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Exploring the value of ecosystem services associated with forest genetic resources in Europe: a preliminary assessment with a focus on the Mediterranean region

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Summary

Forests are essential ecosystems that provide a wide range of ecosystem services, with Forest Genetic Resources (FGR) at their core. These genetic materials, found within and among tree and woody plant species, possess economic, environmental, scientific, and societal value. Nonetheless, their recognition in national policies and strategies often remains inadequate. This thesis delves into the intricate relationship between FGR and ecosystem services, particularly in the context of Italy. Our primary objective in this study was to explore the significance of ecosystem services associated with FGR in Italy, considering both the current situation and a future scenario where Italy will be affected by the impacts of climate change. To achieve this, we chose the Delphi method, a structured communication technique used to gather expert opinions and reach consensus on complex issues. Using the Delphi method, we designed a two-round survey and invited experts in the field of ecosystem services in Italy to participate in our study and provide us with their insights and expertise on the topic. The survey results underscored the importance of regulating ecosystem services, such as habitats for plants and animals, natural hazard protection, and carbon storage. Additionally, they revealed an anticipated shift in the importance of these services due to climate change. Furthermore, an analysis of participants' backgrounds emphasizes the significance of involving experts from diverse fields in decision-making processes. In conclusion, by recognizing the value and importance of FGR and the associated ecosystem services, informed decisions can be made in forest management and conservation, especially in the context of climate change.

1. Introduction

The concept of ecosystem services made its debut in scientific literature in the early 1980s when Ehrlich and Ehrlich introduced the term in their 1981 work, "Extinction: The Causes and Consequences of the Disappearance of Species" (De Groot *et al.*, 2010). In the following decade, ecologists further developed the notion of ecosystems as supportive systems that provide vital life support, ecosystem services, and economic benefits (e.g., Ehrlich and Mooney, 1983; Folke *et al.*, 1991; De Groot, 1992). However, it wasn't until the late 1990s that this idea gained significant attention in academic publications, with researchers like Costanza *et al.* (1997) contributing to its recognition (e.g., Costanza *et al.*, 1997; De Groot *et al.*, 2010). In 2005, the Millennium Ecosystem Assessment (MEA) firmly established the idea that ecosystems are essential for human well-being, and these connections could be understood through the concept of ecosystem services (Millennium ecosystem assessment, 2005). The MEA defined ecosystem services as "*the benefits provided by ecosystems*" and outlined a framework for this concept (Millennium ecosystem assessment, 2005). Since then, numerous definitions and frameworks have emerged. For instance, The Economics of Ecosystems and Biodiversity (TEEB) defined ecosystem services as "*direct and indirect contributions of ecosystems to human well-being*" (De Groot *et al.*, 2010). More recently, the concept of "nature's contributions to people" was developed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), building upon the ecosystem service concept. It aims to incorporate social sciences more inclusively into the economic and ecological aspects of ecosystem services (Díaz *et al.*, 2018). Despite of these efforts, debates regarding definitions and classifications of ecosystem services persist (La Notte *et al.*, 2017). Perhaps no single classification can comprehensively encompass the myriad ways in which ecosystems support human existence and well-being. Nevertheless, these classifications remain essential for understanding, studying and valuing ecosystem services (De Groot *et al.*, 2010).

The MEA classifies ecosystem services into four categories: provisioning services (e.g., food, water, timber, fiber, fuel, biochemicals, and genetic resources, etc.), regulating services (e.g., climate regulation, disease regulation, waste treatment, natural hazard regulation, etc.), cultural services (e.g., recreation, education, landscape, etc.), and supporting services (e.g., nutrient cycling) (Millennium ecosystem assessment, 2005). Most other classifications are based on the MEA's framework with some variations. For example, the Common International Classification of Ecosystem Services (CICES), developed from the environmental accounting work undertaken by the European Environmental Agency, includes only the first three categories defined by the MEA, considering supporting services as the underpinning structures, functions, and processes that ultimately give rise to ecosystem services (CICES, 2023). Additional classification systems include the TEEB and IPBES Classifications.

Forest genetic resources (FGR) have several direct and indirect links to ecosystem services. FGR are defined by the United Nations' Food and Agriculture Organization FAO (2014) as "*heritable materials maintained within and among tree and other woody plant species that are of actual or potential economic, environmental, scientific, or societal value*" (Beardmore *et al.*, 2014). They are crucial components of forest ecosystems, providing the foundation for tree growth, adaptation, and evolution. In the context of ecosystem services, FGR possess a dual nature. On one hand, they are essential underlying factors that contribute to a wide array of ecosystem services such as wood production, carbon sequestration, and water regulation (Beardmore *et al.*, 2014). This enhances the functioning and resilience of forest ecosystems, offering a broad spectrum of benefits to society. Genetic diversity within species and populations, on the other hand, bolsters tree growth, reproduction, and overall forest health, improving forest structure and ecosystem processes, as well as resilience.

FGR contribute to provisioning services by supplying tangible products and resources from forests, including timber production, non-timber forest products (e.g., fruits, nuts, resins), and genetic material for breeding programs aimed at enhancing agricultural crops and forest tree species. Additionally, FGR play a role in regulating services by influencing ecological processes and functions within forest ecosystems, including the regulation of water flow, nutrient cycling, soil formation, and climate regulation, thus supporting overall ecosystem stability and resilience. FGR also hold cultural and social values, contributing to cultural services. They are often intertwined with traditional knowledge, local practices, and cultural identity. FGR can also add to aesthetic, spiritual, and recreational significance, providing opportunities for activities like nature-based tourism, artistic inspiration, and spiritual connection with nature.

Considering the critical importance of FGR concerning ecosystem services and recognizing that climate change and various anthropogenic factors pose threats to FGR, research and conservation of these resources should be a policy-making priority. Climate change has already altered different disturbance regimes, such as insect outbreaks, storms, and forest fires. Over the past few decades, rising temperatures and climatic events, like El Niño-Southern Oscillation, have resulted in increased occurrences of severe cyclones, excessive droughts, fires, flooding, and landslides in tropical forest ecosystems (Beardmore *et al.*, 2014). Some climate change models predict substantial dieback in wet tropical forests, including the Amazon, potentially resulting in the loss of carbon sinks and storage, further exacerbating global warming (Beardmore *et al.*, 2014; Lapola *et al.*, 2018). However, predictions about the effects of climate change on FGR vary; while some scientists, such as Hamrick (2004), believe that most trees possess sufficient genetic diversity at the population level to withstand the negative impacts of climate change, others predict severe consequences for tree populations (e.g., Rehfeldt *et al.*, 2001; Mátyás *et al.*, 2009).

At the same time, FGR face threats from other direct and indirect anthropogenic factors. Predictions suggest that the global population will reach 9.6 billion people by 2050, with the least developed nations experiencing significant growth, potentially reaching 2.9 billion by 2100, while developed nations will likely maintain relatively stable population growth (Beardmore *et al.*, 2014). The increased demand for food, energy, and other commodities due to population expansion is expected to have negative impacts on natural resources, particularly forests and their genetic resources. The growing human population may lead to the conversion of forested lands for purposes such as agriculture, agroforestry production, infrastructure development, human settlements, mining, and planted forests for wood, paper, and fuel production. FAO (2022) predicted a 37 percent increase in the demand for wood products by 2050 compared to 2020. In its 2014 report on the state of FGR, FAO identified land use change and the conversion of forested areas into agricultural land as one of the most significant risks to FGR. Additionally, the use of forests for fuelwood and charcoal, particularly as the primary source of energy in many developing countries, is considered as one of the primary drivers of forest degradation in these regions (Honosuma *et al.*, 2012; Beardmore *et al.*, 2014). Furthermore, the introduction of alien and invasive species, either by chance or as a result of unsustainable management practices, could further threaten the conservation of FGR.

To effectively conserve and manage FGR, national and international strategies are required. These strategies should encompass policy and legislation, research initiatives, sustainable forest management practices, the development of private sector planted forests, community management of FGR, and the establishment of genetic conservation reserves (Beardmore *et al.*, 2014). However, the state of forest genetic diversity and FGR has not been a focal point of research in recent decades. According to a bibliometric analysis conducted by researchers from Mediterranean countries, despite the widespread recognition of the significance of genetic diversity for biodiversity conservation, sustainable forest management, the maintenance of ecosystem services and functions, there remains a substantial knowledge gap regarding the genetic diversity of various tree species globally, particularly within the Mediterranean basin (Fady *et al.*, 2022).

1.1 Problem statement

Forest genetic resources (FGR) are the heritable materials maintained within and among tree and other woody plant species that are of actual or potential economic, environmental, scientific, or societal value (Beardmore *et al.*, 2014). These resources are crucial for the vitality of forests and their adaptation to climate change, providing resilience in relation to stress factors, such as pests and diseases (FAO, 2023). Despite their critical role in maintaining forest vitality, the value of FGR and the ecosystem services they provide are often poorly recognized in national policies and strategies on forests, biodiversity, and climate change (FAO, 2023).

In the Mediterranean region and in particular Italy, forests are diverse and rich in genetic resources, contributing significantly to the provision of ecosystem services. However, assigning a value to FGR and their capacity to deliver benefits under the form of ecosystem services is challenging (Elsasser, 2005; EUFORGEN, 2023). The lack of a comprehensive understanding of the value of ecosystem services associated with FGR in Europe, especially in the Mediterranean region, presents a significant gap in knowledge. This gap hinders the development of effective policies and strategies for the conservation and sustainable use of these resources (FAO, 2023).

Moreover, the use of structured expert elicitation techniques, such as the Delphi method, to assess the importance of FGR in the provision of ecosystem services is limited (Filyushkina *et al.*, 2021, Caglayan *et al.*, 2021). The Delphi method, a structured communication technique, is a reliable tool for gathering expert opinions and reaching a consensus on complex issues (Filyushkina *et al.*, 2018, Beiderbeck *et al.*, 2021, Caglayan *et al.*, 2021). It proves particularly valuable when seeking expert consensus in situations where the available information is limited (Beiderbeck *et al.*, 2021). However, its application in the context of FGR and ecosystem services is not well-documented.

Therefore, this study aims to explore the value of ecosystem services associated with FGR in Italy, using the Delphi method. The findings of this study will contribute to the existing body of knowledge on FGR and ecosystem services, providing valuable insights for policymakers, forest managers, and conservationists in Italy and Europe.

1.2 Objectives and research questions

In this section the objectives and the questions we want to answer in this research is presented.

1.2.1- Objectives

The main objective of this thesis is to explore the importance of the ecosystem services associated with FGR in Italy considering both the current situation and a future scenario.

To this aim, the following specific objectives are defined:

1. Identify the FGR-related ecosystem services experts perceive as relevant under present conditions.
2. Identify the FGR-related ecosystem services experts perceive as relevant under a climate change-driven future scenario.
3. Compare the perceptions about FGR-related ecosystem services in the two scenarios and across different experts.
4. Draw general considerations about possible methodological improvements to assess FGR-related ecosystem services at a European scale.

1.2.2- Research questions:

The study will address the following research questions:

1. How do experts in Italy perceive the importance of ecosystem services associated with FGR?
2. How would climate change affect expert's perception of the of ecosystem services associated with FGR?
3. Could participants' background and years of experience working with ecosystem influence their answers?
4. Was the research methodology effective and how can it be improved to scale-it up at a European level?

1.3 Structure of the thesis

The first chapter introduces the concepts of ecosystem services and FGR, explains their significance, and discusses the global state of FGR.

The second chapter comprises the background and literature review. In this chapter, different approaches to valuation of ecosystem services are discussed, and a brief history of ecosystem service and FGR valuation is presented. The chapter concludes with a summary of key publications in the field of FGR valuation.

The third chapter provides details of the methods used in this study. It first explains the Delphi method and its application. Additionally, a brief overview of Italy's forests is presented. The chapter proceeds with a description of the methodologies employed to design the questionnaires for each round and outlines the data analysis process.

The fourth chapter is dedicated to presenting the study's findings. It presents the results of the first round of the survey and elucidates how this data was analyzed and subsequently used to inform the design of the second round. Building on this, the primary focus of this chapter is on the second survey and the analysis of the collected data.

The fifth chapter provides a comprehensive discussion of the results. The chapter first interprets the importance of ecosystem services. Then, the changes in the importance of ecosystem services in the future scenario is discussed, followed by the role of background and years of experience in the results. The implications of the results for policy and management of forests are explained next. Finally, the limitations of this study and possibility of future research are addressed.

Finally, the sixth chapter offers conclusions drawn from the findings of this study.

2. Background and literature review

In this chapter background information about the topics addressed by the thesis are provided, and a summary of the literature on the valuation of FGR is presented.

2.1 Valuation of ecosystem services

Ecosystem services, defined as "the benefits ecosystems provide to people" (Millennium ecosystem assessment, 2005) or the support ecosystems offer for sustainable human well-being (Costanza *et al.*, 1997), emphasise the value that ecosystems hold in enhancing our quality of life (Costanza *et al.*, 2014).

In the realm of natural resource management and conservation, responsible public and private organizations must not only allocate their funds responsibly, but also provide a rationale for their decisions to the public and stakeholders. These processes require strong technical and scientific groundworks. Valuation of ecosystem services, though complex and at times controversial, stands as a necessary effort within ecosystem assessment. It serves as a valuable tool to verify decisions and aids in the prioritization of programs, policies, or actions that demand resource allocation. Furthermore, valuation could assist in the inclusion of public values in environmental initiatives, encouraging widespread participation and support (Ecosystem valuation, 2000).

Various methodologies are available to measure the economic worth of ecosystem services. For services with established market prices, such as provisioning services (e.g., timber, firewood, and non-timber forest products like NTFPs), market prices serve as the valuation basis, through the Market-Price-based approach. On the other hand, non-market services are evaluated through two principal families of valuation approaches.

The first one, known as the Market-Value approach, employs values existing in the market, directly or indirectly connected to the goods and services rendered by ecosystem services. This method either employs benefits or costs as proxies for valuing ecosystem services. Benefit-based methods leverage the financial benefits derived from these services concerning related market goods and services to estimate the value of non-market goods and services. On the other hand, cost-based methods assess the economic worth of a resource by scrutinizing the expenses linked to replicating or replacing the services provided by that resource (Masiero *et al.*, 2019).

The second one, the Demand-Curve approach, comes into play when no market for the ecosystem services exists. This approach attempts to construct a hypothetical demand curve, depicting the relationship between the quantity of a non-market good or service and the price (or cost) that individuals are willing to pay for it. Demand-curve approaches branch into two categories: direct (stated preference) and indirect (revealed preference) methods (Masiero *et al.*, 2019). Direct methods employ surveys to assess the values individual's express willingness to pay (WTP) for services or goods, while indirect methods observe real-world behaviour in assessing individuals' WTP for services (Dlamini, 2012).

There is a vast body of academic and scientific literature about the value of nature. Balvanera *et al.* (2022) identified more than 79,000 studies within this domain. In most of the cases this literature deals with instrumental values of nature (74% of total studies) – including those referred to ecosystem services – both in biophysical (50% of total studies) and monetary (26%) terms. Forests are the type of habitats most covered by nature valuation studies (25% of total studies). Among studies on the value of nature and ecosystems, one of the first (and most debated) ones was from Costanza *et al.* (1997) who argued that ecosystem services represent an important part of the total economic value of the planet, as they contribute to human welfare, both directly and indirectly. The authors estimated the economic value of 17 ecosystem services for 16 biomes. The results indicated an average value of US$33 trillion per year. About 38% of the estimated value was from terrestrial systems, mainly forests (US$4.7 trillion per year) and wetlands (US$4.9 trillion per year). Costanza *et al.* re-estimated the global value of ecosystem services in 2011, using the same methods but updated data. This time they estimated the global value of ecosystem services to be US$125-145 trillion per year. They estimated a US$4.3-20.2 trillion per year loss of ecosystem services between 1997-2011 due to land use change. In this study the value of forests and wetland were estimated to be between US$16.2-19.5 trillion per year and US$26.4-36.2 trillion per year respectively (Costanza *et al.*, 2014).

Besides scientific publications, several assessments and policy documents dealing with the values of nature have been developed over time: from the above-mentioned MEA in 2005 to the recent Dasgupta Review on the Economics of Biodiversity (2021). More details are available in Balvanera *et al.* (2022).

2.2 Value of forest genetic resources

For millennia FGR have functioned as vital lifelines, bolstering human sustenance, elevating food production, propelling medical advancements, and accelerating scientific progress. This genetic diversity within species further underpins their resilience and adaptability in changing environments (Beardmore *et al.*, 2014), and has been instrumental in developing traits highly prized by humanity (Lott and Read, 2021). Besides being standalone ecosystem services, FGR play a pivotal role in providing various other ecosystem services. Over time, numerous tries have been made to assess the use and non-use values of FGR, with a predominant focus on provisioning services, especially timber production, which directly connects to established markets. Genetically enhanced tree plantations are considered essential for the economic sustainability of forestry, thus emphasizing the importance of preserving genetic diversity in breeding materials to ensure genetic progress and adaptability to future needs (Jansson *et al.*, 2017). Some studies also delve into traits that could enhance wood product competitiveness, fortify resistance against diseases and pests, and augment wood durability against decay (Ahtikoski *et al.*, 2020b).

In the earlier estimates, the importance and value of genetic resources usually showed up at the bottom of estimations, not taking into account the modulating effect they have on the provision of all the other services (Acharya *et al.*, 2019). In Costanza *et al.* (1997) estimate of the global value of ecosystem services, among the several categories of ecosystem services assessed, genetic resources only contributed marginally. The estimate for genetic resources was an average value of US$79 per hectare per year, and it was the lowest ranked service. This is even more evident when comparing it to the estimate of US$17,075 per hectare per year for nutrient cycling, which is the highest-ranked ecosystem service (Costanza *et al.*, 1997). As another example on a smaller scale, Brenner *et al.* (2010) assessed the non-market value of ecosystem services in the Catalan coastal zone in Spain, including FGR, using a spatial value transfer analysis. The study unveiled that disturbance regulation emerged as the most valuable ecosystem service, closely followed by aesthetic and recreational services. In contrast, soil formation and genetic resources were ranked as the two least valued ecosystem services.

Even more recent studies suggest the significance of genetic resources are still not understood outside academic circles. For example, in a study by Acharya *et al.* (2019) on the local users and other stakeholders' perceptions of the identification and prioritization of ecosystem services in Nepal, genetic resources – together with hazard protection and hunting services - were the ecosystem services perceived as having the lowest priority.

Nevertheless, attention paid to genetic resources and FGR among them has increased. FAO set the stage by publishing its inaugural report on The State of the World's Plant Genetic Resources for Food and Agriculture in 1998 (Allender, 2011). Subsequently, FAO has been periodically releasing such reports. Additionally, various organizations globally investigate the status of plant genetic resources, supporting their conservation through national programs and gene banks. These initiatives have spawned thousands of projects worldwide, seeking to study, assess value, and conserve genetic resources across diverse domains of agriculture and forestry. In 2014, FAO extended its coverage by publishing its first report on the State of the World's Forest Genetic Resources. Presently, countries are actively preparing and releasing their national reports, exemplified by Australia (2021), Canada (2022), and the USA (2023), in preparation for the second edition of the Global report, slated for publication in 2023.

Moreover, international projects aimed at evaluating and promoting the conservation and use of FGR are gaining attention. A notable example is the "OptFORESTS - Harnessing Forest Genetic Resources for increasing options in the face of environmental and societal challenges" project. OptFORESTS is one of the projects supported by the European Union through the Horizon Europe research and innovation program. The primary goal of the OptFORESTS project is to promote the protection and sustainable use of FGR in Europe, through: 1- Investigating the selection of diverse forest reproductive material (FRM), including mixtures, suited for future climates, 2- Promoting the sustainable use and resilience of natural forests, 3- Expanding and diversifying nursery production, 4- Developing nature-based solutions and tools like expanded Information Systems, along with cultural strategies to bolster forest biodiversity and ecosystem services, 5- Showcasing biodiversity solutions (EFI, 2023).

2.3 Literature review

In the case of forests, studies on the valuation of genetic resources are rare. Valuating FGR is challenging for a series of factors. FGR are generally classified as public goods and they are not easily substituted by other products. It is hard to assess their potential future value, which may accrue only to later generations which are not represented in today's markets. Furthermore, allocation decisions taken today on FGR may be irreversible if they lead to the extinction of a genetic resource (Elsasser, 2005). Next is a summary of some of these attempts to assess and evaluate FGR.

In a comprehensive review, Jansson *et al.* (2017) scrutinized studies concerning the economic implications of genetically enhanced trees and their ramifications for forest management across Scandinavian countries and Finland. Their findings revealed that genetically enhanced trees have appreciably escalated the value of uncultivated land while exerting pressure on existing forests, leading to shorter rotation intervals in forest management. Their review suggested that tree breeding in Scandinavia could enhance volume growth by a substantial 10% to 25%. Results from breeding programs in Nordic countries demonstrated surplus returns on investment, particularly when considering discount rates between 2% and 4%. The study concluded that, given the consequences of climate change, tree improvement programs play a pivotal role in mitigating adverse environmental impacts by testing and providing genetically adapted material for new environments. Furthermore, international collaboration and testing across diverse environmental gradients stand as essential endeavours for assessing the adaptability and resilience of forest trees (Jansson *et al.*, 2017).

Chang *et al.* (2019) conducted a comprehensive literature review of studies assessing the economic impacts of genetic improvement for planted forests. Their review unveiled four primary findings. Firstly, enhancing trees through tree improvement programs effectively elevates forest productivity and generates financial gains. Secondly, forest managers predominantly adopt new technologies in tree improvement to enhance wood production and economic benefits, emphasizing traits such as high-volume yield and height growth. Thirdly, cost-benefit analysis emerges as the predominant method for measuring the economic effects of tree improvement in planted forests. Finally, research into assessing the non-market benefits of tree improvement, such as improved watershed protection, amenities, and conservation of genetic diversity, remains limited, and there is a dearth of techniques to value these benefits outside of the market (Chang *et al.*, 2019).

Serrano-León *et al.* (2020) analysed the economic impacts of utilizing genetically improved forest reproductive material in European forests, focusing on case studies: Scots pine in southern Finland, central Sweden, and central France, and maritime pine in southwestern France. Employing growth models, they simulated growth in improved stands and computed the financial performance of improved forest reproductive materials compared to unimproved sites. Their research demonstrated that the use of genetically improved material significantly augmented financial performance in terms of soil expectation value across all case studies and silvicultural scenarios.

In a study conducted in Finland in 2020, Ahtikoski *et al.* (2020) assessed the effects of genetically improved reforestation material on economic gain through timber and carbon sequestration. The study involved eight simulated pine reforestation stands, with or without genetically improved material, assessing gains in joint timber and carbon production or considering only timber. The results indicated that, irrespective of the climate zone, the use of genetically improved reforestation material substantially boosted financial performance when considering timber and carbon in tandem. The research team also suggested that the implementation of carbon pricing and taxation would significantly elevate the value of uncultivated land, a value that could be further augmented through genetic gain.

A study by Marcu *et al.* (2020) examined the economic consequences of employing forest reproductive materials derived from valuable Norway spruce stands for afforestation initiatives in Romania. Their investigation yielded significant improvements in diameter at breast height (DBH), height, and volume per hectare in stands utilizing genetically improved materials. This growth surge was estimated to elevate profitability within a range of 540 to 3,366 euros per hectare, with a projected potential of reaching 7,560 euros per hectare by the end of the rotation period (110 years).

Soliño *et al.* (2020) employed a discrete choice experiment to analyse the preferences of Spanish society regarding operational programs for the breeding and conservation of maritime pine (Pinus pinaster), considering trade-offs between program characteristics. This study homed in on both the use and non-use values of forest genetic resources, emphasizing the significance of factoring in citizen preferences when allocating public research funds for conservation and improvement programs. The findings indicated that society is willing to invest in research areas such as resistance to biotic risks but is hesitant regarding the acceptance of transgenic forest resources.

3. Research methodology

In this chapter materials and methods employed for this research are described. It contains the overview of the research methods, a brief description of study area, and the step we took to choose our participants, and prepare the and conduct two rounds of survey.

3.1 Overview of research methods

As the initial step, we conducted a comprehensive review of the literature and publications related to the assessment and valuation of FGR. We employed a wide range of keywords associated with valuation and FGR, using various databases such as the Ecosystem Services Valuation Database (ESVD) and The Environmental Valuation Reference Inventory (EVRI) to identify relevant publications, with a primary focus on Mediterranean countries.

Originally, our plan was to perform a meta-analysis based on available publications concerning the valuation of FGR in the Mediterranean region. However, due to the limited number of related publications in this field, we chose to conduct an exploratory survey with experts in the ecosystem services domain. This survey aimed to explain the significance of FGR in the provision of ecosystem services and to serve as a pilot for future surveys to be performed at a wider scale.

To conduct this survey, we chose the Delphi technique. This is a structured and iterative scientific process designed to collect and synthesize insights from a group of experts on a specific subject. It proves particularly valuable when seeking expert consensus in situations where the available information is limited (Beiderbeck *et al.*, 2021). The method was initially developed by the RAND Corporation in the 1950s to establish reliable agreement among experts and has since then found application across diverse scientific fields, from healthcare and medicine to education, business, engineering, social sciences, information management, and environmental studies (Beiderbeck *et al.*, 2021; Okoli and Pawlowski, 2004).

The Delphi technique employs surveys to anonymously collect opinions from participating experts who assess and comment on various questions and statements. These questions and statements can take various forms, including rank-order questions, rating scales, and open-ended questions. After each round, experts receive the group's responses and are encouraged to review and, if they choose so, revise their answers based on the collective insights. Through successive rounds, experts converge toward a consensus or a clearer understanding of the topic, making the results more accurate than traditional polling methods. Furthermore, the anonymity of participants in the Delphi method minimizes the potentially detrimental effects of group dynamics, as seen in group discussions and brainstorming techniques (Beiderbeck *et al.*, 2021).

Considering time constraints and the exploratory nature of this study, we opted to conduct the Delphi survey in two rounds with a scope limited to Italy. This approach facilitated easier and quicker access to participating experts, including when collecting feedback about the methodology itself.

3.2 Study area (Italy)

Situated along the northern coasts of the Mediterranean Sea, Italy experiences a predominant Mediterranean climate characterized by hot and dry summers and mild and humid winters. This climate extends over most of the country, with an average annual temperature of 15°C. Precipitation, averaging 650 mm annually, primarily occurs from autumn to early spring (FAO, 2008). Italy has a total land area of 302,073 km^2, characterized by largely hilly terrain (41.6% of the total surface area), followed by mountainous regions (35%) and lowlands (23.2%) (ISTAT, 2023). The country's diverse topography, coupled with a wide range of climatic conditions spanning from alpine continental to subtropical-maritime, has given rise to various microclimates. These microclimates allow for the cultivation of subtropical species even in northern regions of the country, such as the production of lemons in Liguria (FAO, 2008).

According to Italy's most recent national forest inventory, wooded areas cover 11,054,458 ha of the country, roughly 35% of Italy's total land area. Forests make up 82.2% of this wooded area (9,085,186 ha, equivalent to 30.2% of the national land area), while the remaining 17.8% (1,969,272 ha, or 6.5% of the national land area) consists of other wooded lands (Gasparini *et al.*, 2022). These forests and wooded areas are home to 469 plant species from 61 families, with woody shrubs accounting for 74% of these species (RETERURALE, 2023). Comprehending the importance of FGR in such a diverse country is critical for informed forest management and conservation strategies in Italy.

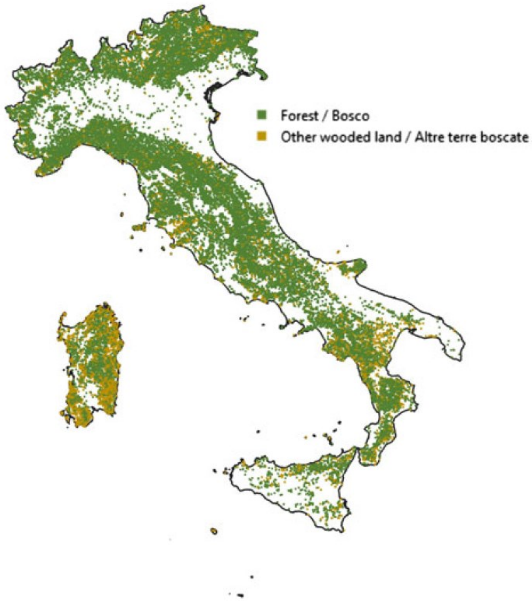


Figure 1: Forest and Other wooded land in Italy (Gasparini et al., 2022)

3.3 Survey

Following the selection of the Delphi technique as our research method, the supervisory team reached out to 12 experts working in the field of forest ecosystem services in Italy to participate in the study. These participants were chosen based on their expertise in the field and their availability to respond to the surveys within the research timeframe. The selected experts represented diverse backgrounds, including both academic research and applied science in the field of ecosystem service projects.

3.3.1 Participant recruitment

Following the selection of the Delphi technique as our research method, the supervisory team reached out to 12 experts working in the field of forest ecosystem services in Italy to participate in the study. These participants were chosen based on their expertise in the field and their availability to respond to the surveys within the research timeframe. The selected experts represented diverse backgrounds, including both academic research and applied science in the field of ecosystem service projects.

3.3.2 First round

To initiate the survey, a questionnaire was designed for the first round. Google Forms served as the platform for conducting the survey. The questionnaire was divided into different sections. The introduction provided a brief overview of the research, its main objectives, and the survey's structure. Subsequent sections collected participants' personal information and professional backgrounds.

In the second section, a brief definition of FGR was presented, and participants were asked to provide a preliminary assessment of the most important ecosystem services provided by FGR. This section began with a brief explanation of FGR and their significance. It then featured two questions, asking participants to name the three most important ecosystem services provided by FGR in Italy and to explain the reasons behind their choices.

While studying the literature on FGR, a list of 19 ecosystem services associated with FGR was extracted from the literature, in the following two sections Participants were with this list of ecosystem services related to FGRs. In the third section, participants were asked to rate these ecosystem services in terms of importance on a scale from 1 to 10, with 1 signifying "not important at all" and 10 signifying "extremely important." In the next section, participants were again requested to rate the importance of these same ecosystem services but in the context of future scenarios, considering the risks and threats posed by climate change. Finally, participants were encouraged to introduce any additional references related to the assessment and valuation of FGRs and to provide contact information for experts in the field of ecosystem services who could assist in future similar studies. The full questionnaire used for the first survey round can be found in Annex 1.

On August 1, 2023, invitation emails, including links to the survey, were sent to the participants, who were given a two-week period to complete the survey.

3.3.3 Data analysis

Upon receiving participants' responses for the first round, the data was assessed and analysed. To analyse these preliminary questions, we the given answers into the three groups of the ecosystem services, to understand which group is the most important to our expert participants. The mean, mode, and standard deviation of the data from the Likert scale was calculated. These statistical measures facilitated a comprehensive analysis of expert viewpoints, helping to identify areas of agreement, disagreement, and the overall level of uncertainty within the survey data. This statistical analysis forms the foundation for deriving meaningful insights and drawing conclusions from the collected expert opinions.

3.3.4 Second round

Based on the results from the first round, a second questionnaire was individually designed for each respondent. Microsoft Word was employed as the platform for the second round. The questionnaire consisted of three sections, commencing with a brief introduction and summarization of the second round of the survey. The subsequent two sections presented the participants with their first-round responses regarding the current and future importance of ecosystem services provided by FGRs. Additionally, the mode and mean results as from the first round were provided for each ecosystem service.

To reach a consensus, participants were asked to review the results and decide if they wish to revise their answers. They were also invited to provide their reasoning if they chose not to make changes. The participants were contacted again by email on September 4, 2023 with the new questionnaire and a short description of the second-round survey, and were given a two-week period to complete the survey. The second-round questionnaire can be found in Annex 2**.**

After collecting the data with the questionnaire, first we used scatter plot to visualize the data. Then calculated the mode, mean and standard deviation and draw bar charts for comparison. To assess if our experts have reached consensus, we decided to use interquartile range with a maximum of 25% threshold (Aczel *et al.*, 2018, Beiderbeck *et al.*, 2021).

Finally, we decided to farther analyze the data by examining the influence of the participants' background and their years of experience working with ecosystem services with our results. First, for the background, we also divided the participants into two groups, first group the academics working at TESAF, and the second group, the project managers working at ETIFOR. For years of experience, we divided the participating experts into two groups based on their years of experience in the field of ecosystem services. We set 8 years as the threshold and based on that divided the participants into higher work experience and lower work experience group. After the divisions, we ran independent t-tests on them to determines whether there is a statistically significant difference among them.

4. Results

In this chapter, we present the results of the survey conducted to explore the value of ecosystem services associated with FGR. In the first section the results of the first round of the Delphi survey are explained, including the preliminary assessment and present and future importance of ecosystem services based on the participants. Then the results of the second round are addressed. This section consists of description of the mean diagram, consensus

4.1 First round of the Delphi survey

To conduct this pilot study, we contacted 12 experts to participate in our survey. Out of the 12 experts contacted, 10 responded to the questionnaire in time to proceed with the second round. During the designated response period, some participants encountered complications with the Google Forms platform used for the survey. Consequently, the remaining participants were provided with the questionnaire in Microsoft Word format to avoid further complications. Data collected through the two different channels/tools – i.e., Google Form and Word file – were initially kept separated in order to check any possible inconsistency due to the survey tools.

4.1.1 Preliminary assessment

As the initial step in assessing the first round of the survey, we analysed the responses to the preliminary question, which asked participants to name the three most important ecosystem services provided by FGR in Italy. The experts' responses encompassed a wide range of services. To facilitate a better understanding and analysis, we classified these services into three groups, in consistency with CICES ecosystem service classification: Provisioning, Regulating, and Cultural services. Table 1 presents the type of ecosystem services named by respondents, grouped according to this classification. The majority of services identified by the experts fall under Regulating services, with Provisioning and Cultural services following suit.

Table 1: Three most important ecosystem services provided by FGR in Italy based on the opinion of the participants (number within brackets indicate frequencies for each ecosystem service, i.e., the number of times each ecosystem service was mentioned)

Type of ecosystem services	Ecosystem services

Provisioning	1- Genetic material and resources (3) 2- Food, timber and medicine (3)	
Regulating	1- Biodiversity (5) 2- Climate regulation (1) 3- CO2 sequestration (3) 4- Disturbance regulation (1) 5- Habitat (3) 6- Hazard protection (1) 7- Hydrogeological protection (2)	8- Landscape (1) 9- Lifecycle maintenance (2) 10- Pest resistant genes (1) 11- Water and air purification (2) 12- Water cycle regulation (1)
Cultural	1- Cultural services (in particular landscape value) (1) 2- Cultural values (1) 3- Education (1)	1- Elder trees (as part of cultural ecosystem services) (1) 2- Recreational services (1)

4.1.2 Present and future importance of ecosystem services

In the first round of the Delphi survey, participants were asked to score the importance of 19 ecosystem services on a Likert scale to assess the significance of ecosystem services provided by FGR in Italy, both in the present and under future scenarios featuring a warmer and drier climate. To analyze the responses, we initially calculated the mode, mean, and standard deviation for each service in both the present and future scenarios. Figure 1 visually represents the means for each ecosystem service.

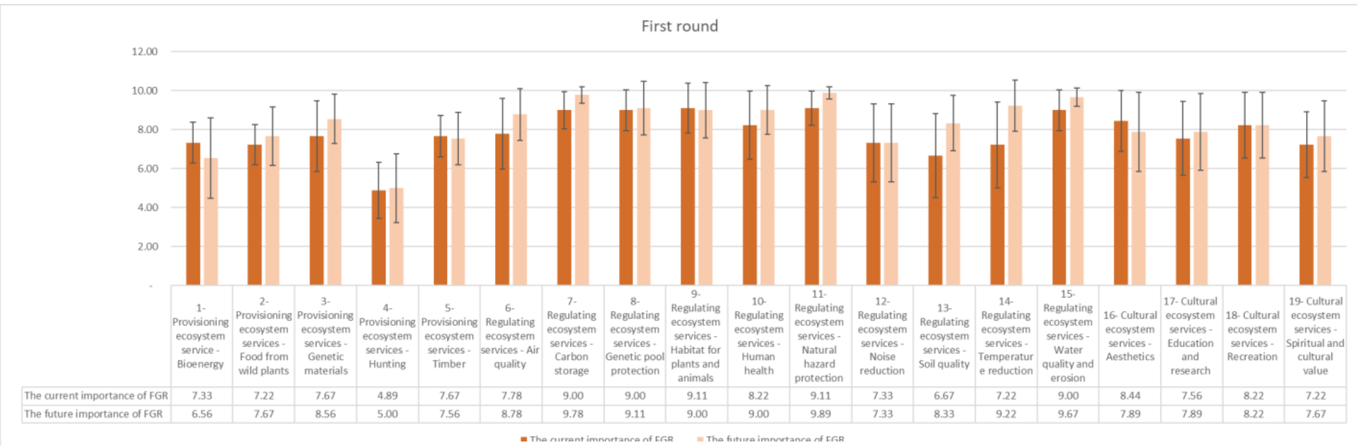


Figure 2:Average grades given to each ecosystem service by the participants in the first round of the Delphi survey

Based on the results, regulating services received the highest scores in both the current and future scenarios. The most important ecosystem services in the present include: 1) habitats for plants and animals, 2) natural hazard protection, and 3) carbon storage. Conversely, the least important services are: 1) hunting,

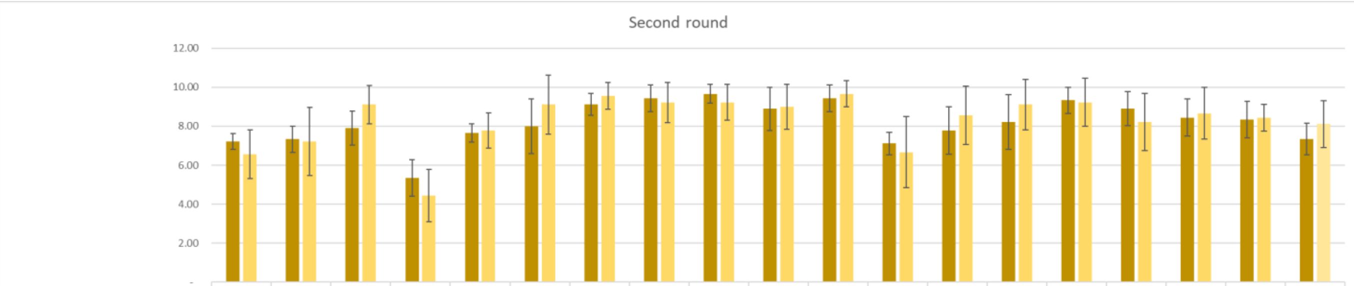
2) soil quality, and 3) food from wild plants. In the future scenario with climate change, the most important ecosystem services are: 1) natural hazard protection, 2) carbon storage, and 3) water quality and erosion. Conversely, the least important services are: 1) hunting, 2) bioenergy, and 3) noise reduction. Among all the ecosystem services, only hunting has an average bellow 6 (which could be considered to be the middle scale line) both in the present condition and future scenario.

The diagram also illustrates that the importance of almost all ecosystem services increases in the future scenario, except for four. According to the participants, bioeconomy, aesthetics, timber, and habitats for plants and animals are expected to lose some of their importance in Italy's future. Meanwhile, temperature reduction, soil quality, and air quality are predicted to significantly increase in importance.

Based on the calculated standard deviations, temperature reduction, soil quality and noise reduction were the ecosystem services that our experts had the least agreement on for the present condition, while bioenergy, aesthetic and noise reduction would be the spot as bottom three for the future scenario. On the other hand, participants had closer opinions on natural hazard protection and carbon storage for both present and future.

4.2 Second round of the Delphi survey

For the second round, we designed a revised questionnaire, asking participants to reconsider their answers based on the calculated means and modes from the first round. Nine participants responded to the second round of the survey.



	1- Provisioning ecosystem service - Bioenergy	2- Provisioning ecosystem services - Food from wild plants	3- Provisioning ecosystem services - Genetic materials	4- Provisioning ecosystem services - Hunting	5- Provisioning ecosystem services - Timber	6- Regulating ecosystem services - Air quality	7- Regulating ecosystem services - Carbon storage	8- Regulating ecosystem services - Genetic pool protection	9- Regulating ecosystem services - Habitat for plants and animals	10- Regulating ecosystem services - Human health	11- Regulating ecosystem services - Natural hazard protection	12- Regulating ecosystem services - Noise reduction	13- Regulating ecosystem services - Soil quality	14- Regulating ecosystem services - Temperature reduction	15- Regulating ecosystem services - Water quality and erosion	16- Cultural ecosystem services - Aesthetics	17- Cultural ecosystem services - Education and research	18- Cultural ecosystem services - Recreation	19- Cultural ecosystem services - Spiritual and cultural value
The current importance of FGR - revised	7.22	7.33	7.89	5.33	7.67	8.00	9.11	9.44	9.67	8.89	9.44	7.11	7.78	8.22	9.33	8.89	8.44	8.33	7.33
The future importance of FGR - revised	6.56	7.22	9.11	4.44	7.78	9.11	9.56	9.22	9.22	9.00	9.67	6.67	8.56	9.11	9.22	8.22	8.67	8.44	8.11

Figure 3: Average grades given to each ecosystem service by the participants in the second round of the Delphi survey

Similar to the first round, regulating services received the highest scores in the second round as well. Following the revision, the most important ecosystem services in Italy in the present are: 1) habitat for plants and animals, 2) genetic pool protection, and 3) natural hazard protection. In the future scenario, the most important ecosystem services would be: 1) natural hazard protection, 2) carbon storage, and 3) genetic pool protection. On the other hand, the least important services for both present and future scenarios in Italy are: 1) hunting, 2) noise reduction, and 3) bioenergy. In the second round, similar to the first round, only hunting has an average rating below 6, both in the present condition and the future scenario.

In this round, the perceived importance of ecosystem services such as genetic materials, air quality, and noise reduction increases the most in the future scenario. Conversely, hunting, aesthetics, and bioenergy are the top three services that lose their significance in the future.

In the second round, air and soil quality, as well as temperature reduction for the present condition, and noise reduction, food from wild plants, and air quality for the future scenario, exhibit the widest range of perceived importance and demonstrate the least consensus among the experts. On the contrary, experts show the highest level of agreement regarding bioenergy, timber, and habitat for plants and animals in the present scenario. These ecosystem services are then replaced at the top of the list by natural hazard protection, recreation, and carbon storage in the future scenario.

4.2.1 Consensus

The Delphi technique's purpose is to reach consensus among experts, and the survey continues until consensus is achieved. To assess consensus, we initially plotted the data to visually compare the data from the two rounds of the survey. The scatter plot (Figure 3) illustrates a reduction in data dispersion in the second round for nearly all ecosystem services in both present and future scenarios.

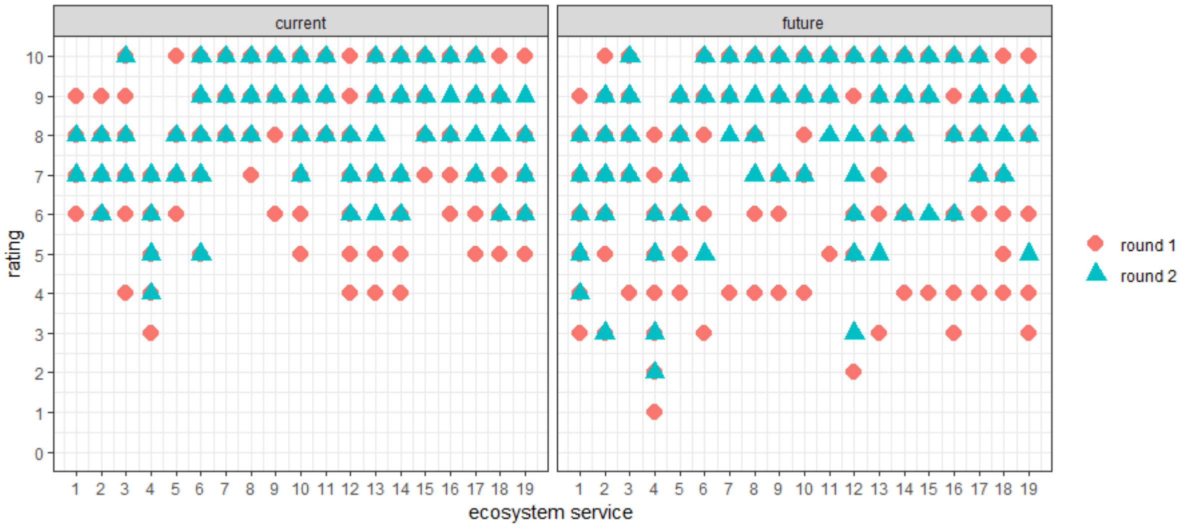


Figure 4: Scatter plot of the data from the two rounds of the Delphi survey

To evaluate if consensus was reached among the experts in the second round, we used the interquartile range, a measure of statistical dispersion. This technique is commonly employed to assess consensus in Delphi surveys, and we set our threshold at 25%. Based on the interquartile range technique, we successfully achieved consensus among the experts for all 19 ecosystem services in question, eliminating the need for additional rounds. Interquartile range data are provided in table 2.

Table 2: the results for the interquartile range used to assess the consensus

Current condition					***Future scenario***				
Percentile	**Q1**	**Median**	**Q3**	**IQR**	**Percentile**	**Q1**	**Median**	**Q3**	**IQR**
1- Bioenergy	7	7	7.5	0.5	**1- Bioenergy**	5.5	7	7.5	2
2- Food from wild plants	7	7	8	1	**2- Food from wild plants**	6.5	8	8.5	2
3- Genetic materials	7	8	8	1	**3- Genetic materials**	8.5	9	10	1.5
4- Hunting	4.5	5	6	1.5	**4- Hunting**	3	5	5.5	2.5
5- Timber	7	7	8	1	**5- Timber**	7	8	8.5	1.5
6- Air quality	7	8	9	2	**6- Air quality**	9	10	10	1
7- Carbon storage	9	9	9.5	0.5	**7- Carbon storage**	9	10	10	1

Current condition					Future scenario				
8- Genetic pool protection	9	10	10	1	8- Genetic pool protection	8.5	10	10	1.5
9- Habitat for plants and animals	9	10	10	1	9- Habitat for plants and animals	9	9	10	1
10- Human health	8	9	10	2	10- Human health	8	9	10	2
11- Natural hazard protection	9	10	10	1	11- Natural hazard protection	9.5	10	10	0.5
12- Noise reduction	7	7	7.5	0.5	12- Noise reduction	5.5	7	7.5	2
13- Soil quality	7	7	9	2	13- Soil quality	8	9	10	2
14- Temperature reduction	7	9	9.5	2.5	14- Temperature reduction	8.5	10	10	1.5
15- Water quality and erosion	9	9	10	1	15- Water quality and erosion	9	10	10	1
16- Aesthetics	8	9	10	2	16- Aesthetics	7	8	10	3
17- Education and research	7.5	9	9	1.5	17- Education and research	7	9	10	3
18- Recreation	8	9	9	1	18- Recreation	8	9	9	1
19- Spiritual and cultural value	7	7	8	1	19- Spiritual and cultural value	8	8	9	1

4.2.2 Independent t-test

Next, we used independent t-test to study the influence of participants' background and years of experience working in the field of ecosystem services on the results. For the background, the result of the independent t-test is statistically significant for seven ecosystem services under current conditions (Table 3). The seven ecosystem services were food from wild plants, gene pool protection, human health, natural hazard protection, temperature reduction, water quality and erosion, education and research. Except for education and research (cultural ecosystem services), all the others belong to regulating services, while the t-test did not show significant results for any of the Provisioning services. In the future scenario, the result of independent t-test only shows education and research (cultural ecosystem services) to be significant.

Table 3: Result of the independent t-test for participants' background

Ecosystem services	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Current condition					
1- Provisioning ecosystem service - Bioenergy	7.17	.408	-.509	7	.626

Ecosystem services	Mean	Std. Deviation	t	df	Sig. (2-tailed)
	7.33	.577			
2- Provisioning ecosystem services - Food from wild plants	7.67	.516	2.646	7	.033
	6.67	.577			
3- Provisioning ecosystem services - Genetic materials	8.17	.983	1.330	7	.225
	7.33	.577			
4- Provisioning ecosystem services - Hunting	5.33	1.211	.000	7	1.000
	5.33	.577			
5- Provisioning ecosystem services -Timber	7.67	.516	.000	7	1.000
	7.67	.577			
6- Regulating ecosystem services - Air quality	8.50	1.225	1.528	7	.170
	7.00	1.732			
7- Regulating ecosystem services - Carbon storage	9.17	.753	.370	7	.722
	9.00	.000			
8- Regulating ecosystem services - Genetic pool protection	9.83	.408	3.564	7	.009
	8.67	.577			
10- Regulating ecosystem services - Human health	9.50	.837	3.361	7	.012
	7.67	.577			
11- Regulating ecosystem services - Natural hazard protection	9.83	.408	3.564	7	.009
	8.67	.577			
12- Regulating ecosystem services - Noise reduction	7.33	.516	1.764	7	.121
	6.67	.577			
13- Regulating ecosystem services - Soil quality	8.17	1.329	1.326	7	.226
	7.00	1.000			
14- Regulating ecosystem services - Temperature reduction	9.00	1.095	3.381	7	.012
	6.67	.577			
15- Regulating ecosystem services - Water quality and erosion	9.67	.516	2.646	7	.033
	8.67	.577			
16- Cultural ecosystem services - Aesthetics	9.17	.983	1.330	7	.225

Ecosystem services	Mean	Std. Deviation	t	df	Sig. (2-tailed)
	8.33	.577			
17- Cultural ecosystem services - Education and research	9.00	.632	3.819	7	.007
	7.33	.577			
18- Cultural ecosystem services - Recreation	8.33	1.211	.000	7	1.000
	8.33	.577			
19- Cultural ecosystem services - Spiritual and cultural value	7.67	.816	1.871	7	.104
	6.67	.577			
Future scenario					
1- Provisioning ecosystem service - Bioenergy	6.33	1.506	-.683	7	.516
	7.00	1.000			
2- Provisioning ecosystem services - Food from wild plants	7.50	2.258	.610	7	.561
	6.67	.577			
3- Provisioning ecosystem services - Genetic materials	9.33	1.211	.882	7	.407
	8.67	.577			
4- Provisioning ecosystem services – Hunting	4.17	1.722	-.810	7	.445
	5.00	.000			
5- Provisioning ecosystem services -Timber	7.67	1.211	-.461	7	.659
	8.00	.000			
6- Regulating ecosystem services - Air quality	9.17	2.041	.137	7	.895
	9.00	.000			
7- Regulating ecosystem services - Carbon storage	9.50	.837	-.306	7	.769
	9.67	.577			
8- Regulating ecosystem services - Genetic pool protection	9.50	1.225	1.091	7	.311
	8.67	.577			
9- Regulating ecosystem services - Habitat for plants and animals	9.33	1.211	.461	7	.659
	9.00	.000			
10- Regulating ecosystem services - Human health	9.33	1.211	1.183	7	.275
	8.33	1.155			

Ecosystem services	Mean	Std. Deviation	t	df	Sig. (2-tailed)
11- Regulating ecosystem services - Natural hazard protection	9.67	.816	.000	7	1.000
	9.67	.577			
12- Regulating ecosystem services - Noise reduction	6.67	2.422	.000	7	1.000
	6.67	.577			
13- Regulating ecosystem services - Soil quality	8.67	1.966	.279	7	.788
	8.33	.577			
14- Regulating ecosystem services - Temperature reduction	9.33	1.633	.667	7	.526
	8.67	.577			
15- Regulating ecosystem services - Water quality and erosion	9.17	1.602	-.170	7	.870
	9.33	.577			
16- Cultural ecosystem services – Aesthetics	8.67	1.633	1.247	7	.252
	7.33	1.155			
17- Cultural ecosystem services - Education and research	9.33	1.211	2.646	7	.033
	7.33	.577			
18- Cultural ecosystem services – Recreation	8.50	.837	.306	7	.769
	8.33	.577			
19- Cultural ecosystem services - Spiritual and cultural value	8.00	1.549	-.350	7	.736
	8.33	.577			

As for the number of years of experience, independent t-test was not statistically significant for any of the ecosystem services (table 4).

Table 4: Result of the independent t-test for participants' years of experience

Ecosystem services	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Present condition					
1- Provisioning ecosystem service - Bioenergy	7.17	.408	-.509	7	.626
	7.33	.577			
2- Provisioning ecosystem services - Food from wild plants	7.33	.816	.000	7	1.000

Ecosystem services	Mean	Std. Deviation	t	df	Sig. (2-tailed)
	7.33	.577			
3- Provisioning ecosystem services - Genetic materials	8.00	1.095	.483	7	.644
	7.67	.577			
4- Provisioning ecosystem services - Hunting	5.33	1.033	.000	7	1.000
	5.33	1.155			
5- Provisioning ecosystem services -Timber	7.67	.516	.000	7	1.000
	7.67	.577			
6- Regulating ecosystem services - Air quality	7.67	1.506	-.935	7	.381
	8.67	1.528			
7- Regulating ecosystem services - Carbon storage	9.33	.516	1.764	7	.121
	8.67	.577			
8- Regulating ecosystem services - Genetic pool protection	9.33	.816	-.624	7	.553
	9.67	.577			
10- Regulating ecosystem services - Human health	8.83	1.329	-.189	7	.855
	9.00	1.000			
11- Regulating ecosystem services - Natural hazard protection	9.33	.816	-.624	7	.553
	9.67	.577			
12- Regulating ecosystem services - Noise reduction	7.00	.632	-.764	7	.470
	7.33	.577			
13- Regulating ecosystem services - Soil quality	7.83	1.472	.170	7	.870
	7.67	1.155			
14- Regulating ecosystem services - Temperature reduction	8.00	1.549	-.611	7	.561
	8.67	1.528			
15- Regulating ecosystem services - Water quality and erosion	9.33	.816	.000	7	1.000
	9.33	.577			
16- Cultural ecosystem services - Aesthetics	9.00	.894	.483	7	.644
	8.67	1.155			
17- Cultural ecosystem services - Education and research	8.33	1.211	-.441	7	.673

Ecosystem services	Mean	Std. Deviation	t	df	Sig. (2-tailed)
	8.67	.577			
18- Cultural ecosystem services - Recreation	8.17	1.169	-.683	7	.516
	8.67	.577			
19- Cultural ecosystem services - Spiritual and cultural value	7.17	.753	-.798	7	.451
	7.67	1.155			
Future scenario					
1- Provisioning ecosystem service - Bioenergy	6.33	1.633	-.683	7	.516
	7.00	.000			
2- Provisioning ecosystem services - Food from wild plants	7.67	1.211	1.018	7	.342
	6.33	2.887			
3- Provisioning ecosystem services - Genetic materials	9.33	.816	.882	7	.407
	8.67	1.528			
4- Provisioning ecosystem services – Hunting	4.33	1.506	-.312	7	.764
	4.67	1.528			
5- Provisioning ecosystem services -Timber	8.00	1.095	.966	7	.366
	7.33	.577			
6- Regulating ecosystem services - Air quality	9.50	.548	1.024	7	.340
	8.33	2.887			
7- Regulating ecosystem services - Carbon storage	9.83	.408	1.852	7	.106
	9.00	1.000			
8- Regulating ecosystem services - Genetic pool protection	9.33	.816	.408	7	.695
	9.00	1.732			
9- Regulating ecosystem services - Habitat for plants and animals	9.33	.516	.461	7	.659
	9.00	1.732			
10- Regulating ecosystem services - Human health	9.00	1.095	.000	7	1.000
	9.00	1.732			
11- Regulating ecosystem services - Natural hazard protection	9.83	.408	1.000	7	.351
	9.33	1.155			

Ecosystem services	Mean	Std. Deviation	t	df	Sig. (2-tailed)
12- Regulating ecosystem services - Noise reduction	6.67	1.033	.000	7	1.000
	6.67	3.512			
13- Regulating ecosystem services - Soil quality	8.83	.983	.718	7	.496
	8.00	2.646			
14- Regulating ecosystem services - Temperature reduction	9.33	.816	.667	7	.526
	8.67	2.309			
15- Regulating ecosystem services - Water quality and erosion	9.50	.548	.894	7	.401
	8.67	2.309			
16- Cultural ecosystem services - Aesthetics	8.33	1.506	.284	7	.785
	8.00	2.000			
17- Cultural ecosystem services - Education and research	8.67	1.506	.000	7	1.000
	8.67	1.528			
18- Cultural ecosystem services - Recreation	8.33	.816	-.624	7	.553
	8.67	.577			
19- Cultural ecosystem services - Spiritual and cultural value	8.50	.548	1.369	7	.213
	7.33	2.082			

5. Discussion

In this chapter, we delve into the findings of our study, offering interpretations of results and insights based on them. Section 5.1 elucidates the significance of ecosystem services based on our study's results. Section 5.2 delves into the changing importance of these services in a future scenario. Section 5.3 provides an analysis of how participants' backgrounds and experience influenced the results. We briefly outline the policy and management implications in Section 5.4. Lastly, Section 5.5 outlines the limitations of our study and suggests avenues for future research

5.1 Ecosystem services importance

Our study revealed that experts who participated in our survey consistently rated regulating ecosystem services as the most vital both in the present and in the projected future with a warmer, drier climate. This finding matches the responses to preliminary questions; however, results underscore the importance of ecosystem services like habitats for plants and animals, natural hazard protection, and carbon storage. These regulating services are critical for maintaining ecosystem stability and functionality in Italian forests, especially under the challenges posed by climate change. They contribute significantly to biodiversity preservation, natural hazard mitigation, and climate change mitigation, aligning with the vital role of FGR in enhancing forest resilience and resistance to various disturbances (Alfaro *et al.*, 2014). Our results align with similar studies; for instance, a survey within the H2020 project found that regulating and cultural ecosystem services were the most highly valued across 33 European countries (Winkel *et al.*, 2022).

On the contrary, provisioning services received substantially lower scores, with services like hunting and bioenergy ranking among the least valued. This suggests that our experts did not prioritize provisioning services, particularly hunting and bioenergy, among the most valued FGR-associated services in Italy. To some extent this is in line with the current state of Italian forests that, for example, show the second lowest (just before Cyprus) share of removals to net increment within European Union countries (Eurostat, 2020). Moreover, this sentiment resonates with findings from Winkel *et al.* (2022). In their survey, participants evaluated provisioning services considerably lower and less important than regulating and culture services, putting hunting, timber and firewood at the bottom of the list (Winkel *et al.*, 2022). Our results may also reflect the environmental orientation of our participants, as verified by studies on societal awareness regarding forest ecosystem services (Pülzl *et al.*, 2021). Emphasis on climate change effects and impacts, in particular in terms of temperature increase and changes in precipitation patterns and regimes, might have induced respondents to focus on Regulating services rather than on others. At the same time our survey did not allow to catch whether and to what extent respondents might have considered policy issues for the aims of their assessment, in particular with reference to future scenarios. This refers, for example, to the fact that they might have over-considered the relevance of certain European policies, such as the Biodiversity Strategy to 2030 and the Nature Restoration Law, and under-considered the importance of certain others, such as the Bioeconomy Strategy.

5.2 Changing importance of services under challenges posed by climate change

Climate change is exerting an increasingly significant impact on ecosystem services, a trend likely to intensify further in the future. The complex, uncertain nature of ecosystems, coupled with interactions with various agents of change, makes predicting future implications challenging (Runting *et al.*, 2017). Forests are facing heightened vulnerability due to climate-induced disturbances such as droughts, wildfires, storms, pests, and diseases, posing a significant challenge to forest resilience and the provision of ecosystem services (Winkel *et al.*, 2022).

Our survey indicates that climate change will alter the importance of specific ecosystem services in the future. Notably, natural hazard protection, carbon storage, and genetic pool protection emerge as the most critical services linked to FGR in the future. Conversely, services like hunting, noise reduction, and bioenergy, already ranking low, are projected to diminish further in importance. A possible interpretation of this results links to the idea that, on the one hand CO_2 concentration in the atmosphere is one of the main direct drivers of climate change, while carbon sequestration by forests is one of the possible tools to tackle it, and on the other climate change is likely to induce more frequent and intense extreme events (fires, droughts, storms etc.), thus increasing the demand for protection against natural hazards. An intriguing finding is the significantly increased importance attributed to genetic materials, which resonates with research emphasizing the crucial role of genetic diversity in bolstering forest ecosystem resilience to climate change (Vinceti *et al.*, 2020). Vinceti *et al.* (2020) underscored the role of genetic diversity in enhancing trees' adaptive responses to environmental shifts and mitigating the impacts of pests and diseases.

5.3 Role of background and experience

perceptions of ecosystem services, especially in the current scenario. Regulating services such as gene pool protection, human health, natural hazard protection, temperature reduction, water quality and erosion, and to a lower extent cultural ones, like education and research, are particularly impacted by background. In contrast, for the future scenario, background's influence is only significant for education and research. These findings highlight the importance of involving experts from diverse backgrounds in decision-making processes to accommodate varying perspectives and priorities. Embracing input from professionals across disciplines can lead to more comprehensive policies and strategies that reflect the intricate value of ecosystem services.

At the same time, the services for which background did not significantly influence perceptions suggest a level of consensus among experts from different fields. These services could serve as common ground for interdisciplinary collaboration among experts with diverse backgrounds within the forest management and conservation realm. Nevertheless, it has also to be noticed that the lack of statistically significant importance of the background for all provisioning services seems to confirm that these services are largely undervalued by all experts, regardless their background and experience. It is possible that this resounds the increasing narratives and emphasis on ecosystem services different from traditional forest products (i.e., timber and firewood) that can be found within the research and policy arena.

Conversely, years of experience did not exert a significant influence on the assessment of ecosystem services. This suggests that expertise in the field of ecosystem services may not solely depend on the length of one's career as it might also be influenced by other factors, such as specificity of research activities on this topic, including with reference to applied research rather than purely theoretical one. It might also suggest that ecosystem service assessment builds – at least to some extent - on issues that are beyond academic and research/professional experience, and rather reflect social and cultural aspects respondents might have in common. Nonetheless it is not possible to draw conclusions on this based on available data as more research would be needed to deepen these aspects.

5.4 Policy and management implications

Our findings hold practical implications for policymakers, forest managers, and conservationists. International organizations and researchers have been advocating for FGR conservation, recognizing their importance in bolstering ecosystem resilience and resistance (e.g., Alfaro *et al.*, 2014; FAO, 2014; Vinceti *et al.*, 2020). Shedding light on the significance of different ecosystem services linked to FGR, especially in the face of climate change, underscores the need to integrate FGR conservation into broader forest management and climate adaptation strategies. Although it is not possible to draw conclusions on this based on available findings, the fact that multiple ecosystem services were highly valued by all respondents seems to indicate that experts to some extent encourage multifunctional forest management solutions, i.e. integrated forest management models within the same landscape or even forest stand, rather than specialised ones focused on a single (or few) ecosystem services. This would also be helpful in improving overall resilience of forests via-a-vis ongoing and future challenges, and, all in all, consistent with the multitude of diverse policies developed and under development within the European Union. On the other hand, management specialisation might be key for certain forest areas and ecosystem services: for example, bioenergy production might be achieved (also) through specialised plantations, to make it possible to manage natural and seminatural forests for different aims.

At the same time, it would be important to link the views of experts in terms of ecosystem service importance with the needs and expectations of people ultimately benefiting from the ecosystem services downstream as well as with the competences and know-how of people that might improve FGR in order to ensure better and more targeted ecosystem services (e.g., nursey managers, FGR collectors and developers, forest planners and managers etc.). Last but not least this should also be framed within existing and future policies, informing policy makers with up-to-date and specific inputs on the management of FGR.

Studies like this, which gather input from experts across various disciplines to reach a consensus, can provide a more profound understanding of FGR's role in ecosystem service provision across multiple groups of actors and stakeholders.

5.5 Limitations and suggestions for future research

While our study offers valuable insights into the perception of ecosystem services linked to FGR, certain limitations should be acknowledged, and opportunities for further research should be considered. Our study was designed as a pilot to gauge method strengths and weaknesses and the validity of results. Challenges inherent to survey research, including time constraints, participant availability, and data collection within a set timeframe, were encountered.

Platform-related issues presented a unique limitation. Transitioning from Google Forms to Microsoft Word due to visual complications introduced a potential error. Future studies should consider employing more reliable and versatile survey platforms to minimize such risks.

The diversity of our expert participants' profiles introduced potential bias, with the majority having strong connections to academia despite being outside of a university setting. To mitigate such bias, future studies should involve a larger and more diverse pool of experts.

Designing questionnaires is pivotal, and our choices may have introduced some level of ambiguity and survey fatigue. Future research should consider shorter questionnaires that request explanations for respondents' choices to yield clearer results. At the same time questions might be improved. For example, respondents might be asked to indicate expected changes between present and future scenarios rather than running the Likert scale exercise twice. In doing so they might be asked in a more specific and more direct way why they expect certain changes to occur. As for future scenarios, respondents might be asked to indicate which factors they were taking into account, e.g., with reference to policy and/or socio-economic aspects besides more direct climate change effects that were suggested by the survey in terms of temperature and precipitation changes.

Since averaging assessment values for a whole country might be challenging, experts might also be requested to indicate if, when replying, they had specific cases in mind.

In closing, further studies are imperative to unravel the intricate dynamics of ecosystem services and the pivotal role of FGR in their provision. Such knowledge is crucial in the context of climate change, which is altering ecosystems and the services they provide. Thus, we recommend conducting deeper studies across different European countries, establishing a foundation for informed decision-making in forest management and conservation. Comparative analyses across regions grappling with similar climate challenges can enhance our understanding of the generalizability of our findings.

6. Conclusions

In this study we explored the value of ecosystem services associated with FGR in Italy by adopting an expert-based approach via the Delphi method. The findings shed light on the complex relationship between these genetic resources and the ecosystem services they provide, offering valuable insights for policymakers, forest managers, and conservationists.

Our study unveiled that regulating ecosystem services, including habitats for plants and animals, gene pool protection, natural hazard protection, and carbon storage, emerged as the most important services both in the present and in the projected future scenario of a warmer and drier climate. These services play a pivotal role in safeguarding biodiversity, mitigating natural hazards, and contributing to climate change mitigation, thus indirectly also contributing to human wellbeing. This underscores the critical role of FGR in the resilience and resistance of forests against various disturbances, in line with previous research.

Conversely, provisioning services such as hunting and bioenergy received lower scores, indicating that our expert participants did not consider them the most valued services associated with FGR in Italy. This finding might be linked to the environmental orientation/sensitivity of our participants and aligns with broader trends in social awareness towards forest ecosystem services.

Climate change is a key factor influencing the importance of ecosystem services. Our experts foresee significant shifts in the importance of ecosystem services under the threats posed by climate change, with genetic pool protection gaining prominence. This aligns with the importance of genetic diversity in enhancing forest ecosystem resilience to climate change.

Furthermore, our analysis highlighted the significance of involving experts from diverse backgrounds in decision-making processes. Background significantly influenced the perception of ecosystem services in the present situation, while years of experience did not show significant influence. This underlines the need for interdisciplinary collaboration to develop a more comprehensive understanding of the value of ecosystem services.

For policymakers, forest managers, and conservationists, our findings underscore the necessity of integrating FGR conservation into broader forest management and climate adaptation strategies. Understanding the importance of ecosystem services associated with FGR is crucial in the face of climate change and its impacts on forests.

In conclusion, our study contributes to the growing body of knowledge on FGR and ecosystem services, emphasizing the importance of these resources for forest vitality and resilience. As climate change continues to exert pressure on ecosystems, the value of FGR and the services they provide becomes increasingly apparent. By recognizing and harnessing this value, we can pave the way for informed decision-making in forest management and conservation.

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Annexes

Annex 1 – The questionnaire designed for the first round of the survey.



Università degli Studi di Padova

TESAF Dipartimento Territorio e Sistemi Agro-Forestali Università di Padova

Forests play an important role in supporting human health and well-being by providing a wide range of ecosystem services. In doing so, however, they are challenged by climate change – in terms of both long-term changing climate conditions and increasing frequency and intensity of natural disasters – biodiversity loss as well by a complex policy framework. Forest genetic resources (FGR) are key to maintain and enhance forest biodiversity and ecosystem services depending on it, nevertheless research on the value of their contribution as well as of their role in ensuring forest resilience vis-à-vis current and future challenges is still limited. Understanding the importance of FGR in supporting ecosystem services is key to inform future forest management and conservation strategies, as well as policy making.

Our research

Developed for a Master thesis project for the Forest Science MSc Program (University of Padova, Italy) and in cooperation with the OptFORESTS Horizon Europe project, this study aims to contribute filling this knowledge gap and advancing research in the field of FGR assessment and estimation.

More precisely we aim to assess the importance of FGR in sustaining ecosystem services in Italy, by considering both the current situation and a future realistic scenario.

The survey

The survey builds on experts' opinions and is organized according to a Delphi method approach. You have been selected due to your robust knowledge and familiarity with the surveyed topics.

The survey is organized into 6 sections and includes both **compulsory** and non-compulsory questions. The formers are marked with a **red star (*)** and cannot be skipped. Completing the survey will take about 20 minutes of your time.

We remind you that this is the first out of two survey rounds: we will get back to you for the second round in the next 2 weeks. Thank you in advance for your support.

Privacy notice

Data collected through this survey will be treated confidentially and anonymously for research purposes only, in compliance with the General Data Protection Regulation (GDPR), Regulation (EU) 2016/679.

By filling the questionnaire, you give UNIPD staff the permission to process data you provide for the purposes of research activities.

Section 1 – Personal and background information

1.1 Please enter you first and family name (e.g., Mario Rossi) *

1.2 Please enter your email address (this is just to be used in case we need to contact you for the aims of the survey) *

1.3 What is your academic background? (e.g., MSc degree in Forestry or PhD in Environmental economics etc.)

1.4 What is your current work position?

1.5 How many years of professional experience you have with forest-based ecosystem service assessment*

Section 2 – Forest genetic resources (FGR) and ecosystem services: definition and a preliminary assessment

Forest genetic resources (FGR) are defined as "***the heritable materials maintained within and among tree and other woody plant species (shrubs, palms and bamboo) that are of actual or potential economic, environmental, scientific or societal value***" (FAO, 2014).

Ecosystem services are defined as "***the benefits people obtain from ecosystems***" (Millennium Ecosystem Assessment, 2005).

Researchers largely agree that FGR are essential components of forest ecosystems, as they provide the basis for tree growth, adaptation, and evolution. Trees are the foundation species of forest ecosystems as well as other ecosystems, such as savannas and agricultural landscapes. Forests and trees provide goods and services which are essential for human well-being and sustainable development, therefore FGR underpin the supply of these goods and services. FGR refers not to the direct benefits of tree and forest resources but to the genetic aptitude that allows the trees and forests to deliver those benefits by providing several ecosystem services.

2.1 Based on your professional experience, name the three most important ecosystem services provided by FGR in Italy. *

2.2 Please explain the reasoning behind your choices.

Section 3 – Present importance of ecosystem services provided by forest genetic resources (FGR)

In this section we present you a list of FGR-related ecosystem services identified from existing literature and matching of different ecosystem service classification systems. The list is organized into three separate blocks, i.e.:

Provisioning ecosystem services, i.e., material benefits people obtain from ecosystems,

Regulating ecosystem services, i.e., benefits provided by ecosystem processes that moderate/regulate natural phenomena, and

Cultural ecosystem services, i.e., immaterial benefits people gain from their interactions with ecosystems.

Based on your knowledge and expertise, we would like you to grade the importance of these services from **1 (not important at all) to 10 (Extremely important)**. When replying please think about the importance of each ecosystem service **for all forest resources across Italy at present time**.

3.1 Based on your knowledge and expertise we would like you to grade the importance of the ecosystem services listed below from 1 (Not important at all) to 10 (Extremely important).

Provisioning ecosystem services

Bioenergy (e.g., firewood, chipwood, etc.)	
Food from wild plants (e.g., leaves, fruits, herbs, edible seeds, mushrooms, etc.)	
Genetic materials (e.g., wild plant seed collection, plant collection for breeding, plant collection for genetic information etc.)	

Hunting (e.g., game and wild fauna meat, bones, hides or skins etc.)	
Timber (e.g., industrial roundwood and other wood in the rough)	

3.2 Based on your knowledge and expertise we would like you to grade the importance of the ecosystem services listed below from 0 (Not important at all) to 10 (Extremely important).

Regulating ecosystem services

Air quality (e.g., oxygen production, pollutants capture, smell reduction etc.)	
Carbon storage (organic carbon sequestration)	
Genetic pool protection (lifecycle maintenance and gene pool protection)	
Habitat for plants and animals (e.g., maintenance of nursery populations and habitats, ecological corridors, pollination etc.)	
Human health (e.g., disease control, mental and physical health, etc.)	
Natural hazard protection (e.g., flood control, regulation of extreme events, protection against gravitational hazards etc.)	
Noise reduction (mitigation of stressful or harmful noises, e.g., from roads, industrial areas etc.)	
Soil quality (e.g., provision of organic matter for soil, fertility/nutrient maintenance etc.)	
Temperature reduction (regulation of temperature and humidity, including ventilation and transpiration (e.g., shelter for crops, cooling etc.)	
Water quality and erosion (e.g., erosion control, sediment retention, water filtration etc.)	

3.3 Based on your knowledge and expertise we would like you to grade the importance of the ecosystem services listed below from 1 (Not important at all) to 10 (Extremely important).

Cultural ecosystem services

Aesthetics (e.g., visual screening, landscape beauty, scenic view etc.)	
Education and research (e.g., environmental education, research activities, schools/kindergartens within forests etc.)	
Recreation (e.g., sport activities, excursions, hiking, fitness, ecotourism, camping etc.)	
Spiritual and cultural value (e.g., sacred sites, forest burial sites, artistic and cultural inspiration, identity and sense of place etc.)	

Section 4 – Future importance of ecosystem services provided by forest genetic resources (FGR)

In this section we present you the same three blocks of FGR-related ecosystem services you have already considered in the previous section, however, we ask you to assess them not according to their importance now rather according to the importance you expect they will have in the future.

Based on your knowledge and expertise, we would like you to grade the importance of these services **from 1 (not important at all) to 10 (Extremely important)** at the **end of the Century**, considering that according to IPCC projections and scenarios (Representative Concentration Pathways, RCP 4.5 and 8.5) climate change is predicted to result in higher temperature (+1.8 to 5.4°C compared to the 1971-2000 period) and lower precipitations (40% decrease in water flow compared to the 1971-2000 period) in Italy, as well as in more frequent and intense extreme events like wildfires, droughts, floods, windstorms etc.

When replying please think about the **importance of each ecosystem service for all forest resources across Italy at the end of the Century considering above-mentioned climate change effects**.

4.1 Based on your knowledge and expertise we would like you to grade the importance of the ecosystem services listed below from 1 (Not important at all) to 10 (Extremely important).

Provisioning ecosystem services

Bioenergy (e.g., firewood, chipwood, etc.)	

Food from wild plants (e.g., leaves, fruits, herbs, edible seeds, mushrooms, etc.)	
Genetic materials (e.g., wild plant seed collection, plant collection for breeding, plant collection for genetic information etc.)	
Hunting (e.g., game and wild fauna meat, bones, hides or skins etc.)	
Timber (e.g., industrial roundwood and other wood in the rough)	

4.2 Based on your knowledge and expertise we would like you to grade the importance of the ecosystem services listed below from 0 (Not important at all) to 10 (Extremely important).

Regulating ecosystem services

Air quality (e.g., oxygen production, pollutants capture, smell reduction etc.)	
Carbon storage (organic carbon sequestration)	
Genetic pool protection (lifecycle maintenance and gene pool protection)	
Habitat for plants and animals (e.g., maintenance of nursery populations and habitats, ecological corridors, pollination etc.)	
Human health (e.g., disease control, mental and physical health, etc.)	
Natural hazard protection (e.g., flood control, regulation of extreme events, protection against gravitational hazards etc.)	
Noise reduction (mitigation of stressful or harmful noises, e.g., from roads, industrial areas etc.)	
Soil quality (e.g., provision of organic matter for soil, fertility/nutrient maintenance etc.)	
Temperature reduction (regulation of temperature and humidity, including ventilation and transpiration (e.g., shelter for crops, cooling etc.)	

Water quality and erosion (e.g., erosion control, sediment retention, water filtration etc.)	

4.3 Based on your knowledge and expertise we would like you to grade the importance of the ecosystem services listed below from 1 (Not important at all) to 10 (Extremely important).

Cultural ecosystem services

Aesthetics (e.g., visual screening, landscape beauty, scenic view etc.)	
Education and research (e.g., environmental education, research activities, schools/kindergartens within forests etc.)	
Recreation (e.g., sport activities, excursions, hiking, fitness, ecotourism, camping etc.)	
Spiritual and cultural value (e.g., sacred sites, forest burial sites, artistic and cultural inspiration, identity and sense of place etc.)	

Section 5 - Additional references and contacts

5.1 If you are aware of any publications on the assessment/value of FGR in Italy or in the Mediterranean region, could you please recommend them to us?

For your convenience, you can also share them via email: please find our email addresses at the end of the survey form.

5.2 We would like to use the assistance of other experts working on ecosystem services and FGR, to expand our research in the future. If you know other experts and specialists in this field in Italy or other Mediterranean countries, could you please indicate them to us?

Section 6 – End of the survey, acknowledgements and next steps

Thanks for participating to the survey: by filling-in the questionnaire and sharing your views you help us gaining a better understanding of the value of FGR in Italy.

What is next?

We will review your replies together with those we received from other experts we have contacted for this study. We will come back to you within max 2 weeks from now for a second round of the survey.

Since then, thanks again for your support.

For any information:

Amir Hossain Khalili Pir - ahkp1369@gmail.com (MSc candidate)

Mauro Masiero - mauro.masiero@unipd.it (research supervisor)

6.1 Would you be interested in receiving a summary of the research?

Annex 2 – The questionnaire designed for the second round of the survey.



Università degli Studi di Padova

TESAF Dipartimento Territorio e Sistemi Agro-Forestali Università di Padova

Forests play an important role in supporting human health and well-being by providing a wide range of ecosystem services. In doing so, however, they are challenged by climate change – in terms of both long-term changing climate conditions and increasing frequency and intensity of natural disasters – biodiversity loss as well by a complex policy framework. Forest genetic resources (FGR) are key to maintain and enhance forest biodiversity and ecosystem services depending on it, nevertheless research on the value of their contribution as well as of their role in ensuring forest resilience vis-à-vis current and future challenges is still limited. Understanding the importance of FGR in supporting ecosystem services is key to inform future forest management and conservation strategies, as well as policy making.

Our research

Developed for a Master thesis project for the Forest Science MSc Program (University of Padova, Italy) and in cooperation with the OptFORESTS Horizon Europe project, this study aims to contribute filling this knowledge gap and advancing research in the field of FGR assessment and estimation.

More precisely we aim to assess the importance of FGR in sustaining ecosystem services in Italy, by considering both the current situation and a future realistic scenario.

The survey

Currently you are participating in the second round of our survey. In this round you are presented with your answers to the questions regarding grading of the present and future importance of FGR. Additionally, the Mean and Mode of the results of the data collected from all participants are also provided to you in tables. You are presented with the choice to revisit your answers to better aligned them with the collected results. If you do not wish to change your response, we ask you to kindly explain the main reasons behind your choice.

The survey is organized into 2 sections, including 3 sub-sections each. Completing the survey will take about 20 minutes of your time.

We remind you that this is the second out of two survey rounds. Thank you in advance for your support.

Privacy notice

Data collected through this survey will be treated confidentially and anonymously for research purposes only, in compliance with the General Data Protection Regulation (GDPR), Regulation (EU) 2016/679.

By filling the questionnaire, you give UNIPD staff the permission to process data you provide for the purposes of research activities.

Name of the participant:

Section 1 – Present importance of ecosystem services provided by forest genetic resources (FGR)

In the first round, we presented you a list of FGR-related ecosystem services identified from existing literature and matching of different ecosystem service classification systems. They were separated into 3 blocks, **Provisioning**, **Regulating** and **Cultural** ecosystem services. You were asked to grade these services based on their importance from **1 (not important at all)** to **10 (Extremely important)** for all forest resources across Italy at present time.

For this round we are presenting you with the grades you gave for each of these ecosystem services. In addition, we are providing the Mean and Mode of the collected data from all the participants. You can either revise your grade or confirm it.

1.1 Based on your knowledge and the presented results in the table below, would like you to revise the grade you gave to these services? If not, please give us your reasons for keeping your original grade.

Provisioning ecosystem services	Grades given by you for the first round	Mode grades from the first round	Mean grades from the first round	Your revised grades for the second round
Bioenergy (e.g., firewood, chip wood, etc.)		7	7.33	
Food from wild plants (e.g., leaves, fruits, herbs, edible seeds, mushrooms, etc.)		7	7.22	
Genetic materials (e.g., wild plant seed collection, plant collection for breeding, plant collection for genetic information etc.)		8	7.67	

Hunting (e.g., game and wild fauna meat, bones, hides or skins etc.)		5	4.89	
Timber (e.g., industrial roundwood and other wood in the rough)		8	7.67	

You are given the chance to revise your grades. If you are not changing them, please provide us with a brief explanation about the main reasons behind your choice.

1.2 Based on your knowledge and the presented results in the table below, would like you to revise the grade you gave to these services? If not, please give us your reasons for keeping your original grade.

Regulating ecosystem services	Grades given by you for the first round	Mode grades from the first round	Mean grades from the first round	Your revised grades for the second round
Air quality (e.g., oxygen production, pollutants capture, smell reduction etc.)		8	7.78	
Carbon storage (organic carbon sequestration)		9	8.89	
Genetic pool protection (lifecycle maintenance and gene pool protection)		9	9.00	
Habitat for plants and animals (e.g., maintenance of nursery populations and habitats, ecological corridors, pollination etc.)		9	9.00	
Human health (e.g., disease control, mental and physical health, etc.)		8	8.00	
Natural hazard protection (e.g., flood control, regulation of extreme events, protection against gravitational hazards etc.)		9	9.11	
Noise reduction (mitigation of stressful or harmful noises, e.g., from roads, industrial areas etc.)		7	7.33	

Soil quality (e.g., provision of organic matter for soil, fertility/nutrient maintenance etc.)		7	6.67	
Temperature reduction (regulation of temperature and humidity, including ventilation and transpiration (e.g., shelter for crops, cooling etc.)		7	7.22	
Water quality and erosion (e.g., erosion control, sediment retention, water filtration etc.)		9	8.89	
You are given the chance to revise your grades. If you are not changing them, please provide us with a brief explanation about the main reasons behind your choice.				

1.3 Based on your knowledge and the presented results in the table below, would like you to revise the grade you gave to these services? If not, please give us your reasons for keeping your original grade.

Cultural ecosystem services	Grades given by you for the first round	Mode grades from the first round	Mean grades from the first round	Your revised grades for the second round
Aesthetics (e.g., visual screening, landscape beauty, scenic view etc.)		8	8.44	
Education and research (e.g., environmental education, research activities, schools/kindergartens within forests etc.)		7	7.56	
Recreation (e.g., sport activities, excursions, hiking, fitness, ecotourism, camping etc.)		9	8.00	
Spiritual and cultural value (e.g., sacred sites, forest burial sites, artistic and cultural inspiration, identity and sense of place etc.)		7	7.22	

You are given the chance to revise your grades. If you are not changing them, please provide us with a brief explanation about the main reasons behind your choice.

Section 2 – Future importance of ecosystem services provided by forest genetic resources (FGR)

According to IPCC projections and scenarios (Representative Concentration Pathways, RCP 4.5 and 8.5) by the end of the Century climate change is predicted to result in higher temperature (+1.8 to 5.4°C compared to the 1971-2000 period) and lower precipitations (40% decrease in water flow compared to the 1971-2000 period) in Italy, as well as in more frequent and intense extreme events like wildfires, droughts, floods, windstorms etc.

In the previous round we asked you to grade FGR-related ecosystem services for their expected importance from **1 (not important at all)** to **10 (Extremely important)** at the **end of the Century**, taking into consideration climate change effects and their expected impacts on forests.

For this round we are providing the grades you gave for each of the ecosystem services. In addition, we are providing the Mean and Mode of the collected data from all the participants. You can either revise your grade or confirm it.

2.1 Based on your knowledge and the presented results in the table below, would like you to revise the grade you gave to these services? If not, please give us your reasons for keeping your original grade.

Provisioning ecosystem services	Grades given by you for the first round	Mode grades from the first round	Mean grades from the first round	Your revised grades for the second round
Bioenergy (e.g., firewood, chip wood, etc.)		6	6.22	
Food from wild plants (e.g., leaves, fruits, herbs, edible seeds, mushrooms, etc.)		8	7.67	
Genetic materials (e.g., wild plant seed collection, plant collection for breeding, plant collection for genetic information etc.)		9	8.56	

Hunting (e.g., game and wild fauna meat, bones, hides or skins etc.)		5	5.00	
Timber (e.g., industrial roundwood and other wood in the rough)		8	7.56	
You are given the chance to revise your grades. If you are not changing them, please provide us with a brief explanation about the main reasons behind your choice.				

2.2 Based on your knowledge and the presented results in the table below, would like you to revise the grade you gave to these services? If not, please give us your reasons for keeping your original grade.

Regulating ecosystem services	Grades given by you for the first round	Mode grades from the first round	Mean grades from the first round	Your revised grades for the second round
Air quality (e.g., oxygen production, pollutants capture, smell reduction etc.)		9	8.78	
Carbon storage (organic carbon sequestration)		10	9.67	
Genetic pool protection (lifecycle maintenance and gene pool protection)		10	9.00	
Habitat for plants and animals (e.g., maintenance of nursery populations and habitats, ecological corridors, pollination etc.)		9	8.89	
Human health (e.g., disease control, mental and physical health, etc.)		9	8.89	
Natural hazard protection (e.g., flood control, regulation of extreme events, protection against gravitational hazards etc.)		10	9.78	
Noise reduction (mitigation of stressful or harmful noises, e.g., from roads, industrial areas etc.)		6	7.33	

Soil quality (e.g., provision of organic matter for soil, fertility/nutrient maintenance etc.)		8	8.33	
Temperature reduction (regulation of temperature and humidity, including ventilation and transpiration (e.g., shelter for crops, cooling etc.)		10	9.11	
Water quality and erosion (e.g., erosion control, sediment retention, water filtration etc.)		10	9.56	
You are given the chance to revise your grades. If you are not changing them, please provide us with a brief explanation about the main reasons behind your choice.				

2.3 Based on your knowledge and the presented results in the table below, would like you to revise the grade you gave to these services? If not, please give us your reasons for keeping your original grade.

Cultural ecosystem services	Grades given by you for the first round	Mode grades from the first round	Mean grades from the first round	Your revised grades for the second round
Aesthetics (e.g., visual screening, landscape beauty, scenic view etc.)		8	7.89	
Education and research (e.g., environmental education, research activities, schools/kindergartens within forests etc.)		8	7.89	
Recreation (e.g., sport activities, excursions, hiking, fitness, ecotourism, camping etc.)		9	8.00	
Spiritual and cultural value (e.g., sacred sites, forest burial sites, artistic and cultural inspiration, identity and sense of place etc.)		8	7.44	

You are given the chance to revise your grades. If you are not changing them, please provide us with a brief explanation about the main reasons behind your choice.

3 - End of the survey, acknowledgements

Thanks for participating to the survey: by filling-in the questionnaire and sharing your views you help us gaining a better understanding of the value of FGR in Italy.

For any information:

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