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# Scanning the solutions for the sustainable supply of forest ecosystem services in Europe

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39 **Abstract**

40 Forests are key components of European multifunctional landscapes and supply numerous forest  
41 ecosystem services (FES) fundamental to human well-being. The sustainable provision of FES has the  
42 potential to provide responses to major societal challenges, such as climate change, biodiversity loss,  
43 or rural development. To identify suitable strategies for the future sustenance of FES, we performed a  
44 solution scanning exercise with a group of transdisciplinary forest and FES experts from different  
45 European regions. We identified and prioritized fifteen major challenges hindering the balanced  
46 provision of multiple FES and identified a series of potential solutions to tackle each of them. The most  
47 prominent challenges referred to the increased frequency and impacts of extreme weather events and  
48 the normative mindset regarding forest management. The respective solutions pointed to the promotion  
49 of forest resilience via climate-smart forestry and mainstreaming FES-oriented management through a  
50 threefold strategy focusing on education, awareness raising, and networking. In a subsequent survey,  
51 most solutions were assessed as highly effective, transferable, monitorable, and with potential for being  
52 economically efficient. The implementation of the solutions could have synergistic effects when  
53 applying the notion of leverage points. Seven emerging pathways towards the sustainable supply of  
54 FES have been identified. These pathways build on each other and are organized based on their potential  
55 for transformation: (1) shifting forest management paradigms towards pluralistic ecosystem valuation;  
56 (2) using integrated landscape approaches; (3) increasing forest resilience; (4) coordinating actions  
57 between forest-related actors; (5) increasing participation in forest planning and management; (6)  
58 continuous, open, and transparent knowledge integration; and (7) using incentive-based instruments to  
59 support regulating and cultural FES. These pathways can contribute to the implementation of the new  
60 EU Forestry Strategy to support the balanced supply of multiple FES.

61 **Keywords:** European forests, ecosystem services, sustainability, solution scanning, leverage points, EU  
62 Forestry Strategy

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## 64 Introduction

65 European forests are ecosystems that deliver manifold benefits to society via so-called Forest Ecosystem  
66 Services (FES) (Orsi et al. 2020). The benefits that people obtain from the forests, so-called Forest  
67 Ecosystem (FES) (MEA 2005), include for example carbon sequestration, protection of soils and water  
68 basins, provision income opportunities, physical and mental health benefits, and contribution to the  
69 general wellbeing of rural and urban inhabitants. Furthermore, forests provide renewable resources that  
70 offer alternatives to fossil-fuel based products, thus contributing to climate change mitigation (Forest  
71 Europe 2020). However, at the same time numerous direct and indirect drivers of change increasingly  
72 challenge the resilience of forests and the provision of FES. These include for example climate change,  
73 which threatens almost 60% of European forests by increasing their vulnerability to windstorms, fires,  
74 and pest infestations (Forzieri et al. 2021), and diverging societal demands ranging from an increased  
75 production of wood or biofuel to the promotion of wilderness for recreational purposes (EEA 2016).

76 To navigate these challenges, it is imperative that forests are sustainably managed so they can continue  
77 being part of the solution to mitigate climate change, biodiversity loss, or to control epidemic outbreaks  
78 (Swaddle and Calos 2008; Khalil et al. 2016), while maintaining a crucial role in the efforts towards a  
79 more sustainable society and economy in Europe (Wolfslehner et al. 2020). Sustainable management is  
80 at the core of the European Union’s (EU) forest policy (EC 2013). The previous EU Forest Strategy  
81 already highlighted the importance of “balancing various forest functions, meeting demands, and  
82 delivering vital ecosystem services”. It called for supporting protection and management efforts aimed  
83 at maintaining, enhancing, and restoring the resilience and multi-functionality of forest ecosystems for  
84 both urban and rural areas (EC 2013). Various studies have highlighted the importance of  
85 multifunctional management for safeguarding different forest functions (Wolf and Primmer 2006;  
86 Gustafsson et al. 2012; Benz et al. 2020). In addition, forest products and services are increasingly an  
87 inherent and integrated element of many other policy sectors, ranging from energy to food production,  
88 conservation and public health (Aznar-Sánchez et al. 2018).

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2 89 Yet, there is a mismatch between the supply of FES and their recognition in policies across Europe  
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5 90 inducing a bias towards timber provision (Primmer et al. 2021).

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7 91 Strategies for a broad supply of FES often entail competing objectives (Lazdinis et al. 2019). Besides,  
8 92 the disproportionate focus on biomass production, especially in large parts of central and northern  
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10 93 Europe, hinder the potential development of other FES. The conflicting demands can be due to the fact  
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12 94 that most actions affecting forest landscapes are primarily associated with policy areas and interests  
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14 95 outside the forest sector. As a result, some forest objectives are torn between different sectoral interests  
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16 96 whenever new targets evolve outside the forest sector (Sotirov et al. 2016).

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20 97 To address the current sustainability challenges, European forests demand innovative solutions for  
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22 98 which the new EU policy frameworks, such as the EU Green Deal and Forestry Strategy, offer emerging  
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24 99 opportunities. To support the development and implementation of the new European Forest Strategy, it  
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26 100 is fundamental to have clarity on the challenges hindering the sustainable provision of multiple FES  
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28 101 and to look for effective solutions. While a plethora of information exists about the measures needed to  
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30 102 ensure the provision of specific services such as wood or biomass, no comprehensive effort has been  
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32 103 made to identify potential solutions to overcome the impediments in the supply of multiple FES  
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34 104 including cultural and regulating services.

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39 105 To shed light on this issue, we conducted a solution scanning exercise with experts working in different  
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41 106 fields of science, policy, and practice in the European forestry sector. Three specific research questions  
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43 107 were addressed in this study:

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47 108 - What are the most pressing challenges hindering the sustainable provision of multiple FES in  
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49 109 Europe?  
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51 110 - Which are the most effective solutions to overcome those challenges?  
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53 111 - How can the solutions be logically implemented so their transformational potential is  
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55 112 maximized?

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## 114 **Materials and methods**

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4 115 In this study, we applied an extended version of the solution scanning method. Solution scanning has  
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6 116 been increasingly used to identify specific solutions for a particular problem (Sutherland et al. 2014).  
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8 117 Solution scanning follows a stepwise methodology to identify a set of actions, interventions, or  
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10 118 approaches that respond to a specific challenge. This can be useful to point out potential policy  
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12 119 interventions in decision-making processes but also for setting research agendas (Dicks et al. 2017).  
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14 120 **First**, an objective is defined. **In most cases**, it emerges from specific societal demands (Pullin et al.  
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16 121 2013). Then, a group of experts is asked to identify courses of action from their own experience that  
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19 122 can leverage the system towards the stated goal. Finally, the proposed solutions are listed and distributed  
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21 123 to the same experts for **assessment and prioritization** according to given criteria (Hernández-Morcillo  
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23 124 et al. 2018).

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27 125 Our solution scanning exercise **included** three phases (Figure 1). The first phase consisted of the  
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29 126 identification of the challenges that hamper the sustainable provision of FES in Europe. To that end, an  
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31 127 exploratory survey was distributed in November 2020 **to** all expert participants **of** the study (S1). The  
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33 128 survey was structured along a series of open questions, which inquired about the most pressing  
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35 129 challenges affecting the sustainable provision of FES in Europe across five thematic areas: economy,  
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37 130 environment, socio-culture, management, and governance. Additionally, the survey assessed key  
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40 131 knowledge gaps hindering progress towards addressing these challenges. **The proposed challenges were**  
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42 132 **structured and bundled according to thematic areas, resulting in a list of 36 challenges, which was shared**  
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44 133 **among all participants to identify additional uncovered challenges prior the next phase in the process.**  
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48 **Figure 1.** Workflow of the solution scanning exercise.  
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136 In the second phase, a two-day participatory solution scanning workshop was organized in December  
137 2020. The aim of the workshop was to prioritize the challenges identified in the first phase and develop  
138 strategic solutions for the most relevant ones. Based on their expertise, participants were divided into  
139 smaller groups of four to five individuals, and distributed across five thematic areas (economy,  
140 environment, socio-culture, management, and governance). On the first day, each thematic group  
141 prioritized and characterized the respective subsets of thematic challenges resulting from the  
142 exploratory survey. The prioritization included, for each challenge, a general assessment of the urgency  
143 (how immediately this challenge needs to be tackled), their impact (degree to which solving this  
144 challenge would contribute to the sustainable supply of multiple FES in Europe), the types of FES  
145 affected, scale, and the inter-relations between each of these challenges and all the thematic areas.  
146 Accordingly, each thematic group reduced the list of challenges to the five most relevant. At the end of  
147 the first day, the number of challenges was reduced through a series of anonymous majority voting  
148 rounds in plenary to the three most pressing challenges for each thematic area. During the second day,  
149 the thematic groups reconvened to formulate and characterize strategic solutions for each of the three  
150 selected challenges. The characterization consisted of a description of the solution, the feasibility of  
151 implementation, a time frame, and the resources needed for application. A detailed account of the whole  
152 process, including the definition, framing and prioritization of the challenges (first day of the  
153 workshop); and the identification and characterization of the strategic solutions (second day of the  
154 workshop) can be found in S3.

155 During the third phase, the identified solutions were evaluated in an online survey distributed to all  
156 participants in January 2021 (S2). The respondents rated each solution according to five different  
157 criteria of optimal solutions, adapted from the concept report on climate policy-mix optimality (Gorlach  
158 2013) (see Box 1). Finally, the notion of leverage points understood as areas of a system where actions  
159 can be implemented to induce transformational changes (Abson et al. 2017; Dorninger et al. 2020) was  
160 used to organize the strategic solutions into pathways of intervention according to their potential to  
161 transform the forestry sector.

### BOX 1. Criteria for solution assessment

- **Social-ecological effectiveness:** the degree to which the solution respects the natural and social environment and/or improves it.
- **Economic efficiency:** the degree to which the resources needed for implementing the solution are allocated to their most valuable uses and waste is avoided.
- **Readiness:** the degree to which the solution can be implemented in the shortest period of time.
- **Feasibility:** the degree to which the solution can be successfully implemented.
- **Transferability potential:** the degree to which the solution can be transferred to other European contexts.

162 The participants in the solution scanning process were 24 experts from academia, policy, and practice  
163 working directly on FES in Europe. Most participants (90%) were related to the EU Horizon 2020  
164 funded projects SINCERE and InnoForESt, both dealing with the promotion of FES-related  
165 innovations. A team of three facilitators selected from both projects supported the implementation of  
166 the solution scanning exercise. About expert participants, particular attention was paid to balance  
167 backgrounds between academia and practice, disciplines, geographic foci, seniority level, and gender  
168 (S4).

169 Most of the selected experts worked at research organizations at the interface between science, policy,  
170 and practice (41%). The covered areas of knowledge of the forestry sector were broad, including experts  
171 on forest ecosystem services governance and innovation, urban forestry and European forest policy.  
172 Partly because the coordination of both of the Horizon 2020 projects is based in Germany, most of the  
173 participants worked at German organizations (41%). However, seven other European countries were  
174 also represented in the exercise, namely Spain, Italy, Austria, Belgium, Switzerland, Finland, and  
175 Sweden. A balanced gender representation was achieved and consciously maintained along the process.

176 This solution scanning exercise synthesizes the currently fragmented views on forest challenges and  
177 targets suitable solutions to foster the sustainable provision of FES. The organization of the exercise  
178 into three well-defined phases allows a clear and transparent communication among the coordinators  
179 and experts, facilitating a smooth iterative process. Due to COVID-19 restrictions, the participatory  
180 process was conducted entirely online. Two important aspects of this sequential participatory method  
181 have been the regular communication with the group to ensure a shared understanding of the process,

182 the use of preparatory materials before and after each workshop through two surveys (S1 and S2), and  
 183 the presentation of the state of the work at the beginning of each phase of the solution scanning session.  
 184 However, we must emphasize that the results highly depend on the participant contributions and the  
 185 specific timing of the survey and workshops, which is a limitation of our approach.

## 186 Results

### 187 The most pressing challenges for the sustainable provision of FES

188 After the prioritization process, 15 challenges were selected, three per thematic area, based on their  
 189 urgency and impact (Table 1).

190 **Table 1.** Definition of the final selected challenges for each sustainability area.

Area	Challenge	Definition
Environment	<b>Challenge 1.</b> Increasing frequency and intensity of extreme weather events	Climate change results in an increase of extreme weather events regarding the frequency and intensity (e.g., storms, droughts, and rainfall) affecting the resilience of forest. It affects the susceptibility to wildfires as well as forest health, functionality, and FES provision all around Europe. Despite the inherent resilience of European forests, the resulted changes in forest structure, composition, and thus ecological functioning could be irreversible.
	<b>Challenge 2.</b> Increasing extent, frequency, and impacts of pests and diseases in forest habitats	Due to climate change, forests are increasingly vulnerable to pests and diseases, as seen in the extent of recent bark beetle infestations. Especially vulnerable are forest dominated by single species stands with a higher density of trees, resulting in a lower provision of all FES at a European scale.
	<b>Challenge 3.</b> Fragmentation of forest habitats	Land use change results in fragmented forest structures, habitat quality decline, and negative impacts on biodiversity. The lack of connectivity especially affects forest dependent and endemic species. Moreover, the lack of spatial continuity could hinder the sustainable provision of FES.
Management	<b>Challenge 4.</b> Narrow focus and normative mindset on forest management	Traditional and often normative mindsets on forest management are focused on timber and biomass production especially in central and north European regions. Biodiversity and FES such as cultural or regulating services could be affected by this challenge. Integrating all forest functions and socio-cultural dimensions is key for preserving healthy ecosystems, local cultures, knowledge, and values.
	<b>Challenge 5.</b> Lack of adaptive forest management practices	Forests are undergoing continuous changes that demand an adaptive approach. The lack of adapted management decreases forest resilience to rapid changes affecting people and forests in specific contexts. Continuous monitoring and flexible forest management practices are challenging to implement, due to strict

		administrative conditions, and lack of resources and knowledge among other factors.
	<b>Challenge 6.</b> Unknown demand and supply of FES	There is a lack of information on the biophysical supply and societal demand of regulating or cultural FES across European countries. Information about the FES flows, synergies, trade-offs, and bundles is missing. As a result, some services are often absent in policy discussions and decisions (e.g., cultural FES). Barriers inducing social inequality can affect the accessibility of specific FES.
<b>Economy</b>	<b>Challenge 7.</b> Insufficient financial support for adapting to changing conditions	Support to cover losses from- and adaptation towards natural hazards are deficient to non-existent. This challenge particularly affects forest owners' capacities to risk investing in innovations, especially when there is no guarantee of receiving sufficient revenue or at least mitigating losses. Facing periodic natural hazards without financial support often exposes forest owners to unbearable risky financial conditions.
	<b>Challenge 8.</b> Economic power asymmetries among actors in the European forestry sector	Power asymmetries are generally influenced by a reduced number of actors, who take decisions, control, and direct the markets. On many occasions, those actors can operate regardless of the negative externalities of intensive wood/timber production.
	<b>Challenge 9.</b> Lack of efficient economic instruments and business models for regulating and cultural FES	Efficient economic instruments and business models capable of recognizing and promoting regulating and cultural FES are scarce to non-existent in Europe. This also affects non-wood forest products, particularly those of public good character. Many forest owners are motivated to provide those services, but there is a lack of economic incentives.
<b>Governance</b>	<b>Challenge 10.</b> Lack of coordination and competition among different policy sectors	This challenge occurs across all administrative levels and policy sectors, especially those with contradicting goals affecting forest owners. As a result, making simple decisions on planning and management activities often becomes an ordeal. Depending on the policies conflicting, the process could lead to irreversible changes in the provision of specific FES.
	<b>Challenge 11.</b> Lack of representation of diverse key stakeholders in forest management decision	Forest planning and management decisions are often made without considering the effects that they can have on actors beyond forest owners, managers, or policy makers. There is almost no space (vertically or horizontally) for participation of other members of the wider community of potential beneficiaries (e.g., local communities) in the decision-making process on the provision and use of FES.
	<b>Challenge 12.</b> Tensions and mismatching expectations about the role of public forests	Planning and management decisions in public forests are particularly complex. Mismatching expectations about the role of public forests might emerge, seeing them as a strategic profitable resource and/or as public goods with the public mandate to provide FES.
<b>Socio-culture</b>	<b>Challenge 13.</b> Homogenization of perceptions of forest values by society	This challenge focuses on the multiplicity of social-cultural values associated with FES as well as the difficulties in their identification, prioritization, and integration in forest planning and management. This is particularly true for the marginalized indigenous peoples, traditional communities and the associated risk with the vanishing forest-related forms of knowledge and livelihoods.
	<b>Challenge 14.</b> Conflicts between FES providers and beneficiaries	The conflicts between FES providers and beneficiaries may arise due to diverging interests, demands and rights. On occasions, private owners are

		<p>expected to supply a series of public goods without any incentive. This incentive is not necessarily an economic reward for the provision of FES. In occasions, the incentive is an acknowledgment or recognition. It is to some extent a communication and conceptual conflict related to the understanding of public-private relationships, power structures, and interests that regulate the use, provision, and access to forests and forest resources.</p>
	<p><b>Challenge 15.</b> Rural migration and impacts on rural areas</p>	<p>European rural areas are increasingly experiencing migratory flows to cities leading to a lack of generational turnover in the forest sector and/or abandonment of forested lands. The trend of urban dwellers moving to the countryside has not stopped the process, as less and less people engages with forest-related economic activities.</p>

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191 Figure 2 displays the prioritization of these 15 most important challenges based on the expert  
192 group perceptions of their urgency and impact. Most of the prioritized challenges were  
193 classified as being urgent and having a high impact. The increasing areal expansion, frequency,  
194 and impacts of pests and diseases (Ch. 2), the tensions and mismatching expectations among  
195 the roles of public forests (Ch. 12), and the homogenization of perceptions of forest values by  
196 society (Ch. 13) were the challenges perceived by the experts as those that should be most  
197 immediately tackled. The resolution of these challenges would have the maximum potential to  
198 contribute to the sustainable supply of multiple FES in Europe. Challenges referring to the  
199 fragmentation of forest habitats (Ch. 3), lack of efficient economic instruments (Ch. 9), and  
200 lack of coordination among policy sectors (Ch. 10) were considered as having a medium impact  
201 due to the fact that solving these challenges would contribute to the sustainable supply of  
202 multiple FES although over a longer period of time. The increasing frequency and intensity of  
203 extreme weather events (Ch.1) was considered as the least urgent challenge, meaning that it  
204 would be occurring during a longer period, although having the biggest impact.

205 **Figure 2.** Prioritization of challenges based on urgency and impact. The colours correspond to five different  
206 areas of sustainability (green=environment, brown=socio-culture, grey=economy, blue=management,  
207 orange=governance); the numbers correspond to the challenges identified (Table 1).

209 **The most suitable solutions to improve the sustainable provision of FES**

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3 210 To address the 15 challenges, 24 solutions were identified by the team of experts (see S5 for a detailed  
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5 211 description of all the solutions). The suitability of each solution was subsequently assessed and ranked  
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7 212 based on the following six criteria: social-ecological effectiveness, economic efficiency, readiness,  
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9 213 feasibility, and transferability potential (Box 1). Table 2 shows the prioritized challenges per thematic  
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11 214 area with the respective solutions and the final ranking (More detailed results on these calculations in  
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13 215 S6). The social-ecological effectiveness, respecting the diverse contexts, and the transferability  
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15 216 potential were the strongest traits shared by the proposed solutions. In contrast, the readiness, or the  
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17 217 short-term implementation potential and the feasibility, understood as the potential for its successful  
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19 218 implementation, were generally the weakest traits. After summing up the rankings of all the different  
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21 219 criteria for all solutions, the top ten solutions were obtained. These 10 solutions are presented in detail  
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25 220 in the next section.  
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**Table 2.** Solutions to foster sustainable FES provision in European forests. The colors indicate the degree to which each solution fulfills the implementation criteria. More detailed results on these calculations are in S6 (white=very low; light grey=low; grey=normal; dark grey=high; black=very high). Bold font indicates the ten highest ranked solutions.

Area	Challenge	Solution	Socio-Ecological Effectiveness	Economic efficiency	Readiness	Ascertain. Monitoring	Feasibility	Transfer. potential	Rank
Environment	Challenge 1. Increasing frequency and intensity of extreme weather events	<b>Solution 1 - Promote climate-smart forestry management</b>	Very High (Black)	High (Dark Grey)	High (Dark Grey)	High (Dark Grey)	High (Dark Grey)	High (Dark Grey)	<b>1</b>
		<b>Solution 2 - Improve integration of regulating forest ecosystem services in local and regional planning</b>	High (Dark Grey)	High (Dark Grey)	Low (Light Grey)	High (Dark Grey)	Low (Light Grey)	High (Dark Grey)	<b>8</b>
	Challenge 2. Increasing extent, frequency, and impacts of events in forest habitats	<b>Solution 3 - Coordinate strategic regional forestry stakeholders to join forces against biological and environmental threats</b>	High (Dark Grey)	High (Dark Grey)	Low (Light Grey)	High (Dark Grey)	Low (Light Grey)	High (Dark Grey)	<b>9</b>
	Challenge 3: Fragmentation of forest habitats	Solution 4 - <b>Implementation</b> of systematic and comprehensive environmental assessments considering multiple scales and cumulative effects of forest fragmentation on FES at landscape level	High (Dark Grey)	Low (Light Grey)	Low (Light Grey)	High (Dark Grey)	Low (Light Grey)	High (Dark Grey)	16
Management	Challenge 4. Narrow focus and normative mindset on forest management	<b>Solution 5 - Mainstream FES-oriented management in a threefold strategy: education, awareness raising, and networking</b>	Very High (Black)	High (Dark Grey)	High (Dark Grey)	High (Dark Grey)	High (Dark Grey)	High (Dark Grey)	<b>2</b>

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men t	Challenge 4. Narrow focus and normative mindset on forest management	<b>Solution 5 – Mainstream FES-oriented management in a threefold strategy: education, awareness raising, and networking</b>							
	Challenge 5. Lack of adaptive forest management practices	Solution 6 - Develop adaptive strategies to sustain multiple FES based on regional scenarios							13
		Solution 7 - <b>Ensure diversity at</b> different levels (genetic, species, and forest)							18
Challenge 6. Unknown demand and supply of FES	Solution 8 - <b>Establish</b> regional observatories for capturing societal FES demand and supply							23	
Eco nom y	Challenge 7. Insufficient financial support to changing conditions	<b>Solution 9 - Foster investments into FES oriented forest management to increase resilience (prevention and adaptation) towards natural hazards</b>							<b>3</b>
		<b>Solution 10 - Increase availability, volume, and accessibility of financial instruments to cover losses from natural hazards</b>							<b>10</b>
	Challenge 8. Economic power asymmetries in the forestry sector	<b>Solution 11 - Support economic instruments and business models promoting regulating and cultural FES with consistent policies</b>							<b>4</b>
		Solution 12 - <b>Align</b> finance and administration of different sectors							22
	Challenge 9. Lack of efficient economic instruments and business models for regulating and cultural FES	Solution 13 – <b>Improve adaptation</b> of business models to particular contexts of implementation							11
Solution 14 - <b>Monitor systematically the socio-ecological impact</b> of economic instruments								15	

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Governance	Challenge 10. Lack of coordination and competition among different policy sectors	Solution.15 - Promote vertical and horizontal coherence in administration							19
		Solution 16 - Delineate clear and stable power and responsibilities							21
	Challenge 11. Lack of representation of diverse key stakeholders in forest management decision	Solution 17 - Generate spaces for stakeholders' engagement and representation in decision making processes in cooperative and participative approaches							14
	Challenge 12. Tensions and mismatching expectations about the role of public forests	<b>Solution 18 - Engage the community in participatory decision-making in management approaches in public forests, while embracing innovations towards efficient use of forest resources</b>							<b>5</b>
		Solution 19 - Integrate all actors in participatory decision making about management goals of public forest lands							20
		Solution 20 - Streamline public forest management organization and administration following the principles of the private forest sector							24
Socioculture	Challenge 13. Homogenization of perceptions of forest values by society	<b>Solution 21 - Implement practices for (re)connecting people with forests</b>							<b>6</b>
		Solution 22 - Strengthen the recognition, identification, and integration of social-cultural values in forest management, governance, and research							12
	Challenge 14. Conflicts between FES providers and beneficiaries	<b>Solution 23 - Promote new forms of communication and interaction between society and FES providers with a focus on public forests</b>							<b>7</b>

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	Challenge 15. Rural migration and impacts on rural areas	Solution 24 - Build capacities as a tool to prevent abandonment and promote generational turnover in the forest sector							17
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225 3.2.1. The top ten solutions for the sustainable provision of FES in Europe

226 **Top 1. Promote climate-smart forestry management**

227 *Sustainability Area: Environment; Challenge 1 - Increasing frequency and intensity of extreme*  
228 *weather events*

229 Climate-smart forestry is a targeted approach to manage forests in response to climate change  
230 (Bowditch et al. 2020). It aims to increase the climate regulation benefits from forests and the forest  
231 sector, in a way that creates synergies addressing other societal needs related to forests while increases  
232 forest resilience. It is a large-scale strategy, which includes three main lines of action: the enhancement  
233 of natural regeneration and avoidance of deforestation; active forest management; and adaptive forest  
234 management to build resilient forests (Nabuurs et al. 2018; Verkerk et al. 2020). For example, a recent  
235 analysis along a climate gradient across Europe showed that mixed forest, particularly those forest  
236 mixing conifer and broadleaved stands, are more resilient and resistant to drought events than  
237 monospecific forests (Pardos et al. 2021). Here, forest resilience refers to the maintenance of regimes  
238 and the adaptive capacity of forests as a coupled human-natural system in the face of drivers of change  
239 (Nikinmaa et al. 2020). As such, climate-smart forestry strives beyond storing carbon to mitigate climate  
240 change and generate synergies with multiple FES and biodiversity. The implementation of this solution  
241 needs to carefully consider the different regional contexts in Europe to identify the most cost-effective  
242 management options. It would also require sustained commitment as the benefits from this solution  
243 would only emerge in a mid-long term.

244 **Top 2. Mainstream FES-oriented management in a threefold strategy: education, awareness raising,**  
245 **and networking**

246 *Sustainability Area: Management; Challenge 4 - Narrow focus and normative mindset on forest*  
247 *management*

248 This solution invites broadening the often-narrow perspective of forest management focused on the  
249 timber and biomass production of highly productive stands (Jönsson and Snäll 2020), with the help of  
250 education and information strategies. In particular, this could be done by diversifying education at the  
251 administration and university level (Nair 2004), fostering knowledge transfer to forest operators (Perera  
252 et al. 2006), starting and reinforcing social campaigns to make visible the multiple services of forest,  
253 and developing and enabling long lasting cross-sectorial networks (Guerrero and Hansen 2021).  
254 Although this solution requires long-term commitment and significant attitudinal change within and  
255 beyond the forestry sector (shifting management goals, seeking long term instead of short-term benefits,  
256 or changing contractual arrangements) before its effects become apparent, this solution has the potential  
257 to largely generate synergistic and long-lasting effects over forest management in Europe. To tackle  
258 complex challenges and developing opportunities for innovation at EU level, collaboration can be  
259 enhanced through existing European Innovations Partnership (EIP) operational groups on forest and  
260 EU projects through multi-actor approaches. Moreover, in the light of the new EU CAP, **Agricultural  
261 Knowledge, and Innovation Systems (AKIS) are key to support more intensely the sharing of  
262 knowledge and innovation.**

263 ***Top 3. Foster investments into FES oriented forest management to increase resilience (prevention  
264 and adaptation measures) towards natural hazards***

265 *Sustainability Area: Economy; Challenge 7 - Insufficient financial support to changing conditions*

266 Investing in increasing forest resilience (Nikinmaa et al. 2020) is key for ensuring the prevention of and  
267 adaptation to natural hazards and ensuring the sustainable provision of FES (Keenan 2015; Lecina-  
268 Diaz et al. 2021). **A first step would be to assess and correct redundancies and ambiguities of forest-  
269 related investments. Then, local to regional forestry and nature conservation administrations should  
270 oversee the articulation and implementation of those investments. This should be implemented and  
271 monitored in a short-medium term to ensure that each forest-related investment fosters sustainable  
272 solutions with regard to multiple forest functions. Every economic support needs to be continuous and  
273 outcome-oriented by designing policies that consider spatial targeting to FES density, threats and cost**

274 levels, payment differentiation, and improved conditionality (Wunder et al. 2020). This solution  
275 requires an integrated forest policy that addresses various system dimensions in terms of policy sectors  
276 and administrative levels, including both local and landscape-level land uses with indicators oriented  
277 towards minimizing socio-ecological damages and losses (Moreira et al. 2020).

278 ***Top 4. Support economic instruments and business models promoting regulating and cultural FES***  
279 ***with consistent policies***

280 *Sustainability Area: Economy; Challenge 8 - Economic power asymmetries in the forestry sector*

281 Effective economic instruments as well as business models that contribute to the sustainable provision  
282 of FES (particularly for regulating and cultural FES) should be consistently supported by cross-scale  
283 European and national policies similar to those in place for timber and biomass production (Wunder et  
284 al. 2019). This could be achieved through, on the one hand, nested multi-scale policies (Ostrom 1990)  
285 and, on the other hand, a strategy of advertising and making available successful business models (along  
286 with the key features leading to their success). The specific purpose would be to stimulate their  
287 replication elsewhere. In relation to incentive-based and result-based payments for ecosystem services  
288 (PES) schemes, it is important to target forest owners of those forest areas that show a) high levels of  
289 FES supply (e.g., high carbon stocks/ha or endemic biodiversity hotspots), and b) areas with high  
290 potential risks (e.g., high threat of deforestation and degradation). This strategy would focus PES in  
291 areas where they can realistically make a difference (Börner et al. 2020; Wunder et al. 2020).

292 ***Top 5. Engage the community in participatory decision-making in management approaches in public***  
293 ***forests, while embracing innovations towards efficient use of forest resources***

294 *Sustainability Area: Governance; Challenge 12 - Tensions and mismatching expectations about the*  
295 *role of public forests*

296 This solution strategy promotes participatory forest management to overcome outdated management  
297 approaches that do not respond to current societal demands and larger social-ecological challenges (such

298 as biodiversity loss or climate change). These strategies are often coupled with a philosophy of  
embracing innovations towards improved forest management for the provision of FES bundles,  
especially for regulating and cultural FES, for the promotion of ecological and societal transformation,  
and for the sustainable use of public goods. Public forests would be used as niches of innovation (Geels  
2005) of, for example, public-private partnerships or novel actor alliances to improve the provision of  
regulating and cultural FES or enhance non-wood forest product (NWFP) value chains. Public forests  
would act as ‘incubation rooms’ for radical novelties, providing locations for learning, and spaces to  
build social networks which support innovation. Initiatives and innovations would be carefully  
addressed so that public resources do not end up creating exclusively private benefits, but rather  
improving local economies with a share of benefits re-invested in improved forest management.

#### 308 ***Top 6. Implement practices for (re)connecting people with forests***

309 *Sustainability Area: Socio-culture; Challenge 13 – Homogenization of perceptions of forest values by*  
310 *society*

311 Understanding forests as a mean to solve economic problems is a reductionist standpoint. In the pursuit  
of sustainable forest management, increased identification and inclusion of cultural bonds is crucial. To  
achieve a deeper understanding of the mutual constitution of the society-forest relation, it is also  
necessary to recognize the multi-layered spectrum of forests’ contributions (Ritter and Dauksta 2013).  
Mainstreaming forest models that (re)connect people and forests (like forest kindergartens and forest  
schools) is crucial. Increasingly, studies show the perceived linkages of people to spiritual and cultural  
values in forests that are not necessarily related to livelihoods (Rodríguez-Morales et al. 2020; Torralba  
et al. 2020). In parallel, there is a need to strengthen the social and cultural sciences in FES assessments  
with a clearer representation of non-material values (Jacobs et al. 2016) and more-than-human thinking  
(Whatmore 2006).

321 ***Top 7. Promote new forms of communication and interaction between society and FES providers***  
322 ***with a focus on public goods***

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3 323 *Sustainability Area: Socio-culture; Challenge 14 - Conflicts between FES providers and beneficiaries*

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5 324 When forests provide more regulating or cultural services than provisioning services, governance  
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7 325 mechanisms are key to maintaining the supply of FES, especially in **privately** owned forests. To  
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9 326 overcome the lack of markets to deal with public goods and services, social support is needed to finance  
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11 327 the expenses that keep the sustainable forest management ongoing. This is especially important in  
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13 328 situations where management is key to guarantee the provision flow of these goods and services, but  
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15 329 where these are under high threat (e.g., wildfire risk in the Mediterranean region that increases with the  
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17 330 lack of active forest management). European studies of public perception (Rametsteiner et al. 2009)  
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19 331 have revealed that forestry issues are not well understood outside the forestry community and have  
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21 332 suggested that improving communication to the general public is essential. Management goals and  
22  
23 333 objectives must be identified and communicated on the short as well as long term, a wide variety of  
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25 334 channels should be used, messages should be simple and clear, and collaboration with other  
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27 335 organizations (agriculture, wood construction, etc.) should be enhanced. **A joint effort with media**  
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29 336 **professionals would lead to results that are more successful.** In parallel, further research into the public  
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31 337 perception of forests and forestry is needed to define targeted communication strategies (Fabra-Crespo  
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33 338 and Rojas-Briales 2015).

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38 339 ***Top 8. Improve integration of regulating forest ecosystem services in local and regional planning***

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41 340 *Sustainability Area: Environment; Challenge 1 - Increasing frequency and intensity of extreme*

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43 341 *weather events*

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47 342 This solution proposes that forest planning authorities consider to a larger **extent** those specific  
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49 343 strategies that have been proven to enhance regulating services such as watershed protection, erosion  
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51 344 prevention, or flood control, for example by promoting mixed forest stands of uneven ages (Bravo-  
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53 345 Oviedo 2018; Felipe-Lucia et al. 2018). These should be economically supported to cover the  
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55 346 opportunity costs needed to restructure forests. Such measures, like PES, already exist in some settings  
56  
57 347 worldwide with different degrees of success (Wunder et al. 2020). The implementation of PES has been

1 348 polarized between pro-market and anti-neoliberal arguments. A political–cultural reconceptualization  
2 349 should be achieved to attain their potential while ensuring an improved environmental governance, (Van  
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4 350 Hecken et al. 2015). Moreover, PES implementation may encounter obstacles hampering the promotion  
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6 351 of regulating FES and impeding the improvement of the socioeconomic situation of forest-dependant  
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8 352 communities and stakeholders. Some of these obstacles are on the social side, the lack of know how,  
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10 353 insecure property rights, and problematic benefits distribution, on the market side, the adverse PES self-  
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12 354 selection, inadequate administrative targeting, and enforced conditionality (Pagiola et al. 2005; Wunder  
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14 355 et al. 2020). There is a large potential for the adaptation of these experiences to the European context.  
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19 356 ***Top 9. Coordinate strategic regional forestry stakeholders to join forces against biological and***  
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21 357 ***environmental threats***  
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24 358 *Sustainability Area: Environment; Challenge 2 - Increasing extent, frequency and impacts of events in*  
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26 359 *forest habitats*  
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30 360 This solution proposes the regional-level implementation of coordinated actions and monitoring  
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32 361 strategies. Risk can be assessed using analytical techniques that account for threats both spatially and  
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34 362 temporally. Subsequently, risk-management strategies need to account more fully for multi level  
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36 363 responses that act to balance conflicting interests between stakeholder organizations concerned within  
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38 364 the managed and natural environments (Mills et al. 2011). These strategies would integrate private and  
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40 365 public forest owners together with the regional-national administration and other sectors depending on  
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42 366 the context (e.g., nature conservation, local communities), and be backed with national support. The  
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44 367 objective would be to share knowledge about affected areas and to join forces for specific forest  
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46 368 interventions, increasing the readiness, monitoring capacity, and hence increasing the resilience of the  
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48 369 system to these perturbations. An example comes from some regions in the Mediterranean, where civil  
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50 370 society engages in wildfires extinction through volunteer groups (Górriz-Mifsud et al. 2019).  
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52 371 Coordination strategies would need to be specifically adapted to each context. Transferability can be  
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54 372 hampered by the heterogeneous systems of management and governance in Europe.  
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2 373 **Top 10. Increase availability, volume, and accessibility of financial instruments to cover losses**  
3 374 **from natural hazards**

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5 375 *Sustainability Area: Economy; Challenge 7 - Insufficient financial support to changing conditions*  
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9 376 The current natural hazards require planning and management strategies that increase forests capacity  
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11 377 for adaptive transformation. This could provide an opportunity to steer the objectives of forest  
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13 378 management towards a more sustainable and less production-oriented model. To be efficient, financial  
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15 379 instruments need to be conditional upon sustainable practices that ensure a diverse FES provision, while  
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17 380 being adapted to the different realities existing in the European forestry sector. This could be achieved  
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19 381 by dedicating part of existing economic support (e.g., EU rural development fund, common agricultural  
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21 382 policy, and other regional/local funds) for business model implementation to strengthen their adaptation  
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23 383 to each specific context. For example, by refocusing on forest protection measures (Alliance  
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25 384 Environment EEIG 2017) and encouraging the use of result-based schemes to increase the impact of  
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27 385 the funding, while linking the business model with a positive and measurable impact on the FES  
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29 386 provision (ECA 2020). Within such a scheme, a requirement for eligibility to receive funds would be  
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31 387 the direct link between the business model and a positive impact FES provision (Wunder et al. 2018;  
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33 388 Ovando et al. 2019).  
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39 389 **Discussion - Strategic pathways towards the sustainable supply of FES in Europe**  
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42 390 European forests are exposed to fundamental and interconnected threats that put many forest ecosystem  
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44 391 services that are vital for human wellbeing at risk. At the same time, various national and EU-wide  
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46 392 policies are rapidly emerging in Europe, which try to solve pressing societal challenges with a forward-  
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48 393 looking view on FES potential (Primmer et al., 2021). A diagnosis of FES provision, integrating  
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50 394 different perspectives from science, policy, and practice is crucial to understand where the flaws of  
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52 395 forest socio-economic systems are so that solutions can be strategically designed and implemented.  
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56 396 **Deep and shallow leverage solutions**  
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397 Most of the proposed solutions were considered as highly effective, transferable, and susceptible of  
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2 398 being monitored over time. while none of them was evaluated as economically inefficient by the team  
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4 399 of experts. However, more than half of the proposed solutions were considered not to be yet ready for  
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6 400 implementation or currently feasible. This is particularly relevant for those solutions that imply a  
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8 401 multilevel governance component and/or coordination among vertical and horizontal levels of actors  
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10 402 (e.g., solutions 5 and 21). These types of solutions would normally require long-term commitment,  
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12 403 institutional changes, and socio- political will (e.g., solutions 18, 24). Furthermore, they directly or  
13  
14 404 indirectly interfere with long-established cultural elements or strong economic interests (e.g., solution  
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16 405 12). These solutions can be considered as aiming for or being dependent on larger, perhaps even  
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18 406 fundamental system changes which require the alteration of existing paradigms, institutions (such as  
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20 407 policies but also mindsets), and actors' behaviors.  
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25 408 A closer look at the solutions' definitions and prioritization suggests a possible sequence of  
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27 409 implementation. Inspired on the notion of leverage points, where solutions can induce shallow or deep  
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29 410 changes (Abson et al. 2017; Dorninger et al. 2020), we could arrange the prioritized solutions according  
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31 411 to their potential to solve the challenges for the sustainable provision of FES. While there are some low-  
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33 412 hanging fruits, which could be easily implemented, some of the proposed solutions require a longer and  
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35 413 more sustained effort due to their profound transformative potential and respective resistance. Advances  
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37 414 towards the implementation of the former, which could be seen as encompassing fundamentally  
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39 415 paradigm change solutions, would smooth the way for the later, which could be seen as managerial  
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41 416 solutions. This is best illustrated with the highest ranked solutions. The strategic solution of  
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43 417 "mainstreaming FES oriented management in a threefold strategy: education, awareness, and  
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45 418 networking" is focused on changing mindsets towards an integrated multiple FES thinking and has the  
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47 419 potential to shift the classic market-oriented economic rationale that reinforces a timber production-  
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49 420 oriented paradigm. Similarly, the solution of the "promotion of climate-smart and resilient forest" is  
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51 421 fundamental to ensure the adaptation of existing forests to the conditions and disturbance regimes  
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53 422 associated to climate change so that they can continue to provide FES. This solution is the precondition  
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55 423 for targeting several economic, socio-cultural, and environmental challenges.  
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1 424 Due to the complexity inherent to the forestry sector and the entangled character of the challenges, the  
2 425 proposed solutions are highly interconnected, which pledges for a need for system change across all  
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4 426 sectors, levels, and actors. A paradigm shift affecting institutions, academia, and forestry  
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6 427 administrations is needed to go beyond forest biomass production and leverage the costs induced by  
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8 428 investing into regulating and cultural FES.

### 12 429 **The seven pathways towards sustainable FES supply**

15 430 Many of the solutions have synergistic effects if they are combined and implemented in an orchestrated  
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17 431 manner according to their capacity to enable transformation. For example, the integration of social-  
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19 432 ecological values proposed in solution 21, could support and benefit from the regional observatories  
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21 433 proposed in solution 8. By looking into the elements that are at the core of each individual solution, we  
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23 434 propose seven emerging pathways on which European forest policies should focus in the mid- and long-  
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25 435 term to ensure the sustainable supply of multiple FES. These strategic pathways could collectively build  
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27 436 the backbone of European forest policy implementation. Although all of them are relevant, they can be  
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29 437 distinguished by their capacity to leverage change in European forests and to secure the supply of  
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31 438 multiple FES in relation to future disturbances and social-ecological changes (Fig. 3). Collectively, the  
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33 439 seven identified strategic pathways can be organized in a hierarchical order, where deep forestry system  
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35 440 transformation would be in the basis, followed in the middle and top by system-based management  
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37 441 strategies and concrete measures.

### 44 442 *Changing production focused forest management paradigm towards pluralistic ecosystem valuation* 45 46 443 *(Core element of solutions 6, 11, 22, 23, and 24; relevant for challenges 5, 8, 13, 14 and 15)*

49 444 Decision-making processes affecting FES provision need to embrace broader views, preferences, and  
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51 445 values from a multi-actor perspective. Expanding the focus towards regulating, cultural, and supporting  
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53 446 FES and understanding their valuation from a pluralistic and integrative point of view would advance  
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55 447 the (re)connection between people and nature. Forestry education at all levels, forest management, and  
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1 448 policies need to pursue a shift from the consideration of instrumental values, to increasingly considering  
2 449 intrinsic and especially relational value dimensions (Chan et al. 2016; Jacobs et al. 2016).  
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5 450 *Using integrated landscape approaches to adapt the solutions to local-regional contexts (Core*  
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7 451 *element of solutions 1, 2, 5, 7 and 10; relevant for challenges 1, 4, 5 and 7)*  
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10 452 Due to the inherent heterogeneity of European forests, future policies need to embrace the context-  
11  
12 453 specificity of forest social-ecological dynamics, and use the landscape scale as the most appropriate one  
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14 454 to address the multi-scalar pressures on forests (Opdam et al. 2018). A landscape scale provides the  
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16 455 framework to orchestrate problems related to improving coordination and transparency in decision-  
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18 456 making processes (Termorshuizen and Opdam 2009; Sayer et al. 2013).  
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23 457 *Increasing forest resilience to boost forest multifunctionality (Core element of solutions 3, 8, 13, 14*  
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25 458 *and 23; relevant for challenges 2, 6, 9 and 14)*  
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29 459 Integrated landscape solutions promoting forest resilience and multifunctionality should therefore be at  
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31 460 the forefront of forest policies. It is fundamental to increase European forest resilience by lessening  
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33 461 intensive management to ensure adaptation to fluctuating climatic conditions. As recently observed by  
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35 462 Pohjanmies et al. (2021) in boreal forests, multifunctionality is substantially diminished under intensive  
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37 463 forestry and recovers slower, the longer intensive forestry has been implemented.  
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42 464 *Coordinating actions between forest-related actors (Core element of solutions 4, 5, 12, 15 and 16;*  
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44 465 *relevant for challenges 3, 4, 8 and 10)*  
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47 466 The lack of coordination across forestry stakeholders and among different administrative levels can  
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49 467 currently be considered an entrenched problem in the European forestry context (Winkel and Sotirov  
50  
51 468 2016). However, its disentanglement is a requirement for the successful implementation of any forest  
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53 469 policy. Once a multifunctional view on forests is emerging and impregnated through educational  
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55 470 programmes and policies, the forest institutional and social fabric would be better disposed to  
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57 471 implement coordinated actions.  
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2 473 *Increasing participation from a larger diversity of stakeholders during forest planning and*  
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4 474 *management, with a focus on public forests (Core element of solutions 5, 7, 17, 18, 20 and 22;*  
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8 475 *relevant for challenges 4, 5, 11, 12 and 13)*

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10 476 Greater levels of participation from the public into forest management decision making is at the essence  
11 of several solutions. To do so, forest policies should increasingly promote participation in **coordinated**  
12 477 multi-level governance models (Muradian and Rival 2013) by using for example collaborative digital  
13 478 tools, and capitalize from ongoing and former initiatives engaged in the provision of FES and nature  
14 479 models that have proved successful in ecosystem management and conservation (Armitage et al. 2020).  
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20 480 *Continuing, open and transparent knowledge integration from different stakeholders, disciplines,*  
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22 481 *and policy sectors (Core element of solutions 5, 6, 9 and 21; relevant for challenges 4, 5, 8 and 13)*  
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26 482 Translating sustainable management policy objectives into action on the ground has been described as  
27 a “wicked problem” (Duckett et al. 2016). This leverage area is fundamental to establish a fluid dialog  
28 483 to value and to integrate perspectives from “outsiders” disciplines and sectors affecting forests. To do  
29 484 so, several solutions point towards the use of inter- and transdisciplinary approaches as a way to  
30 485 integrate available knowledge and to create ownership for problems and solution options (Lang et al.  
31 486 2012).  
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40 488 *Using incentive-based instruments to support regulating and cultural FES (Core element of solutions*  
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42 489 *2, 8, 11, 13 and 14; relevant for challenges 1, 6, 8 and 9)*  
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46 490 PES and PES-like schemes are currently scarce in Europe. An increased role for PES could manifest  
47 491 itself through government-financed PES (e.g., through flexible reforms of the Common Agricultural  
48 492 Policy), or through user-financed PES in those areas where there is sufficient willingness to pay for a  
49 493 specific FES (Wunder et al. 2020).  
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56 494 **Figure 3.** Seven strategic pathways for the sustainable supply of FES in Europe.  
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59 495 **Conclusions**  
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1 496 EU policy frameworks such as the New Green Deal and the Forestry Strategy offer a unique opportunity  
2 497 to serve as catalysts for solving the challenges hindering the sustainable supply of FES. To support this  
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4 498 endeavor, the scanning exercise presented here not only disentangles the most pressing challenges in  
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6 499 all sustainability areas but also offers a set of prioritized solutions to each of those challenges. Just as  
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8 500 the assessed hindrances affect each other, similarly the strategic solutions can be used synergistically.  
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10 501 This way, like concentric levels of mutually supportive implementation (Figure 3), a paradigm shift to  
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12 502 better integrate pluralistic values of forests in a more balanced way would sustain the rest of the strategic  
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14 503 solutions. Next, increasing forest resilience through integrated landscape approaches should be  
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16 504 prioritized followed by strategies promoting coordinated, inclusive, and transparent decision processes.  
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18 505 The next strategies would focus on enabling forest's biophysical conditions to support the balanced  
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20 506 supply of FES, while reinforcing the social fabric of forest governance to make it more cohesive.  
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22 507 Finally, incentive-based mechanisms could, depending on the local context, promote a management  
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24 508 that strengthens the sustainable supply of multiple FES.  
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#### 30 **Authors contributions**

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33 510 MHM, MT, TP and CM conceived the original idea. MT and MHM led the coordination team,  
34  
35 511 performed the survey, workshop, analysis of the results and led the writing of the manuscript. NP, SS  
36  
37 512 and MT supported the coordination of the workshop, guiding and reporting the information from the  
38  
39 513 focus groups. All authors discussed the interpretation of the results and contributed to the final  
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41 514 manuscript.  
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674 **Tables**

675 **Table 1.** Definition of the final selected challenges for each sustainability area.

676 **Table 2.** Solutions to foster sustainable FES provision in European forests.

677

678 **Figures**

679 **Figure 1.** Workflow of the solution scanning exercise.

680 **Figure 2.** Prioritization of challenges based on urgency and impact.

681 **Figure 3.** Seven strategic pathways for the sustainable supply of FES in Europe.





