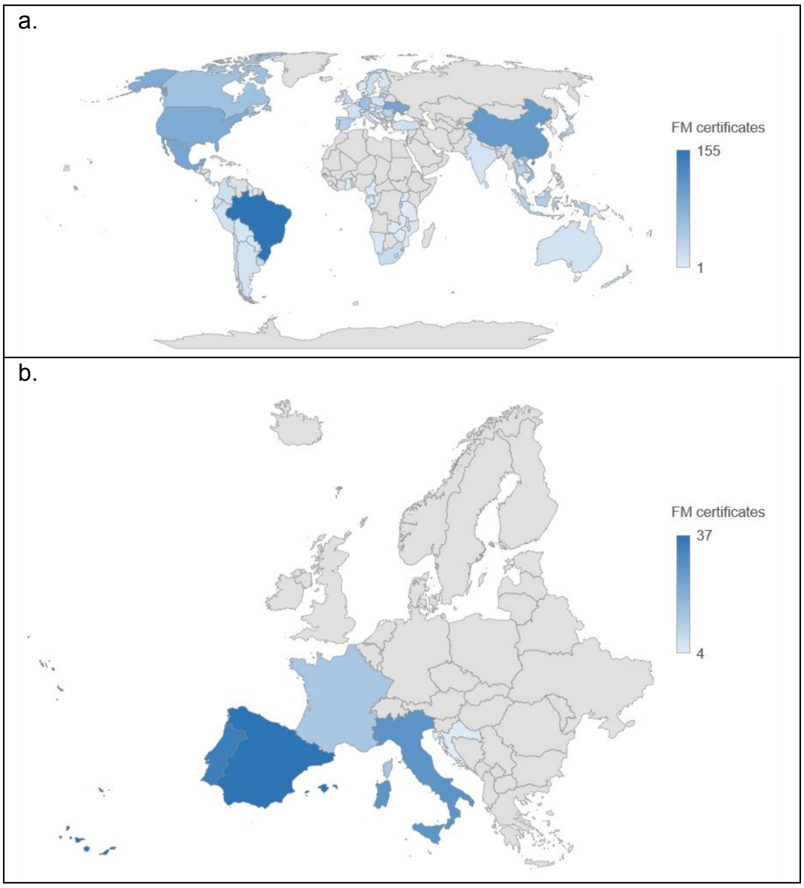

Figure 5: Countries with FSC certificates incorporating ES verification in the World (a) and the Mediterranean region (b) (FSC, 2023).

[1] This includes the 21 signatory countries to the Barcelona Convention (Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syrian Arab Republic, Tunisia, Turkey), but also additional six countries and territories that are part of the Mediterranean bioclimatic basin: Bulgaria, Jordan, Palestine, Portugal, Serbia and Northern Macedonia.

3.2 Data collection

The research was conducted using both qualitative and quantitative data. Only secondary data was used, and no primary field work was performed.

The data collection methodology involved a preliminary literature review targeting existing scientific and grey literature on ES and ES certification with a specific focus on the Mediterranean region. This was intended to establish solid foundations about existing knowledge and research in the field of forest certification and ES. This review helped identify gaps, trends, and areas of interest to guide the subsequent stages of the research. With this aim, scientific databases like Scopus were used, as well as search engines (like Google Scholar) to identify relevant grey literature.

To collect updated figures and data about FSC certification, the online FSC Facts and Figures tool[2] (FSC, 2023a) was used: data were identified both globally and with a specific focus on Mediterranean countries. Then the FSC Search online public database[3] (FSC, 2023b) was queried for identifying valid forest certificates including ES verification within their scope.

The database search was performed across three different tiers that are described below.

For the first one (Tier 1), a general search was conducted without any geographical limitations. The main searching criteria for this stage were:

- Valid (i.e. not expired, suspended or withdrawn) forest management (FM) and joint forest management and chain of custody (FM/CoC) certificates
- Including verified ES impacts
- Collecting data aggregated per certificate holders and not per single site.

From the search, a list of certificates was obtained and further filtered to identify certificates referring to the Mediterranean countries (Tier 2). This shortlist was further analyzed by identifying and collecting publicly available reports, such as audit reports and the ESCD, for all valid certificates within Mediterranean countries (Tier 3).

The third tier encompassed collecting data through every single report for each of the Mediterranean countries. Data collection was done from a total of 88 ESCD reports.

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[2] https://connect.fsc.org/impact/facts-figures
[3] https://search.fsc.org/en/

3.3 Data analysis and elaborations

An assessment framework to structure and analyses the collected data from ESCD reports was developed building on existing literature and in particular according to WWF (2022). The framework has been designed to categorize and organize the extracted information from ESCDs, enabling structured analysis. It includes parameters such as the types of ES verified, the impacts and management activities selected by each certificate holder, the methodologies employed for determination of the impact, the indicators, and the area of the ES certified forests that will be incorporated into the framework. This structured approach allowed a comparative analysis and for meaningful insights into the ES verification.

The database was filled in by scrutinizing and reading through every single report, and then extracting and reporting the key information from these reports. This information was then fed into the excel file that has the database. The database was further elaborated by analyzing specific issues or aspects by the means of basic or descriptive statistics as well as by the means of graphic visualizations (charts, graphs).

4. Results

In this chapter the results of the data analysis are presented. In section 4.1, forest certification in targeted countries is presented. In section 4.2, type and number of the verified ES is shown. Section 4.3 presents what impacts were selected. Section 4.4 shows the methodologies used for ES assessment while indicators are presented in section 4.5. At last, the results of financial and economic data are presented.

At the moment when this thesis is being developed (August 2023), there exist a total of 1,498 FM/CoC certificates worldwide, with 49 of them bearing verified ES certificates in 24 countries (FSC, 2023).

Italy, France, Spain, Portugal, and Croatia are the only countries within the Mediterranean region that include ES verification within some of their FSC FM/CoC certificates.

4.1 Forest certification in targeted countries

Out of the 117 valid FSC FM and FM/CoC certificates within the five targeted Mediterranean countries, 31 certificates – equivalent to 26.5% – also include verified ES impacts. Table 2 provides a breakdown of the total count of ES certificates in each of the five Mediterranean countries. It's notable that not all FM certificates include the verification of ES, showcasing a discernible differentiation between the two. While Spain and Portugal are the two Mediterranean countries hosting the highest number of the FSC FM and FM/CoC certificates, just a smaller share of these certificates includes ES verification when compared to the other Mediterranean countries. Italy and France, on the contrary show higher shares (39.3% and 35.7% respectively).

Table 2: Total ecosystem service certificates in the Mediterranean countries

Country	a. Total FM and FM/CoC certificates	Share %	b. Total number of certificates with ES verification within their scope	Share %	b/a %
France	14	12.0	5	16.1	35.7
Portugal	34	29.1	5	16.1	14.7
Spain	37	31.6	9	29.0	24.3
Italy	28	23.9	11	35.5	39.3
Croatia	4	3.4	1	3.2	25.0
Total	**117**		**31**		**26.5**

Under these certificates, there are 88 ESCD reports.

Table 3 displays the comprehensive extent of FSC FM and FM/CoC certified land area for each of the five targeted Mediterranean countries, totaling 3,522,728 ha. Within this, the aggregate area for verified ES is 129,516 ha. However, in the assessment process, the calculated area for certified ES is 2,366,720 ha. This discrepancy arises because the second column of Table 3 incorporates area values from all reports, which are occasionally duplicated due to the presence of multiple ES or, in numerous instances, multiple impacts.

Spain and Portugal host more than 73% of the total FSC certified area within the five targeted countries, but just 42% of the total area with verified ES. In particular, while hosting about one third of the certified area Portugal hosts only less than 5% of the total area with verified ES. On the contrary, Italy has just 13.5% of the total FSC certified area within the targeted countries, but more than 40% of the total area with verified ES. All in all, more than 76% of the total area with verified ES falls within Italy and Spain, followed by France (about 11%) while Portugal and Croatia lag behind.

Table 3: Total FSC certified area with total area with verified ES for the Mediterranean countries.

Country	Total FSC certified area (ha)	% over total	FSC certified area from assessed reports	% over total	FSC certified area verified for ES	% over total
France	159,332	4.5	216,861	9.1	14,143	10.9
Portugal	586,930	16.7	769,757	32.5	6,304	4.9
Spain	653,287	18.5	963,678	40.7	46,968	36.3
Italy	84,993	2.4	318,482	13.5	52,307	40.4
Croatia	2,038,186	57.9	97,943	4.1	9,794	7.6
Total	**3,522,728**		**2,366,720**		**129,516**	

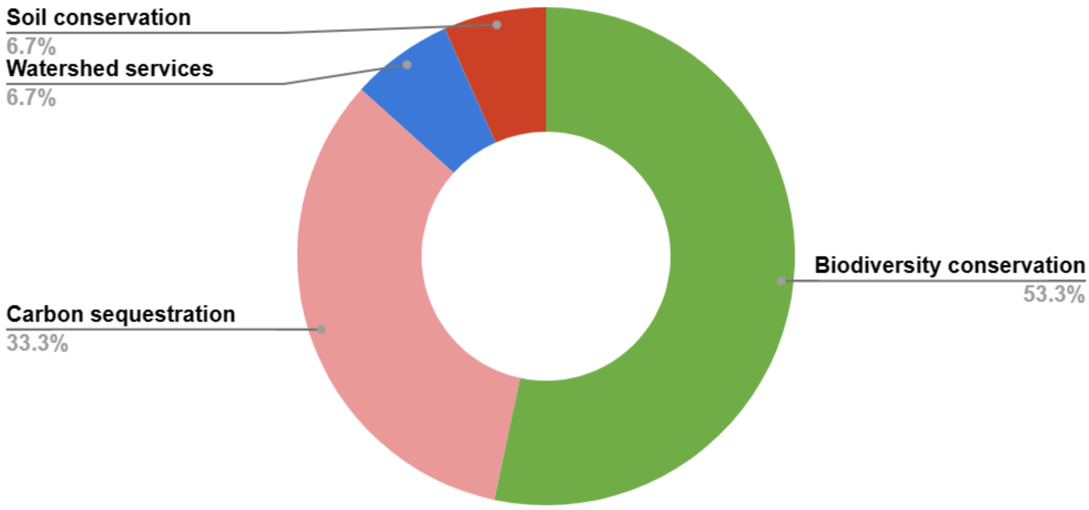
4.2 Type and number of verified ecosystem services

It is important to note that the total count of certifications surpasses the reported number of certificates, as a single certificate might encompass multiple ES verifications. This also depends on the fact that many of such certificates are group certificates, concluding multiple owners within a single certificate.

Among the FSC-defined categories of five distinct ES, not all countries have achieved certification across every ES type. While France holds verifications for four ES types (i.e. all but recreational services), both Portugal and Spain have obtained verifications for three, Croatia for just one (i.e. Carbon sequestration and storage), whereas Italy is the only country having secured verification for all five ES types. Notably, Carbon sequestration and storage emerge as the sole ES type verified within all five countries.

Pie charts illustrating the breakdown of ES verifications by type for each country are reported in Figures 6 to 9. Furthermore, Figure 10 provides a comprehensive view of the aggregate number of ES verifications encompassing the entire Mediterranean region.

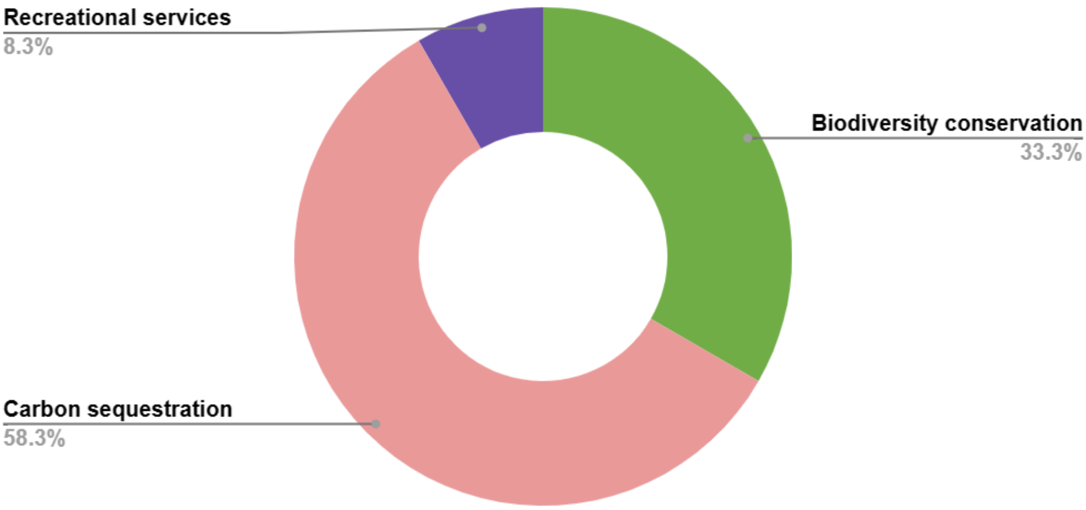
France features verifications across four distinct types of ES. Notably, the most prominent among these is Biodiversity conservation (53.3%). Following this is the Carbon sequestration with 26.7%. Both Watershed services and Soil conservation has very low number of verified ES in France (one verification each) (Figure 6).



Total n. of certificates: 5

Figure 6: Share of verified ES within FSC certificates in France

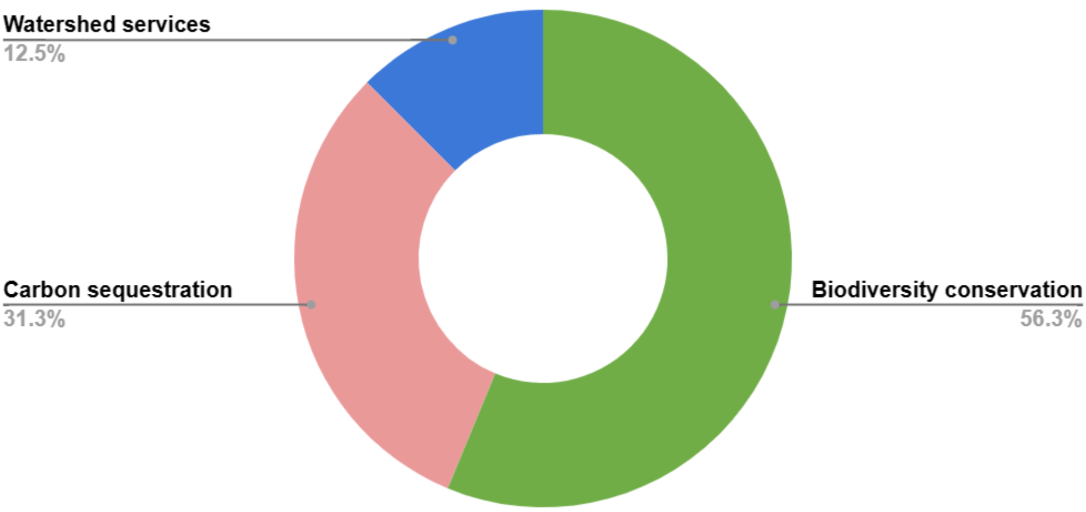
Portugal holds certifications including the verification for three distinct types of ES. Notably, the most prominent among these is Carbon sequestration, accounting for more than half of Portugal’s verified ES, followed by Biodiversity conservation. Recreational services show the lower number of verifications (Figure 7).



Total n. of certificates: 5

Figure 7: Share of verified ES within FSC certificates in Portugal

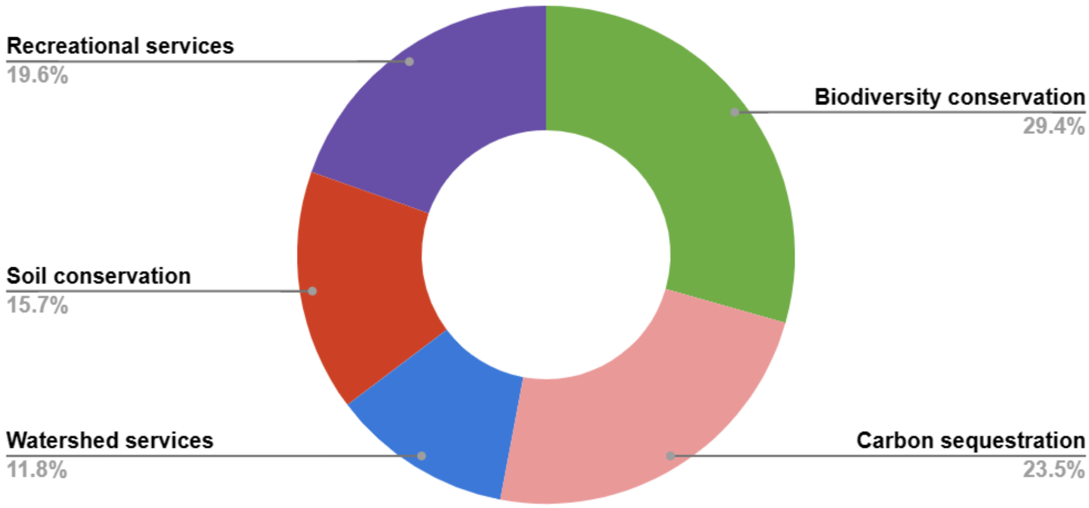
Spain also possesses verifications for three different types of ES. The most significant among these is Biodiversity conservation with 56.3% of ES verifications in Spain. Carbon sequestration follows through with 31.3% and watershed is the least with only 12.5% of the total (Figure 8).



Total n. of certificates: 9

Figure 8: Share of verified ES within FSC certificates in Spain

Italy features verifications encompassing all five ES categories. Biodiversity conservation has the highest number of verifications (15) accounting for 29.4%, followed by Carbon sequestration with 23.5% and Recreational services with 19.6%. Watershed services accounts for the least verified ES in Italy (11.8%) (Figure 9).



Total n. of certificates: 11

Figure 9: Share of verified ES within FSC certificates in Italy

The first ES verification in Croatia was issued just very recently and results in certification solely for carbon sequestration at the moment.

Taking into account the whole Mediterranean region, the most popular ES selected to be verified is Biodiversity conservation (37.5%) with Carbon sequestration close behind (32.3%). On the other end, Soil conservation and Watershed services lag behind with only 9 of verifications each (9.4%) in the Mediterranean along with 11 verifications in Recreational services (11.5%) (Figure 10).

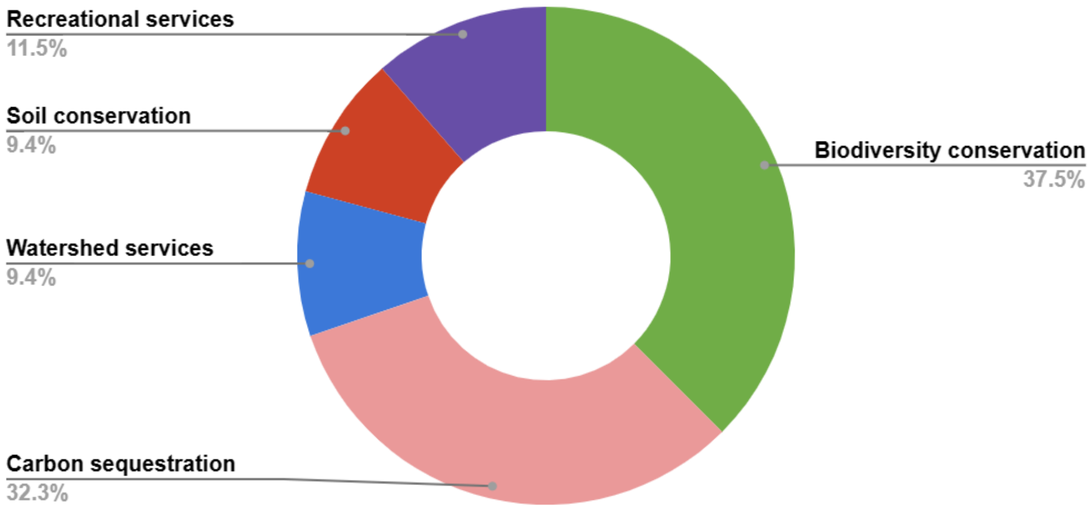


Figure 10: Share of verified ES within FSC certificates in the five targeted Mediterranean countries

4.3 Selected forest management impacts in ecosystem services

Each certificate holder selects their desired impacts for the ES verification from a list of 20 different types of impacts defined according to the FSC Procedure (Table 4).

Table 4: List of the different types of impacts for the ES verification as defined by the FSC Procedure

N.	Impact
1.1	Restoration of natural forest cover
1.2	Conservation of intact forest landscapes
1.3	Maintenance of an ecologically sufficient conservation area network
1.4	Conservation of natural forest characteristics
1.5	Restoration of natural forest characteristics
1.6	Conservation of species diversity
1.7	Restoration of species diversity
2.1	Conservation of forest carbon stocks
2.2	Restoration of forest carbon stocks
3.1	Maintenance of water quality
3.2	Enhancement of water quality
3.3	Maintenance of the capacity of watersheds to purify and regulate water flow
3.4	Restoration of the capacity of watersheds to purify and regulate water flow
4.1	Maintenance of soil condition
4.2	Restoration/enhancement of soil condition
4.3	Reduction of soil erosion through reforestation/restoration
5.1	Maintenance/conservation of areas of importance for recreation and/or tourism
5.2	Restoration or enhancement of areas of importance for recreation and/or tourism
5.3	Maintenance/conservation of populations of species of interest for nature-based tourism
5.4	Restoration or enhancement of populations of species of interest for nature-based tourism

Figure 11 shows the total number of impacts that have been selected for each of the targeted countries.

In France, 9 different impacts have been verified with impact 1.3 (Maintenance of an ecologically sufficient conservation area network) being the most common (27% of total verified impacts). The impacts for carbon follow (2.1, 20%, and 2.2, 13%). The remaining six only have one verification each (7%). Both Portugal and Spain have 6 different impacts having been verified, with impact 2.1 (Conservation of forest carbon stocks) being the most common for both countries. Croatia only has verified impacts for carbon, i.e. 2.1 and 2.2. Italy shows the highest coverage of potential impacts within the given range: 14 selected out of 20.

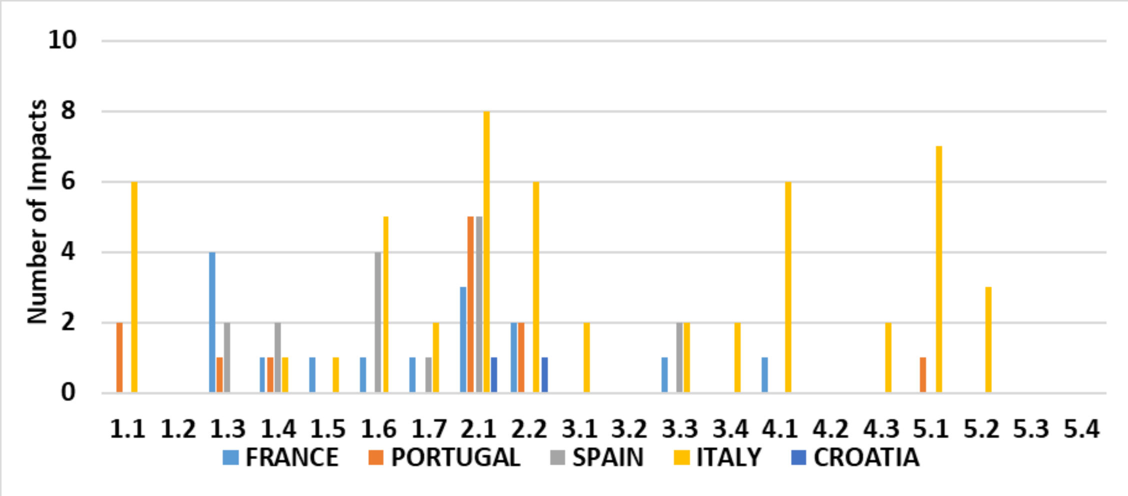


Figure 11: Total number of ES impacts verified in each targeted country

Overall, impact 2.1 is found to be the most selected one (22.4%), followed by impacts 2.2 (11.2%), 1.6 (10.2%), and 5.1 and 1.1 (8.2% each). Other impacts show lower frequencies, while impacts 1.2, 3.2, 4.2, 5.3 and 5.4 have not yet been considered and addressed within existing FSC FM and FM/COC certificates including ES verification in the Mediterranean countries.

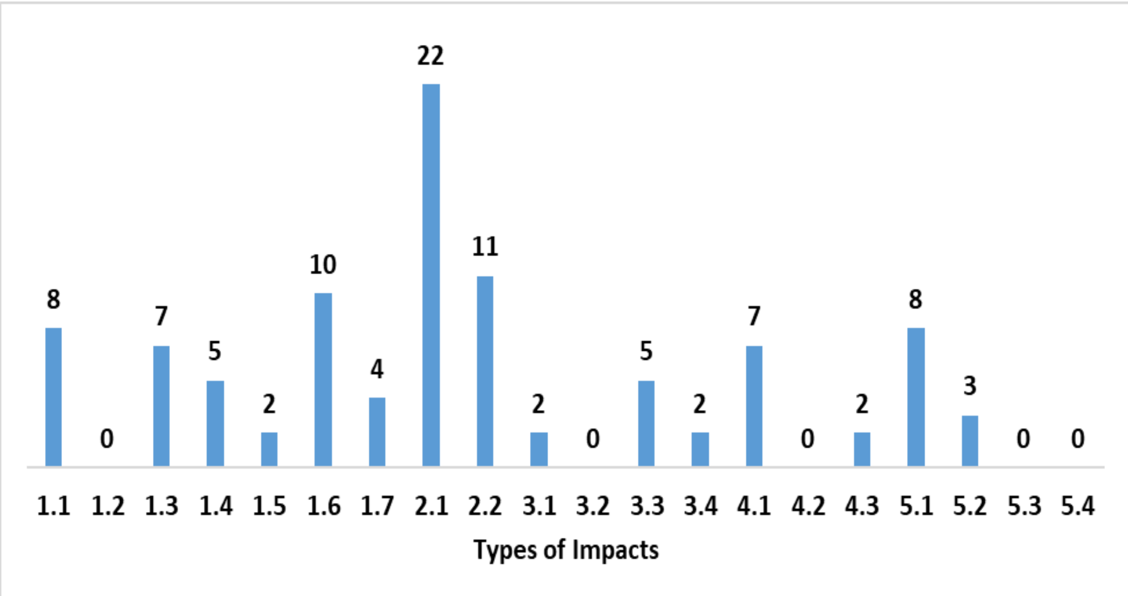


Figure 12: Total number of ES impacts verified in the Mediterranean countries

4.4 Methodologies for ecosystem service assessment

In this study, all the methodologies adopted by each forest management unit (FMU) for every selected impact were recorded and further categorized into 10 categories. These 10 categories are the ones taken into account and referred as the methodologies for ES assessment. For simplicity and to shorten the text, within the following text and figures methodologies will be referred to according to their corresponding number (from 1 to 10) reported in Table 5.

Table 5: Methodologies for ecosystem service assessment

N.	Methodologies
1	Inventorying, mapping and monitoring
2	Calculation of total carbon present
3	Geographic information system and Remote sensing
4	Reference to existing studies
5	Measuring the degraded forest area
6	Universal Soil Loss Equation
7	Management practices
8	Data collection from reports and surveys
9	Measurement of abundance or vitality of focal species or rare and threatened species
10	Measure the length of the paths dedicated to forest welfare

France uses four types of methodologies with methodology 2 (Calculation of total carbon present) being the most selected one with 35.3% of total methodologies. Methodologies 3 (Geographic information system and Remote sensing) and 4 (Reference to existing studies) are also in par with 23.5% and 29.4%, respectively. Methodology 1 (Inventorying, mapping and monitoring) is the least selected one.

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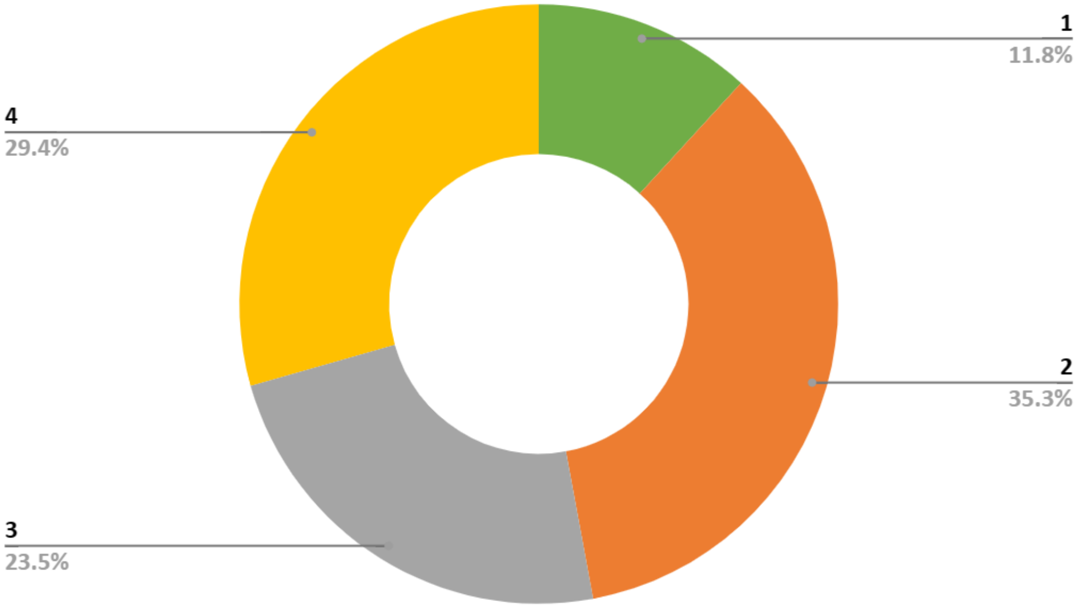

Figure 13: Methodologies (%) for ecosystem service assessment used by France

Portugal uses 5 different methodologies with methodology 2 (Calculation of total carbon present) being the most selected one (55.6%). Methodology 4 (Reference to existing studies) is the least selected one with only 7.4%. The other two are methodology 1 (Inventorying, mapping and monitoring) and 3 (Geographic information system and Remote sensing).

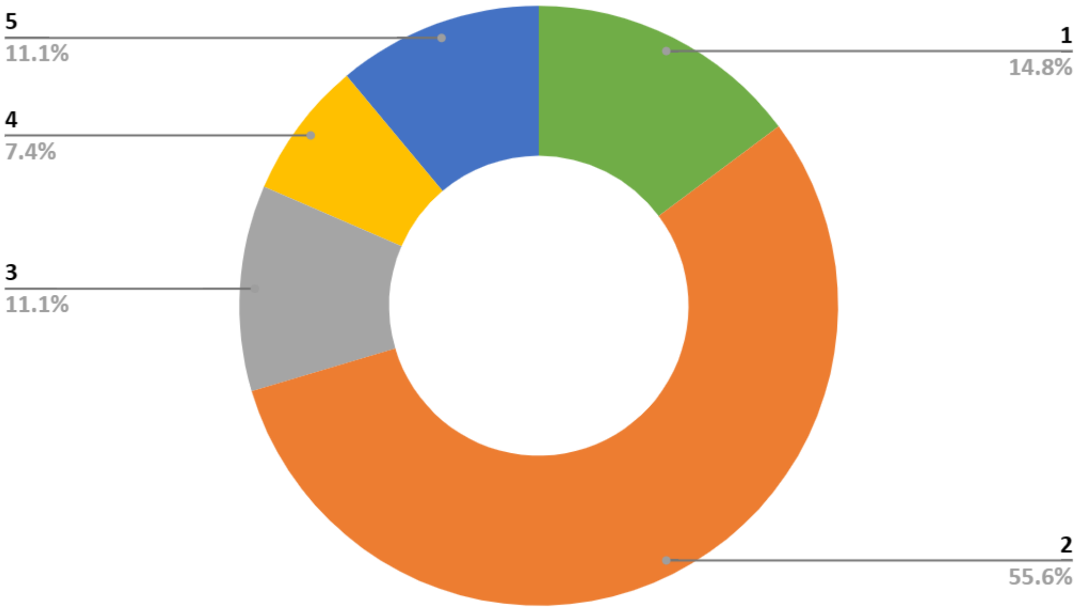

Figure 14: Methodologies (%) for ecosystem service assessment used by Portugal

Spain uses 4 different methodologies with methodology 2 (Calculation of total carbon present) being the most selected one (37.1%). Methodology 4 (Reference to existing studies) is the least selected one (17.7%). The other two are methodology 1 (Inventorying, mapping and monitoring) and 3 (Geographic information system and Remote sensing).

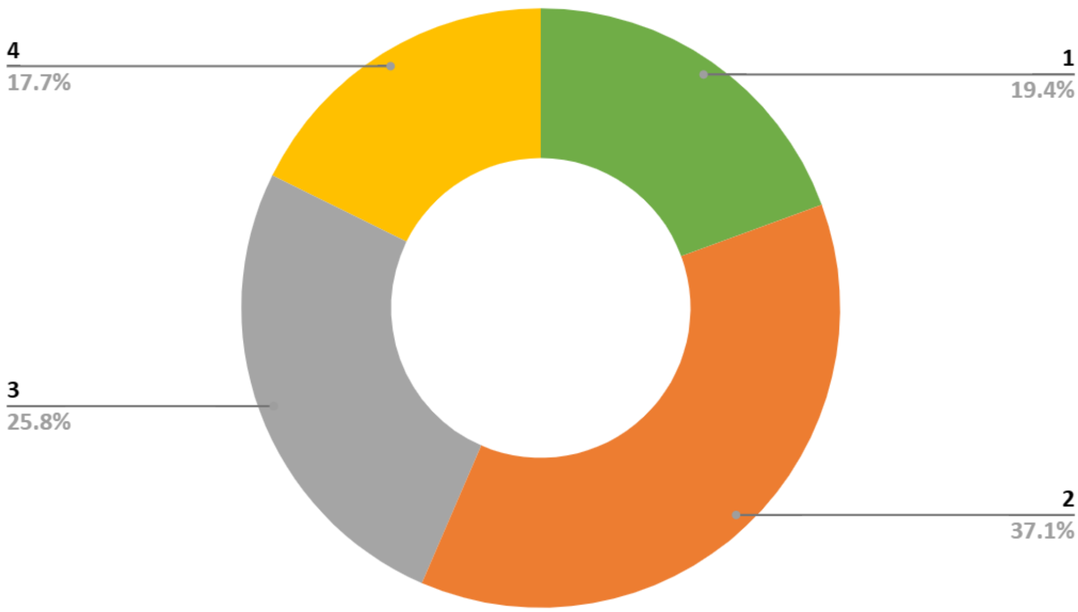

Figure 15: Methodologies (%) for ecosystem service assessment used by Spain

Italy has the greatest number of methodologies selected (9 out of 10). The most selected one is methodology 4 (Reference to existing studies) (29%) closely followed by methodology 2 (Calculation of total carbon present) (25.8%). The third most selected methodology is 1 (Inventorying, mapping and monitoring). The other methodologies were found to be relatively very low in use.

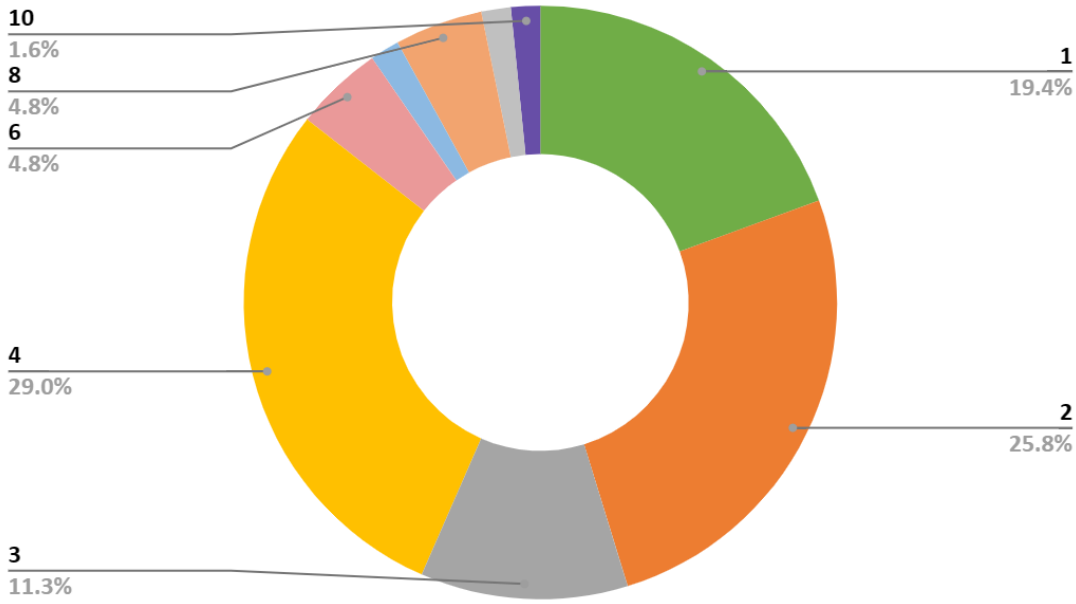

Figure 16: Methodologies (%) for ecosystem service assessment used by Italy

Croatia only has one ESCD report and this results in only one methodology having been adopted so far, i.e., Methodology 1 (Inventorying, mapping and monitoring.)
Figure 17 depicts together the use of different methodologies in each of the five countries. It is clear that methodology 2 is the most used in almost all of the countries except for Croatia and, to a lower extent, Italy. Methodologies 1, 3 and 4 also are quite frequently used.

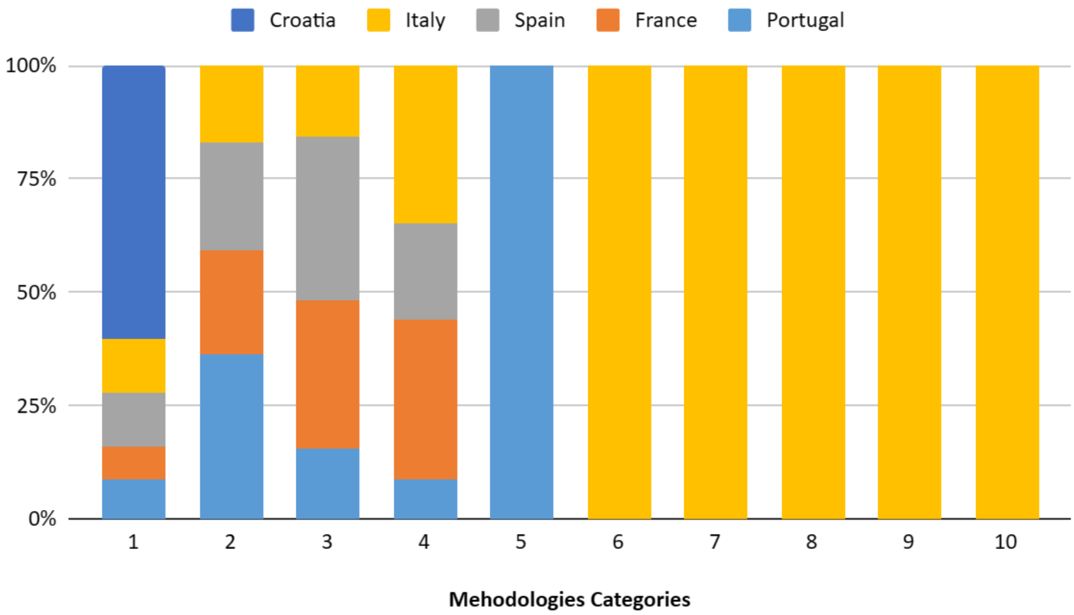

Figure 17: Comparison of methodologies (%) for ecosystem service assessment used by all targeted countries

Figure 18 presents how many times each methodology has been selected. Methodology 2 is clearly the highest being used 60 times followed by methodology 1 being selected 40 times. Methodologies 3 and 4 are also right behind, 30 and 36 respectively.

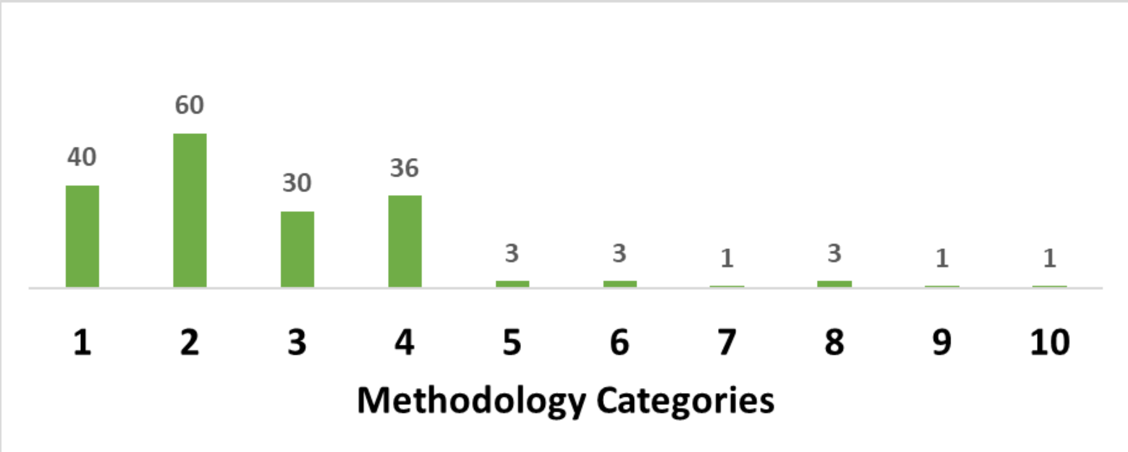

Figure 18: Frequency of methodology usage for ecosystem service assessment in targeted countries

4.5 Indicators

There are many different types of indicators that can be chosen to show the positive ES impacts. Some indicators might be exclusively used for a specific ES and some might be used across multiple ES. Here we have matched the indicators to the methodologies adopted to ES assessment. This allowed linking indicators both to methodologies and targeted ES.

Tables from 6 to 10 show the total number of indicators selected within each of the five targeted countries. To help visualizing results, a colored scale is adopted to highlight, through different shades of green, different values: the darker and more intense the color, the higher the number of the corresponding indicators.

Table 6 shows the number of indicators for France. Indicators are only found for methodologies from 1 to 4. Examples include Size, Representativeness and Connectivity of Conservation areas; Forest carbon stocks in living biomass estimated across the management unit; Soil properties and conditions; Forest cover (%), etc.

The largest number of indicators is found for the verification of Carbon sequestration with the methodology 2. These indicators include Carbon stocks of biomass and forest soil; Total amount of carbon stored; Increase in carbon fluxes compared to the average forest management in the territory.

While only Methodology 2 is adopted for Carbon, Biodiversity indicators encompass a broader range of methodologies, along with a larger total number of indicators. Water and Soil also has only one Methodology each (5 and 1, respectively).

Table 6: Quantification of ES Verification Indicators by ES Type and Assessment Methodology in France

ES\Methods	1	2	3	4	5	6	7	8	9	10	Total
Biodiversity	2	0	3	4	0	0	0	0	0	0	9
Carbon	0	8	0	0	0	0	0	0	0	0	8
Water	0	0	0	5	0	0	0	0	0	0	5
Soil	0	0	1	0	0	0	0	0	0	0	1
Recreation	0	0	0	0	0	0	0	0	0	0	0

Table 7 presents indicators used for Portugal. Indicators are only found for methodologies from 1 to 5. Examples include Presence of natural environmental values; Total tons of carbon stored per year; Area occupied by ecosystem; Protected and accessible area (ha) for nature-based recreation with visitor satisfaction, Degraded forest area as area ratio total land (ha), etc.

The largest number of indicators is found for the verification of carbon sequestration with the methodology 2. These indicators include Reservations from forest carbon estimated at the whole area, Total tons of carbon stored per year.

While Methodology 2 and 3 are adopted for Carbon, Biodiversity indicators encompass three different Methodologies (1,3,5), along with a larger total number of indicators. Recreation has only Methodology 4.

Table 7: Quantification of ES Verification Indicators by ES Type and Assessment Methodology in Portugal

ES\Methods	1	2	3	4	5	6	7	8	9	10	Total
Biodiversity	12	0	2	0	6	0	0	0	0	0	18
Carbon	0	15	1	0	0	0	0	0	0	0	16
Water	0	0	0	0	0	0	0	0	0	0	0
Soil	0	0	0	0	0	0	0	0	0	0	0
Recreation	0	0	0	2	0	0	0	0	0	0	2

Table 8 shows indicators for Spain. Indicators are only found for methodologies from 1 to 4. Examples include Forest or ecosystem structure, Estimated forest carbon stocks in the entire management unit, Area of the network of conservation areas within the management unit, Native species diversity, etc.

The largest number of indicators is found for the verification of carbon sequestration with the methodology 2. There is only one type of indicator for this i.e., the 'Estimated forest carbon stocks in the entire management unit'.

While only Methodology 2 is adopted for Carbon, Biodiversity indicators encompass a broader range of methodologies, along with a larger total number of indicators. Only one methodology is adopted for water i.e. Methodology 3 which includes indicators like Forest cover and density, Condition of the hydrographic basins, Percentage of the shoreline of a body of water with forest cover, etc.

Table 8: Quantification of ES Verification Indicators by ES Type and Assessment Methodology in Spain

ES\Methods	1	2	3	4	5	6	7	8	9	10	Total
Biodiversity	22	0	6	22	0	0	0	0	0	0	50
Carbon	0	23	0	0	0	0	0	0	0	0	23
Water	0	0	22	0	0	0	0	0	0	0	22
Soil	0	0	0	0	0	0	0	0	0	0	0
Recreation	0	0	0	0	0	0	0	0	0	0	0

Table 9 presents indicators used for ES assessment in Italy. Indicators are found for almost all the methodologies, except for Methodology 5. Examples include: Degraded or deforested areas where the regeneration of native species has been successfully established, Organic carbon (%), Hectares of surface affected by reforestation, No. of Surveys of forest parameters, Soil stability (erosion t/year), Correctly maintained area containing valuable elements typical of the landscape, Managed and accessible area for recreation in a natural area, Hectares of forestry-pastoral heritage planned, managed and FSC certified, Extension of the trail network dedicated to forest welfare, etc.

The largest number of indicators is found for the verification of Recreational services with the methodology 4. These indicators include Increased viability on natural ground, Extension of the area of importance for tourist recreational activities which are protected, Average number of daily passages recorded on the main routes, and many more.

Biodiversity follows with Methodology 1 and Carbon with Methodology 2 with indicators being selected 12 times in each. Biodiversity indicators were selected a larger total number of times (34) with Recreation close behind (28). Italy is the only country where indicators for all the ES have been selected.

Table 9: Quantification of ES Verification Indicators by ES Type and Assessment Methodology in Italy

ES\Methods	1	2	3	4	5	6	7	8	9	10	Total
Biodiversity	12	0	7	10	0	0	0	2	3	0	34
Carbon	0	12	0	3	0	2	0	0	0	0	17
Water	7	0	3	5	0	0	0	0	0	0	15
Soil	1	8	2	6	0	4	0	0	0	0	21
Recreation	3	0	1	17	0	0	2	3	0	2	28

Table 10 presents indicators for Croatia, which are only found for methodology 1 (Carbon sequestration) and consist of only one type of indicator i.e. 'Increases in wood stock on surfaces which we manage as proof of increased carbon binding' used 10 times.

Table 10: Quantification of ES Verification Indicators by ES Type and Assessment Methodology in Croatia

ES\Methods	1	2	3	4	5	6	7	8	9	10	Total
Biodiversity	0	0	0	0	0	0	0	0	0	0	0
Carbon	10	0	0	0	0	0	0	0	0	0	10
Water	0	0	0	0	0	0	0	0	0	0	0
Soil	0	0	0	0	0	0	0	0	0	0	0
Recreation	0	0	0	0	0	0	0	0	0	0	0

Table 11 presents the total frequency for each indicator and each methodology. The largest number of indicators is found for the verification of carbon sequestration with the methodology 2. However, Biodiversity indicators encompass a larger total number of indicators with indicators being selected a whopping 107 times.

Table 11: Quantification of ES Verification Indicators by ES Type and Assessment Methodology in the targeted Mediterranean countries

ES\Methods	1	2	3	4	5	6	7	8	9	10	Total
Biodiversity	48	0	18	36	6	0	0	2	3	0	107
Carbon	10	58	1	3	0	2	0	0	0	0	74
Water	7	0	25	10	0	0	0	0	0	0	42
Soil	1	8	3	6	0	4	0	0	0	0	22
Recreation	3	0	1	19	0	0	2	3	0	2	30

Each of the five Mediterranean country has several numbers of indicators, as they have been repeated in each report over all the ES verified. When grouping indicators per type and avoiding multiple accounting, Italy shows the highest number of indicators types employed, while, as already mentioned, Croatia has only one type of indicator (Table 12).

Table 12: Types of indicators in each targeted country

Country	Types of indicators	%
France	9	8.0
Portugal	12	10.6
Spain	14	12.4
Italy	77	68.1
Croatia	1	0.9

Table 13 provides an overview of the indicator counts corresponding to each methodology identified within the reports.

Table 13: Indicators assessed for each methodology used to verify ES impacts in the targeted Mediterranean countries

Methods	Number of indicators
1	69
2	66
3	48
4	74

Methods	Number of indicators
5	6
6	6
7	2
8	5
9	3
10	2
TOTAL	**281**

4.6 Financial and economic data

Annex D from the FSC ES Procedure gives the financial sponsorship information for every certificate holder.

By analyzing the reports, it was possible just to find this information being made explicit for France, Portugal and Italy. In the case of France and Portugal information was reported for only a single certificate each while Italy has information for 3 certificate holders. All in all, this accounts for only 16.1% of the total certificates (Table 14).

Table 14: Certificate holders with the financial information

Country	Certificate Holder with Financial Sponsorship Information
France	Sarl Alcina Forets
Portugal	2B Forest Lda.
Italy	Unione di Comuni Valdarno e Valdisieve
	Gianna Masu
	WaldPlus srl

5. Discussion

In this chapter, the theoretical implications of the findings of this study will be discussed first in section 5.1, accompanied by providing plausible explanations to the findings produced in this study. Section 5.2 provides the practical implications of this study. The last section 5.3 identifies the limitations existed in this study and the recommendations for further research.

In this section, we explore into the discussion of findings, interpretations, and implications arising from the comprehensive analysis of ES verification against FSC standards in Mediterranean countries. The primary objective of this study was to critically assess the current state of ES verification within the context of FSC standards, focusing on the Mediterranean region. The specific objectives guided us in dissecting various aspects of ES verification, including the scope of certification, targeted ES, verification methodologies, economic considerations, and the potential trajectory of ES verification practices.

5.1 Theoretical implications

Two documents will be used as main references for this stage of the discussion.

- ‘Ecosystem Services Procedure: Impact Demonstration and Market Tools’ (FSC-PRO-30-006 V1-0 EN; FSC, 2018)
- 'Paying Foresters to Provide Ecosystem Services?’ (Vallauri *et al*., 2022; WWF 2022)

The study conducted by WWF (2022), titled 'Paying Foresters to Provide Ecosystem Services?', stands as the central literature source for comparison within this discussion. Notably, it is the sole study conducted to date that presents outcomes derived from the FSC ES Procedure. The paper encompassed all countries globally that had embraced the FSC ES Procedure.

The paper identifies significant gaps within the FSC ES procedure. The ES procedure is not adapted at the national level unlike the FM standards. It stresses on the essential role of considering the local context for defining financial regulations concerning public goods. To rectify this, the paper recommends the establishment of a distinct governance structure at the national level under the establishment of FSC. An urgent gap that needs to be addressed is the lack of financial/marketing rules in the ES Procedure. This is addressed by Motion 49 from FSC. FSC is presently engaged in a motion, formally approved during the most recent general assembly, known as Motion 49 (FSC, 2022c). This motion aims to refine the ES procedure to facilitate ES marketing. Within the working group dedicated to this motion, FSC is deliberating the potential development of procedures and approaches that render ES statements not only applicable but also effective for marketing purposes. FSC currently prohibits the utilization of verified ES for offsetting purposes. However, they are actively striving to develop statements or claims that would enable a company willing to offset its impacts to sponsor forest management activities that aid in producing the ES, without buying any credits. The FSC Procedure and Guidelines state that the verification of ES is not primarily intended for generating FSC-verified credits. However, it also does not impede the exploration of other financial mechanisms, such as sponsorships.

It also mentions the shortcomings of the ESCD and its role in ensuring project transparency. Despite its central importance, the ESCD falls short in terms of effective communication and accessibility. The document is often complex, failing to effectively communicate information to the interested parties. Additionally, inconsistencies in the quality and thoroughness of ESCDs across different certificate holders contribute to information gaps and undermine the document's reliability.

Unlike WWF (2022), the scope of our study is limited to Mediterranean countries currently undergoing ES verification according to FSC standards. Croatia, France, Italy, Portugal and Spain are the only five countries in the Mediterranean that have valid FSC FM certificates including ES verification within their scope. Among the 117 certificates of FSC FM and FM/CoC, in these countries, only 31 of them have incorporated ES verification. This might be suggesting the lack of availability of public information and awareness about the ES procedure and its benefits, but also the inability/unpreparedness of forest owners and managers to implement the procedure unless properly supported by external experts (which might, however, results in extra costs) and, last but not least, unwillingness to adopt the procedure for some reasons that are not possible to detect based on available data. In addition to this, significant differences emerged within targeted countries: ES verification at the moment is more common in countries, like Italy, hosting less total certified forest area, while it is less present in countries with largest FSC certified area, like Spain and, even more, Portugal. One possible reason behind this is that certified forests in Spain and Portugal largely consist of production forests and, in many cases, even industrial plantations mainly (if not solely) oriented to timber production. As a consequence, interest for ES assessment and marketing might be less prominent compared to other countries were forest owners might be less competitive in terms of timber production capacity and owners might be looking at alternative income sources and management objectives.

Since this research was conducted using data collected up until August 2023, this report encompasses a greater number of ESCDs compared to the WWF study. This rise in document count signifies an evident increase in the inclination of forest owners/organizations to undergo ES verification. Notably, the escalation in ESCDs corresponds to a corresponding growth in the impacts and benefits derived from ES. For example, Waldplus, an Italian ES certificate holder, was identified with seven benefits according to the WWF study. However, within a year, it expanded its benefits, increasing the count to eight.

5.1.1 Verified ecosystem services

FSC divided the ES into five categories for the ES Procedure: Biodiversity conservation, Carbon sequestration and storage, Watershed services, Soil conservation and Recreational services. The results show that different countries cover a different number and type of ES. France has verification for four of the ES, Spain and Portugal for three, Croatia only for one, while Italy is the only targeted country currently covering all five ES. Italy's comprehensive verification across all five ES types reflects a dedication to considering the broader ecosystem context when making forest management decisions, however it is also connected to a pioneer role played by the country that was the first one to cover all ES at world level. This was possible also thanks to a combination of factors enabling a favorable environment, in particular the presence of a very active and dynamic group of smallholders (Waldplus) and the innovation capacity brought in by an external consultant specialized in ES assessment and valuing (Etifor Srl, a spinoff of Padova University), associated to a growing interest by local companies willing to invest in natural capital for their Corporate Social Responsibility goals. Notably, in the last year, Etifor has launched their own forest certification group scaling up the model.

The variation in verified ES types is indicative of the differing ecological priorities and challenges faced by each country, as well as by marketing potential. It is important to acknowledge that certain countries may have chosen to focus on specific ES, such as Biodiversity and Carbon, primarily in response to specific environmental issues or market opportunities.

5.1.2 Impacts

FSC defines the impacts as "*The long-term maintenance, conservation, enhancement, or restoration of ecosystem services, or benefits derived from them, which results, at least in part, from contributing management activities*" (FSC-PRO-30-006 V1- 2 EN; FSC 2021).

There are 20 different impacts that are under the five ES given by the FSC. Biodiversity conservation has seven different impacts under it, Carbon sequestration and storage has two impacts, Watershed services have four impacts, Soil conservation has three impacts and Recreational services has four different impacts. A certificate holder/organization can propose one or more impacts that they wish to verify under each ES. Each of the selected impacts will have a ToC for the management activities to get the desired outcomes.

The most selected impact in the Mediterranean is impact 2.1 (Conservation of forest carbon stocks) and 2.2 (Restoration of forest carbon stocks). The other most selected impacts are 1.6 (Conservation of species diversity) and 1.1 (Restoration of natural forest cover) from Biodiversity conservation which goes to show that Carbon and Biodiversity are the most popular and desired ES verified. This can be due to the fact that these ES are more visible and promoted compared to others, thanks to specific policy initiatives (e.g., in the case of Biodiversity: Kunming-Montreal Global Biodiversity Framework, EU Biodiversity Strategy, EU Nature Restoration Law etc.) and the development of associated market initiatives for offsetting and compensations. This is also in line with findings from past studies highlighting these two ES are among the most studied and assessed (e.g. Nijnik and Miller, 2013; Mortimer *et al*., 2018; Bayley *et al*., 2021; Kangas and Ollikainen, 2022 and 2023).

5.1.3 Methodologies and indicators

We have observed a significant diversity of methodologies employed within the FSC for assessing ES. This diversity provides flexibility for forest owners and managers to choose the most suitable approach according to their specific needs and capabilities. However, it can potentially create challenges in terms of making comparative assessments and ensuring overall consistency.

The absence of predefined methodologies for ES assessment allows certificate holders to develop their own methods, offering flexibility by permitting the use of existing data and preferred methodologies. Nonetheless, this diversity could hinder result comparisons and, in the future, pose challenges in maintaining consistency, especially as the number of verified ES increases. FSC may encounter difficulties in ensuring transparency, consistency, and robustness due to the potentially substantial variety of methodologies in use.

There is an evident necessity to enhance the formulation and standardization of methodologies and indicators utilized in the verification of ES. This would establish a common matrix for managers, rendering the process more feasible and comprehensible to them. Moreover, such standardization could also result in improved clarity and accessibility for external observers because currently, navigating solely through publicly available reports is somewhat confusing.

The current array of methodologies and indicators, as it stands, might also hinder managers from devising tailored approaches that could better suit specific cases. Managers often opt for effective and resource-efficient methods, potentially neglecting exploration of more optimal approaches due to increased efforts and costs involved.

It could be intriguing also to implement an approach similar to the one utilized for FM standards, which are customized to local conditions while adhering to an internationally consistent framework of Principles and Criteria. This approach could be further enhanced by integrating a set of International Generic Indicators (IGIs) that can be universally adopted or adapted according to specific and standardized rules. This strategy aligns with recommendations made by WWF in 2022, emphasizing that the ES procedure lacks adaptation at the national level, unlike FM standards. The importance of considering the local context when formulating financial regulations pertaining to public goods is underscored. To address this gap, the paper had suggested establishing a distinct governance structure at the national level under the auspices of the FSC (WWF, 2022).

5.1.4 The marketing of the verified ecosystem services

There are very few data about the markets for the certified ES. However, having the information about the economic data and about the financial sponsorship serves as the basis for further developing the market.

The economic values and data pertaining to ES are, in fact, not readily available, with only a few exceptions sourced from the publicly available data. Various reasons could account for this limitation. It could be speculated that some services were not genuinely traded as ES, although a handful of cases do present empirical evidence of the sale of these particular services such as the case of Etifor.

The economic data results were found to be extremely patchy based on the publicly available information. Given the time constraints during this study, conducting interviews with certificate holders wasn't feasible, which could have yielded more insights. Nevertheless, even if relying solely on publicly available data, a key recommendation emerges, i.e. there is a need to enhance this aspect and ensure its accessibility. This information proves valuable in comprehending the economic condition in global context.

There is also a pressing need for enhanced transparency concerning the economic dimensions. FSC should strive to disclose all economic and financial data and make it accessible to the public. This move could offer insights to other forest managers and companies, aiding them in economically managing the verified ES. The establishment of a common matrix, encompassing methodologies and indicators for assessing ES, could further facilitate the development of economic mechanisms for the marketing of verified ES. This could also prove beneficial in terms of delineating clear economic mechanisms and fortifying the market for these ES in a resilient manner.

5.1.5 Comparing to other existing ecosystem service standard

While there are other forest certification schemes, like the Programme for the Endorsement of Forest Certification (PEFC), FSC remains the only one that has developed a full internationally applicable procedure for ES verification to date. However, it is important to note that PEFC-Italy has developed an ES standard with a geographical scope limited to Italy. Comparing the two, FSC pioneered the ES procedure, which is internationally applicable and based on the ToC framework. An additional key distinction lies in the fact that PEFC allows the sale of certified credits as *sustainability credits* and is developing a manual for their sale (PEFC ITA 1001-SE:20211 - Certification standard of ES generated by sustainably managed forests and plantations) while for FSC transaction of ES claimed as FSC certified is not allowed, though sponsoring management activities that support verified positive impacts on ES is possible.

5.2 Practical implications

A research gap exists regarding whether the five ES grouped by FSC adequately encompass the most relevant ES. For instance, there is a growing interest in Italy in green care, including activities like forest bathing, for human well-being (Guardini *et al*., 2023; Scartazza *et al*., 2020). However, this aspect of ES is currently not addressed in the FSC Procedure. While there is one indicator mentioning forest bathing, it does not enable forest managers to assess this ES comprehensively, and they may not be aware of it, even though it holds potential interest for future development. For those looking to develop this ES, it is important to explore broadening the scope of ES categories while concurrently establishing robust methodologies.

Another often overlooked aspect pertains to additional ES, such as protection against gravitational hazards. While there are measures in place for soil protection, there are currently no specific provisions for safeguarding against soil erosion or avalanches, which are more traditional protective functions carried out by forests.

Hence, incorporating additional or expanding the list of ES and promoting the development of relevant indicators and methodologies could be a path to advance the procedure.

5.3 Limitations and suggestions for future research

While developing this research, several challenges and gaps emerged that influenced the study's development. A significant hurdle was encountered in the data collection process, particularly in acquiring comprehensive and consistent information from the ESCD reports as many lacked to report several information like the name of the FMUs, some did not have the date of the verification/ validation.

Additionally, the classification of methodologies was based on subjectively defined categories, which introduced potential biases and limitations in the analysis.

One notable omission was the absence of interviews with experts or certified certificate holders, which could have provided valuable insights, validation, and a deeper understanding of the data. For instance, the possibility to gather economic data directly from individual certificate holders was not explored due to time constraints, which could have enriched the study's economic analysis.

The disparities between the information on ESCDs and the FSC website pose challenges in locating reliable and consistent data and information. This issue was also encountered by the WWF study.

These difficulties and gaps underscore the need for further research and methodological refinement to enhance the robustness and comprehensiveness of future investigations in this area.

6. Conclusions

This thesis explores ES verification against the FSC standards in Mediterranean countries. Our study aimed to shed light on the current state of FSC ES verification, the specific ES being targeted, verification methodologies adopted, economic implications, and potential future developments in this field. Through our analysis we have unearthed several key findings and theoretical implications.

First and foremost, our study reveals that the Mediterranean region – namely Croatia, France, Italy, Portugal, and Spain - is witnessing a growing interest in ES verification within the FSC framework, albeit with significant variations among countries. Italy emerges as a pioneer, covering all five ES categories, emphasizing the importance of considering the broader ecosystem context and benefits it can deliver in terms of ES in forest management decisions. However, the scope of ES verification remains limited in some countries, suggesting a potential lack of awareness, readiness among forest owners, or competing timber-focused priorities. Biodiversity and Carbon sequestration appear to be the most popular and desired, likely driven by specific policy initiatives and market opportunities. We also identified a significant diversity of methodologies employed in ES assessment within the FSC framework.

While economic implications of verified ES remain largely unexplored and patchy due to limited data availability, this study identifies the need for enhanced transparency and standardized methodologies for assessing economic values. The establishment of a common matrix for methodologies and indicators for ES assessment, besides improving consistency, could attract more investors/sponsors, ensuring reliable investment conditions and thus facilitating economic mechanisms for marketing verified ES, ultimately strengthening market opportunities for them.

It would be beneficial to conduct such a study periodically, ideally on an annual basis, encompassing the full range of the verified ES certificates. This also should yield an updated yearly report that proves valuable to both the FSC and market operators. Implementing this initiative is something that FSC should consider.

As ES and their assessments gain popularity and their financial and market implications become more significant, it is becoming increasingly relevant to foster a close collaboration among market operators, academia, and government departments. This collaboration aims to ensure that these assessments and marketing practices remain as robust as possible. It is well recognized that certification has been an instrumental tool in achieving this objective from the outset.

This study is focused on analyzing impacts of the FSC procedure for ES verification, thus it represents a contribution to monitoring of FSC certification impacts. Monitoring is a critical aspect that serves the dual purpose of maintaining oversight of the certification process and assessing its robustness. Furthermore, this analysis can provide valuable insights to inform ongoing processes, such as Motion 49 approved at the last FSC General Assembly in Bali (October 2022), which seeks to review and enhance the existing Procedure.

In moving forward, this study highlights the necessity for enhanced transparency, improved methodologies, and standardized indicators. It also emphasizes the importance of considering local contexts in crafting financial regulations for ES. The findings underscore the dynamic nature of ES verification and its potential to contribute to both local and global sustainability goals, while also pointing towards avenues for further research and development in this evolving field.

Quoted literature

Abraham, A., Sommerhalder, K., and Abel, T. (2010). Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments. *International journal of public health*, 55, 59-69.

Adhikari, K., and Hartemink, A. E. (2016). Linking soils to ecosystem services-A global review. *Geoderma*, *262*, 101-111.

Andreella, M., Biliotti, M., Bonella, G., Cinquepalmi, F., Duprè, E., La Posta, A., ... and Vindigni, V. (2010). Strategia Nazionale per la Conservazione della Biodiversità. *Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Roma, IT*.

Aznar-Sánchez, J. A., Belmonte-Ureña, L. J., López-Serrano, M. J., and Velasco-Muñoz, J. F. (2018). Forest ecosystem services: An analysis of worldwide research. *Forests*, *9*(8), 453.

Barrios, E. (2007). Soil biota, ecosystem services and land productivity. *Ecological economics*, *64*(2), 269-285.

Bayley, D., Brickle, P., Brewin, P., Golding, N., and Pelembe, T. (2021). Valuation of kelp forest ecosystem services in the Falkland Islands: A case study integrating blue carbon sequestration potential. *One Ecosystem*, *6*, e62811.

Bennett, G., Ruef, F. (2016). Alliances for Green Infrastructure: State of Watershed Investment 2016. *Ecosystem Marketplace*, Washington DC, USA.

Bennett, G., Leonardi, A., Ruef, F. (2017). State of European Markets 2017: Watershed Investments. Forest Trends' Ecosystem Marketplace, Washington DC, USA. https://doi.org/10.13140/RG.2.2.33756.59521

Birdsey, R. A., Jenkins, J. C., Johnston, M., and Huber-Sanwald, E. (2007). Principles of forest management for enhancing carbon sequestration. *The first state of the carbon cycle report (SOCCR)–the North American carbon budget and implications for the global carbon cycle. Global Change Research Information Office, Washington, DC*, 175-176.

Blondel, J. (2006). The 'design' of Mediterranean landscapes: a millennial story of humans and ecological systems during the historic period. *Human ecology*, *34*, 713-729.

Bonan, G. B. (2008). Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science*, *320*(5882), 1444-1449.

Bouma, J. (2014). Soil science contributions towards sustainable development goals and their implementation: linking soil functions with ecosystem services. *Journal of plant nutrition and soil science*, *177*(2), 111-120. http://dx.doi.org/10.1002/jpln.201300646.

Bouriaud, L. (2005). Causes of illegal logging in Central and Eastern Europe. *Small-scale Forest Economics, Management and Policy*, *4*, 269-291.

Brevik, E. C., Cerdà, A., Mataix-Solera, J., Pereg, L., Quinton, J. N., Six, J., and Van Oost, K. (2015). The interdisciplinary nature of SOIL. *Soil*, *1*(1), 117-129.

Brevik, E. C., Calzolari, C., Miller, B. A., Pereira, P., Kabala, C., Baumgarten, A., and Jordán, A. (2016). Soil mapping, classification, and pedologic modeling: History and future directions. *Geoderma*, *264*, 256-274.

Brogna, D., Michez, A., Jacobs, S., Dufrêne, M., Vincke, C., and Dendoncker, N. (2017). Linking forest cover to water quality: A multivariate analysis of large monitoring datasets. *Water*, 9(3), 176.

Bruner, A. G., Gullison, R. E., Rice, R. E., and Da Fonseca, G. A. (2001). Effectiveness of parks in protecting tropical biodiversity. *Science*, *291*(5501), 125-128.

Caboun, V., Kovalcik, M., and Sarvasova, Z. (2014). Concept of the integrative aspects of the forest ecosystem services with case study on recreation services assessment in Slovakia. *Ecological Processes*, 3, 1-6.

Chapin, F. S., Matson, P. A., Mooney, H. A., and Vitousek, P. M. (2002). Principles of terrestrial ecosystem ecology.

Daily, G. C. 1997. Nature's services: Societal dependence on natural ecosystems. Washington: *Island Press*.

Dhanwantri, K., Sharma, P., Mehta, S., and Prakash, P. (2014). Carbon sequestration, its methods and significance. *Environmental Sustainability: Concepts, Principles, Evidences and Innovations*, *151*(2), 151-157.

Dias, F. S., Bugalho, M. N., Rodríguez-González, P. M., Albuquerque, A., and Cerdeira, J. O. (2015). Effects of forest certification on the ecological condition of Mediterranean streams. *Journal of applied ecology*, *52*(1), 190-198. https://doi.org/10.1111/1365-2664.12358

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., ... and Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, 359(6373), 270-272.

Dixon, R., Brown, S., Houghton, R., Solomon, A., Trexler, M., Wisniewski, J. (1994) Carbon pools and flux of global forest ecosystems. *Science* 263:185–190

Doimo, I., Masiero, M., and Gatto, P. (2020). Forest and wellbeing: Bridging medical and forest research for effective forest-based initiatives. *Forests*, 11(8), 791.

Edwards, D. M., Jay, M., Jensen, F. S., Lucas, B., Marzano, M., Montagné, C., ... and Weiss, G. (2012). Public preferences across Europe for different forest stand types as sites for recreation. Ecology and Society, 17(1).

Eggers, J., Lindhagen, A., Lind, T., Lämås, T., and Öhman, K. (2018). Balancing landscape-level forest management between recreation and wood production. Urban Forestry and Urban Greening, 33, 1-11.

Engel, S., Pagiola, S., and Wunder, S. (2008). Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological economics*, 65(4), 663-674.

Enríquez-de-Salamanca, Á. (2021). Carbon versus timber economy in Mediterranean forests. *Atmosphere*, 12(6), 746.

ETIFOR (2022a). Etifor and the revision of the FSC Ecosystem Services Procedure, July 19, 2022. Available at: https://www.etifor.com/en/updates/revision-fsc-ecosystem-services-procedure/ (Last accessed on September 10, 2023)

ETIFOR (2022b). FSC and the Ecosystem Services Procedure. Available at: https://www.etifor.com/en/procedure-fsc-ecosystem-services/ (Last accessed on September 10, 2023)

European Commission. (2006). Thematic Strategy for Soil Protection (COM (2006), 231). http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52006DC0231&from=EN.

European Commission. (2011). *Our Life Insurance, Our Natural Capital: An EU Biodiversity Strategy to 2020: Communication from the Commission to the European Parliament, the Council, the European Economic and*

Social Committee and the Committee of the Regions. Publications Office of the European Union.

European Commission (2023). Water Framework Directive. Available at https://environment.ec.europa.eu/topics/water/water-framework-directive_en (last access September 10th, 2023)

Fahey, T. J., Woodbury, P. B., Battles, J. J., Goodale, C. L., Hamburg, S. P., Ollinger, S. V., and Woodall, C. W. (2010). Forest carbon storage: ecology, management, and policy. *Frontiers in Ecology and the Environment*, *8*(5), 245-252.

FAO and Plan Bleu. (2013). State of Mediterranean Forests 2013. Rome, Italy.

FAO and Plan Bleu. (2018). *State of Mediterranean Forests 2018*. Food and Agriculture Organization of the United Nations, Rome and Plan Bleu, Marseille. Available at: https://www.fao.org/documents/card/en/c/CA2081EN/ (Last accessed on September 10, 2023)

Filoso, S., Bezerra, M. O., Weiss, K. C., and Palmer, M. A. (2017). Impacts of forest restoration on water yield: A systematic review. *PloS one*, 12(8), e0183210.

Ford, C. R., Laseter, S. H., Swank, W. T., and Vose, J. M. (2011). Can forest management be used to sustain water-based ecosystem services in the face of climate change? *Ecological Applications*, 21(6), 2049-2067.

Forest Trends (2023). Available at https://www.forest-trends.org/project-list/#project-action (Last accessed September 10, 2023)

FSC (2021). FSC-PRO-30-006 V1-2 EN. Ecosystem Services Procedure. Available at: https://connect.fsc.org/document-centre/documents/resource/316 (Last access September 10, 2023)

FSC (2022a). Ecosystem Services for Forest Managers. Available at: https://fsc.org/en/ecosystem-services-for-forest-managers (Last access September 10, 2023).

FSC (2022b). Ecosystem Services. Available at: Ecosystem Services | Forest Stewardship Council (fsc.org) (Last access September 10, 2023).

FSC (2022c). Shaping Solutions for Resilient Forests at the 9th FSC General Assembly, November 2, 2022. Available at: https://ga.fsc.org/en/newsfeed/shaping-solutions-for-resilient-forests-at-the-9th-fsc-general-assembly (Last accessed on September 10, 2023)

FSC (2023a). FSC Facts and Figures. Available at: https://connect.fsc.org/impact/facts-figures (Last access September 10, 2023).

FSC (2023b). FSC Search (August 24, 2023). Available at: https://search.fsc.org/en/ (Last access September 10, 2023).

García-Ruiz, J. M., López-Moreno, J. I., Vicente-Serrano, S. M., Lasanta–Martínez, T., and Beguería, S. (2011). Mediterranean water resources in a global change scenario. *Earth-Science Reviews*, 105(3-4), 121-139.

Gebbers, R., and Adamchuk, V. I. (2010). Precision agriculture and food security. *Science*, *327*(5967), 828-831.

Graber, J., Amthor, J., Dahlman, R., Drell, D., and Weatherwax, S. (2008). *Carbon cycling and biosequestration integrating biology and climate through systems science report from the march 2008 workshop* (No. DOE/SC-108). DOESC (USDOE Office of Science (SC)). http://genomicsgtl.energy.gov/carboncycle/

Greiner, L., Keller, A., Grêt-Regamey, A., and Papritz, A. (2017). Soil function assessment: review of methods for quantifying the contributions of soils to ecosystem services. *Land use policy*, *69*, 224-237.

Guardini, B., Secco, L., Moè, A., Pazzaglia, F., De Mas, G., Vegetti, M., ... and Rapisarda, S. (2023). A Three-Day Forest-Bathing Retreat Enhances Positive Affect, Vitality, Optimism, and Gratitude: An Option for Green-Care Tourism in Italy? *Forests*, *14*(7), 1423.

Gundersen, V. S., and Frivold, L. H. (2008). Public preferences for forest structures: A review of quantitative surveys from Finland, Norway and Sweden. *Urban Forestry and Urban Greening*, 7(4), 241-258.

Gunes, Y., and Elvan, O. D. (2005). Illegal logging activities in Turkey. *Environmental Management*, *36*, 220-229.

Gutierrez Garzon, A. R., Bettinger, P., Siry, J., Abrams, J., Cieszewski, C., Boston, K., ... and Yeşil, A. (2020). A comparative analysis of five forest certification programs. *Forests*, 11(8), 863.Haines-Young, R., and Potschin, M. (2012). Common international classification of ecosystem services (CICES, Version 4.1). *European Environment Agency*, *33*, 107.

Haines-Young, R., and Potschin-Young, M. (2018). Revision of the common international classification for ecosystem services (CICES V5. 1): a policy brief. *One Ecosystem*, 3, e27108.

Helbling, T. (2010). What are externalities. *Finance and development*, *47*(4), 198.

Hewitt, A., Dominati, E., Webb, T., and Cuthill, T. (2015). Soil natural capital quantification by the stock adequacy method. *Geoderma*, *241*, 107-114. http://dx.doi.org/10.1016/j. geoderma.2014.11.014.

Hoek van Dijke, A. J. H., Herold, M., Mallick, K., Benedict, I., Machwitz, M., Schlerf, M., ... and Teuling, A. J. (2022). Shifts in regional water availability due to global tree restoration. *Nature Geoscience*, 15(5), 363-368.

Holmes, T. P., Aukema, J. E., Von Holle, B., Liebhold, A., and Sills, E. (2009). Economic impacts of invasive species in forests: past, present, and future. *Annals of the New York Academy of Sciences*, 1162(1), 18-38.

Horal, L., Khvostina, I., Shyiko, V., Radin, M., Korol, S., and Panevnyk, T. (2021). Sustainable development of forest recreation management as a basis for environmental safety. In IOP Conference Series: Earth and Environmental Science (Vol. 628, No. 1, p. 012013). IOP Publishing.

Ingram, J. C., Redford, K. H., and Watson, J. E. (2012). Applying ecosystem services approaches for biodiversity conservation: benefits and challenges. *SAPI EN. S. Surveys and Perspectives Integrating Environment and Society*, (5.1).

Jaung, W., Putzel, L., Bull, G. Q., Kozak, R., and Elliott, C. (2016a). Forest Stewardship Council certification for forest ecosystem services: An analysis of stakeholder adaptability. *Forest Policy and Economics*, 70, 91-98.

Jaung, W., Bull, G. Q., Putzel, L., Kozak, R., and Elliott, C. (2016b). Bundling forest ecosystem services for FSC certification: an analysis of stakeholder adaptability. *International Forestry Review*, 18(4), 452-465.

Jaung, W., Putzel, L., Bull, G. Q., Guariguata, M. R., and Sumaila, U. R. (2016c). Estimating demand for certification of forest ecosystem services: A choice experiment with Forest Stewardship Council certificate holders. Ecosystem services, 22, 193-201.

Jaung, W., Putzel, L., Bull, G. Q., and Kozak, R. (2016d). Certification of forest watershed services: AQ methodology analysis of opportunities and challenges in Lombok, Indonesia. *Ecosystem Services*, 22, 51-59.

Jaung, W., Bull, G. Q., Sumaila, U. R., and Putzel, L. (2018). Estimating water user demand for certification of forest watershed services. *Journal of environmental management*, 212, 469-478.

Jaung, W., Putzel, L., Naito, D. (2019). Can ecosystem services certification enhance brand competitiveness of certified products? Sustainable Production and Consumption, 18: 53-62.

Kangas, J., and Ollikainen, M. (2022). A PES scheme promoting forest biodiversity and carbon sequestration. *Forest Policy and Economics*, *136*, 102692.

Kangas, J., and Ollikainen, M. (2023). Reforming a pre-existing biodiversity conservation scheme: Promoting climate co-benefits by a carbon payment. *Ambio*, 1-14.

Karavani, A., De Cáceres, M., de Aragón, J. M., Bonet, J. A., and de-Miguel, S. (2018). Effect of climatic and soil moisture conditions on mushroom productivity and related ecosystem services in Mediterranean pine stands facing climate change. *Agricultural and Forest Meteorology*, *248*, 432-440.

Kefalas, G., Lorilla, R. S., Xofis, P., Poirazidis, K., and Eliades, N. G. H. (2023). Landscape Characteristics in Relation to Ecosystem Services Supply: The Case of a Mediterranean Forest on the Island of Cyprus. *Forests*, *14*(7), 1286.

Keskitalo, E. C. H., and Pettersson, M. (2012). Implementing multi-level governance? The legal basis and implementation of the EU Water Framework Directive for forestry in Sweden. *Environmental Policy and Governance*, 22(2), 90-103.

Lamrani-Alaoui, M., and Hassikou, R. (2018). Rapid risk assessment to harvesting of wild medicinal and aromatic plant species in Morocco for conservation and sustainable management purposes. *Biodiversity and Conservation*, *27*(10), 2729-2745.

Le Quéré, C., Raupach, M. R., Canadell, J. G., Marland, G., Bopp, L., Ciais, P., ... and Woodward, F. I. (2009). Trends in the sources and sinks of carbon dioxide. *Nature geoscience*, *2*(12), 831-836.

Liu, X., Ferreira-Rodríguez, N., Wu, R., Ouyang, S., and Wu, X. (2023). Sixty years of species diversity and population density decline of freshwater mussels in a global biodiversity hotspot. *Global Ecology and Conservation*, *46*, e02573.

Mace, G. M., Norris, K., and Fitter, A. H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends in ecology and evolution*, *27*(1), 19-26.

Madsen, Becca; Carroll, Nathaniel; Moore Brands, Kelly; 2010. State of Biodiversity Markets Report: Offset and Compensation Programs Worldwide. Available at: http://www.ecosystemmarketplace.com/documents/acrobat/sbdmr.pdf

Mansourian S., Vallauri D. (2020). Tree Planting by Businesses in France, Switzerland and the UK. A study to inspire corporate commitments. Paris: WWF France, 64 pages Masiero, M., Pettenella, D., and Secco, L. (2016). From failure to value: economic valuation for a selected set of products and services from Mediterranean forests. *Forest systems*, *25*(1), e051. https://doi.org/10.5424/fs/2016251-08160

May, R. M. (2023). Loss of biodiversity: concerns and threats. In *Biological and Environmental Hazards, Risks, and Disasters* (pp. 183-189). Elsevier.

McDermott, C. L., Noah, E., and Cashore, B. (2008). Differences that 'matter'? A framework for comparing environmental certification standards and government policies. *Journal of Environmental Policy and Planning*, 10(1), 47-70.

Meijaard, E., Sheil, D., Guariguata, M.R., Nasi, R., Sunderland, T. and Putzel, L. (2011). Ecosystem services certification: opportunities and constraints. *Occasional Paper* 66. CIFOR, Bogor, Indonesia.

MEA (2005). Ecosystems and Human Well-being: Synthesis. *Island Press*, Washington, DC (USA)

Metzger, M. J., Rounsevell, M. D., Acosta-Michlik, L., Leemans, R., and Schröter, D. (2006). The vulnerability of ecosystem services to land use change. Agriculture, ecosystems and environment, 114(1), 69-85.

Montgomery, D. R. (2007). Soil erosion and agricultural sustainability. *Proceedings of the National Academy of Sciences*, *104*(33), 13268-13272.

Mortimer, R., Saj, S., and David, C. (2018). Supporting and regulating ecosystem services in cacao agroforestry systems. *Agroforestry Systems*, *92*(6), 1639-1657.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R. E., Lehner, B., ... and Ricketts, T. H. (2008). Global mapping of ecosystem services and conservation priorities. *Proceedings of the National Academy of Sciences*, *105*(28), 9495-9500. 10.1073/pnas.0707823105

Nicholson, E., Mace, G. M., Armsworth, P. R., Atkinson, G., Buckle, S., Clements, T., ... Milner-Gulland, E. J. (2009). Priority research areas for ecosystem services in a changing world. *Journal of Applied Ecology*, 46(6), 1139-1144.

Nijnik, M., and Miller, D. (2013). Targeting sustainable provision of forest ecosystem services with special focus on carbon sequestration. *Developments in Environmental Science*, *13*, 547-568.

Ningsih, I. K., Ingram, V., and Savilaakso, S. (2020). Voluntary sustainability certification and state regulations: Paths to promote the conservation of ecosystem services? Experiences in Indonesia. *Forests*, 11(5), 503

Nocentini, S., Travaglini, D., and Muys, B. (2022). Managing Mediterranean forests for multiple ecosystem services: research progress and knowledge gaps. *Current Forestry Reports*, *8*(2), 229-256.

Nussbaum, R., and Simula, M. (2013). *The forest certification handbook*. Taylor and Francis.

Olano, J. M., Martínez-Rodrigo, R., Altelarrea, J. M., Ágreda, T., Fernández-Toirán, M., García-Cervigón, A. I., ... and Águeda, B. (2020). Primary productivity and climate control mushroom yields in Mediterranean pine forests. *Agricultural and Forest Meteorology*, *288*, 108015.

Ouyang, Z., Zheng, H., Xiao, Y., Polasky, S., Liu, J., Xu, W., ... and Daily, G. C. (2016). Improvements in ecosystem services from investments in natural capital. *Science,* 352(6292), 1455-1459.

Palahi, M., Mavsar, R., Gracia, C., and Birot, Y. (2008). Mediterranean forests under focus. *International forestry review*, *10*(4), 676-688.

Paluš, H., Krahulcová, M., and Parobek, J. (2021). Assessment of forest certification as a tool to support forest ecosystem services. *Forests*, 12(3), 300.

Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., ... and Hayes, D. (2011). A large and persistent carbon sink in the world's forests. *Science*, *333*(6045), 988-993.

PEFC (2023). Sviluppo standard di Servizi Ecosistemici di Foreste e Piantagioni PEFC Italia. Available at:https://www.pefc.it/cosa-facciamo/sviluppo-standard-di-servizi-ecosistemici-di-foreste-e-piantagioni-pefc-italia/sviluppo-standard-di-servizi-ecosistemici-di-foreste-e-piantagioni-pefc-italia?gclid=EAIaIQobChMIiY3P25WEgQMVeotoCR09GADDEAAYASAAEgJWbPD_BwE (Last accessed on September 10, 2023)

Perry, C. D., Vellidis, G., Lowrance, R., and Thomas, D. L. (1999). Watershed-scale water quality impacts of riparian forest management. *Journal of Water Resources Planning and Management*, 125(3), 117-125.

Pezdevšek Malovrh, Š., Bećirović, D., Marić, B., Nedeljković, J., Posavec, S., Petrović, N., and Avdibegović, M. (2019). Contribution of forest stewardship council certification to sustainable forest management of state forests in selected Southeast European countries. *Forests*, *10*(8), 648.

Pirard, R., and Lapeyre, R. (2014). Classifying market-based instruments for ecosystem services: A guide to the literature jungle. *Ecosystem Services*, 9, 106-114.

Powlson, D. S., Whitmore, A. P., and Goulding, K. W. (2011). Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. *European Journal of Soil Science*, *62*(1), 42-55.

Protected Planet (2023). Discover the world's protected and conserved areas. Available at https://www.protectedplanet.net/en (Last access September 10, 2023)

Raupach, M. R. (2011). Pinning down the land carbon sink. *Nature Climate Change*, *1*(3), 148-149.

Robinson, D. A., Lebron, I., and Vereecken, H. (2009). On the definition of the natural capital of soils: A framework for description, evaluation, and monitoring. *Soil Science Society of America Journal*, *73*(6), 1904-1911. http://dx.doi.org/10.2136/sssaj2008.0332.

Robinson, D. A., Hockley, N., Cooper, D. M., Emmett, B. A., Keith, A. M., Lebron, I., ... and Robinson, J. S. (2013). Natural capital and ecosystem services, developing an appropriate soils framework as a basis for valuation. *Soil Biology and Biochemistry*, *57*, 1023-1033. http://dx.doi.org/10.1016/j.soilbio.2012.09.008.

Sabine, C. L., Heimann, M., and Artaxo, P. (2004). Current status and past trends of the global carbon cycleU U Field CB, Raupach MR, MacKenzie S H. The global carbon cycle: integrating humans, climate and the natural world.

Sánchez, J. J., Marcos-Martinez, R., Srivastava, L., and Soonsawad, N. (2021). Valuing the impacts of forest disturbances on ecosystem services: An examination of recreation and climate regulation services in US national forests. Trees, Forests and People, 5, 100123.

Savilaakso, S., and Guariguata, M. R. (2017). Challenges for developing Forest Stewardship Council certification for ecosystem services: How to enhance local adoption? *Ecosystem Service*s, 28, 55-66.

Scartazza, A., Mancini, M. L., Proietti, S., Moscatello, S., Mattioni, C., Costantini, F., ... and Massacci, A. (2020). Caring local biodiversity in a healing garden: Therapeutic benefits in young subjects with autism. *Urban Forestry and Urban Greening*, *47*, 126511.

Schneider, C., Laizé, C. L. R., Acreman, M. C., and Flörke, M. (2013). How will climate change modify river flow regimes in Europe? *Hydrology and Earth System Sciences*, 17(1), 325-339.

Schröter, D., Cramer, W., Leemans, R., Prentice, I. C., Araújo, M. B., Arnell, N. W., ... Zierl, B. (2005). Ecosystem service supply and vulnerability to global change in Europe. *science*, 310(5752), 1333-1337.

Seijger, C., Kleinschmit, D., Schmidt-Vogt, D., Mehmood-Ul-Hassan, M., and Martius, C. (2021). Water and sectoral policies in agriculture–forest frontiers: An expanded interdisciplinary research approach. *Ambio*, 50, 2311-2321.

Shah, N. W., Baillie, B. R., Bishop, K., Ferraz, S., Högbom, L., and Nettles, J. (2022). The effects of forest management on water quality. *Forest Ecology and Management*, 522, 120397.

Shvidenko A, Barber CV, Persson R (2007) Forest and woodland systems, chap 21. *Island Press, Washington, D.C.*, pp 585–621

Sierra, C. A., Crow, S. E., Heimann, M., Metzler, H., and Schulze, E. D. (2021). The climate benefit of carbon sequestration. *Biogeosciences*, *18*(3), 1029-1048.

Skogen, K., Helland, H., and Kaltenborn, B. (2018). Concern about climate change, biodiversity loss, habitat degradation and landscape change: Embedded in different packages of environmental concern? *Journal for Nature Conservation*, *44*, 12-20.

Steffen, W., Sanderson, R. A., Tyson, P. D., Jäger, J., Matson, P. A., Moore III, B., ... and Wasson, R. J. (2005). *Global change and the earth system: a planet under pressure*. Springer Science and Business Media.

Stupak, I., Lattimore, B., Titus, B. D., and Smith, C. T. (2011). Criteria and indicators for sustainable forest fuel production and harvesting: a review of current standards for sustainable forest management. *Biomass and Bioenergy*, 35(8), 3287-3308.

Sugiura, K., Yoshioka, T., and Inoue, K. (2013). Improvement of forest management in Asia, through assessment of Forest Stewardship Council certification. *Forest science and technology*, *9*(3), 164-170.

Sukhdev, P.W., Schröter-Schlaack, H., Nesshöver, C., Bishop, C., Brink, J., Gundimeda, H., Kumar, P. and Simmons, B. 2010. The economics of ecosystems and biodiversity. Mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB. 333.95 E19. Geneva, Switzerland, UNEP. 36 pp.

(WWF) Vallauri D, Darteyron L-E, Laurans Y, 2022. Paying Foresters to Provide Ecosystem Services? Principles, Analysis of Results to Date in the FSC procedure and the Way Forward. Paris, WWF report, 32 pages.

Zanchi, G., Lucander, K., Kronnäs, V., Lampa, M. E., and Akselsson, C. (2021). Modelling the effects of forest management intensification on base cation concentrations in soil water and on tree growth in spruce forests in Sweden. *European Journal of Forest Research*, 140(6), 1417-1429.

Web sites

Forest Stewardship Council (FSC)
https://fsc.org/en

FSC Connect
https://connect.fsc.org/

International Monetary Fund
https://www.imf.org/external/pubs/ft/fandd/2010/12/basics.htm

Annexes

Annex 1 – Certificate holders with verified ecosystem services within the scope of their certificate per targeted country

Country	Certificate. no.	Certificate holder	Certificate code	Area (ha)
Croatia	1	Sunčane Šume Ltd	SA-FM/COC-003082	9,794.29
France	1	Syndicat Intercommunal de Gestion Forestière de la Région d'Auberive	SGSCH-FM/COC-008560	8,139
	2	Dambach Groupe c/o Evrard de Turckheim	IMO-FM/COC-020126	4,601
	3	Cabinet Bechon	SA-FM/COC-008667	999.5657
	4	Sarl Alcina Forets	SA-FM/COC-010233	397.5114
	5	Sylvamo Foret Services	BV-FM/COC-011160	5.969
Portugal	1	APFCertifica Group Scheme (APFC)	SA-FM/COC-001873	1,356.50
	2	Attractice Cascade Unipessoal Lda	GFA-FM/COC-003058	4,027.21
	3	Parques de Sintra - Monte da Lua, S.A.	SA-FM/COC-004977	772.52
	4	2BForest Lda.	SA-FM/COC-005773	143.6
	5	Florestal, S.A.	SGSCH-FM/COC-005081	3.71
Spain	1	Biesca Agroforestal y Medioambiente, S.L	NC-FM/COC-021968	3,583.44
	2	Consejería de Desarrollo Sostenible de Castilla-La Mancha	NC-FM/COC-029995	4,863.11
	3	Delegación Provincial de Desarrollo Sostenible de Guadalajara	NC-FM/COC-067072	11,097.98
	4	ENCE Energía y Celulosa S.A.	GFA-FM/COC-002886	6,279.19

Country	Certificate. no.	Certificate holder	Certificate code	Area (ha)
	5	Enxeñeria Forestal Asefor S.L. Dba Alvariza	SCS-FM/COC-005374	13,457.99
	6	Promociones Azarbe, Sa	NC-FM/COC-067369	3,507.06
	7	Junta de Castilla-La Mancha - Toledo	NC-FM/COC-065236	2,921.14
	8	Selga, Compañía Galega De Silvicultores	SCS-FM/COC-004741	8.87
	9	Xunta de Galicia; Consellería do Medio Rural	GFA-FM/COC-004211	1,249.33
Italy	1	Agris Sardegna	SA-FM/COC-001436	67
	2	Azienda Agricola Maria Luisa Rosseghini Di Giorgio Invernizzi And C. Società Semplice Agricola	ICILA-FM/COC-002919	148.85
	3	Azienda Agricola Rosa Anna E Rosa Luigia S.S.	ICILA-FM/COC-001010	352
	4	Comune di Ala' Dei Sardi	ICILA-FM/COC-004514	466.17
	5	Ente Parco Nazionale Dell'appennino Tosco-Emiliano	ICILA-FM/COC-004483	10,315
	6	ERSAF - Ente Regionale Per i Servizi All'agricoltura e Alle Foreste	ICILA-FM/COC-000334	16,594
	7	Gianna Masu	ICILA-FM/COC-004356	27.92
	8	Magnifica Comunita' di Fiemme	ICILA-FM/COC-002650	19,598
	9	Partecipanza dei Boschi	ICILA-FM/COC-001009	584.42
	10	Unione di Comuni Valdarno e Valdisieve	ICILA-FM/COC-004098	1448
	11	Waldplus Srl	ICILA-FM/COC-004076	2,706.09

Annex 2 – Verified ecosystem services and impacts per targeted country

Note: For detailed information about impacts look within table 4 in the main text.

Country	Certificate no. (see Annex 1)	ES verified	Impacts
Croatia	1	Carbon sequestration and storage	2.1
		Carbon sequestration and storage	2.2
France	1	Biodiversity Conservation	1.3
	2	Biodiversity Conservation	1.3
		Carbon sequestration and storage	2.1
		Carbon sequestration and storage	2.1
	3	Soil conservation	4.1
		Biodiversity conservation	1.3
	4	Biodiversity Conservation	1.3
		Carbon sequestration and storage	2.1
		Watershed services	3.3
	5	Biodiversity Conservation	1.4
		Biodiversity Conservation	1.5
		Biodiversity Conservation	1.6
		Biodiversity Conservation	1.7
		Carbon sequestration and storage	2.2
		Carbon sequestration and storage	2.2
Portugal	1	Carbon sequestration and storage	2.1
	2	Biodiversity Conservation	1.4
		Carbon sequestration and storage	2.1
	3	Carbon sequestration and storage	2.1
	4	Biodiversity Conservation	1.1
		Biodiversity Conservation	1.3
		Carbon sequestration and storage	2.1
		Carbon sequestration and storage	2.2
		Recreational services	5.1
	5	Biodiversity Conservation	1.1
		Carbon sequestration and storage	2.1
		Carbon sequestration and storage	2.2
Spain	1	Biodiversity Conservation	1.7
		Carbon sequestration and storage	2.1
		Watershed services	3.3
	2	Biodiversity Conservation	1.6
	3	Biodiversity Conservation	1.6
		Carbon sequestration and storage	2.1
	4	Biodiversity Conservation	1.3
		Biodiversity Conservation	1.6
	5	Biodiversity Conservation	1.4
		Biodiversity Conservation	1.4
	6	Carbon sequestration and storage	2.1
	7	Biodiversity Conservation	1.6
	8	Biodiversity Conservation	1.3

Country	Certificate no. (see Annex 1)	ES verified	Impacts
		Carbon sequestration and storage	2.1
	9	Carbon sequestration and storage	2.1
		Watershed services	3.3
Italy	1	Biodiversity Conservation	1.1
		Biodiversity Conservation	1.6
		Carbon sequestration and storage	2.2
		Watershed services	3.4
		Soil conservation	4.1
		Recreational services	5.2
	2	Biodiversity Conservation	1.1
		Biodiversity Conservation	1.7
		Carbon sequestration and storage	2.1
		Soil conservation	4.1
		Recreational services	5.1
	3	Biodiversity Conservation	1.1
		Carbon sequestration and storage	2.1
		Soil conservation	4.1
		Recreational services	5.1
	4	Biodiversity Conservation	1.6
		Carbon sequestration and storage	2.1
		Watershed services	3.3
		Recreational services	5.1
		Soil conservation	4.1
	5	Carbon sequestration and storage	2.1
		Recreational services	5.1
		Biodiversity Conservation	1.6
		Soil conservation	4.1
		Watershed services	3.3
	6	Biodiversity Conservation	1.6
		Recreational services	5.1
		Carbon sequestration and storage	2.2
		Watershed services	3.1
	7	Biodiversity Conservation	1.1
	8	Recreational services	5.2
		Biodiversity Conservation	1.1
		Biodiversity Conservation	1.6
		Carbon sequestration and storage	2.1
		Carbon sequestration and storage	2.2
		Watershed services	3.1
		Soil conservation	4.3
		Recreational services	5.1
	9	Biodiversity Conservation	1.5
		Biodiversity Conservation	1.7
		Carbon sequestration and storage	2.2
	10	Carbon sequestration and storage	2.2
		Recreational services	5.1

Country	Certificate no. (see Annex 1)	ES verified	Impacts
		Biodiversity Conservation	1.4
		Watershed services	3.4
		Soil conservation	4.1
		Soil conservation	4.3
	11	Carbon sequestration and storage	2.2
		Biodiversity Conservation	1.1
		Recreational services	5.2
		Carbon sequestration and storage	2.1
		Carbon sequestration and storage	2.1
		Carbon sequestration and storage	2.1

Annex 3 – Number of impacts verified per targeted country

Note: For detailed information about impacts look within table 4 in the main text.

Impacts	France	Portugal	Spain	Italy	Croatia
1.1	0	2	0	6	0
1.2	0	0	0	0	0
1.3	4	1	2	0	0
1.4	1	1	2	1	0
1.5	1	0	0	1	0
1.6	1	0	4	5	0
1.7	1	0	1	2	0
2.1	3	5	5	8	1
2.2	2	2	0	6	1
3.1	0	0	0	2	0
3.2	0	0	0	0	0
3.3	1	0	2	2	0
3.4	0	0	0	2	0
4.1	1	0	0	6	0
4.2	0	0	0	0	0
4.3	0	0	0	2	0
5.1	0	1	0	7	0
5.2	0	0	0	3	0
5.3	0	0	0	0	0
5.4	0	0	0	0	0

Annex 4 – Different types of methodologies adopted for the verification of ecosystem services, categorised per methodology categories adopted for this study

Inventoring, mapping and monitoring
A field check
Analyze the presence of classified habitats
Comparing the amount of surface covered by conservation areas
Conducting study in spawning area
Evaluate the habitat conservation status
For representativeness, periodic visits for general monitoring and intensive sampling of biodiversity
Forest Integrity Assessment for “Abundance and vitality of focal species or rare and threatened species”
Habitat Mapping using cartography
Implement enhanced natural regeneration on plot edges and stream banks
Implement the control of weeds and the eradication of eucalyptus
Information deduced from forest parameter sheets and documents of the plan
Maintenance, restoration and monitoring of vulnerable soils.
Mapping and measurement of the total management unit (island)
Mapping habitats and protected flora species
Measure area with natural forest cover corresponding to oak habitats
Measure number of flora species
Measure number/diameter of seedlings of sporadic species, released necromass per particle, annual samplings of tall trees and coppice to be cut
Monitoring habitat structural heterogeneity
Monitoring protected fauna species
Monitoring the situation of springs, basins and wells.
Monitoring the species through investigation and stratified systematic sampling
Monitoring to assess the conservation status
Periodically documenting the extension of the surfaces destined for naturalistic conservation for a comparison over time with respect to previous situations

Physical and chemical monitoring
Proper management choices like reduced harvesting
Reliable cartography of the areas where hunting is expressly prohibited
Topological analysis of land use and coverage
Verifying that the maintenance and maintenance activities of the access paths are constant over time
Calculation of total carbon present
Calculate the amount of carbon corresponding to the total biomass and compare with the base value
Calculate the biomass of each tree to give carbon reserve present
Calculate the total amount of carbon in the forest area (IPCC) to compare with the reference value
Calculation of the carbon present through biomass present in the cork oak forest only considering above and below ground woody biomass
Compare carbon fluxes through simple management plan and reference scenario
Determination of organic carbon and other elements in soil
Estimate Above-ground biomass (AGB), Below-ground biomass (BGB), Dead organic matter (DOM) and Soil organic matter
Estimate the carbon content in trees, shrubs and sequestered carbon in extracted wood products
Estimation of tree biomass and carbon storage
IPCC methodology (2006) for the measurement and quantification of CO uptake.
Measurement of carbon stock as result of reduced harvesting
Use of LiDAR technology for the evaluation of the amount of carbon stored and the amount fixed annually
Volume estimation and carbon calculation Using of FSC Carbon Monitoring Tool
Geographic information system and remote sensing
Field visits and GIS analysis
For the shoreline, use of images of the National Plan for Aerial Orthophotography (PNOA) of different dates
Forest inventories and comparison of the various aerial photos taken in successive periods
GIS to measure the area, carry a phytosociological inventory, classify the communities
Mapping of the different conservation areas identified in the forest and possible distances between the conservation areas using GIS for connectivity
Stratification of area using GIS calculations
Use GIS for calculation on the basis of the survey of test areas

Use of GIS and IGN aerial maps and calculation and mapping of intact forest cover in stand typology map
Use of GIS and IGN aerial maps for size
Use of GIS for finding the value of result indicators to compare with the reference value
Use remote sensing techniques based on the calculation of the NDVI to measure the forest cover and condition
Using a thematic GIS for delimination of the area
Reference to existing studies
A documentary check
Calculation based on the history of the management practiced verifiable during the FSC audits
Collect the values of pH and Nitrate concentration and compare them with the standard
Compare the present value of each outcome indicator with the specified value
Compare the values obtained from the Forest Integrity Assessment (EIF) tool with the base data.
Comparing the amount of surface covered by the conservation areas currently with past values
Comparing the current situation of the ecosystem service with the situation prior to the creation of the infrastructure that allows the use of such service
Comparison between the reference value and current value
Identifying conservation within the Management Plan and any integration of new areas
The current value compared to the estimated value of the forest carbon stock immediately following the 2018 Vaia storm
Measuring the degraded forest area
Measuring the degraded forest area without successfully established native tree species [Indicator 1 - Indicator 2]
Universal Soil Loss Equation
Calculation through equation from USLE
Evaluation of the risk of erosion
Management practices
Maintenance of poplar groves and access paths in conservation areas with management of conservation areas
Data collection from reports and surveys
Data collection from reports and surveys

Questionnaire to assess visitor satisfaction
Measurement of abundance or vitality of focal species or rare and threatened species
Measure the abundance or vitality of focal species or rare and threatened species
Measure the length of the paths dedicated to forest welfare
Measurement of the overall length of the paths dedicated to forest welfare and data collection

Annex 5 – Different types of indicators under different ecosystem service

1 Biodiversity Conservation

- % Forest Integrity Assessment Tool (FIAT)
- Abundance of selected species
- Abundance, vitality and habitat availability of focal species or rare and threatened species
- Annual withdrawals (m3/ha)
- Area (ha) of forest cover natural in all management unit
- Area degraded/deflowers stay with seedlings of native trees established with success (ha)
- Area occupied by ecosystem
- Area of the network of conservation areas within the management unit
- Available clasiified habitats
- Characteristics of the forest area. Inventory (No. of plants and average diameter)
- Connectivity to areas of conservation
- Degraded forest area as area ratio total land (ha)
- Degraded or deforested areas where the regeneration of native species has been successfully established
- Disturbance level
- Exotic forest area converted to natural forest cover
- Forest area (ha) mixture of coniferous and broadleaf forest and oak gallery converted to covered natural forest.
- Forest or ecosystem structure
- Habitat area available
- Habitat availability within the management unit for focal species or rare and threatened species
- Hectares of forestry-pastoral heritage planned, managed and FSC certified
- Hectares of surface affected by reforestation (productive and naturalistic) post 1989
- Indices on composition and floristic diversity post 2013
- Level of anthropogenic disturbance at the landscape level
- Living habitat trees per hectare, presence of vertical stratification, limited exploitation
- m3/ha necromass
- Native species diversity
- Natural forest coverage over the entire management unit
- No. of Classical floristic surveys
- No. of native tree plants present
- No. of post-2013 floristic surveys
- No. of Surveys of forest parameters
- Num/ha large trees (habitat For Lucanus cervus And Barbastella barbastellus - focal species)
- Num/ha seed carrier sporadic and “B” trees
- Number of species contacted during avifauna survey activities
- Percentage of habitats of Community Interest with a state of conservation evaluated as favourable.

- Presence of natural environmental values
- Representativeness (number of habitats and number of species present)
- Road density
- Size, Representativeness and Connectivity of Conservation areas
- Song thrush abundance index

2	**Carbon Sequestration and Storage**

- Carbon stocks of biomass and forest soil
- Estimated carbon stock in the cork oak forest
- Forest carbon stock in the whole management unit
- Increase in carbon fluxes compared to the average forest management in the territory.
- Increases in wood stock on surfaces which we manage as proof of increased carbon binding
- Land surface with forest cover or soil vegetation
- Organic carbon (%)
- Soil stability (erosion t/year)
- Total amount of carbon stored
- Total tons of carbon stored per year

3	**Watershed Services**

- % of native deciduous and softwood trees in the 15 m buffer zone on either side of the river axis
- Absence of clean cuts
- Area affected by vulnerable soils
- Condition of the catchment area
- Condition of the hydrographic basins
- cubic meters of water infiltrated annually
- Forest area as a proportion of total land area
- Forest cover (% of UG)
- Forest cover and density
- ICM-Star Index
- Length of outflow channels
- Monitoring and maintenance of hydrographic evidence
- Nitrate concentration
- No. of plants and diameter distribution
- Percentage of the shoreline of a body of water with forest cover
- pH of the water
- Presence of marble trout
- Surface hectares affected by reforestation on vulnerable soils
- Trial areas for characteristics control of the forest area

4	**Soil Conservation**

- Biomass fallout on the ground
- Hectares potentially affected by the phenomena of erosion
- Land surface with forest cover or soil vegetation
- Number of test areas for characteristics control forest stands and

phytosanitary status

- Organic carbon (%)
- Reforested forest area
- Soil properties and conditions
- Vegetation cover and land use factor C

5 Recreational services

- Appreciation of events related to the promotion of the tourist-recreational service of forest bathing
- Area planned and managed for forest welfare
- Average number of daily passages recorded on the main routes
- Correctly maintained area containing valuable elements typical of the landscape
- Creation of rest areas
- Extension of the area of importance for tourist recreational activities which are protected
- Extension of the trail network dedicated to forest welfare
- Improvement of the protected and accessible forest area for educational and scientific activities
- Increase in the number of visitors to the company
- Increased viability on natural ground
- Maintenance interventions on roads, rest areas, viewpoints, springs
- Managed and accessible area for recreation in a natural area
- Media participating in Foreste da Vivere events
- Number of members in the equestrian center
- Number of participants in events
- Number of participants in hiking activities
- Placing of billboards
- Planned, managed and certified hectares
- Properly maintained area containing valuable elements typical of the landscape
- Protected and accessible area (ha) for nature-based recreation with visitor satisfaction
- Survey of tourist attendance
- Tourist presence in hotels in Val di Fiemme
- User satisfaction
- Visitor experience