Governing Europe's forests for multiple ecosystem services: opportunities, challenges, and policy options

Policy Paper

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Contents

1. Introduction and objectives

Forests and other wooded lands currently cover 43.5% of the EU's territory (European Commission 2021). They provide the European society with multiple forest ecosystem services (FES), including provisioning (e.g., wood for construction and energy, non-wood forest products), regulating (e.g., local and global climate mitigation, hydrological regulation and soil protection) and cultural (e.g., recreational and health benefits). Most forests in the EU are privately owned (58%). A large share of the EU's forests are actively managed, in many cases primarily for wood production, but with substantial regional variation (Levers et al., 2014).

Forests offer employment and income along various value chains relating to wood and non-wood forest products and multiple other FES (Winkel, 2017), including recreation and nature-based tourism (Tyrväinen et al., 2017a). Forest-based products and services play a critical role in the envisaged transition towards a European circular bioeconomy (Hetemäki et al., 2017). Europe's inhabitants furthermore appreciate forests as natural and recreational spaces (Ranacher et al., 2017, Ranacher et al., 2020). While nature-based tourism is mainly located in rural areas, most recreational forest use takes place in urban and peri-urban areas; both are examples of forests providing substantial health benefits (Tyrväinen et al., 2017a). Recent EU forest-related policies particularly emphasise the importance for biodiversity conservation and climate change mitigation (European Commission, 2021).

Aligning the variety of societal and political demands for FES with FES supply, given the management objectives that private and public forest owners defined for their forests, is one of the main tasks for forest policy making in Europe (Wolfslehner et al., 2020). Matching supply and demand needs to be placed in a context of three interconnected mega-challenges that European forests are facing: 1) the need to adapt forests to a rapidly changing climate (Seidl et al., 2017), 2) the progressing "biodiversity crisis" (Watson et al., 2018), and 3) the need to transition the economy towards more reliance on renewable energy and materials (Hurmekoski et al., 2019, Navare et al. 2021). This paper aims to provide ideas for how future European forest governance can support such an alignment. To do this, we first identify challenges and opportunities related to the supply of FES in Europe. Subsequently, we outline four

future pathways for European forest policy to address the challenges and make use of the opportunities.

Methodologically, this paper is based on insights from the European research and innovation projects SINCERE (H2020), Nobel (Forest Value ERA Network) and CLEARING HOUSE (H2020). Key findings and recommendations included in this paper were discussed with policy stakeholders in two virtual events in September and December 2021. In addition, relevant scholarly literature was consulted to cover and deepen aspects that were not addressed sufficiently in the research projects. While acknowledging the inevitable limits of the presented findings and emphasized issues, we are confident this paper provides a useful basis to support EU policymaking to foster the supply of multiple FES from Europe's forests.

2. Challenges for the supply of multiple forest ecosystem services in Europe

2.1 Insufficient alignment of FES supply and demand

FES can be conceptually approached by distinguishing supply and demand (Luck et al. 2009). Supply refers to forests' ability to supply ES; it relates to forest attributes and is often significantly impacted not only by the size and location of the forest, but also its management. Demand refers to expectations and needs arising from forest users, ultimately from the whole society.

Table 1 presents findings from a European-wide survey conducted within the H2020 project CLEARING HOUSE. Focusing on the importance of FES as an indication of societal demand, the survey encompasses 10,391 responses from 33 European countries. Regulating and cultural FES were viewed as most important, while provisioning services were evaluated as considerably less important (Table 1). These findings are well in line with other studies published on social perceptions towards forests (e.g. Pülzl et al., 2021), and ecosystem services demand, as reviewed recently by Ranacher et al., (2020), as well as studies assessing the welfare economic values of biodiversity as assigned by the public (Jacobsen and Hanley 2009; Bakhtiari et al., 2018).

Table 1: Importance of different FES for European citizens (Roitsch et al., 2022). Data is from a representative sample of 10,391 responses from 33 countries. The question posed was: "How important are the following benefits of this forest to you?" Citizens were asked to respond in reference to a specific forest they visit most often and that they could locate on a map. Scale: 0=Not important, 100=Most important.

FES (Provisioning, Regulating, Cultural)	Median	IQR	FES (Provisioning, Regulating, Cultural)	Median	IQR
Habitat for plants and animals (R)	95	21	Water quality and erosion (R)	80	40
Aesthetics (C)	95	22	Spiritual and cultural value (C)	80	39
Air quality (R)	95	21	Food from wild plants (P)	66	47
Human health (R)	93	23	Education (C)	70	43
Carbon storage (R)	89	29	Employment (C)	50	50
Noise reduction (R)	85	32	Fuelwood (P)	31	56

Natural hazard protection (R)	81	38	Timber (P)	26	54
Temperature reduction (R)	81	38	Hunting (P)	13	47
Recreation (C)	82	38			

Legend: FES categories are "provisioning" (P), "regulating" (R), and "cultural" (C). The median value is the frequency distribution midpoint. The interquartile range (IQR) measures the range from the 75th percentile to the 25th percentile of the overall measured values.

Figures 1 and 2 present key findings from another European-wide survey on the importance of FES that was conducted within the H2020 project SINCERE, in collaboration with the H2020 project InnoForESt (see Mann et al., 2022). This survey focuses on forest owners' and managers' perceptions of various aspects relating to FES supply and demand.

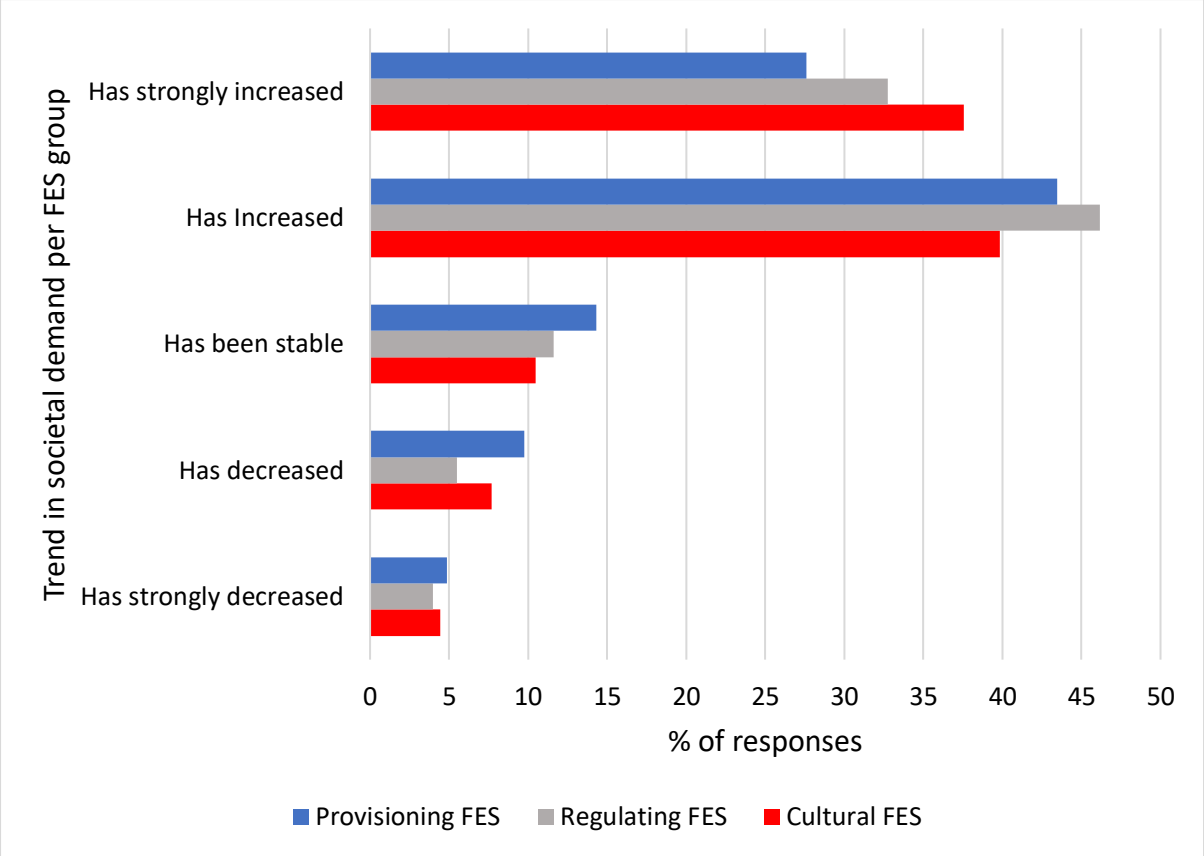

Figure 1: Societal demand towards FES as perceived by European forest owners and managers (Source: Torralba et al., 2020). Data is from a sample of 1186 responses from forest owners and managers across Europe. The question posed was: "If you consider the last two decades, have societal demands for forest ecosystem services in your forest changed?" Respondents were asked to answer this question in reference to a specific forest they own or manage in a scale from 0 (Has strongly decreased) to 100 (Has strongly increased). Values ranging between 0 and 20 were categorised as "has strongly decreased", between 20 and 40 as "Has decreased", between 40 and 60 as "Has been stable", between 60 and 80 as "Has increased", and between 80 and 100 as "Has strongly increased".

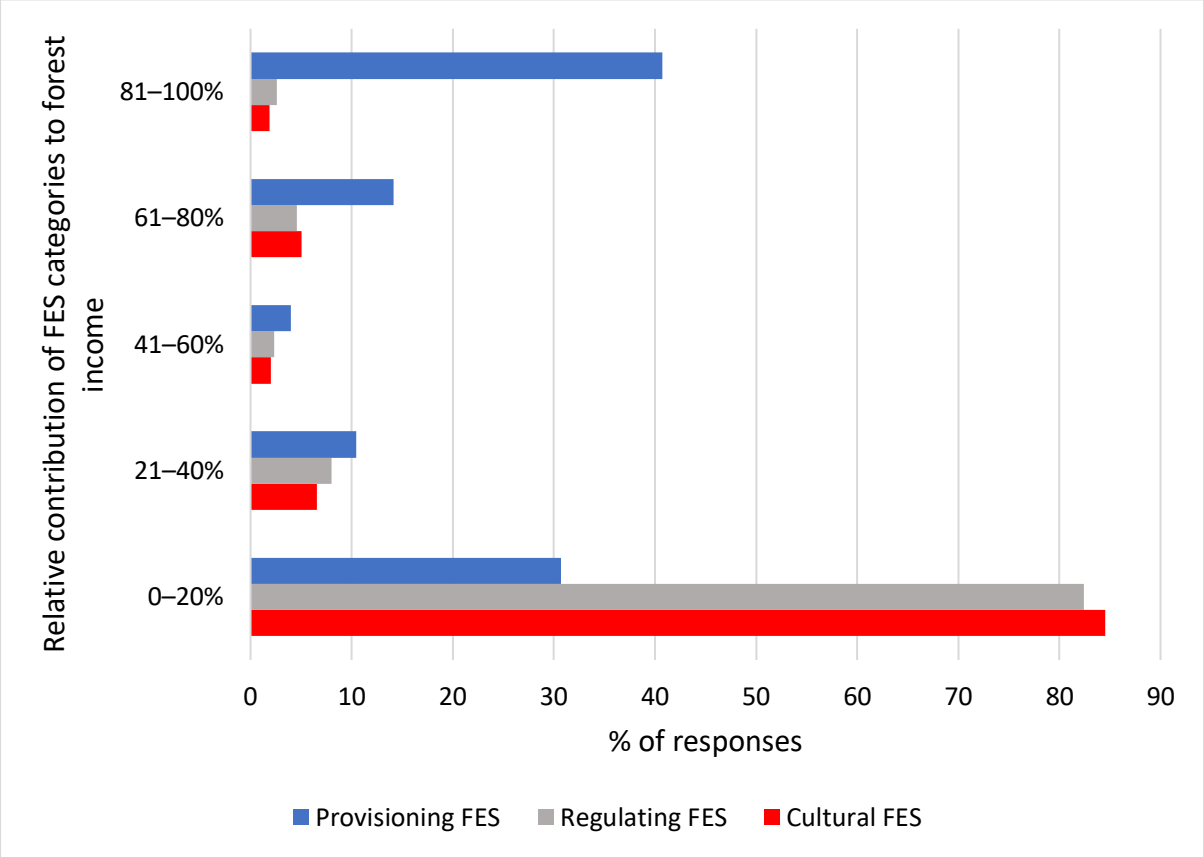

Figure 2: Relative importance of forest income from provisioning, regulating and cultural FES as reported by European forest owners and managers (Source: Torralba et al., 2020). Same data source as for Figure 1. The respondents were asked to assess the relative contribution of income linked to supplying provisioning, regulating and cultural FES (including income from subsidies and other public funds) in the total forest income (expressed as percentages of total forest income).

First, most forest owners and managers in the sample perceive that the societal demand for FES has increased or even strongly increased. Complementary to the societal perception survey data presented in Table 1, this increase is most significant for regulating FES, followed by cultural services; while it is less pronounced for provisioning services (Figure 1).

Second, provisioning services (meaning mostly wood) are by far the most important source of income, while regulating and cultural FES each provide less than 20 percent of their income according to a majority (over 80 percent) of the owners/managers surveyed (Figure 2). The importance of provisioning FES for incomes was, according to the survey, even more pronounced in Northern and Eastern Europe, while incomes were more balanced across different ecosystem services in Southern and Western Europe.

Taken together, these findings point at a potentially major challenge for European forestry: On average across Europe, the stated societal demand for cultural and regulating FES is high (as measured by societal perceptions, Table 1) and is perceived to be increasing (as measured by perceptions of forest owners and managers, see Figure 1); there is relatively less societal appreciation for provisioning FES such as wood and hunting (Table 1). In contrast, the economic importance of provisioning services for forestry enterprises and owners is high, with wood supply being by far the most important source of income (Figure 2). Given potentially major trade-offs in forest management relating to the provision of regulating and cultural FES vis-a-vis provisioning FES (Torralba et al., 20202), the considerable mismatch between societal demands for regulating and cultural FES and the limited income possibilities of these services for landowners and managers is possibly to result in a FES supply that falls short in satisfying societal demand to an optimal level.

2.2 Lack of policy integration and missing political support for FES incentives

Many EU policies relate to forests and forest products, even though forest policy is only weakly institutionalised at the EU level (Pülzl and Hogl, 2013; Pülzl et al., 2018). There are ongoing disputes about the level and extent of EU competencies concerning forest issues (Winkel et al., 2013; Lazdinis et al., 2019; Wydra, 2013; Onida 2020; Sotirov et al., 2021). Many of the forest-related policies include their own objectives and goals, often targeting specific FES, resulting in a multiplicity of partly conflicting goals for forests (Wolfslehner et al., 2020; Aggestam and Pülzl, 2018; Edwards and Kleinschmit, 2013; Lazdinis et al., 2019; Pülzl et al., 2018; Pülzl and Hogl, 2013; Winkel and Sotirov, 2016). As a result, the challenges of prioritizing among different policy goals are passed on to policy implementation at lower levels, from (sub-)national policy to the practical forest management levels (Aggestam and Pülzl, 2020; Maier and Winkel, 2017).

Traditionally in most European countries forest policies have focused mainly on wood production – by far the most significant FES forestry enterprises can sell on the current market – over other FES such as non-wood products, or regulating and cultural FES (Wolfslehner et al., 2019; Weiss et al., 2011). This is also visible in

the lack of support for innovation relating to FES other than wood and wood products (Rametsteiner and Weiss, 2006; Weiss 2019). For instance, while research has shown that non-wood products play a significant role for society, and to some degree also for the local economy, this significance is not visible in market statistics or other information systems that focus on wood production (Amici et al., 2020; Lovric et al., 2020; Vacik et al., 2020). Consequently, the potential of non-wood products is often neglected by forest policymakers, who conceive them as "by-products" of sustainable wood production (Weiss et al., 2019). In addition, established interests may hinder the development of new business models around forest products when they are seen as competing with existing production systems focusing on wood production (Buttoud et al., 2011).

The same challenges apply for cultural ecosystem services: while they are sometimes acknowledged as policy goals in forest or bioeconomy strategies, the incentives to manage forests for recreation and tourism are usually missing (e.g. Tyrväinen et al., 2017b).

In science and policy debates, market-based instruments have been proposed as a remedy or solution to incentivize the supply of ecosystem services other than biomass production. Advocating for such approaches, however, often overlooks that many FES have public-good characteristics, which cannot be easily marketed (Ruppert-Winkel and Winkel, 2009; Weiss et al., 2011b). This can be changed to some extent through product development and institutional transformation (Mantau et al., 2001), or marketing and institutional innovations (Weiss, 2019). For many FES, however, public-good characteristics make the development of private ES user-driven Payments for Ecosystem Services (PES) schemes very difficult. In other cases, for locally bound services such as the protection against natural hazards, a functioning market often cannot be created because the set of providers and beneficiaries is too small. In such settings, PES instruments need to be based on non-market privately negotiated contracts.

Furthermore, many services such as biodiversity conservation or watershed protection are biophysically complex, including vis-a-vis their spatial and temporal

scales: FES impacts of management are thus difficult to prove concretely. Hence, payments to incentivize specific management often have to indirectly assume positive final impacts from featured land-use proxies, rather than directly rewarding measurable FES impacts. In addition, the range of beneficiaries is often so broad that state governments need to represent them. In these cases, market-based instruments can become state subsidies, which run the risk of becoming insufficiently performance-based, and thus potentially inefficient (Weiss, 2000).

Even though innovative approaches with market-based instruments, such as competitive tenders for biodiversity conservation, could improve the efficiency of FES supply in certain situations, such solutions may be hindered by conventional bureaucratic logics of public administrations (Primmer et al., 2013). For instance, market-based instruments have been proposed in the context of the European biodiversity policy Natura 2000. These have not been pursued seriously by governments or forestry interest groups, however, because they are seen to run counter to wood production interests – the primary orientation of forestry – and because there are doubts about the permanence of such financial support (Weiss et al., 2017; Geitzenauer et al., 2017).

2.3 Ambiguous and conflicting institutional settings

In the SINCERE-InnoForESt survey with European landowners and forest managers, the regulatory framework and policymakers/stakeholders are evaluated, respectively, as the second and third most inhibiting factor for FES-related innovations (Figure 3).

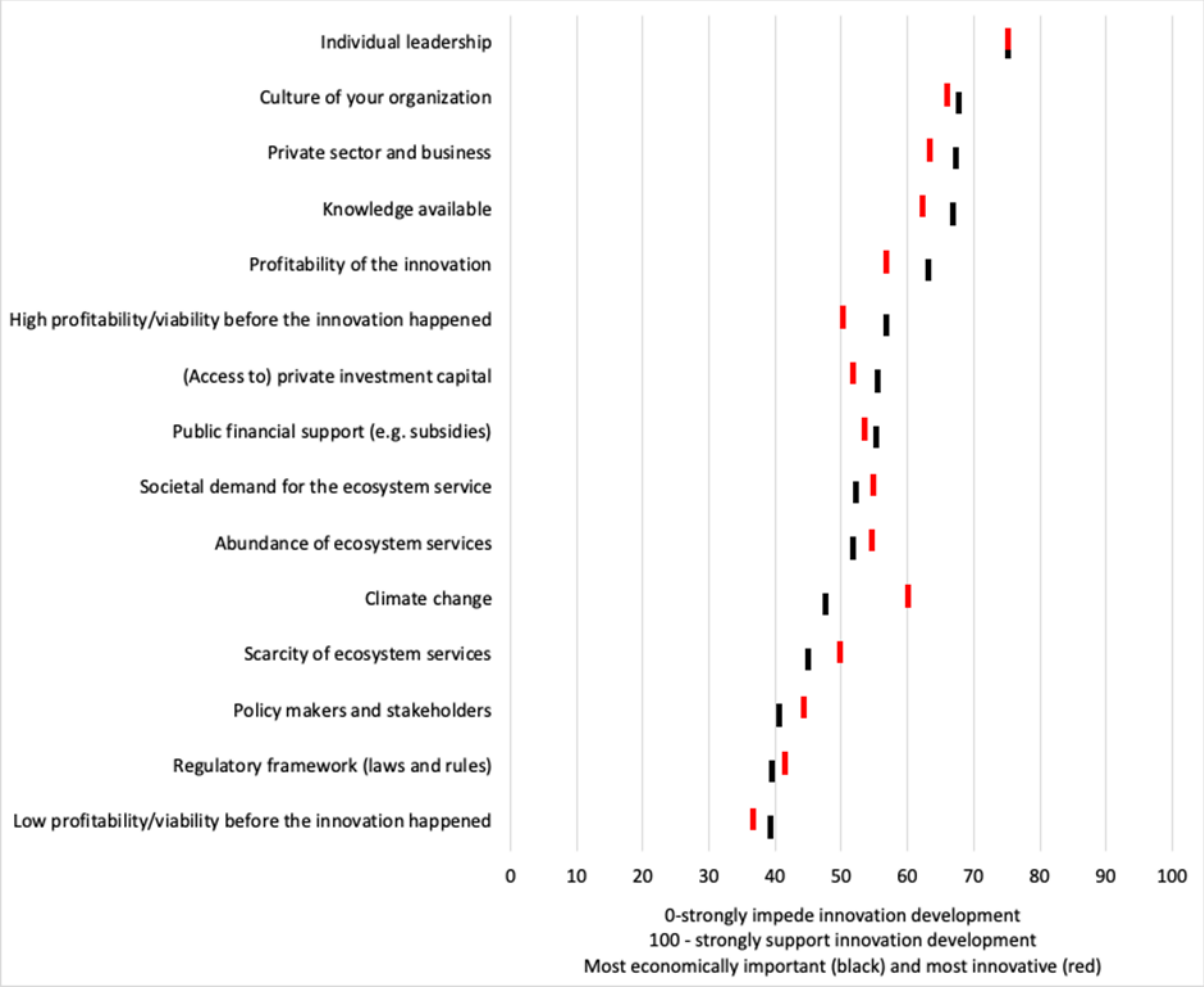

Figure 3: Enabling and impeding factors for FES-related innovations, as reported by European forest owners and managers (Torralba et al., 2020). Forest owners and managers across Europe were asked, in a case that they have developed some FES-focused innovation in the last twenty years, which factors have affected their development (scaled from 0 – strongly impeded to 100 – strongly supported). Please see Figure 1 and 2 for specification of the surveyed sample.

The significance of these factors in the perceptions of land managers is not surprising, as the regulatory framework defines property rights for FES, which are a strong determinant for landowners' possibilities to innovate with FES supply. Across Europe, the institutional frameworks for FES vary greatly (see Figure 4). While in northern Italy, for instance, the right to pick mushrooms can be sold privately, in Scandinavia mushrooms are predominantly a common-pool resource allocation, i.e. they can be collected by everybody. In some European forests, recreational access (e.g. horse-riding) can be excluded, in others not. Where these goods and FES are supplied to society or specific groups of users for free (e.g. "everyone's right" regarding the collection of non-timber forest products and free recreational access to undeveloped land in some Nordic countries), or at a price that is far below the production costs of

equivalent goods and services, forest owners have little or no monetary incentive to provide them. Hence, limited access rights can allow on-site markets for FES club or private good types to develop; whereas this will not happen for FES of a common-pool type when access is free. How far this enhances supply of such FES remains subject to debate. In any case, EU policy needs to acknowledge the strong variations in national regulatory frameworks, and any FES policy instrument must be contextualized vis-à-vis pre-existent regulations.

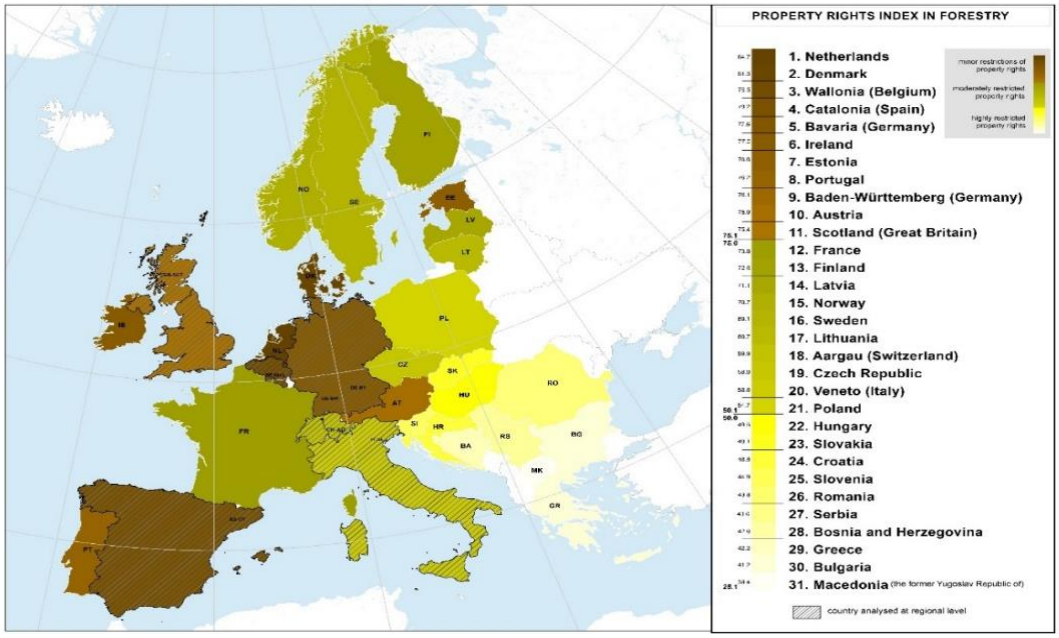

Figure 4: Level of restrictions in private forest management identified across Europe (calculated based on 37 indicators assessing owner's rights (Nichiforel et al., 2018)).

For public good FES with a spatial divide between ES provision and use, from watershed protection to climate change mitigation, beneficiaries cannot be excluded from enjoying any enhanced supply, even when they are far away from the supplying forests. In some cases, local PES schemes, e.g. within a watershed, can be developed to pay landowners to provide for these services. Yet, especially in cases at larger scales, regulation may need to ensure forest management practices for safeguarding such FES. Yet, regulation also risks shortcomings, such as lacking compliance if not monitored and sanctioned effectively. Regulation may face opposition from landowners if it pushes ambitious targets that conflict with owners' economic interests. Furthermore, in contrast to market-based instruments, regulation may not be easily adaptable to e.g. temporarily variable values and prices of FES, nor to a-significant

spatial heterogeneity of forest owner objectives (Boon et al., 2004; Vedel et al., 2015). Consequently, regulation alone normally cannot ensure a societally optimal supply, leading to suggestions for organizing FES governance through a mix of policy instruments (Winkel, 2007). However, adjusting different policy instruments in such a mix is also demanding: It will include contextually defining what is enhanced FES supply above the levels required by law. Yet, when payments to forest owners transform into legal compliance subsidies, FES additionality will be limited. In the worst case, already compliant providers may be disincentivized causing some owners to reduce supply they would have otherwise offered for free (motivational crowding-out) (Ezzine de Blas et al. 2019).

2.4 Lack of precise information on FES demand and provision, and innovations to align both

The practice of mapping and assessing existing ecosystems and their services is increasing among EU Member States. Several Spatial Information Platforms (SIPs) provide information on the spatial distribution of ecosystem services. Examples include the Ecosystem Services Partnership Visualization Tool (ESP-VT) developed by the Joint Research Centre, the Mapping and Assessment of Ecosystems and their Services (MAES) digital atlas, and the Mapping Ecosystem Services to Human Well-Being (MESH) of CGIAR. These initiatives, however, are not specifically designed to support the development and implementation of business models and policies. A crucial gap is that they do not connect ecosystem services to related policy objectives and targets. Current SIPs are populated with information on the (potential) supply of ecosystems services, but they tend to lack spatial information about ecosystem services providers, beneficiaries, and demands for these services now and in the future. Moreover, the SIPs tend to utilize global, EU and national datasets, whereas business model development requires regional and local data as well.

Despite the progressive advances in generating robust information on FES across Europe, there are still considerable knowledge gaps obstructing the practical operationalization of FES data at a European scale and its integration into the design of forest governance instruments (ranging from information to financial instruments)

and forest management practices, including operational forest management planning. The major obstacle is the lack of comprehensive datasets accounting for (potential) supply, (potential) demand and access to the full range of FES at different scales, as well as for the linkages between FES and specific forest areas, characteristics and management approaches.

Forest inventories and forest management plans are decisive for how forests are managed. In many cases they focus largely on data relating to standing timber stock and forest growth, and partially to vitality (relating to biomass production) and related information (e.g. about soil fertility). Other services are usually not accounted for, despite their significant socio-economic importance, such as recreation or non-wood forest products (Sheppard et al., 2020). Biodiversity-related information remains scattered in forest inventories (Knoke et al., 2021, Muys et al., 2022). Demand and access to FES other than wood production, and related changes, have received limited attention in the past, and are thus rarely reflected in management planning. Consideration of other demands is, however, necessary to successfully manage forests for a broad range of FES, and to integrate these demands into landscape or forest planning and management (Meyer and Schulz, 2017). In many contexts this results in a disconnect: whereas large-scale FES mapping activities focus on FES potential, regional and local operational forest management planning rarely considers this potential, and thereby inhibits innovation. Adding to this, there is little information exchange regarding (business) models and innovations relating to FES other than wood, and extension services providing advice to forest owners largely focus on sustainable wood production and related silvicultural measures.

2.5 Increasing pressure to adapt to climate change

Forests are increasingly affected by climate change and a related higher intensity and frequency of disturbances such as drought, fire, storms, pests and disease (Seidl et al., 2017). This situation challenges forest resilience and threatens the supply of FES (Nikinmaa et al., 2020). Innovative mechanisms to support a more balanced FES supply need to include climate change adaptation. Successful climate change adaptation strategies will increase the overall resilience of forests and the ecosystem services they supply.

How to pursue adaptation and ecosystem resilience depends significantly on the targeted ecosystem service(s). Mechanisms targeting wood production and other provisioning ecosystem services emphasize “healthy” forests, adoption of adapted tree species and genetic provenances, adapted management practices (e.g. shorter rotations, increasing thinning intensity), and enhancing climate change mitigation through an increased use of forest products. In contrast, mechanisms targeting regulating and cultural services, such as biodiversity conservation, may rather strive for low management intensity or protection, longer forest rotations, and increasing species mixture and uneven-agedness. Arguably, there is substantial tension between these two perspectives (Winkel et al., 2011; De Koning et al., 2014). However, their integration may be possible at the landscape level.

Climate change adaptation adds substantial complexity and uncertainty for the development of innovations to support FES supply. Surveys among European forest managers showed a strong need for knowledge and information to address climate-related challenges (Sousa-Silva et al. 2018). Optimization of FES supply in an adaptation context is exemplified by two case studies in the SINCERE project that both worked on the idea to establish a payment system for water provisioning FES: one in Catalonia, the other the extra-European comparative case of Peru. Both are located in water-scarce areas that are strongly affected by climate change, which exacerbates the risk of forest disturbances (e.g. fire risk). This resulted in long and complex stakeholder processes to explore and fine-tune the aim and approach of the innovative mechanism, and the necessity to consider watershed-related risk-mitigating mechanisms to manage increasing forest disturbances. Certainly, climate change increased the (perceived and manifested) risks to forest resilience (Messier et al. 2021), thus endangering water provisioning FES (Muys et al. 2021).

2.6 Striking diversity constraining one-size-fits-all solutions

Forests and the ecosystem services they provide across the EU are notably diverse. In the SINCERE-InnoForESt survey for of forest managers and owners, the reported profitability of supplying provisioning FES increased along a gradient from South-Western to North-Eastern Europe, while no such clear geographical trends can be observed for profitability of supplying regulating and cultural FES.

In the following, we illustrate the diversity of FES supply and demand with examples. Figure 5 provides an overview on the forest harvesting intensities across Europe in the 2000–2010 period (Kraxner et al., 2017, based on Levers et al., 2014), while Figure 6 presents the percentage of households who engaged in the collection of non-wood forest products in 2015. The significant regional variations in both figures exemplify the large variation in forest product harvesting (provisioning FES) in Europe, shaped by the context-specific interplay related to demand and supply.

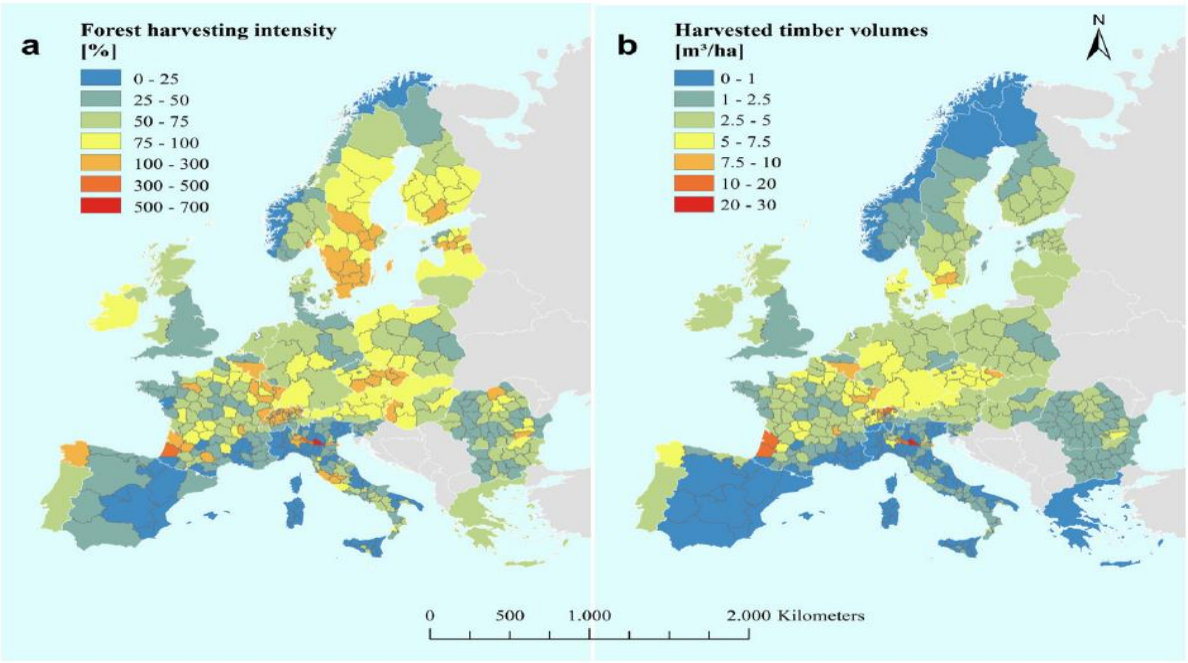

Figure 5: Average harvesting intensity (a; %) and harvested timber volumes (b; m3/ha) for the period 2000–2010 (Source: Levers et al., 2014, here based on Kraxner et al., 2017).

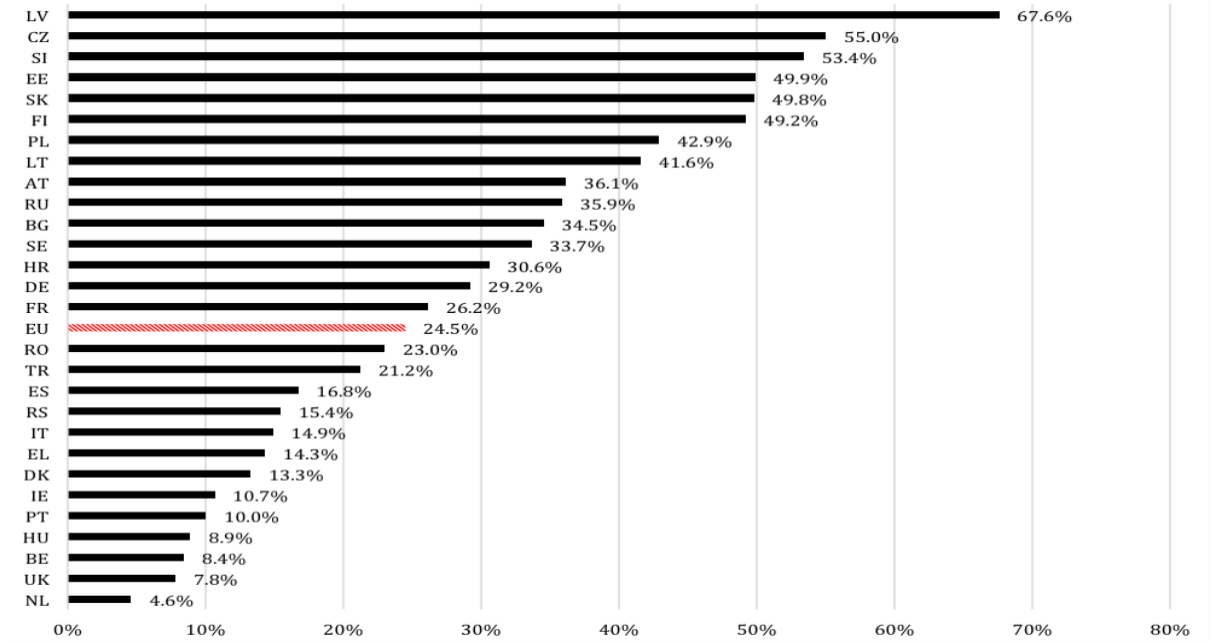

Figure 6: Percentage of European households engaged in non-wood forest product harvesting in 2015 (Lovrić et al., 2020).

Differences in the demand for FES are also indicated in the findings of a European survey conducted in the CLEARING HOUSE project. Figures 7, 8 and 9 illustrate the societal perceptions regarding the importance of a specific forest for the provision of 1) habitats for plants and animals (Figure 7), 2) recreation (Figure 8) and timber production (Figure 9). In short, the findings indicate significant regional variations in the importance that citizens attributed to these FES. For instance, wood production is generally considered more important in Northern and Eastern Europe. At the same time, as described earlier (Table 1), in all regions of Europe the reported societal demand towards FES mostly focuses on regulatory and cultural FES, and less on provisioning FES (Table 1).

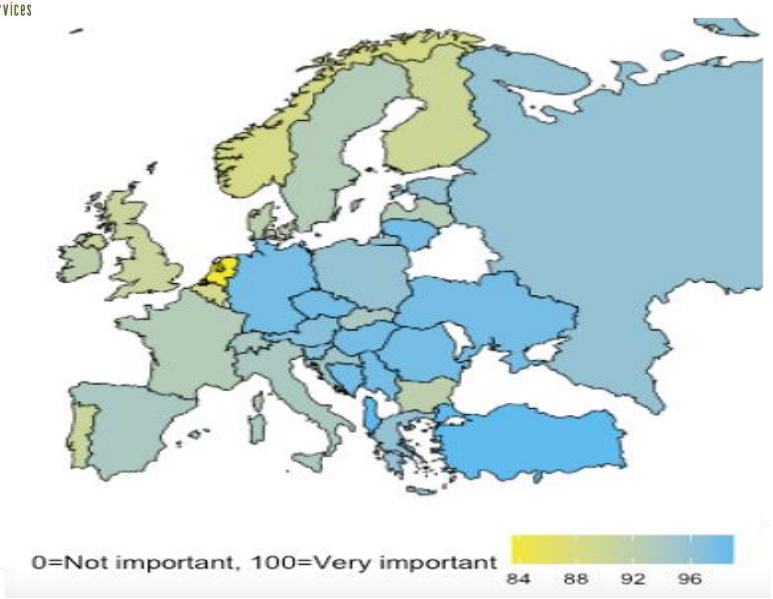

Figure 7: Societal perception of the importance of a most frequently visited forest as habitat for plants and animals on a scale from: 0=Not important to 100=Very important (Roitsch et al., 2022). Data is from a representative sample of 10,391 responses from 33 countries (here N=5,658 as only those respondents who responded for a specific forest were considered). The question posed was: "How important are the following benefits of this forest to you?"

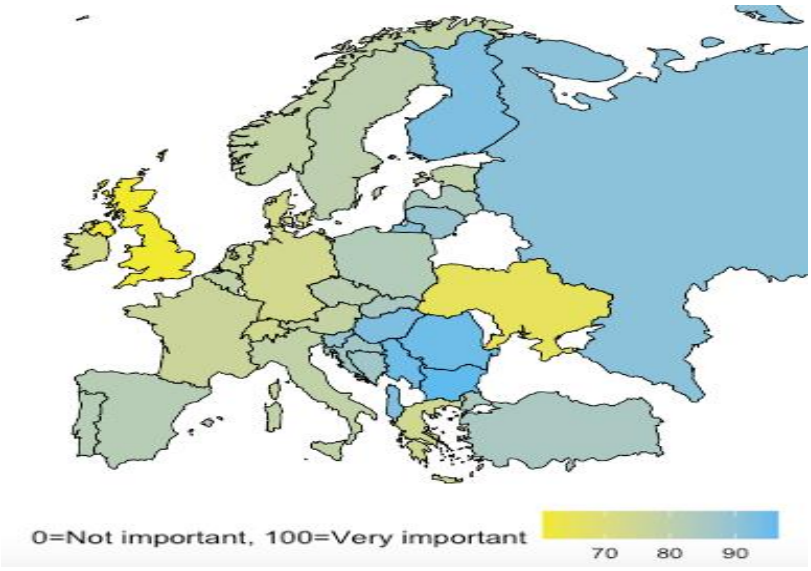

Figure 8: Societal perception of the importance of a most frequently visited forest for recreation on a scale from: 0=Not important to 100=Very important (Roitsch et al., 2022). Data is from a representative sample of 10,391 responses from 33 countries (here N=5,658 as only those respondents who responded for a specific forest were considered). The question posed was: "How important are the following benefits of this forest to you?"

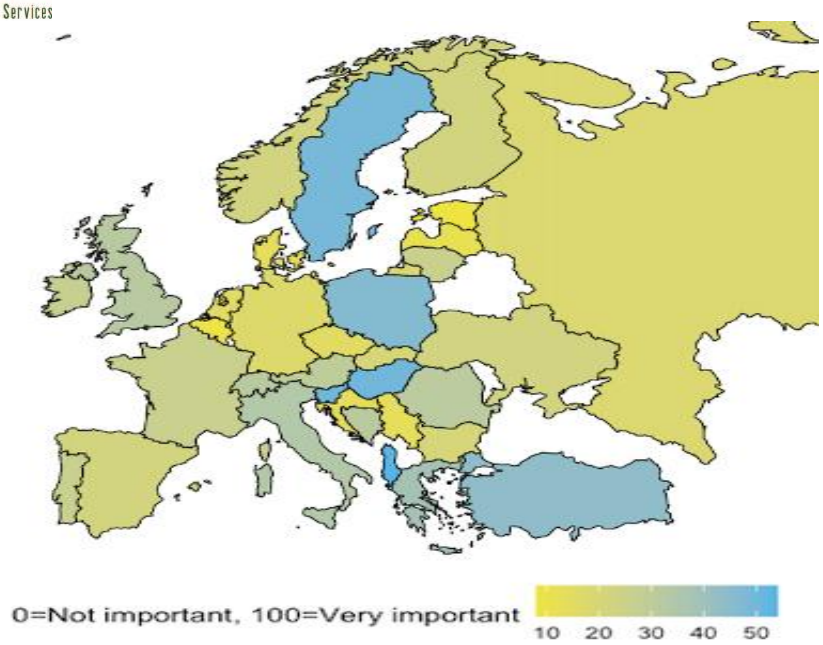

Figure 9: Societal perception of the importance of a most frequently visited forest for timber production on a scale from: 0=Not important to 100=Very important (Roitsch et al., 2022). Data is from a representative sample of 10,391 responses from 33 countries (here N=5,658 as only those respondents who responded for a specific forest were considered). The question posed was: “How important are the following benefits of this forest to you?”

3. Opportunities related to forests supplying multiple ecosystem services

3.1 United in diversity? Heterogenous forest owner objectives can match pluralistic societal demands

New opportunities for the supply of a broader set of FES arise from various social changes – both on the side of forest owners and the potential beneficiaries. The changes can be categorized into: 1) increasing societal demand for FES; 2) new types of forest owners; and 3) changing ownership structures and new rural-urban interrelations impacting innovations.

On the first point, new market opportunities related to FES are mostly connected to the tertiary sector and an "experience economy" (Tyrväinen et al., 2017; Weiss et al., 2020; Haukeland et al., 2021; Zivojinovic et al., 2020). There is a growing demand for experiential services such as recreation and nature-based tourism, educational, health and wellbeing-related or spiritual activities in forests or in nature (Tyrväinen et al., 2017a,b; Haukeland et al., 2021, Roux et al., 2022). Market trends for natural, retro- or sustainable products create new demand for wild foods, traditional modes of production, as well as artisanal and handcrafted products (Weiss et al., 2019a; Wiersum et al., 2019).

Secondly, changing societal demands towards forests are also often mirrored in forest owners' values and expectations. Amongst private forest owners, there is an increasing share of "urban" or "non-traditional" forest owners who are not productively and economically depending on farming or forestry, and/or hold "urban" values and attitudes towards forests (Lidestav et al., 2019; Weiss et al., 2019b). Although they may own only small parcels far away from their forest, shifting societal demands align with those landowners, opening up new opportunities to innovate business models for regulatory or cultural FES.

Finally, a broader spectrum of FES may also be provided through new forms of ownership, or relationships between forest management and users. Examples are new forms of common local forest ownership and social enterprises that support management for multiple or specific local forest values or services (Lawrence et al.,

2020; Barlagne et al., 2021; Lidestav et al., 2017; Ludvig et al., 2018). Another example of social and institutional innovation is participatory forest management in state or municipal forest land or local partnership forms such as the Model Forest approach and movement (Angelstam et al., 2019). Rapidly evolving IT and virtual networks and marketplaces may offer additional possibilities to connect FES suppliers with the demand side.

3.2 Money for everything? Rising demand and diversifying forest enterprises may lever innovations in regulating and cultural FES

In recent years there has been an increase in innovations relating to the supply of regulating and cultural FES. On the side of landowners and managers, these innovations may also result from increasing climate change-related risks, unsteady prices, and the related pressure to diversify incomes away from an exclusive focus on wood. Innovative business models include, for instance, funeral forests or natural burials (Becher, 2022) which are now widespread in parts of Central and Western Europe, creating new cultural FES-related income possibilities for landowners (Mäntymaa et al., 2019; Tyrväinen et al., 2020).

The data generated by the SINCERE-InnoForESt survey of European forest owners and managers indicates that the share of forest income related to provisioning FES grows from South-Western to North-Eastern Europe, while no similar geographical pattern could be observed for regulating and cultural FES (Torralba et al., 2020). In this survey, most innovations reported by forest owners and managers related to provisioning FES (mostly wood production). At the same time, forest owners and managers perceive their innovations for regulating and cultural FES as qualitatively being more innovative and promising. Reportedly, FES innovations are supported by organizational capacity, (e.g. leadership), by available knowledge, by cooperation among private actors, and by public financial support (Figure 3).

3.3 Climate champions? Reconfirming the potential of forests to mitigate climate change

Forests, and their management and products, can significantly contribute to climate change mitigation as carbon sinks, including substitution effects (Lindner et al., 2017; Ludvig et al., 2021, Brunet et al., 2021). Although carbon sequestration in forests can be more (cost-)effective outside of Europe, e.g. in the tropics (Larjavaara et al., 2018), European forests are also a significant carbon sink, especially when wood products and substitution effects are included (Ludvig et al., 2021). They store annually around 9 percent of the EU's Greenhouse Gas Emissions (Janssens et al., 2003: Lindner et al., 2017), albeit possibly with a declining trend (Nabuurs et al., 2013),

With the Farm-to-Fork Strategy approved in May 2020, the EC is committed to implement the Carbon Farming Initiative aimed at the «generation of tradable carbon certificates» to be sold in the European Trading System (ETS). The New EU Forestry Strategy, approved in July 2021, clarified that forest investments will be included in the Carbon Farming Initiative. This is a significant change in EU forest policy considering that in 2003 the potential inclusion of forestry into the ETS was categorically dismissed: "forest activities when used as C credits do not bring technology transfer, they are inherently temporary and reversible, and uncertainty remains about the effects of emission removal by carbon sink" (Advisory Group on Forestry and Cork 2003; Sotirov et al. 2021).

Consequently, carbon forest investments have only grown in the voluntary markets, i.e. through private initiatives and spontaneous action by member states (e.g. Woodland Carbon Code, UK, or Label Bass Carbon scheme, France), regional and local authorities (e.g. Carbomark scheme, Italy). The institutionalisation of these voluntary initiatives follows the mandate defined by the Paris Agreement on the involvement of "non-Party stakeholders" in developing the carbon markets, a line of policy action confirmed by the outcomes of the Glasgow CoP26 of the UNFCCC, where the implementation of carbon markets was enhanced.

Still several technical issues have to be defined in this pilot phase (permanency and risk management, leakage, additionality, monitoring, carbon sequestered in wood products, relation to other FES), but the EC is committed to make the certification

system for forest carbon removal operational by 2023. With ETS carbon prices reaching 97 €/t $C0_2eq$ (February 2022), boosted by the very ambitious EU decarbonization targets (-55% by 2030; zero emissions by 2050), carbon sequestration could become an economically attractive objective in European forest management.

4. Policy pathways for the future

4.1 Better information: monitor FES supply and demand broadly

Governing Europe's forests for multiple ecosystem services requires monitoring systems to ensure that policymakers, but also the wider spectrum of FES providers and demanders, have spatially explicit information about the potential supply and demand of relevant types of ecosystem services. Importantly, this should include regulating and cultural services that are rising in importance but are less covered by current forest monitoring systems (See section 2.4; Knoke et al., 2021). In addition, better information about forest owners' preferences, capacities and behaviour in regard to management for FES is an important knowledge base for developing targeted policy instruments (Weiss et al., 2019b). Although data acquisition is challenging , the conceptual and methodological tools to create a European-wide FES database are already largely available, while different strategies exist to make such an effort effective and cost-efficient.

Beyond the data provided by National Forest Inventories and relevant EU policies (e.g. monitoring Natura 2000), and further efforts (e.g. MAES, 2015), new mapping strategies should lean on advances in remote sensing and environmental modelling, featuring fine-scaled information for the supply of multiple FES (Orsi et al., 2020). To assess the demand for and access to FES, socio-cultural assessment methods, such as online Public Participation GIS (PPGIS) mapping tools, can show where and how forests can contribute to human wellbeing (Baumeister et al., 2020). The interpretation and contextualization of FES assessments require diverse, interdisciplinary teams, including expertise about different FES categories and heterogeneous European forestry contexts.

An assessment of the entire spectrum of FES could in principle be conducted at any scale, from local to EU. To achieve comparability, inform EU forest-related policies, and allow regional priority setting, the gathering of basic FES-related data could be done at the EU level. In this context a common definition of FES indicators would allow a standardized monitoring and comparison of the quality and quantity of FES in different regions. At the same time, specific FES-related information could be gathered nationally or sub-nationally, responding to specific demands and conditions. Providing

the information about FES supply could support the collaborative design of business models between landowners and various interest groups. Specifically, the integration and interpretation of results on FES demand and supply may require a landscape perspective that incorporates forest dynamics and FES with those of the landscape in which a given forest is embedded.

The supply and demand of FES are not fixed over time. Instead, they are sensitive to management interventions, climate change and disturbances, and context-related social-ecological changes. For this reason, any assessment effort must be accompanied by a monitoring strategy. Such a strategy could capitalize on citizen science methods for environmental education (Conrad et al., 2011; European Commission 2020a), articulated through a network of regional FES observatories that harmonize and synthesize the collected data.

It is obvious that new monitoring activities will come with additional costs, as well as questions related to the legal basis, responsibilities and competency. Therefore, expert and policy dialogues are needed to ensure that monitoring schemes are cost-effective (inter alia by combining alternative data gathering strategies ranging from remote sensing to on-the-ground information), do not put too much burden on public budgets, and specifically deliver the politically and societally required information regarding FES supply and demand.

4.2 Policy integration: coherently align EU forest objectives and policy instruments

Forests, at the EU and national policy levels, are subject to a striking diversity of societal demands, translating into (sectoral) policy areas that formulate distinct, and partially rivalling, objectives. Some of these policies are approaching forests from a single key perspective with ambitious targets (e.g. EU biodiversity policy targeting 30 percent protected, and 10 percent strictly protected areas; European Commission, 2020b)), others are broad yet generically lacking clear priorities (e.g. forest policy focusing on the SFM concept; see Winkel and Sotirov, 2016). The new EU Forest Strategy has advanced EU forest policy development with a clear catalogue of objectives and concrete instruments, but its effectiveness will depend on the implementation through policy areas such as environment and agriculture, and EU

member states' willingness to engage (Aggestam and Puelzl, 2018, Wolfslehner et al., 2020). Recent studies on EU forest policymaking leave doubts about how much specifically forest-rich member states will support implementation, given the ongoing ideological polarization between forest use and conservation interests (Sotirov et al., 2021). This could result in conflicts, even a blockage situation, and may hamper the possibilities of advancing policies that provide strong incentives for forest owners and managers to provide multiple FES for societies across Europe.

This pathway aims to support dealing with mixed policy objectives promoted by different policy instruments at the European and national levels. The main idea is to achieve policy integration, hence, to ensure that forest policy not only sets policy objectives but also embodies concrete processes for dealing with trade-offs, e.g. by involving all major concerned societal groups and representing a range of different and partially conflicting actor perspectives in goal formulation and implementation (Aggestam and Puelzl, 2020). Science can play an important role here by providing the knowledge basis for understanding the synergies and trade-offs between different FES, and options to achieve the provision of FES bundles, instead of narrowly targeting single goals.

Policy consistency is thereby linked to horizontal and vertical integration within a given time span, and involves the necessity to align different types of instruments (e.g. subsidy schemes that compliment regulation and address the entire spectrum of policy objectives). To be clear, policy integration does not require all goal conflicts in European forest policy to be resolved at the EU level, but that the policy framework across policy levels is consistent in supporting multiple objectives, with transparent procedures in place to set priorities in the case of irresolvable goal conflicts that can be adopted/put into practice at national or local levels.

To achieve such a policy framework, we highlight the following principles:

- Give all forest related societal groups access to the relevant policymaking processes at the relevant scale and context and ensure transparent decision making. This should facilitate the development of a shared understanding of the different objectives for forest management in acknowledgement of different views and interests, in the various contexts and scales, thus reflecting multiple views on the potential

supply and demand for FES into the policymaking system at relevant contextualised scales. As forest policies and strategic planning is conducted at different scales, the leading policy and planning institutions at the respective policy levels must develop more participatory processes .

- Align policy objectives with instruments to ensure that objectives are “backed up” by regulatory, but importantly also financial policy instruments, and provide for flexibility to achieve regional priority setting in integration, reflecting specific regional or national socio-economic demands in a manner that is transparent and inclusive for the respective policy stakeholders and societal groups.

- Ensure that policies, policy instruments and their implementation are monitored through the collection of reliable and up-to-date information regarding key targets and are adapted as needed.

Access to the policymaking process by various forest-related interest groups, and by groups that are affected by policies, and whenever possible society at large, policy objectives that are well translated into policy instruments, and a transparent flow of information on the supply of multiple FES seem a robust basis for integrated EU forest policies, and the basis for governing Europe’s forests well for the supply of multiple FES.

4.3 Payments for Ecosystem Services: towards a European PES system?

PES are seen as a tool to incentivize the supply of FES in cases where other policy instruments such as regulation may not be feasible or appropriate, especially designed to bridge trade-offs across stakeholders’ interests (Wunder 2015). An EU-wide PES system – or policy framework to enable PES schemes at various spatial levels – might potentially be an powerful component of a future integrative EU forest policy approach. However, both pros and cons can be raised vis-à-vis establishing such a system at the EU scale.

In terms of arguments in favour of a European PES system, some 85% of EU forests are available for wood production, yet nearly 90% are also accessible for Europe’s citizens demanding recreational FES, and many provide further unpaid provisioning,

regulating and cultural FES to societies (Figure 1). Externalities and trade-offs between multiple management goals are thus omnipresent, which PES are a customized tool to address. Especially global or aggregate-scale FES, such as climate mitigation and biodiversity protection, are in society's focus; a PES system may be an elegant way to collect the needed resources to remunerate forest owners for prioritizing these services. Arguably, forest owners would carry significant costs of FES supply if, for instance, (strict) protection for biodiversity purposes is planned to be enlarged on private lands. Making these cost burdens remunerated might thus make good sense. Finally, many environmental outcomes in Europe are affected by large agricultural subsidies through the CAP; an equivalent EU-wide forest PES scale may thus be an effective sectoral counterpart towards a landscape-level policy mix of productive and protective functions.

On the other hand, counterarguments also exist. Legal competency for forest issues remains in the EU more nested at the national than at the EU level, and the legal contexts vary greatly among EU countries. This makes it potentially difficult to define comparable "baseline standards" of FES supply, which could result in situations where forest owners in one country receive payments for the same FES measure that in another country forest owners are legally obliged to provide without payment, thus resulting in a competitive advantage for the former. Furthermore, club-good FES, such as watershed or recreational benefits, are better targeted by PES systems that are locally rather than EU-wide financed. The financing of an EU-wide PES system is also an open question: would member states be willing to co-fund it? Would Europe's citizens be willing to pay for FES, given a long tradition of seeing FES supply as a public sector responsibility of assuring legal compliance?

Moreover, for some global FES supply, Europe is not particularly competitive compared to forests in the tropics: carbon sequestration in Europe is climatically constrained (see section 3.3.), and tropical forests harbour more biodiversity than European forests. Finally, a large share of European forest owners are smallholders, potentially leading to high transaction costs of PES contracting and monitoring.

Therefore, if an EU-wide PES system was to be developed, it may require some principles and preconditions:

- *Agree upon systemic objectives*: Inter alia, define the scope of a PES system (forests, or landscapes including different types of land use – calling for a larger systematic reform of the way how land use subsidies are spent in the EU) and key FES to be supported (for instance biodiversity provision, climate mitigation and cultural FES).

- *Clarify sources of finance:* There is a necessity to earmark sufficient EU resources. Co-funding at the member state level (national to regional) would ensure sufficient national/regional government commitment. Participation should, as in all PES programmes, be guided by the principle of voluntariness.

- *Scale innovative design:* There may be trade-offs between ambition (i.e. how much does the system demand from participating landowners) and flexibility (i.e. how far can the system adapt to contextual forest owner demands). Yet, innovative contracting mechanisms (e.g. reverse or forward auctions, as practiced in the SINCERE and NOBEL projects, where forest owners competed on price and biodiversity protection actions, Lundhede et al., 2022) can be one cost-effective way to achieve ambitious targets while keeping implementation flexible. More publicly funded, larger-scale experiments are needed, however, to adapt such instruments to each regulatory context for cost-effective supply. Experimenting with new formats will need some courage though; here it is important to note that in both the USA and in Australia, auctions have become commonplace in the contract allocation of public PES programmes (Stoneham et al 2003, Whitten et al. 2017).

- *Set concrete FES foci:* With a huge variety of forest management practices and featured ecosystem services across Europe, a PES system needs to have transparently pre-identified what FES matter to whom. A combination of a participatory societal process involving the general public, business sectors profiting from the services, and science-based assessment of FES supply potentials may help determine FES priorities at regional levels.

- *Adopt generous time horizons:* In forestry, long-term durations and changes of environmental and economic cycles are a key challenge. The system should prioritize measures that have a sufficiently long-term perspective and commitment for impact. For instance, there would be little value in forest biodiversity conservation contracts relating to the retention of deadwood or habitat trees that run for just half a dozen of years.

Considering limited budgets, priority geographical areas may need to be identified where PES schemes should be developed first. These could be areas where they are most likely to bring about social welfare gains from better alignment between landowners' decisions and societal objectives, but also areas of special societal or environmental importance. Examples include:

- Biodiversity hotspots and/or forestland protected under Natura 2000.

- Ecosystem services demand hotspots, i.e. forest landscapes with high societal FES demand (e.g. peri-urban areas, key nature-based tourism destinations) and/or the highest discrepancy between societal demand and current supply of ecosystem services. As flagged above: when objectives are highly conflictive, PES can help to soften hard trade-offs.

- Adaptation hotspots and forest landscapes that are specifically hit by climate change related disturbances or where there is the highest adaptation pressure, combined with the greatest potential to restore resilient and diverse ecosystems that deliver multiple FES.

Finally, solid monitoring, sanctioning of non-compliance, and impact-evaluating accompanying research are needed for an effectively implemented system: without a manifested conditionality mechanism, PES systems will tend to lose their credibility (Wunder et al., 2018). Easy “self-assessment” tools by forest owners to evaluate their environmental performance can increase transparency and acceptance, but contract compliance and environmental additionality eventually need to be more objectively measured.

4.4 Bottom-up participation: enable participation and encourage learning amongst FES innovators

Engaging with stakeholders across sectors and policy levels is key for supporting innovations for the supply of multiple FES. The opening up of spaces facilitating participatory, bottom-up processes at the regional and local levels permits explicitly exploring the underlying factors for FES prioritization; it also allows the promotion of learning and helps to develop skills and capacity regarding FES demand-driven partnerships between forest owners and managers, business, society, policymakers and scientists.

Despite the growing research addressing FES, there is still a gap in how to integrate cultural and socio-economic assessments of different FES into traditional modelling tools for forest planning. Understanding and unveiling the underlying values at play in different decision-making processes concerning FES is crucial also for raising social awareness, considering that FES face competing demands that will be exacerbated in the future due to increased pressure on forests in the context of climate change. An integrative approach is needed to elicit stakeholders' preferences, socio-economic and cultural values of FES, and to make better-informed choices.

While most FES valuations are performed at a national or regional scale (Bryce et al., 2016), participatory bottom-up processes could focus on a local scale to integrate local differences, values and preferences into decision-making in a forestry context. Moreover, a participatory modelling approach challenges the inherent power asymmetry in expert-based modelling of local contexts, and therefore enhances local acceptability of FES-related decisions. In fact, as evidence from the SINCERE regional multi-actor processes demonstrates, stakeholders consider such participatory processes beneficial for the development of customized local solutions to handle FES supply. Moreover, local participatory processes involving a broad spectrum of actors (beyond the "usual suspects") have proven to significantly improve mutual trust, understanding and reduce historically rooted conflicts frequently associated with competing local demands for FES (Devente et al., 2016; Idrissou et al., 2013).

Scientists can support this by advancing understanding of how different types of forest management affect the supply of different FES, which is an essential basis for

advancing a European forest policy that incentivizes FES supply. Understanding the basic interconnections is necessary for designing management interventions (and policies to support them) at all levels, and knowledge needs to be accessible for all concerned stakeholders – those directly involved in forest management and planning, and those who benefit from FES directly or indirectly. Trade-offs between different outcomes and values need to be clearly articulated and discussed in order to reach consensus or to find a compromise about different forest management options in a specific context. Participatory action research led by social scientists can support the collective learning about the different views and values regarding forests and FES, and can establish clear linkages between potential PES and ecosystem service supply.

5. Conclusions

Above we have introduced selected relevant findings on the supply of FES in Europe, assessing challenges and opportunities, and outlining possible pathways for EU policy to support the supply of multiple FES in Europe. We selectively focused on key challenges and opportunities, and possible actions. Under our four suggested main pathways (and eventually beyond), further elements not covered in this paper could be important, for instance looking into the importance of innovation policies (Weiss et al., 2021) or participatory policy approaches specifically for public forestlands (Buchy and Hoverman, 2000; Maier et al., 2014). Moreover, our four introduced pathways are not mutually exclusive, but often complementary parts of a larger policy framework. Yet, given the momentum in European forest policy in relation to the European Green Deal, and the environmental and socio-economic challenges for EU forests, the time seems right for advancing these pathways, hoping to contribute to an EU framework for a future forest policy that governs Europe's forests for a better demand-aligned multifunctional FES supply.

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