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Research article

Can nature conservation and wood production be reconciled in managed forests? A review of driving factors for integrated forest management in Europe

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ABSTRACT

Integrated forest management (IFM) can help reconcile critical trade-offs between goals in forest management, such as nature conservation and biomass production. The challenge of IFM is dealing with these trade-offs at the level of practical forest management, such as striving for compromises between biomass extraction and habitat retention. This paper reviews some of the driving factors that influence the integration of nature conservation into forest management. The review was conducted in three steps – a literature review, an expert workshop and an expert-based cooperative analysis. Of 38 driving factors identified, three were prioritised by more of the participants than any of the others: two are socio-cultural factors, identity (how people identify with forest) as well as outreach and education, and one is economic – competitiveness in forest value chains. These driving factors correspond to what are considered in the literature as enablers for IFM. The results reveal that targeted, group-oriented, adaptive and innovative policy designs are needed to integrate nature conservation into forest management. Further, the results reveal that a "*one-size-fits-all*" governance approach would be ineffective, implying that policy instruments need to consider contextually specific driving factors. Understanding the main driving factors and their overall directions can help to better manage trade-offs between biodiversity conservation and biomass production in European forests.

1. Introduction

It is commonly recognised that forests provide multiple ecological, economic and social ecosystem services. In the last few decades several new forest management paradigms have appeared in order to address the increasing demand for varying forest ecosystem services, not only in Europe but also globally (Gustafsson et al., 2019; Naumov et al., 2018; Sousa-Silva et al., 2018). These paradigms seek to move beyond the ideas that forestry focuses primarily on one ecosystem service – wood production – and that ecosystem service provisions need to be spatially segregated, for instance separating wood production and conservation areas. Notably, the rise of sustainable forest management has helped pave the way for a more thorough consideration of multiple ecosystem services (Hoogstra-Klein et al., 2017; Sutherland and Huttunen, 2018). For instance, biodiversity conservation is now considered to be an integral part of forest management. Efforts are ongoing to resolve trade-offs inherent in the demand for timber and the demand for other goods and services (e.g., recreation). Next to strictly protected areas, new and integrative approaches are being developed, such as retention forestry (Gustafsson et al., 2019), multifunctional or multi-use forestry (Hoogstra-Klein et al., 2017; Başkent, 2018), close-to-nature forestry (O'Hara, 2016) and integrated forest management (Kraus and Krumm, 2013; Maier and Winkel, 2017).

Integrated forest management (IFM) is a form of combined-objective forestry to satisfy multiple societal demands in a limited spatial context (e.g., a forest stand) rather than maximising individual objectives in separate plots, such as at a larger forest landscape or even country level (Blattert et al., 2018; Phalan et al., 2011). While it has been variously

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defined across the globe (Cairns and Meganck, 1994; Corona et al., 2015; Kreutzwiser and Wright, 1990), IFM can be described as a management approach that takes into account: (a) forest ecosystem dynamics, (b) forest policy and management decision-making in view of diverse objectives, and (c) a large set of system-wide factors such as economic and demographic developments, technological innovations, public opinion, and cultural and political changes (Sotirov and Arts, 2018). It aims to integrate conflicting forest-related objectives such as timber production, habitat provision, water and soil protection, game management, avalanche and fire prevention, as well as recreation and public health (Sutherland and Huttunen, 2018).

IFM is a promising approach to help reconcile critical trade-offs that affect the forest-based sector, most prominently the trade-off between nature conservation and wood (biomass) production (Bauhus et al., 2009; Bonsu et al., 2017; Borrass et al., 2017; Gustafsson et al., 2019; Maier and Winkel, 2017). The challenge of implementing IFM is dealing with those trade-offs at the level of forest management, such as striving for compromises between biomass extraction and habitat retention. Moreover, local decision-making happens in a complex context; social, economic and ecological driving factors determine how willing or able forest managers and owners are to adopt IFM (Deuffic et al., 2018; Maier and Winkel, 2017; Sotirov et al., 2019).

This paper's key objective is to review and analyse the driving factors that prevent or enable IFM implementation in Europe in order to gain a comprehensive perspective on the possibilities to advance the approach. In doing so, we focus on perhaps the most critical and challenging dimension of IFM and forest management in Europe (Winkel, 2013), namely, the integration and reconciliation of nature conservation and wood production.

2. Approach

We use a three-stage methodology in this paper. The first step was a literature review on the driving factors of IFM, so as to collate state-of-the-art knowledge on the integration of nature conservation into forest management and to identify knowledge gaps. The screening of relevant publications, studies, reports and projects focused on documents that relate directly to IFM, nature conservation, wood production, sustainable forest management and climate change. The review contributed towards the preparation of a draft list of 32 driving factors for the expert workshop (see below).

Second, an expert workshop was conducted. The workshop was carried out in the context of the Integrated Forest Management Learning Architecture (INFORMAR) project launch[1]; and was attended by 34 participants including European academic institutions/organisations, private forest owners associations, public forest companies, international cooperation organisations, non-governmental organisations (NGOs), ministries as well as the European Commission (see INFORMAR. (2018)).

During the workshop participants were divided into groups. One group, which was comprised out of 16 experts, took part in an interdisciplinary focus group discussion on driving factors for IFM. The composition of the group was mixed to involve a large set of complimentary perspectives from science, policy and forest management practices across Europe (see Table 1).

The STEEP approach (Bowman, 1998; Kim-Keung Ho, 2014) was used to structure the focus group discussion and categorise the driving factors that facilitate or impede the integration of nature conservation and wood production into forest management. The STEEP typology covers socio-cultural, technological, economic, environmental and political driving factors (see Table 2). The discussion was carried out as an open exercise where each participant was asked to add driving factors under each category (socio-cultural, technological, economic, environmental and political) that had been introduced. The initial draft list of driving factors served to kick-off the discussion. This was followed by a round-table discussion where all the participants could comment on the relevance of the driving factor to IFM. In this way the participants jointly formulated, discussed and validated several driving factors as well as complemented and expanded on the draft list. The last step of the discussion was for the experts to select, according to their own opinions, the three most important driving factors for IFM. This was achieved by having each participant put 3 stickers on the list of driving factors that had been jointly formulated. The results from this exercise are presented in Table 2; the full range of considered driving factors areelaborated in the Appendix (see Table 1 in Supplementary Materials).

Third and finally, following the workshop-based analysis, an expert-based cooperative analysis was conducted, including a review of the inputs received during the workshop (Gibert et al., 2010). The principal goal of the cooperative analysis was to prepare a draft narrative (around 500 words) covering the driving factors under each STEEP category. This was subsequently shared with a panel of experienced scientists. The purpose of sharing the draft narratives was to elicit expert-based knowledge, building on the inputs from the interdisciplinary focus group discussion, and to compliment the review of scientific literature in response to new aspects elaborated on during the focus group discussion.

Table 1
Participants and their background in the focus group discussion on driving factors of IFM.

Organisation	No. participants[a]
Academic institutions/organisations	4
Private forest owners' associations	2
Public forest companies	2
International cooperation organisations	2
Non-governmental organisations	1
Ministries and agencies	4
European Commission	1

[a] For a more detailed description of the participants, see INFORMAR (2018).

3. Results and analysis

The output from the expert workshop is a list of categorised and prioritised driving factors that were considered to prevent or enable the integration of nature conservation in forest management in Europe (see Table 2 and supplementary Table 1). The prioritisation corresponds to the ranking based on the points allocated by the workshop participants. It should be emphasised here that the list contains driving factors that at least one participant of the focus group discussion considered important, while the ranking indicates how many experts prioritised a given driving factor.

Of the 38 driving factors identified and discussed, three were prioritised by a large number of participants as being especially important for the implementation of IFM. These driving factors relate to (economic) competitiveness and (socio-cultural) identity as well as outreach and education. Notably, socio-cultural driving factors were prioritised significantly more, representing 48 per cent of the points having been allocated by the workshop participants, as compared with economic, environmental, political or technological driving factors.

3.1. Socio-cultural driving factors

Socio-cultural driving factors were considered the most relevant by the workshop participants in terms of their importance for IFM to be applied more widely in forest management. Specifically, changing and competing perspectives on forests by different societal groups (e.g., forest owners vs. tourists, urban population vs. rural population, foresters vs. conservationists) result in diverse demands on forests that are shaping forest use (Bonsu et al., 2017; Deuffic et al., 2018; Maier and

[1] See https://informar.eu/.

Table 2
Prioritisation of driving factors that prevent or enable the uptake of IFM in forest management in Europe[a].

Typology	Driving factor	Prioritisation[a]	Typology	Driving factor	Prioritisation[a]
Socio-cultural	• Identity	7		• Incentives	0
	• Outreach & Education	5		• Bioeconomy	0
	• Nature Connectedness	3		• Diversification	0
	• Social capital	3		• Certification	0
	• Skilled labour	2	**Environmental**	• Regional variations	3
	• Forest Ownership	2		• Climate change	1
	• Public Opinion	1		• Naturalness	0
	• Entrepreneurship	0		• Land use change	0
	• Urbanisation	0		• Degradation	0
Technological	• Mechanisation	1		• Nitrogen deposition	0
	• Product development	1			
	• R&D	0	**Political**	• Leadership	4
	• Information and Communication Tools	0		• Policy coherence	3
	• Data sharing	0		• Policy incentives	2
	• Educational tools	0		• Regional variations	1
Economic	• Competitiveness	7		• Soft policy instruments	1
	• Global competition	1		• Policy barriers	0
	• Cross-sectoral competition	0		• Taxes	0
	• Economic viability	0		• Regulatory burden	0

[a] For a detailed description of the driving factors, see Supplemantary Table 1 in the Appendix.

Winkel, 2017). Societal perspectives on nature are moreover shaping public opinion and policymaking (Rametsteiner et al., 2009). Some of the trends at work in this regard include demographic changes (e.g., urbanisation, ageing populations and changing household composition), changing forest management culture and traditions, as well as reduced reliance on forests for livelihoods or income, and increasing demands for (nature-based) recreation. All of these changes are triggering new expectations towards ecosystem services, which in turn modify the demands towards forest management (Borrass et al., 2017). With this come increased prospects for IFM implementation. For instance, there is increasing demand for multifunctional forest use, especially in or near urban areas, where more products and services need to be simultaneously provided by forests, such as recreation, provision of green space and public health (Borrass et al., 2017; Ciesielski and Stereńczak, 2018; Başkent, 2018). These types of socio-cultural factors can be harnessed to generate momentum to integrate nature conservation objectives into forest management as they tend to increase societal demands towards the "non-material" benefits derived from forests (Bjärstig and Kvastegård, 2016).

Another significant socio-cultural driving factor (associated with societal perspectives on nature) concerns the increasing prevalence of new types of forest owners, notably the growing number of so-called urban forest owners that do not rely financially on their forests. This group's focus is more centred on aspects of nature connectedness and personal identity where their forests are managed for aesthetic, emotional and sentimental reasons rather than being driven by purely economic considerations (Feliciano et al., 2017; Weiss et al., 2019). This development has been associated with controversial trends, such as land abandonment and limited possibilities to manage forestland, but it also offers new possibilities for synergies and the integration of biodiversity conservation in forest management through increasing interest towards alternative forest management objectives.

The growing number of urban forest owners has been linked, be it coincidental or causal, to a decrease in the number of active forest workers and the resultant loss of forest-based professional skills (Lawrence et al., 2017). Rural markets and local entrepreneurship are affected by this phenomenon as forests no longer generate the employment and income levels for local communities they once did. These developments are highly ambiguous for IFM. On the one hand, they open the door for better integration of nature conservation into forest management as forests are increasingly seen as having more than just economic value. On the other hand, the diminished pool of skilled forestry landowners and workers, indeed even a decreased interest in forest management, may lead to increased land abandonment or take-overs by industrial contractors with little interest in IFM approaches. While the increasing share of urban forest owners is important with regards to private forests, on publicly owned forest lands (e.g., state-owned or municipal forests) the attitudes of the forest managers are crucial in determining how forests are being managed. Various management cultures, traditions and education affect how foresters perceive their duties (Maier and Winkel, 2017), resulting in different forest management regimes (Deuffic et al., 2018; Verkerk et al., 2011).

The workshop participants also highlighted social capital and reputation as a driving factor. For instance, the workshop participants noted that the reputation of foresters in rural communities may be high, which implies that there is a trust in the competence of foresters in rural areas where personal relationships have evolved over time (Guillén et al., 2015). In contrast, urban populations unfamiliar with or critical towards forest management may not appreciate the role that foresters play (Buijs and Lawrence, 2013; Guillén et al., 2015; Primmer and Karppinen, 2010). This has led to conflicts where foresters are perceived as being responsible for the unjustified exploitation of forests, causing a decline in biodiversity, and being insufficiently concerned with nature conservation. The different modes of communication and language of forestry professionals are in need of careful consideration and modification in order to diminish barriers to understanding, bidirectional communication and trust building (Bethmann et al., 2018). Increasing the social capital among the various actors involved, especially with regard to trust and understanding, is a fundamental driving factor for improving relationships between the groups and ultimately in enhancing the prospects of IFM, which aims to satisfy a diversity of societal demands being successfully implemented.

Furthermore, nearly half of the workshop participants prioritised outreach and education (e.g. platforms for dialogue and the exchange of views and values). The argument for improved outreach and education is that it serves to deepen the knowledge base regarding the possibilities (and limits) to integrate the provision of various forest ecosystem services through IFM amongst relevant actors, whether public or private (Coll et al., 2018; Leban et al., 2016). Participants highlighted that forest owners and managers need improved social support and education on how to implement IFM effectively to accompany for the diverse and conflicting demands on forests.

3.2. Technological driving factors

Technological driving factors was the least prioritised category according to the workshop participants; however, it was clearly recognised that new technologies and forest products can create silvicultural

opportunities for IFM as well as address fundamental challenges for sustainable forestry, including nature conservation. For example, improved capacities for mapping and monitoring the ecological aspects of forest resources (e.g., ecologically valuable habitats and stands) through improved geo-spatial monitoring (Reddy et al., 2016) and non-invasive methods for tree biomass estimation (Dittmann et al., 2017) can facilitate more precise multipurpose forest management. Employing new tools and technologies can help reduce the environmental footprint associated with forest management (e.g., reducing and rationalising in-stand machine traffic) while improving capacities for the integration of nature conservation into forest management (e.g., to exploit synergies between conservation and wood production values more effectively based on better information for forest management planning).

Information plays a crucial role here. This involves the provision of data and knowledge to and among practitioners, policymakers and the general public. Improved access to high quality information not only contributes towards better forest management planning and operations; however, lack of awareness about IFM among forest owners and access to environmental information is a barrier to its uptake (Aggestam, 2019). Data accessibility, which directly correlates to the quality of the infrastructure for data sharing, not only helps to increase the transparency of forest management for the public but can also change perspectives and attitudes on conservation (Baycheva-Merger et al., 2018). New technologies associated with data transfer/translation, including platforms that improve access to information on markets (e.g., private as well as commercial demands) have a significant role to play in facilitating a change towards the integration of nature conservation and timber production (Bonsu et al., 2017).

Connected to outreach and education noted in the preceding section, the tools employed to educate were highlighted as a central driving factor for the transfer of knowledge to current and future practitioners during the workshop discussion. For example, the European network of demonstration sites for IFM using Marteloscopes is an educational tool that provides practical experience in weighing the economic and ecological values of a forest stand (Kraus et al., 2018). These types of educational tools can be used to demonstrate and compare the short- and long-term consequences of forest management decisions, such as outcomes from preserving or removing high-value trees for microhabitats (Bütler et al., 2013). The development of this enhanced know-how is crucial when applying more sophisticated silvicultural concepts for integrated management. One example of this can be found in close-to-nature forestry approaches with strong IFM characteristics that are heavily reliant on advanced silvicultural knowledge (O'Hara, 2016).

The continued mechanisation of forestry brings both risks and opportunities in relation to nature conservation. For instance, there is a trend towards the use of increasingly larger machines, with a growing potential for adverse impacts on the soil and the residual stand (Magagnotti et al., 2012). Modern machines, however, feature innovative devices that mitigate site impact, enabling them to handle complex silvicultural prescriptions better than conventional, lighter technologies (Vanclay, 2011). Another example is GPS navigation, which allows the plotting of optimal route plans designed to avoid sensitive spots such as soft terrain, habitat trees and cultural and archaeological sites as well as infrastructure such as cables and pipes (Mohtashami et al., 2017). Similarly, improved booms and hydraulics allow for more controlled tree fall and log handling, minimising collateral damage to the residual stand during harvesting (Spinelli et al., 2014). These examples show that mechanisation in forestry has relevance for nature conservation.

Innovation, research and development play a cross-cutting and more long-term role in affecting the uptake of IFM. For instance, new methods that assess the market potential of ecosystem services (e.g., Payment for Ecosystem Services (PES) schemes) or mapping their supply may not only improve nature conservation but may allow for the development of new services (e.g., non-wood forest products). This can supplement (or substitute) revenues generated through timber production (Bösch et al., 2018; Kant et al., 2016), thereby increasing the acceptability of IFM to a broader base of involved actors.

3.3. Economic driving factors

Nearly half the workshop participants deemed the competitiveness of the forest-based sector as one of the most important driving factors for IFM. Like virtually all industries, the forest-based sector usually tries to increase profitability. This implies a continued need to add value to forest products and services to increase profits for enterprises and workers. Due to increased international competition (e.g., lower labour costs outside Europe), the forest-based sector is seeing diminishing financial returns (Rivera León et al., 2016). Moreover, while competitiveness helps to ensure economic viability, it may also escalate conflicts with regards to nature conservation (Damania et al., 2018). For instance, there is a trade-off between the interests to harvest forest biomass or to retain it for biodiversity conservation, such as enriching deadwood and habitat trees in the stands (Bauhus et al., 2017; Sabatini et al., 2019; Winkel et al., 2015). This is a conflict that has been exacerbated by a growing awareness of climate change (Augustynczik et al., 2018). Even more, demands for variable and small-scale single tree forest management that create artificial structural diversity in forest stands may clash with industrial interests seeking access to large amounts of wood (or bioenergy) at lower costs. The literature is ambivalent when it comes to the cost-efficiency of different silvicultural approaches, especially when forest risks are considered; much depends on local ecological and socio-economic conditions (Müller et al., 2019). The relationship between the economic viability of the forest-based sector and the integration of conservation interests and values thus remains unclear.

In this regard, the workshop participants further noted that there is significant interest from the wood producing industry and forest owners to demonstrate that they can meet conservation demands. Moreover, sustainability, including the protection of forest biodiversity, can be an essential asset for the forest-based sector to be competitive as well as to retain political support and social licence to operate (Winkel, 2017). Despite these factors supporting IFM, it is equally clear that conflicts remain between conservation and economic developments that affect the long-term viability of the forest-based sector (Naumov et al., 2018). One challenge for the improved integration of nature conservation is to demonstrate how biodiversity can add value, such as new market opportunities for wood-based products (e.g., biofuels and fabrics), non-wood forest products (e.g., medicinal plants and fungi), and also for a broader spectrum of forest ecosystem services. There is, for example, economic value in conserving forest genetic resources as a part of standard production systems, such as high-value species used to produce timber (Loo et al., 2014). Moreover, there is generally a positive relationship between the diversity of tree species in a forest stand and its economic and environmental resilience. For instance, increased biodiversity in an area means access to more diverse forest products and services while also buffering against the loss of some tree species through disturbances, pathogens or changing climate.

Changing market demands may serve to facilitate the integration of nature conservation. For instance, the development of certification schemes, such as FSC certification (Galati et al., 2017), have provided new opportunities for increasing nature conservation (e.g., demands to leave habitat trees or deadwood in managed forests) while also increasing revenues for forest owners (Kalonga et al., 2016). Incentives are, in the absence of a mature market for non-wood forest products and services, consequently fundamental in enabling IFM. Specifically, it allows primarily profit-oriented forest owners to invest in nature conservation in situations where trade-offs occur (Rode et al., 2015). This additionally implies that new and innovative incentive mechanisms such as tax reforms (e.g., tax breaks) and the provision of social benefits (e.g., health insurance) as a complement to basic payment schemes will even further improve conservation efforts.

The bioeconomy, highlighted as a driving factor during the

workshop, further emphasises the inherent complex relationship between the sustainability and competitiveness of the forest-based sector (e.g., trade-offs that must be overcome) and the challenges that remain to integrate economic and conservation objectives in forest management (Winkel, 2017). The bioeconomy may be creating new economic opportunities, such as supplying biomass and other ecosystem services (Landis et al., 2018), while the increasing reliance on multiple ecosystem services holds great potential for exploring synergies in relation to conservation. This will involve new business models (e.g., funeral forests), that create value for forest owners through cultural forest ecosystem services and contribute to supporting forest ecosystem services (e.g., retention of old single trees with high habitat values) (Winkel, 2017). While the increasing demand for wood supplies may limit the uptake of IFM (e.g., due to financial incentives to harvest more), it will ultimately depend on whether forest owners (public and private) can move towards an ecosystem service focus that favours adopting integrative approaches.

3.4. Environmental driving factors

Topics such as climate change, land use change and degradation were discussed extensively by the workshop participants. Regarding the prospects for IFM implementation, the participants prioratised regional variations in forest composition and the specific bio-geographical context (e.g., tree species composition, soil conditions, precipitation, temperature, altitude and geology) as a driver of nature conservation integration into forest management. For example, IFM differs significantly in practice in a boreal biome compared to a temperate or Mediterranean setting (Halbe et al., 2018; Puettmann et al., 2015). In this context, the relationship between different categories of driving factors is crucial. For example, bio-geographic variations are inherently interlinked with socio-cultural driving factors (e.g., management history), which affect the way nature conservation is being (or can be) implemented (Blattert et al., 2018; Maier and Winkel, 2017). IFM needs to adopt different stategies specific to the site and region of implementation, such as small clear-cuts in boreal zones or retention schemes (Gustafsson et al., 2013, 2019).

While climate change is a cross-cutting driving factor for IFM, its effects are subject to regional variations that affect forests, such as rising temperatures, changing precipitation and disturbance regimes. Enhancing forest diversity at different levels (e.g., genetic, tree species, structure and landscape) is one key strategy to enhance the inherent adaptive capacity of forests to cope with climate change and to increase inherent ecosystem resilience (Sousa-Silva et al., 2018), creating synergies with nature conservation objectives. Moreover, disturbance regimes (e.g., forest fires and bark beetle outbreaks) are a crucial driving factor for IFM. Biotic threats and storms are frequently more devastating in even-aged management systems with only one or two tree species, which suggests that rich structured forests (e.g., with continuous cover forestry) with several tree species are more resilient to such threats than plantations (Jactel et al., 2005). While diversification in terms of stand structures and tree species may affect nature conservation positively, another strategy to address climate change has been to reduce forest biomass in the stands (e.g., through shorter rotation periods to decrease risks) (Kolström et al., 2011), which may decrease the conservation value of managed forests (Winkel et al., 2011).

Workshop participants also considered forest naturalness[2] as a driving factor. This relates to the processes and structures of a forest and its species composition – specifically whether the composition is native for a given forest area (Bončina et al., 2017). For example, the introduction of exotic tree species can affect soil conditions, which in turn may disturb forest nutrition (e.g., nitrogen inputs) and negatively affect the biodiversity of forest-dwelling species (Paillet et al., 2010). Forests with a high level of naturalness (e.g., primary forests) are quite rare in Europe (Sabatini et al., 2018). Native species maintenance could help stabilise soil conditions and maintain habitat for native wildlife.

Land use, as a product of environmental and socio-cultural driving factors (e.g., historical and cultural heritage) as well as economic driving factors, fundamentally affects the present and future use of forest resources (Naumov et al., 2018). For instance, historical socio-cultural driving factors have caused acidified soils (e.g., spruce plantations in unsuitable forest sites) that today act as an environmental driving factor. This also relates to intensively managed forests with high importance for nature conservation as well as introduced tree species with high local/regional economic importance (e.g., coppice forestry or chestnut plantations). Yet another example is the need for game management, as the browsing pressure from game can cause regeneration failure of many tree species with subsequent adverse economic and environmental impacts in forest ecosystems (Beguin et al., 2016), including reduced diversity of forest dwelling species (Boulanger et al., 2018). The history and trends of forest and land use and land abandonment (Morales-Molino et al., 2017) created checkered local landscape patterns, which set the framework conditions for how IFM can be implemented.

3.5. Political driving factors

IFM implementation ultimately requires political frameworks that support integrative approaches (Schulz et al., 2014). This point was echoed by the workshop participants, who noted the need for policy coherence. Increasing the uptake of IFM requires clear targets regarding policy coherence as well as streamlining forest-related policy, particularly taking into account how different policy frameworks coordinate diverse forest management objectives (e.g., timber production, biodiversity protection and carbon sequestration) (Pülzl et al., 2013). Policy coherence is a central driving factor for IFM (Aggestam and Pülzl, 2018; Sotirov and Arts, 2018). Evidence for this can be seen in the legislative frameworks and related policy instruments, such as new forms of incentives, that vary on an international and/or regional level, which in turn generate conflicting horizontal and vertical policy objectives for forests (Aggestam and Pülzl, 2018; Vogelpohl and Aggestam, 2011). In Europe, specific examples include timber-production-oriented forestry measures incentivised through Rural Development Programmes that conflict with nature conservation and bioenergy targets set at the EU and national levels (Aggestam and Pülzl, 2018; Sotirov and Storch, 2018). For IFM to work effectively in practice, current policy frameworks need to identify existing trade-offs and address the competition between forestry, conservation and agriculture. Alternatively, IFM needs to address these trade-offs through forest management decisions "on the ground", even if policy frameworks remain conflicted.

The workshop participants further highlighted that the uptake of IFM is inextricably linked with leadership. The literature also notes leadership capabilities and associated skills applied to advocate and reach established conservation goals as a crucial driving factor (Evans et al., 2015). Leadership consequently remains the key, whether in policy-making or amongst forest managers, to move away from traditional, production-oriented forest management and to integrate nature conservation in practice (Borrass et al., 2017; Sotirov et al., 2019).

Coupled with the need for leadership and clear legislative frameworks, it can be noted that the approaches to incentivise IFM vary significantly. For instance, providing financial compensation (e.g., for income forgone by leaving deadwood and/or conserving species and their habitats (Sotirov, 2017)) as well as reducing the tax burden (e.g., personal income tax credits for nature conservation investments) can facilitate the integration of biodiversity concerns into forest management (L'Roe and Rissman, 2017), especially on private land. While economic incentives have gained prominence in environmental policy, particularly as a means for promoting biodiversity and ecosystem

[2] Forest Europe defines the "degree of naturalness" as the distance between the current and the potential natural status of a particular forest to describe to what extent it was (or was not) changed by human impact.

service conservation, other forms of policy incentives can be equally effective (Mayer and Tikka, 2006). This can be seen in bottom-up, soft and/or participatory policy instruments and strategies that promote the integration of nature conservation in forestry (Sotirov et al., 2017) as well as vertical and horizontal networking amongst relevant actors in the forest-based sector (Kleinschmit et al., 2018; Mattijssen et al., 2018). This use and success of policy-initiated incentives highlights the important role of politics in IFM, especially in those parts of Europe where the concept is politically prominent (Borrass et al., 2017; Sotirov and Storch, 2018; Winkel and Sotirov, 2016).

4. Conclusions and perspectives

4.1. What factors drive the implementation of IFM?

This paper set out to improve our understanding of the framework conditions that surround IFM uptake, focusing on the driving factors that influence the integration and reconciliation of biodiversity conservation and wood production as an inherent component of IFM. With this objective in mind, 38 driving factors were identified during the expert workshop (see Table 2 and supplemantary Table 1). It can be noted that all 38 driving factors were considered as influential by at least one participant.

The driving factors range from being more dynamic and interactive in nature, such as economic conditions, policy frameworks and climate change, to those that are relatively static or slow-moving, such as biogeographical conditions or forest ownership structures. These findings at the forest–biodiversity nexus are in harmony with recent definitions, theoretical expectations and empirical evidence with regards to IFM (Blattert et al., 2018; Bonsu et al., 2017; Maier and Winkel, 2017). Interestingly, the driving factors prioritised by the most participants (when asked to pick 3) are similar to what can be considered as "key enablers" for IFM in the literature (relating to societal expectations/pressure on the one hand, and economic pressure related to competitiveness in forest value chains on the other). For instance, earlier studies have identified policies, laws and regulations (political driving factors) and forest ownership (socio-cultural driving factors) as particularly important, with the global timber market (economic driving factors) and climate change (environmental driving factors) as relevant for the future (Rivera León et al., 2016; Sotirov and Arts, 2018).

What can be noted from the analysis of inputs from experts is the prevailing importance of socio-cultural driving factors in determining how forests are being managed. It is effectively individuals and families, local cultures and social networks that shape how forests are being utilised; it is this diverse fabric of people and culture that will determine whether IFM (or any other approach) is successful or not. Perhaps on par with the socio-cultural driving factors is the economic relevance of the forest-based sector. Competitiveness, as an economic driving factor, was stressed as essential for a viable forest-based sector and, more crucially, for implementing IFM. The environmental driving factors that were prioritised highlight the importance of regionally specific environmental conditions that determine how IFM can be implemented, including foreseen impacts from climate change. From a technological perspective, the experts principally highlighted tools that can enable forest owners or managers (both public and private) to achieve IFM, ranging from less invasive machinery to educational tools. Finally, the political driving factors reveal how policies and regulations can either facilitate or impede the implementation of IFM, as well as the need for leadership in promoting and facilitating the uptake of IFM, whether in policymaking or in practice.

Returning to the driving factors prioritised by the most participants, the analysis reveals that social identity and how people as well as society perceive forests (public or private) are central to how forests are being managed. Emerging and new types of forest owners demonstrate that forest planning and integrative management decisions have moved well beyond being purely based on economic factors (Weiss et al., 2017, 2019), if they were ever of such a nature. Different types of forest owners and forest managers have different objectives, capacities, and decision-making rationalities that make them behave and respond differently to political, economic and socio-cultural driving factors (Deuffic et al., 2018). There is tremendous potential for the promotion of IFM to meet diversifying societal demands and to combine important "new" forest owner motivations (nature protection) with "old" economic interests (resource use). Yet an increasing lack of forest management knowledge amongst forest owners and the public is a major impediment to IFM being more widely embraced. Outreach and education is thus a key pillar for integration at the forest–biodiversity nexus. Educating relevant actors (e.g., forest owners, foresters and conservationists) about the prospects to identify and address the trade-offs and synergies of both nature conservation and wood production in managed forests is key for successfully implementing any IFM regime.

Competitiveness is principally seen as crucial with regards to generating economic revenues from land management throughout the connected value chains. This implies that the relationship between IFM and the competitiveness of the forest-based sector needs considerable attention (Rivera León et al., 2016). As shown in this paper, competitiveness is a double-edged sword for IFM. On one hand, pressure to produce more biomass while at the same time reducing costs for forest management will result in challenges to integrate any other considerations in forest management that go against this principle (basically all of them), particularly biodiversity conservation measures (e.g., trade-offs between biomass harvest and deadwood retention, rich structured forests versus economies of scale harvesting approaches that favour clear-cuts). How far this principal pressure will affect forest management practices depends on many contextual factors, including forest ownership type, forest owners' motivations and exact demands from forest product markets. On the other hand, competitiveness in the forest-based sector may increasingly be linked to credibility in demonstrating sustainability (Toppinen et al., 2017). This may be an efficient driver supporting the integration of biodiversity measures, and IFM as a whole (e.g., granting a license to operate in many European forest settings).

Finally, it can be noted that the STEEP typology proved to be a useful framework to structure the driving factors, both during the workshop and the analysis (see approach). However, while taking a "silo-based" approach is useful to simplify a complex environment, it should be recognised that most of the driving factors are interconnected. For instance, socio-cultural driving factors establish important framework conditions for the economic, environmental and political context in which forest management takes place. This highlights that the typologies and driving factors cannot be considered in isolation; a more encompassing perspective is required to understand the entire setting of factors that impact IFM (Deuffic et al., 2018).

4.2. How can the implementation of IFM be strengthened?

At the operational level, IFM uptake is often determined by early adopters, entrepreneurs and community leaders that can demonstrate the added value of this new approach and convince others to follow suit (Deuffic et al., 2018; Maier and Winkel, 2017). This suggests that the performance of any forest management approach (whether integrated or not) initially depends largely on persons that facilitate policy or practical integration. At the policy level, effective leadership can contribute towards prudent forest policy formulation and implementation, as well as good public service delivery in support of IFM. Workshop participants also recognised the importance of leadership for IFM integration (see Table 2).

Effectively facilitating IFM requires identifying the most suitable governance approach. For example, should forest owners be "obliged" or "encouraged" to conserve deadwood or habitat trees in their forests, and who (conservation or forest experts, landowners, the public) should have the right to decide on the amounts? These questions are directly

linked with the policy and institutional frameworks that affect forestry and nature conservation. With this in mind, command-and-control approaches are often associated with reducing the decision-space for the target groups, and may thus meet greater resistance. They can have immediate and long-lasting positive effects on biodiversity by creating obligations and a pull towards compliance (given that implementation is secured). Self-regulation, on the other hand, offers flexibility in terms of decision-making, but largely depends on the availability and use of substantial public and private resources (e.g., funding, education) as well as the goodwill and voluntary commitments of forest owners and managers as there is no direct mechanism to set higher standards or address non-compliance (Aggestam and Pülzl, 2018; Weiss et al., 2019). Moreover, coming back to the variety of forest owners and managers, their behavioural responses often lead to different provisions and reconciliation of the trade-offs arising in forest ecosystem services, which in turn can lead to anything from token to full implementation of IFM (Gustafsson et al., 2019; Sotirov et al., 2019; Weiss et al., 2017). This means that targeted, group-oriented, adaptive and innovative policy designs are needed for integrating nature conservation into forest management. A "one-size-fits-all" governance approach is unsuitable; policy instruments need to consider contextually specific driving factors when making provisions for the integration of biodiversity into IFM.

Changing environmental conditions, namely climate change, will result in challenges regarding the nature of measures needed for biodiversity conservation within IFM. Integrative approaches are currently focusing on working with native tree species, natural regeneration, rich forest structures, as well as deadwood and habitat trees (Kraus and Krumm, 2013). A changing environment may render it more challenging than in the past to define objectives and measures related to forest biodiversity, such as "naturalness". In fact, public, political and professional convictions relating to forest management and conservation strategies in an era of changing climate vary largely between the forest and the nature conservation sector (Winkel et al., 2011). How efforts to address such climate change can be combined with nature conservation and wood production will remain a challenge in Europe for the foreseeable future (Gustafsson et al., 2019; Maier and Winkel, 2017; Sotirov and Storch, 2018).

As a final thought, better implementation of IFM will largely depend on a better understanding of how different driving factors play out across different contexts, as determined by the distinct social, environmental, economic, technological and political conditions present in a given setting. A general understanding of the main driving factors and their overall directions, as presented in this paper, can help to better manage trade-offs between biodiversity conservation and biomass production in European forests. More in-depth and contextually specific information is needed to efficiently and effectively help forest managers and owners implement IFM. The driving factors identified in this paper provide an initial departure point for necessary discussions amongst forest owners and/or policymakers interested in advancing IFM and for research that either tackles single critical drivers (e.g., competitiveness and how it relates to the prospects of IFM in Europe) or the entirety of driving factors in certain regional or socio-economic contexts. Together these activities may pave the way for IFM as an approach that ensures forest management in Europe is able to deliver multiple ecosystem services as needed in the twenty-first century.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

F. Aggestam: Conceptualization, Methodology, Formal analysis, Writing - original draft. **A. Konczal:** Conceptualization, Formal analysis, Writing - original draft. **M. Sotirov:** Writing - review & editing. **I. Wallin:** Writing - review & editing. **Y. Paillet:** Writing - review & editing. **R. Spinelli:** Writing - review & editing. **M. Lindner:** Writing - review & editing. **J. Derks:** Writing - review & editing. **M. Hanewinkel:** Writing - review & editing. **G. Winkel:** Supervision, Conceptualization, Writing - review & editing.

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Appendix A. Supplementary data

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References

Aggestam, F., 2019. Setting the stage for a shared environmental information system. Environ. Sci. Pol. 92, 124–132.
Aggestam, F., Pülzl, H., 2018. Coordinating the uncoordinated: the EU forest strategy. Forests 9, 125. https://doi.org/10.3390/f9030125.
Augustynczik, A., Yousefpour, R., Hanewinkel, M., 2018. Multiple uncertainties require a change of conservation practices for red-listed insects in temperate forests. Sci. Rep. 8, 14964. https://doi.org/10.11038/s41598-14018-33389-14969.
Bauhus, J., Kouki, J., Paillet, Y., Asbeck, T., Marchetti, M., 2017. How does the forest-based bioeconomy impact forest biodiversity? In: Winkel, G. (Ed.), Towards a Sustainable European Forest-Based Bioeconomy – Assessment and the Way Forward. What Science Can Tell Us 8. European Forest Institute.
Bauhus, J., Puettmann, K., Messier, C., 2009. Silviculture for old-growth attributes. For. Ecol. Manag. 258, 525–537. https://doi.org/10.1016/j.foreco.2009.1001.1053.
Başkent, E.Z., 2018. A review of the development of the multiple use forest management planning concept. Int. For. Rev. 20, 296–313.
Baycheva-Merger, T., Sotirov, M., Holmgren, S., Selter, A., 2018. Institutional and actor-oriented factors constraining expert-based forest information exchange in Europe: a policy analysis from an actor-centred institutionalist approach. Forests 9, 129.
Beguin, J., Tremblay, J.-P., Thiffault, N., Pothier, D., Côté, S.D., 2016. Management of forest regeneration in boreal and temperate deer–forest systems: challenges, guidelines, and research gaps. Ecosphere 7, e01488.
Bethmann, S., Simminger, E., Baldy, J., Schraml, U., 2018. Forestry in interaction. Shedding light on dynamics of public opinion with a praxeological methodology. For. Pol. Econ. 96, 93–101.
Bjärstig, T., Kvastegård, E., 2016. Forest social values in a Swedish rural context: the private forest owners' perspective. For. Pol. Econ. 65, 17–24. https://doi.org/10.1016/j.forpol.2016.1001.1007.
Blattert, C., Lemm, R., Thees, O., Hansen, J., Lexer, M.J., Hanewinkel, M., 2018. Segregated versus integrated biodiversity conservation: value-based ecosystem service assessment under varying forest management strategies in a Swiss case study. Ecol. Indicat. 95, 751–764. https://doi.org/10.1016/j.ecolind.2018.1008.1016.
Bončina, A., Klopčič, M., Simončič, T., Dakskobler, I., Ficko, A., Rozman, A., 2017. A general framework to describe the alteration of natural tree species composition as an indicator of forest naturalness. Ecol. Indicat. 77, 194–204. https://doi.org/10.1016/j.ecolind.2017.1001.1039.
Bonsu, N.O., Dhubháin, A.N., O'Connor, D., 2017. Evaluating the use of an integrated forest land-use planning approach in addressing forest ecosystem services conflicting demands: experience within an Irish forest landscape. Futures 86, 1–17. https://doi.org/10.1016/j.futures.2016.1008.1004.
Borrass, L., Kleinschmit, D., Winkel, G., 2017. The "German model" of integrative multifunctional forest management—analysing the emergence and political evolution of a forest management concept. For. Pol. Econ. 77, 16–23. https://doi.org/10.1016/j.forpol.2016.1006.1028.
Bösch, M., Elsasser, P., Franz, K., Lorenz, M., Moning, C., Olschewski, R., Rödl, A., Schneider, H., Schröppel, B., Weller, P., 2018. Forest ecosystem services in rural areas of Germany: insights from the national TEEB study. Ecosyst. Serv. 31, 77–83. https://doi.org/10.1016/j.ecoser.2018.1003.1014.
Boulanger, V., Dupouey, J.-L., Archaux, F., Badeau, V., Baltzinger, C., Chevalier, R., Corcket, E., Dumas, Y., Forgeard, F., Mårell, A., Montpied, P., Paillet, Y., Picard, J.-F., Saïd, S., Ulrich, E., 2018. Ungulates increase forest plant species richness to the benefit of non-forest specialists. Global Change Biol. 24, e485–e495.
Bowman, C., 1998. Strategy in Practice. Prentice Hall Europe.
Buijs, A., Lawrence, A., 2013. Emotional conflicts in rational forestry: towards a research agenda for understanding emotions in environmental conflicts. For. Pol. Econ. 33, 104–111. https://doi.org/10.1016/j.forpol.2012.1009.1002.

Bütler, R., Lachat, T., Larrieu, L., Paillet, Y., 2013. Habitat Trees: Key Elements for Forest Biodiversity. European Forest Institute.
Cairns, M.A., Meganck, R.A., 1994. Carbon sequestration, biological diversity, and sustainable development: integrated forest management. Environ. Man 18, 13–22. https://doi.org/10.1007/BF02393746.
Ciesielski, M., Stereńczak, K., 2018. What do we expect from forests? The European view of public demands. J. Environ. Manag. 209, 139–151. https://doi.org/10.1016/j.jenvman.2017.1012.1032.
Coll, L., Ameztegui, A., Collet, C., Löf, M., Mason, B., Pach, M., Verheyen, K., Abrudan, I., Barbati, A., Barreiro, S., Bielak, K., Bravo-Oviedo, A., Ferrari, B., Govedar, Z., Kulhavy, J., Lazdina, D., Metslaid, M., Mohren, F., Pereira, M., Peric, S., Rasztovits, E., Short, I., Spathelf, P., Sterba, H., Stojanovic, D., Valsta, L., Zlatanov, T., Ponette, Q., 2018. Knowledge gaps about mixed forests: what do European forest managers want to know and what answers can science provide? For. Ecol. Manag. 407, 106–115. https://doi.org/10.1016/j.foreco.2017.1010.1055.
Corona, P., Ascoli, D., Barbati, A., Bovio, G., Colangelo, G., Elia, M., Garfì, V., Iovino, F., Lafortezza, R., Leone, V., Lovreglio, R., Marchetti, M., Marchi, E., Menguzzato, G., Nocentini, S., Picchio, R., Portoghesi, L., Puletti, N., Sanesi, G., Chianucci, F., 2015. Integrated forest management to prevent wildfires under Mediterranean environments. Annals of Silvicultural Research 39, 1–22. https://doi.org/10.12899/asr-12946.
Damania, R., Russ, J., Wheeler, D., Barra, A.F., 2018. The road to growth: measuring the tradeoffs between economic growth and ecological destruction. World Dev. 101, 351–376. https://doi.org/10.1016/j.worlddev.2017.1006.1001.
Deuffic, P., Sotirov, M., Arts, B., 2018. "Your policy, my rationale". How individual and structural drivers influence European forest owners' decisions. Land Use Pol. 79, 1024–1038. https://doi.org/10.1016/j.landusepol.2016.1009.1021.
Dittmann, S., Thiessen, E., Hartung, E., 2017. Applicability of different non-invasive methods for tree mass estimation: a review. For. Ecol. Manag. 398, 208–215. https://doi.org/10.1016/j.foreco.2017.1005.1013.
Evans, L.S., Hicks, C.C., Cohen, P.J., Case, P., Prideaux, M., Mills, D.J., 2015. Understanding leadership in the environmental sciences. Ecol. Soc. 20, 50. https://doi.org/10.5751/ES-07268-200150.
Feliciano, D., Bouriaud, L., Brahic, E., Deuffic, P., Dobsinska, Z., Jarsky, V., Lawrence, A., Nybakk, E., Quiroga, S., Suarez, C., Ficko, A., 2017. Understanding private forest owners' conceptualisation of forest management: evidence from a survey in seven European countries. J. Rural Stud. 54, 162–176. https://doi.org/10.1016/j.jrurstud.2017.1006.1016.
Galati, A., Gianguzzi, G., Tinervia, S., Crescimanno, M., La Mela Veca, D.S., 2017. Motivations, adoption and impact of voluntary environmental certification in the Italian Forest based industry: the case of the FSC standard. For. Pol. Econ. 83, 169–176. https://doi.org/10.1016/j.forpol.2017.1008.1002.
Gibert, K., García-Alonso, C., Salvador-Carulla, L., 2010. Integrating clinicians, knowledge and data: expert-based cooperative analysis in healthcare decision support. Health Res. Pol. Syst. 28, 1–16. https://doi.org/10.1186/1478-4505-1188-1128.
Guillén, L.A., Wallin, I., Brukas, V., 2015. Social capital in small-scale forestry: a local case study in Southern Sweden. For. Pol. Econ. 53, 21–28. https://doi.org/10.1016/j.forpol.2014.1012.1006.
Gustafsson, L., Bauhus, J., Asbeck, T., Augustynczik, A.L.D., Basile, M., Frey, J., Gutzat, F., Hanewinkel, M., Helbach, J., Jonker, M., Knuff, A., Messier, C., Penner, J., Pyttel, P., Reif, A., Storch, F., Winiger, N., Winkel, G., Yousefpour, R., Storch, I., 2019. Retention as an integrated biodiversity conservation approach for continuous-cover forestry in Europe. Ambio 1–13. https://doi.org/10.1007/s13280-13019-01190-13281.
Gustafsson, L., Bauhus, J., Kouki, J., Lõhmus, A., Sverdrup-Thygeson, A., 2013. Retention Forestry – an integrated approach in practical use. In: Kraus, D., Krumm, F. (Eds.), Integrative Approaches as an Opportunity Fir the Conservation of Forest Biodiversity. European Forest Institute, Freiburg, pp. 74–81.
Halbe, J., Knüppe, K., Knieper, C., Pahl-Wostl, C., 2018. Towards an integrated flood management approach to address trade-offs between ecosystem services: insights from the Dutch and German Rhine, Hungarian Tisza, and Chinese Yangtze basins. J. Hydrol. 559, 984–994. https://doi.org/10.1016/j.jhydrol.2018.1002.1001.
Hoogstra-Klein, M.A., Brukas, V., Wallin, I., 2017. Multiple-use forestry as a boundary object: from a shared ideal to multiple realities. Land Use Pol. 69, 247–258. https://doi.org/10.1016/j.landusepol.2017.1008.1029.
INFORMAR, 2018. In: Aggestam, F., Konczal, A., Lindner, M., Schuck, A., Winkel, G., Schifferdecker, G. (Eds.), Meeting Report 1: Integrated Forest Management Learning Architecture. European Forest Institute. https://informar.eu/.
Jactel, H., Brockerhoff, E., Duelli, P., 2005. A test of the biodiversity-stability theory: meta-analysis of tree species diversity effects on insect pest infestations, and re-examination of responsible factors. For. Div. Fun. 176, 235–262. https://doi.org/10.1007/1003-1540-26599-26596_26512.
Kalonga, S.K., Midtgaard, F., Klanderud, K., 2016. Forest certification as a policy option in conserving biodiversity: an empirical study of forest management in Tanzania. For. Ecol. Manag. 361, 1–12. https://doi.org/10.1016/j.foreco.2015.1010.1034.
Kant, S., Deegen, P., Hostettler, M., Wang, S., Xu, J., Valatin, G., 2016. New Frontiers of Forest Economics: forest economics beyond the perfectly competitive commodity markets. For. Pol. Econ. 72, 1–6. https://doi.org/10.1016/j.forpol.2016.1006.1009.
Kim-Keung Ho, J., 2014. Formulation of a systemic PEST analysis for strategic analysis, 2. European Academic Research, pp. 6478–6492.
Kleinschmit, D., Pülzl, H., Secco, L., Sergent, A., Wallin, I., 2018. Orchestration in political processes: involvement of experts, citizens, and participatory professionals in forest policy making. For. Pol. Econ. 89, 4–15. https://doi.org/10.1016/j.forpol.2017.1012.1011.
Kolström, M., Lindner, M., Vilén, T., Maroschek, M., Seidl, R., Lexer, M.J., Netherer, S., Kremer, A., Delzon, S., Barbati, A., Marchetti, M., Corona, P., 2011. Reviewing the Science and Implementation of Climate Change Adaptation Measures in European Forestry. Forests 2.
Kraus, D., Krumm, F., 2013. Integrative Approaches as an Opportunity for the Conservation of Forest Biodiversity. European Forest Institute. http://www.integrateplus.org.
Kraus, D., Schuck, A., Krumm, F., Bütler Sauvain, R., Cosyns, H., Courbaud, B., Wilhelm, G., 2018. Seeing Is Building Better Understanding-The Integrate+ Marteloscopes. Integrate+ Technical Paper, European Forest Institute. https://informar.eu/marteloscope-sites.
Kreutzwiser, R.D., Wright, C.S., 1990. Factors influencing integrated forest management on private industrial forest land. J. Environ. Manag. 30, 31–46. https://doi.org/10.1016/0301-4797(1090)90035-U.
L'Roe, A.W., Rissman, A.R., 2017. Factors that influence working forest conservation and parcelization. Landsc. Urban Plann. 167, 14–24. https://doi.org/10.1016/j.landurbplan.2017.1005.1021.
Landis, D.A., Gratton, C., Jackson, R.D., Gross, K.L., Duncan, D.S., Liang, C., Meehan, T. D., Robertson, B.A., Schmidt, T.M., Stahlheber, K.A., Tiedje, J.M., Werling, B.P., 2018. Biomass and biofuel crop effects on biodiversity and ecosystem services in the North Central US. Biomass Bioenergy 114, 18–29. https://doi.org/10.1016/j.biombioe.2017.1002.1003.
Lawrence, A., Spinelli, R., Toppinen, A., Salo, E., 2017. What are the implications of the bioeconomy for forest-related jobs? In: Winkel, G. (Ed.), Towards a Sustainable European Forest-Based Bioeconomy – Assessment and the Way Forward. What Science Can Tell Us 8. European Forest Institute.
Leban, V., Pezdevšek Malovrh, S., Zadnik Stirn, L., Krč, J., 2016. Forest biomass for energy in multi-functional forest management: insight into the perceptions of forest-related professionals. For. Pol. Econ. 71, 87–93. https://doi.org/10.1016/j.forpol.2015.1007.1005.
Loo, J., Souvannavong, O., Dawson, I.K., 2014. Seeing the trees as well as the forest: the importance of managing forest genetic resources. For. Ecol. Manag. 333, 1–8. https://doi.org/10.1016/j.foreco.2014.1008.1014.
Magagnotti, N., Spinelli, R., Güldner, O., Erler, J., 2012. Site impact after motor-manual and mechanised thinning in Mediterranean pine plantations. Biosyst. Eng. 113, 140–147.
Maier, C., Winkel, G., 2017. Implementing nature conservation through integrated forest management: a street-level bureaucracy perspective on the German public forest sector. For. Pol. Econ. 82, 14–29. https://doi.org/10.1016/j.forpol.2016.1012.1015.
Mattijssen, T., Buijs, A., Elands, B., 2018. The benefits of self-governance for nature conservation: a study on active citizenship in The Netherlands. J. Nat. Conserv. 43, 19–26. https://doi.org/10.1016/j.jnc.2018.1001.1006.
Mayer, A.L., Tikka, P.M., 2006. Biodiversity conservation incentive programs for privately owned forests. Environ. Sci. Pol. 9, 614–625. https://doi.org/10.1016/j.envsci.2006.1007.1004.
Mohtashami, S., Eliasson, L., Jansson, G., Sonesson, J., 2017. Influence of soil type, cartographic depth-to-water, road reinforcement and traffic intensity on rut formation in logging operations: a survey study in Sweden. Silva Fenn. 51.
Morales-Molino, C., Colombaroli, D., Valbuena-Carabaña, M., Tinner, W., Salomón, R.L., Carrión, J.S., Gil, L., 2017. Land-use history as a major driver for long-term forest dynamics in the Sierra de Guadarrama National Park (central Spain) during the last millennia: implications for forest conservation and management. Global Planet. Change 152, 64–75. https://doi.org/10.1016/j.gloplacha.2017.1002.1012.
Müller, F., Augustynczik, A.L.D., Hanewinkel, M., 2019. Quantifying the risk mitigation efficiency of changing silvicultural systems under storm risk throughout history. Ann. For. Sci. 76, 116.
Naumov, V., Manton, M., Elbakidze, M., Rendenieks, Z., Priednieks, J., Uhlianets, S., Yamelynets, T., Zhivotov, A., Angelstam, P., 2018. How to reconcile wood production and biodiversity conservation? The Pan-European boreal forest history gradient as an "experiment". J. Environ. Manag. 218, 1–13. https://doi.org/10.1016/j.jenvman.2018.1003.1095.
O'Hara, K.L., 2016. What is close-to-nature silviculture in a changing world? Forestry 89, 1–6. https://doi.org/10.1093/forestry/cpv1043.
Paillet, Y., Bergès, L., Hjälten, J., Odor, P., Avon, C., Bernhardt-Romermann, M., Bijlsma, R.J., De Bruyn, L., Fuhr, M., Grandin, U., Kanka, R., Lundin, L., Luque, S., Magura, T., Matesanz, S., Meszaros, I., Sebastia, M.T., Schmidt, W., Standovar, T., Tothmeresz, B., Uotila, A., Valladares, F., Vellak, K., Virtanen, R., 2010. Biodiversity differences between managed and unmanaged forests: meta-analysis of species richness in Europe. Conserv. Biol. 24, 101–112. https://doi.org/10.1111/j.1523-1739.2009.01399.x.
Phalan, B., Onial, M., Balmford, A., Green, R.E., 2011. Reconciling Food production and biodiversity conservation: land sharing and land sparing compared. Science 333, 1289–1291. https://doi.org/10.1126/science.1208742.
Primmer, E., Karppinen, H., 2010. Professional judgment in non-industrial private forestry: forester attitudes and social norms influencing biodiversity conservation. For. Pol. Econ. 12, 136–146. https://doi.org/10.1016/j.forpol.2009.1009.1007.
Puettmann, K.J., Wilson, S., Baker, S.C., Donoso, P.J., Drössler, L., Amente, G., Harvey, B. D., Knoke, T., Lu, Y., Nocentini, S., Putz, F.E., Yoshida, T., Bauhus, J., 2015. Silvicultural alternatives to conventional even-aged forest management - what limits global adoption? Forest Ecosyst 2, 8. https://doi.org/10.1186/s40663-40015-40031-x.
Pülzl, H., Hogl, K., Kleinschmit, D., Wydra, D., Arts, B., Mayer, P., Palahi, M., Winkel, G., Wolfslehner, B., 2013. European forest governance: issues at stake and the way forward. In: What Science Can Tell Us, vol. 2. European Forest Institute. https://www.efi.int/publications-bank.

Rametsteiner, E., Eichler, L., Berg, J., Aggestam, F., Binda Zane, E., Plumet, C., 2009. Shaping Forest Communication in the European Union: Public Perceptions of Forests and Forestry, ECORYS, Final Report.

Reddy, C.S., Manaswini, G., Satish, K.V., Singh, S., Jha, C.S., Dadhwal, V.K., 2016. Conservation priorities of forest ecosystems: evaluation of deforestation and degradation hotspots using geospatial techniques. Ecol. Eng. 91, 333–342. https://doi.org/10.1016/j.ecoleng.2016.1003.1007.

Rivera León, L., Bougas, K., Aggestam, F., Pülzl, H., Zoboli, E., Ravet, J., Griniece, E., Vermeer, J., Maroulis, N., Ettwein, F., Van Brusselenm, J., Green, T., 2016. An Assessment of the Cumulative Cost Impact of Specified EU Legislation and Policies on the EU Forest-Based Industries. DG GROW, Brussels.

Rode, J., Gómez-Baggethun, E., Krause, T., 2015. Motivation crowding by economic incentives in conservation policy: a review of the empirical evidence. Ecol. Econ. 117, 270–282. https://doi.org/10.1016/j.ecolecon.2014.1011.1019.

Sabatini, F.M., Burrascano, S., Keeton William, S., Levers, C., Lindner, M., Pötzschner, F., Verkerk Pieter, J., Bauhus, J., Buchwald, E., Chaskovsky, O., Debaive, N., Horváth, F., Garbarino, M., Grigoriadis, N., Lombardi, F., Marques Duarte, I., Meyer, P., Midteng, R., Mikac, S., Mikoláš, M., Motta, R., Mozgeris, G., Nunes, L., Panayotov, M., Ódor, P., Ruete, A., Simovski, B., Stillhard, J., Svoboda, M., Szwagrzyk, J., Tikkanen, O.-P., Volosyanchuk, R., Vrska, T., Zlatanov, T., Kuemmerle, T., 2018. Where are Europe's last primary forests? Divers. Distrib. 24, 1426–1439. https://doi.org/10.1111/ddi.12778.

Sabatini, F.M., De Andrade, R.B., Paillet, Y., Ódor, P., Bouget, C., Campagnaro, T., Gosselin, F., Janssen, P., Mattioli, W., Nascimbene, J., Sitzia, T., Kuemmerle, T., Burrascano, S., 2019. Trade-offs between carbon stocks and biodiversity in European temperate forests. Global Change Biol. 25, 536–548. https://doi.org/10.1111/gcb.14503.

Schulz, T., Krumm, F., Bücking, W., Frank, G., Lier, M., Lovrić, M., van der Maaten-Theunissen, M., Paillet, Y., Parviainen, J., Vacchiano, G., Vandekerkhove, K., 2014. Institutional determinants of integrative nature protection in forest policy in Europe: a comparative analysis. Biodivers. Conserv. 23, 3425–3450. https://doi.org/10.1007/s10531-10014-10817-10530.

Sotirov, M., 2017. Natura 2000 and forests: assessing the state of implementation and effectiveness. In: What Science Can Tell Us, vol. 7. European Forest Institute. https://www.efi.int/publications-bank.

Sotirov, M., Arts, B., 2018. Integrated Forest Governance in Europe: an introduction to the special issue on forest policy integration and integrated forest management. Land Use Pol. 79, 960–967. https://doi.org/10.1016/j.landusepol.2018.1003.1042.

Sotirov, M., Blum, M., Storch, S., Selter, A., Schraml, U., 2017. Do forest policy actors learn through forward-thinking? Conflict and cooperation relating to the past, present and futures of sustainable forest management in Germany. For. Pol. Econ. 85, 256–268. https://doi.org/10.1016/j.forpol.2016.1011.1011.

Sotirov, M., Sallnäs, O., Eriksson, L.O., 2019. Forest owner behavioral models, policy changes, and forest management. An agent-based framework for studying the provision of forest ecosystem goods and services at the landscape level. For. Pol. Econ. 103, 79–89. https://doi.org/10.1016/j.forpol.2017.1010.1015.

Sotirov, M., Storch, S., 2018. Resilience through policy integration in Europe? Domestic forest policy changes as response to absorb pressure to integrate biodiversity conservation, bioenergy use and climate protection in France, Germany, The Netherlands and Sweden. Land Use Pol. 79, 977–989. https://doi.org/10.1016/j.landusepol.2017.1004.1034.

Sousa-Silva, R., Verbist, B., Lomba, A., Valent, P., Suškevičs, M., Picard, O., Hoogstra-Klein, M.A., Cosofret, V.-C., Bouriaud, L., Ponette, Q., Verheyen, K., Muys, B., 2018. Adapting forest management to climate change in Europe: linking perceptions to adaptive responses. For. Pol. Econ. 90, 22–30. https://doi.org/10.1016/j.forpol.2018.1001.1004.

Spinelli, R., Lombardini, C., Magagnotti, N., 2014. The effect of mechanization level and harvesting system on the thinning cost of Mediterranean softwood plantations. Silva Fenn. 48.

Sutherland, L.-A., Huttunen, S., 2018. Linking practices of multifunctional forestry to policy objectives: case studies in Finland and the UK. For. Pol. Econ. 86, 35–44. https://doi.org/10.1016/j.forpol.2017.1010.1019.

Toppinen, A., Korhonen, J., Hurmekoski, E., Hansen, E., 2017. What makes a European forest-based bioeconomy competitive? In: Winkel, G. (Ed.), Towards a Sustainable European Forest-Based Bioeconomy – Assessment and the Way Forward. What Science Can Tell Us 8. European Forest Institute.

Vanclay, J.K., 2011. Future harvest: what might forest harvesting entail 25 years hence? Scand. J. For. Res. 26, 183–186.

Verkerk, P.J., Anttila, P., Eggers, J., Lindner, M., Asikainen, A., 2011. The realisable potential supply of woody biomass from forests in the European Union. For. Ecol. Manag. 261 https://doi.org/10.1016/j.foreco.2011.2002.2027, 2007–2015.

Vogelpohl, T., Aggestam, F., 2011. Public policies as institutions for sustainability: potentials of the concept and findings from assessing sustainability in the European forest-based sector. Eur. J. For. Res. 131, 57–71. https://doi.org/10.1007/s10342-10011-10504-10346.

Weiss, G., Lawrence, A., Hujala, T., Lidestav, G., Nichiforel, L., Nybakk, E., Quiroga, S., Sarvašová, Z., Suarez, C., Živojinović, I., 2019. Forest ownership changes in Europe: state of knowledge and conceptual foundations. For. Pol. Econ. 99, 9–20. https://doi.org/10.1016/j.forpol.2018.1003.1003.

Weiss, G., Lawrence, A., Nichiforel, L., 2017. How does forest ownership in Europe affect the forest-based bioeconomy? In: Winkel, G. (Ed.), Towards a Sustainable European Forest Based Bioeconomy – Assessment and the Way Forward. European Forest Institute.

Winkel, G., 2013. Forest conservation policy in a changing climate. For. Pol. Econ. 36, 1–5.

Winkel, G., 2017. Towards a sustainable European forest-based bioeconomy- assessment and the way forward. In: What Science Can Tell Us, vol. 8. European Forest Institute. https://www.efi.int/publications-bank.

Winkel, G., Blondet, M., Borras, L., Frei, T., Geitzenauer, M., Gruppe, A., Jump, A., De Koning, J., Sotirov, M., Weiss, G., Winter, S., Turnhout, E., 2015. The implementation of Natura 2000 in forests: a trans- and interdisciplinary assessment of challenges and choices. Environ. Sci. Pol. 52, 23–32.

Winkel, G., Gleißner, J., Pistorius, T., Sotirov, M., Storch, S., 2011. The sustainably managed forest heats up: discursive struggles over forest management and climate change in Germany. Crit. Pol. Stud. 5, 361–390. https://doi.org/10.1080/19460171.19462011.19628002.

Winkel, G., Sotirov, M., 2016. Whose integration is this? European forest policy between the gospel of coordination, institutional competition, and a new spirit of integration. Environ. Plann. C. 34, 496–514. https://doi.org/10.1068/c1356j.