

**The European
Integrate Network**



Challenges & experiences in adapting forest management to a changing climate – a practitioner's view

Integrate MDTF Evidence Study, 2023

Authors: Lyla O'Brien, Silvester Boonen, Andreas Schuck

Funded by: Swiss Federal Office for the Environment (BAFU) under the Integrate Network Multi-Donor Trust Fund

Recommended citation:

O’Brien, L., Boonen, S., Schuck, A., 2023. Challenges and experiences in adapting forest management to a changing climate – a practitioner’s view. Integrate MDTF Evidence Study, Study Report 1. 22 p.

Acknowledgements:

We would like to thank all questionnaire respondents for taking part in our study, as well as the Integrate Multi-Donor Trust Fund (MDTF) and Integrate Practice Network, and many colleagues for helping to translate and distribute the questionnaire in so many countries. Thanks also to Jakob Derks for developing the study concept. Finally, we would particularly like to thank the Integrate Network MDTF and the Swiss Federal Office for the Environment (BAFU) for funding this study.

Disclaimer:

This Integrate MDTF Evidence Study was carried out by the European Forest Institute (Bonn Office). The views expressed in this publication are those of the authors and do not necessarily represent those of the European Forest Institute, the donor, or the Integrate MDTF.

Contents

1. Study context	4
Increasing climatic extremes in European forests	4
Adapting managed forests to climate change	4
The relationship between biodiversity conservation and CCA	4
Forest practitioners’ perceptions of CCA and related challenges	5
2. Study aim	5
3. Methodology	5
3.1. Questionnaire	5
3.2. Analysis	6
4. Results	6
4.1. Climate change impacts and implemented CCA measures	6
4.1.1. Climate change impacts on forest enterprises	6
4.1.2. CCA measures implemented by respondents	7
4.1.3. Reasons for not implementing CCA measures	9
4.2. Challenges implementing CCA measures	10
4.3. Compatibility and importance of CCA and biodiversity conservation	12
4.3.1. Synergies between CCA and biodiversity conservation measures	12
4.3.2. Conflicts between CCA and biodiversity conservation measures	13
4.3.3. Importance of CCA vs biodiversity conservation	14
4.4. Types of knowledge sources used in decision-making	14
4.5. Impact of CCA measures on the day-to-day functioning of forest enterprises	15
5. Summary and outlook	17
6. References	19
7. Annex	21
7.1. Annex 1: Questionnaire: Practitioner’s challenges and experiences in adapting forest management to a changing climate	21
7.2. Annex 2: Table of questionnaire responses by country	22

1. Study context

Increasing climatic extremes in European forests

In the past decades and in particular the last few years, climate change has increased the frequency and intensity of natural disasters in European forests such as large-scale storms, wildfires, droughts, and heat waves (Lindner et al., 2010; Seidl et al., 2011, 2017). These extreme events have decreased forest vitality, which in turn has made them more prone to pests and diseases, including bark beetle infestations most prominently in Norway spruce (*Picea abies*) (Patacca et al., 2023). Global trade has also increased the spread of certain non-native species in European forests, for example the introduction of the Asian longhorn beetle (*Anoplophora glabripennis*) and the pine wood nematode (*Bursaphelenchus xylophilus*). Also, high browsing pressure in some European countries has put additional stress on forests, in particular on forest regeneration (Carpio et al., 2021; Pfeffer et al., 2021).



*Storm damage in the Härebësch forest, Luxembourg.
Photo: Silvester Boonen*

Adapting managed forests to climate change

Around three-quarters of forests in Europe are managed (FOREST EUROPE, 2020). They deliver a wide range of ecosystem services to society, including, e.g., timber production, carbon sequestration, water regulation, recreation, and cultural identity (MEA, 2005). Given the diversity of demands for forest ecosystem services and the threat that climate change poses to their long-term provisioning, there is a need to increase forest resilience to climate change impacts. While forests have a natural capacity

to respond to climate change, legacies of forest management have altered natural forest structure and composition, sometimes reducing their ability to adapt to climate change (Seidl et al., 2011). A prominent example of this is the common occurrence of even-aged monocultures of Norway spruce across central Europe, which are prone to changes in climate and bark beetle (*Ips typographus*) outbreaks (Bolte et al., 2009; de Groot et al., 2019; Spiecker et al., 2004). In addition, forests may not always be able to adapt naturally, given the rapid rate of climate change (Lindner et al., 2010). Consequently, there is a window of opportunity for forest management to increase adaptive capabilities in managed forests with the help of climate change adaptation measures (Bolte et al., 2009; de Koning et al., 2020; Jandl et al., 2019).

Climate change adaptation measures (CCA) aim at increasing forest resistance and resilience to change, as well as enabling them to respond to change (Millar, 2008). CCA measures can be implemented at stand level (e.g. tree species diversity, regeneration options, thinning and harvesting regimes, deadwood retention), as well as at landscape scale (e.g., forest protection and risk management, forest management planning) (de Koning et al., 2020; Duncker et al., 2012; Kolström et al., 2011). Overarching forest management approaches such as close-to-nature forestry have also been recognised as having a strong potential to adapt forests to climate change, e.g., through the implementation of measures such as increasing structural diversity (Brang et al., 2014).

While types of CCA measures and management approaches that foster CCA are well known in the literature, few studies have investigated what kind of CCA measures practitioners use. An exception to this is a recent study by Roitsch et al. (2023), which found that the most important strategies for CCA among practitioners are diversification of tree species and artificial and natural regeneration with improved and adapted forest reproductive material.

The relationship between biodiversity conservation and CCA

Biodiversity loss and the climate crisis are intrinsically linked (EU commission, 2021; IPCC, 2021). However, strategies to integrate biodiversity into forest management, also known as integrative forest management, have often developed separately from strategies to enhance CCA in European forests (de Koning et al., 2020). Effectively addressing these

crises makes it necessary to discuss synergies and conflicts between measures aimed at biodiversity conservation and CCA measures. Previous studies have shown that the complementarity between the two may be complicated. de Koning et al. (2020) found that both synergies and challenges exist between integrative forest management and CCA. Similarly, some forest professionals perceive that CCA can have positive effects on biodiversity while others perceive it to prevent the integration of biodiversity in forest management (Konczal et al., 2023). Despite these trade-offs, some CCA methods are well recognized for having positive effects on biodiversity, for example, promoting higher tree species diversity is commonly seen as a means to reduce the risk associated with the use of a single tree species while simultaneously being beneficial for biodiversity (de Koning et al., 2020; Konczal et al., 2023). In addition, increasing the structural diversity in forest stands can increase forest resilience (i.e., decrease the recovery time needed after calamities), while increasing biodiversity by diversifying habitat types (de Koning et al., 2020). Understanding how forest practitioners view the relationship between the CCA measures they implement, and biodiversity conservation is crucial for understanding potential synergies and conflicts, however few studies have investigated this in-depth.

Forest practitioners’ perceptions of CCA and related challenges

Understanding forest practitioners’ perceptions of CCA is important to inform decision-making related to climate change adaptation. Several studies have looked at forest practitioners’ perceptions of climate change. For example, Blennow et al. (2012) found that private forest owners’ beliefs in climate change and its local effects had a strong impact on whether they chose to adapt their forest enterprise or not. A similar study by Sousa-Silva et al. (2018) found that nearly three-quarters of the forest owners and managers they interviewed believe that climate change will impact their forest, however only around one-third actually implement CCA measures, due to several challenging factors including lack of knowledge and lack of information. More studies that investigate forest practitioners’ perspectives on the challenges and impacts of implementing CCA measures in forest enterprises are needed.

2. Study aim

This study aims to complement previous studies on

forest practitioners’ perspectives on CCA in Europe, specifically by looking into what measures they are currently implementing, the challenges faced, how they inform their decision-making, and whether and in which way other aspects of their forest management and enterprise are impacted by the implementation of such measures. Therefore, this study investigates the following research questions in a questionnaire targeted at forest practitioners:

- 1. What climate change impacts do forest enterprises experience and which practical CCA measures are implemented on the ground?**
- 2. What challenges are associated with implementing CCA measures in forest enterprises?**
- 3. What knowledge sources are used to inform decision-making related to implementation of CCA measures?**
- 4. What is the relationship between CCA and biodiversity conservation measures?**
- 5. What changes occur in the day-to-day functioning of a forest enterprise as a result of implementing CCA measures?**

We present the results of our questionnaire below and provide insights from forest practitioners across Europe. Overall, the study aims to support practitioners in their work of implementing CCA measures in their forest enterprises as well as inform decision-makers on potential barriers to implementation.

3. Methodology

3.1. Questionnaire

This study is based on the results of an online questionnaire that was distributed in Spring/Summer 2023. The questionnaire targeted forest practitioners across Europe, specifically forest managers, heads of forest enterprises, and private forest owners. It was designed in English and translated by native speakers into 15 different languages. If the questionnaire was not available in a country’s native language, an English version was provided. The questionnaire was distributed by the country representatives of the

Integrate Network Multi-Donor Trust Fund (<https://integratenetwork.org/>), the Integrate Practice Network, as well as other professional contacts.

The questionnaire contained six major sections that consisted of multiple-choice and open-ended questions (see Annex 1 for complete questionnaire) on: (1) The practitioner’s forest enterprise and location; (2) Impacts of climate change on their forest enterprise and CCA measures implemented; (3) Challenges implementing measures; (4) Types of knowledge sources used in decision-making; (5) Synergies and conflicts between CCA and biodiversity conservation measures; and (6) Changes in the day-to-day functioning of their forest enterprise as a result of implementing CCA measures.

3.2. Analysis

The questionnaire received a total of 368 responses from 19 European countries (see Annex 2 for overview). The majority of responses received were from forest practitioners (e.g., forest managers and owners), but due to the questionnaire’s wide distribution, there were also responses from research institutes and academia, NGOs, forest ownership and forest practitioner associations, and forest advisory services. Despite that these stakeholders were not the original target of the questionnaire, their responses were found to be valuable and closely related to those from practitioners and therefore not excluded from the analysis.

Each response was sorted according to the location of the biogeographical region (EEA, 2019) of the forest enterprise (or company/institute) and translated. Responses came from six biogeographical regions: Continental (merged with responses from the Pannonian region) (58%, n=212), Alpine (22%, n=76), Atlantic (12%, n=45), Mediterranean (6%, n=28), and Boreal (2%, n=7) (Figure 1). Due to the low number of responses from the Boreal region, it was excluded

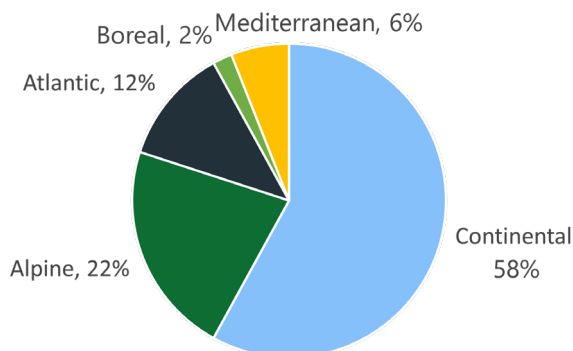


Figure 1: Questionnaire responses by biogeographical regions

from comparisons between biogeographical regions. Multiple-choice answers were analysed in either Excel or with R software. Open-ended responses sorted by biogeographical region and were coded using MAXQDA software. The coded segments were then extracted and summarised.

4. Results

4.1. Climate change impacts and implemented CCA measures

4.1.1. Climate change impacts on forest enterprises

The vast majority of respondents reported that their forest enterprise was impacted by climate change (84 %, n=310) while 9 % (n=45) reported no impacts and only 3 % (n=13) did not know if their enterprise was impacted or not (Figure 2). Responses were

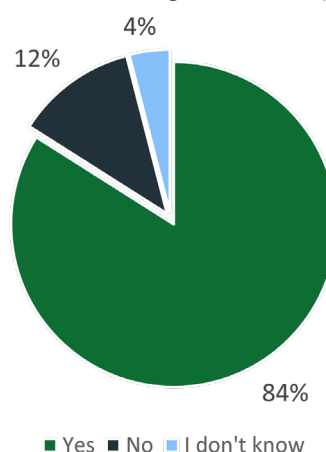


Figure 2: Respondents impacted by climate change in their forest enterprise (in %)

similar across biogeographical regions with the highest percentage of respondents (93 %) reporting climate change impacts in the Mediterranean. For the respondents that reported that their forest enterprise was impacted by climate change, the most commonly reported impacts were decreases in forest health and dieback (n=175), followed by weather extremes, (e.g., drought, wildfires, and windstorms) (n= 171), pests and diseases e.g., bark beetle outbreaks) (n=124), changes in the composition of tree and vegetation species (n=42), and increased game populations and competition (n=5) (Figure 3). A small number of respondents (n=19) also referred to other impacts such as increased recreational pressure, rural abandonment (specific to the Mediterranean region), and soil acidification (Figure 3). Climate change effects were also experienced similarly across

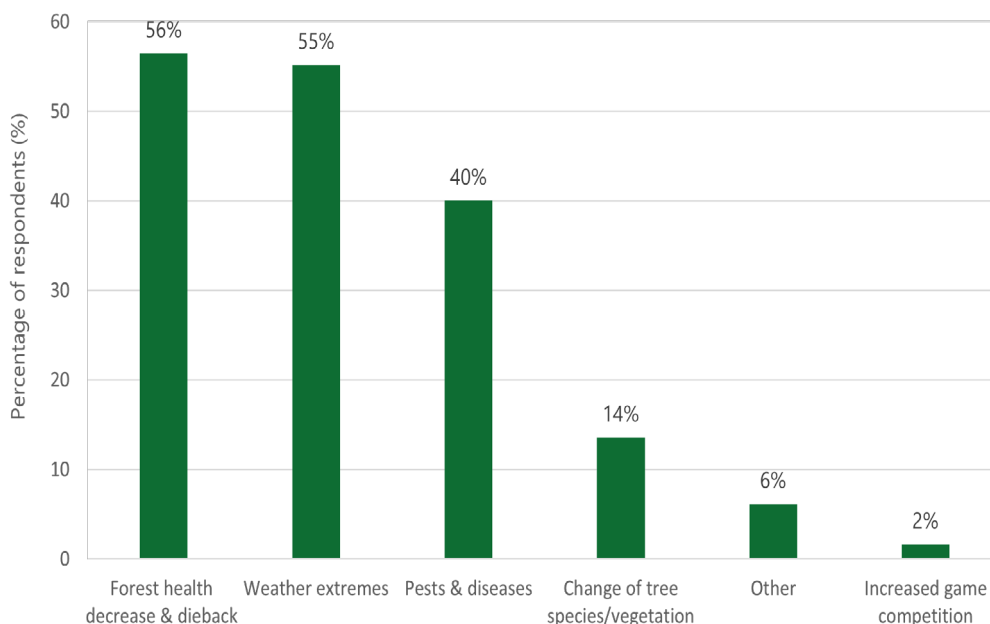


Figure 3: Overview of types of climate change effects on respondents’ forest enterprises

biogeographical regions. However, the percentage of respondents that experience weather extremes in their forest enterprise was notably highest in the Mediterranean and lowest in the Continental and Alpine regions. Meanwhile, pests and diseases were reported most in the Continental region and Alpine regions compared to the other two regions.

4.1.2. CCA measures implemented by respondents

The percentage of respondents reporting that they implement CCA measures matched those impacted by climate change (89 %, n=326), while around 11 % (n=42) said that they did not implement any CCA measures (Figure 4). Implementation of CCA measures was similar across biogeographical regions, with the exception of the Mediterranean, where 64 %

of respondents implement such measures, compared to around 90 % in the other regions.

Types of CCA measures implemented by respondents were diverse and aggregated into the following eight categories (ordered according to frequency of responses): Change in tree species selection/composition (n=266); Regeneration (n=123); Harvesting and thinning (n=102); Structural diversity and deadwood (n=55), Abiotic stand conditions (n=54); Biodiversity conservation/habitat protection (n=46); Disturbance mitigation (n=46), and Other (n=35) (Figure 5).

Change in tree species selection/composition included all answers regarding the selection of a certain types of climate adapted tree species, the diversification of tree species, and the conversion to a certain tree species composition, e.g., conversion of spruce monocultures to more mixed forest stands. Regeneration aggregated all answers regarding forest regeneration, i.e., either artificial (plantings and seedlings) or natural regeneration. Answers related to the creation of new forests through afforestation were also added to this category. Harvesting and thinning included responses relating to changes in the intensity or scale of harvesting and thinning methods. This category also included overarching management approaches such as continuous cover forestry. Structural diversity and deadwood consisted of replies that were related to changes or improvements to the diversity of forest and stand structure, especially increasing and diversifying

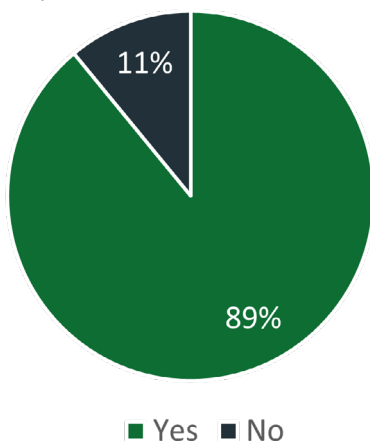


Figure 4: Respondents that implement CCA in their forest enterprise (in %)

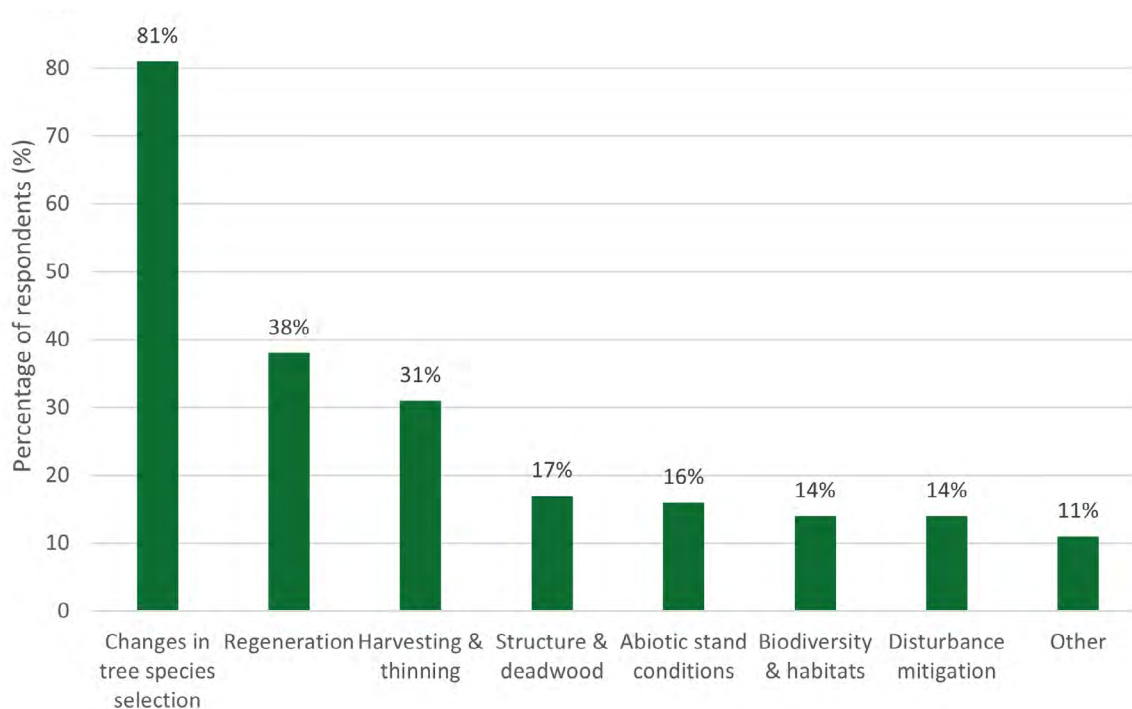


Figure 5: Types of CCA measures implemented by forest enterprises

deadwood, but also creating variation in age class structures and improving vertical diversity in the stand. Abiotic stand conditions included all answers that related to the improvement of stand conditions, such as water management (e.g. reducing drainage or improving water retention), microclimate, and soil protection. Biodiversity conservation/habitat protection grouped all answers that focused on improving the conservation of forest biodiversity and forest habitats in order to promote forest resilience, such as retainment or promotion of old-growth elements, the reduction of neophytes and

invasive species, and forest restoration. Disturbance mitigation aggregated answers that aimed at the reduction of disturbance effects, including game management to reduce browsing, sanitation and mitigation measures for pest and diseases, as well as fire prevention. Finally, the Other category grouped non-technical measures such as planning and monitoring, funding and legislations, change in procedures, energy, infrastructure, training, communication, and education. When the types of CCA measures implemented by forest enterprises are examined across biogeographical regions, interesting

An example from Belgium – Holistic forest management that contributes to CCA

Sometimes, measures that increase forest resilience to climate change may be part of a larger, holistic approach of future-looking forest management. One questionnaire respondent with a forest enterprise in Ravels, Belgium, detailed what such an approach might look like. Noticing that clearcutting has a negative effect on forest microclimate and young trees, the enterprise has transitioned from classical clearcutting and currently uses under-canopy regeneration. This has resulted in several benefits, including that young trees grow better, especially under intense dry periods. The enterprise usually prefers and tries to stimulate natural regeneration of desirable tree species, however sometimes these species are not present. In this case, the enterprise plants small groups of trees (around 25 plants) placed at least 15 m apart. A few trees are then removed during a defined rotation period, so that the remaining trees receive more light. At the end of this process, only one adult tree remains. When possible, these plantings are done under or near species that are being negatively impacted by climate change. The enterprise explains that climate change adaptation is “subtly woven into this process” because planting allows them to take into account more southern species and provenances, thus introducing an adapted gene pool into the forest. In addition, the introduction of rich litter species (e.g., Lime tree (*Tilia spp.*)) also makes the forest more robust against climate changes due to faster nutrient turnover.

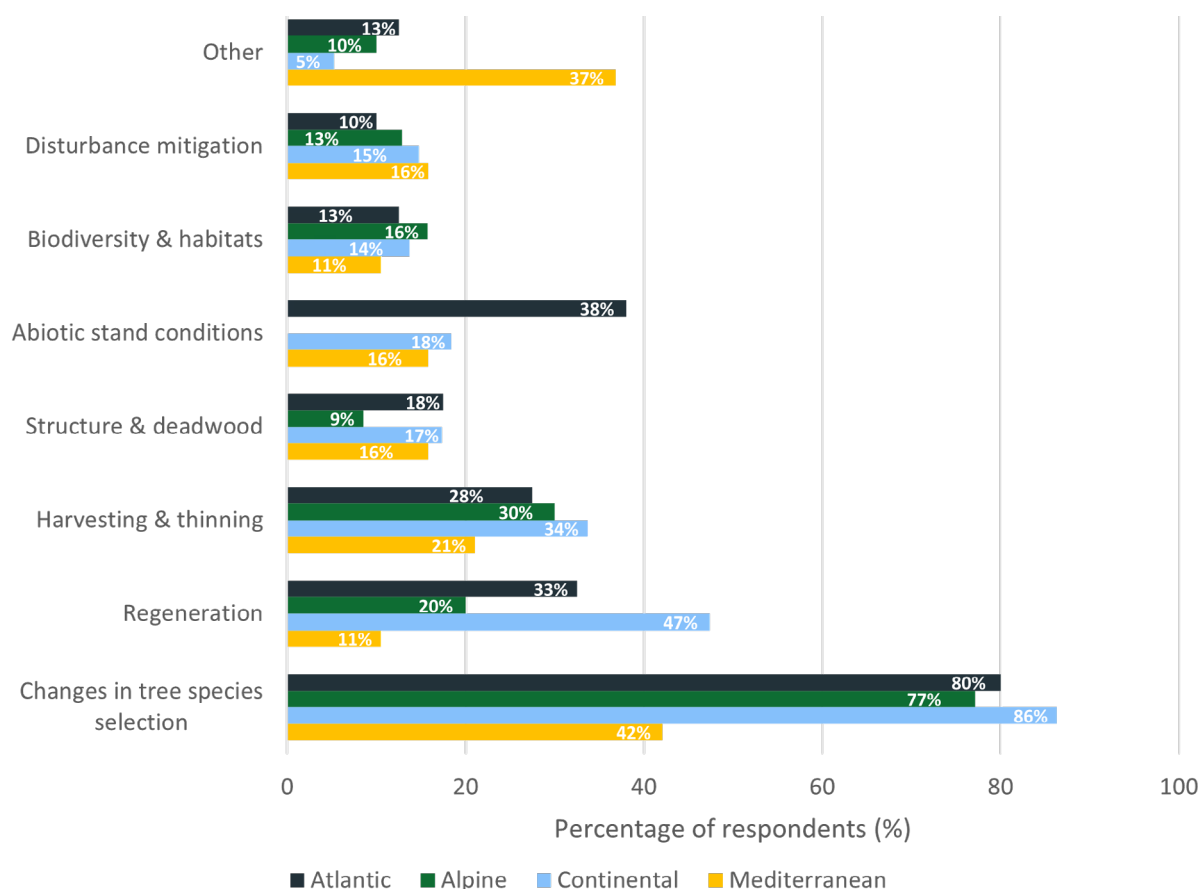


Figure 6: Types of CCA measures implemented by biogeographical region

patterns emerge. All types of CCA measures were implemented in all regions, except for changes to abiotic stand conditions, which were not implemented by respondents in the Alpine region (Figure 6). Overall, tree species selection was the most popular measure for each region. Most measures were implemented at a similar frequency across the regions, however, some differences stood out, including that measures concerning changes in tree species selection and regeneration were notably lower in the Mediterranean as compared to the Alpine, Atlantic, and Continental regions. Instead, “other” types of CCA measures were popular in the Mediterranean region. These included, e.g., the use of new wood processing technologies. Certain measures appeared more popular in some regions as compared to others. Such included, for example, regeneration and abiotic stand conditions being notably more popular in the Continental, and Atlantic regions, respectively.

4.1.3. Reasons for not implementing CCA measures

When the 11 % (n=42) of questionnaire respondents that do not implement CCA measures were

prompted to explain why, their responses were divided between those that found that implementing such CCA measures is unnecessary (52 %, n=22), or that capacities and resources were lacking (33 %, n=16). A remaining small number of responses were grouped as other (14 %, n=6) (Figure 7). For those that reported that implementing CCA measures is unnecessary, most explained that they saw no climate change impacts or no severe impacts that required immediate response in their forest enterprise, or they thought that nature is able to regulate itself and therefore no intervention is necessary or may even be harmful. Responses falling under this category were highest in the Continental and Alpine regions and lowest in the Mediterranean. Respondents that answered that a lack of capacities and resources were preventing them from implementing CCA measures commonly referred to high costs and a lack of financial incentives, as well as lack of knowledge on the measures themselves, which creates uncertainty in the long-term. The rate of responses for lack of capacities and resources was highest in the Mediterranean and Alpine regions. A small number of respondents referred to other factors that influence

their decision not to implement CCA measures, including challenging terrain in the forest enterprise.

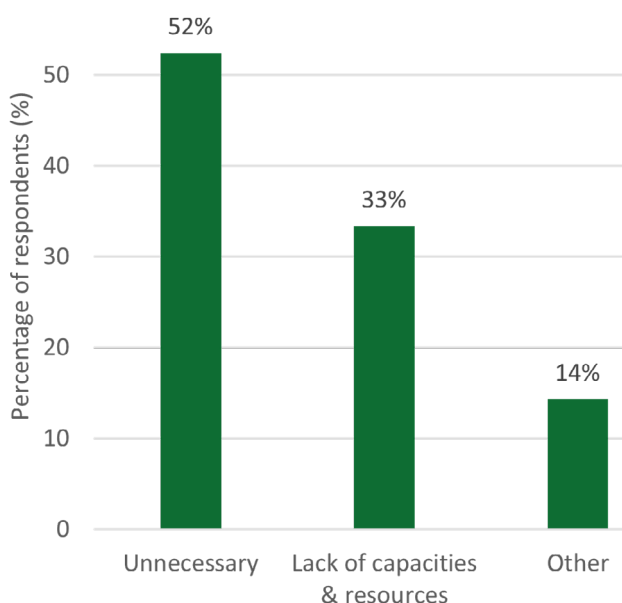


Figure 7: Reasons why forest enterprises do not to implement CCA measures

4.2. Challenges implementing CCA measures

Of the respondents that implement CCA measures, the majority experienced related challenges (75 %, n=243) (Figure 8). Reported challenges were diverse and divided into the following eight categories (ordered according to frequency of responses): Lack of capacities and resources (n=172); Climate change and extreme events (n=49); Forest regeneration

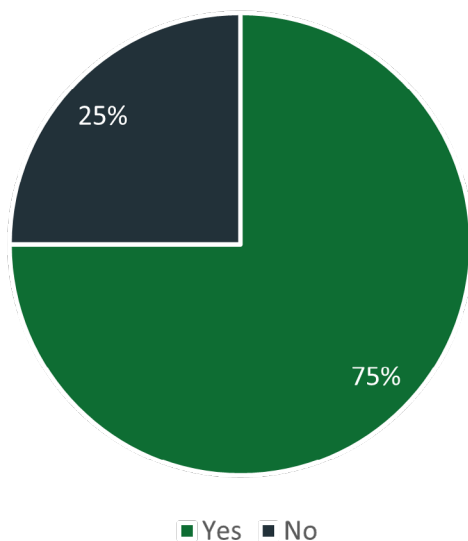


Figure 8: Respondents that face challenges implementing CCA measures (in %)

(n=42); Stakeholders (n=48); Legislation, policies, and bureaucracy (n=28); Technical challenges (n=20); Other (n=8); and Invasive species (n=5) (Figure 9).

Lack of capacities and resources commonly included answers related to high costs and lack of financial incentives, lack of trained staff and knowledge on long-term effects of CCA measures leading to uncertainty, but also bottlenecks in the supply of tree seeds and saplings. Climate change and extreme events aggregated all answers related to events like droughts, windstorms, and wildfires that make it challenging to implement measures, as well as uncertainty in the way that climate change will progress in the long term. Forest regeneration included answers related to challenges with natural or artificial forest regeneration. Responses in this category were almost entirely limited to high game populations that negatively impact forest regeneration. Stakeholders grouped together all stakeholder related challenges, including difficulties communicating and cooperating with stakeholders, lack of stakeholder acceptance of CCA measures, tourism and recreation, and topics around safety for hiking and walking trails resulting from the high quantities of deadwood in the forest. Legislation, policies, and bureaucracy included responses that discussed current forest policies that do not support or hinder the implementation of CCA measures and slow and cumbersome bureaucratic procedures that hinder changes to the management of the forest enterprise. Examples of policies included a lack of or poorly designed subsidies, as well as outdated hunting regulations that contribute to high levels of game in the forest. Technical grouped together responses that described technical challenges with implementing CCA measures, whether due to the skill and experience required, or because certain factors such as terrain pose significant challenges. Other grouped together miscellaneous answers, which included, for example, expansion of agricultural land around the forest enterprise. Finally, invasive species included challenges related to invasive or non-native species, especially neophytes.

When challenges experienced by forest enterprises are examined across biogeographical regions, certain patterns emerge that suggest that most challenges are present regardless of the region. Generally, lack of capacities and resources was the most prominent challenge for each region (Figure 10). This was experienced by around 80 % of respondents in the Atlantic, Continental, and Mediterranean regions, whereas in the Alpine region about 50 % of respondents saw this as a challenge. However, some

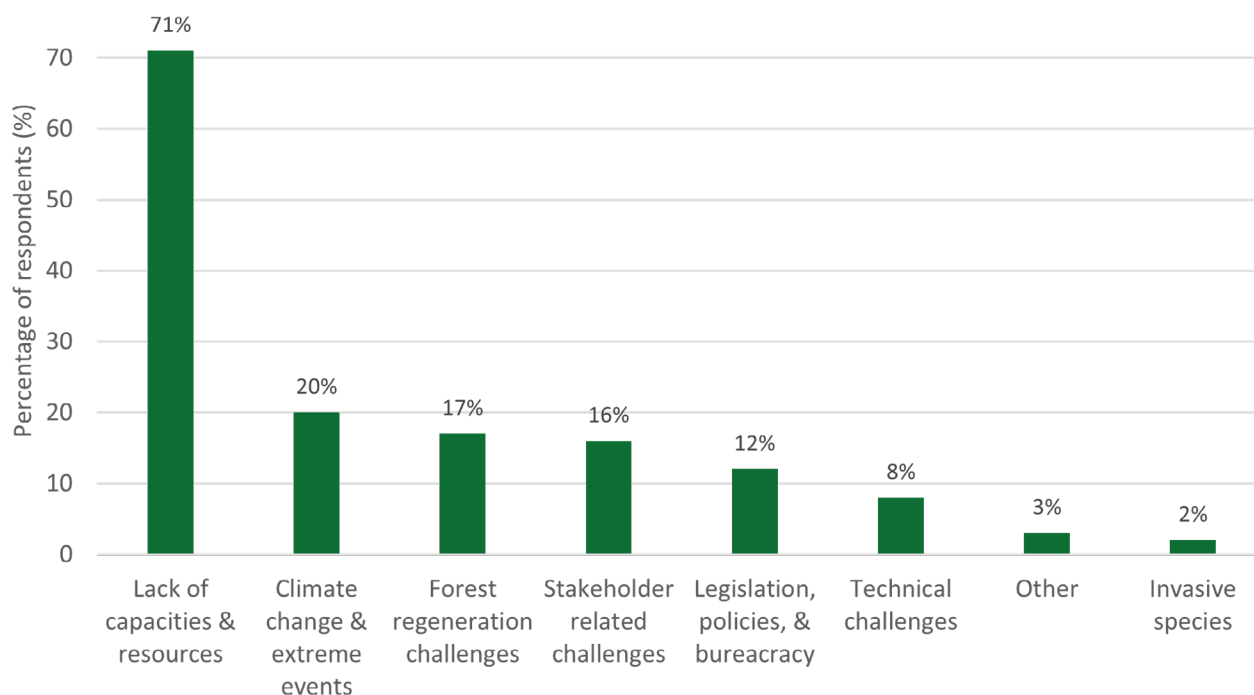


Figure 9: Types of challenges faced by forest enterprises implementing CCA measures

challenges appear more prominent in some regions than others (e.g., forest regeneration challenges in the Alpine region and climate change and extreme events in the Mediterranean region). Additionally, challenges related to stakeholders, legislation, policies, and bureaucracy, and technical challenges were all more common in the Atlantic region as compared to the others. Forest regeneration and invasive species related challenges were also only reported in the Continental and Alpine regions.

“ [Game browsing]... is still understood as being a forestry issue. Experts must succeed in convincing that browsing by game and the conversion of forests are an economic problem (which it is). In all Alpine cantons of Switzerland, sustainable, climate-friendly and resilient protection forests and their regeneration are of utmost importance. Politicians have not yet fully understood this...it is about providing future generations with forests that can fulfil all functions and services demanded by society, especially the protective function. Otherwise, there will be major socio-economic implications at least in the mountain cantons.

– a Swiss forest enterprise on how to approach the challenge of game browsing and its impact on forest regeneration

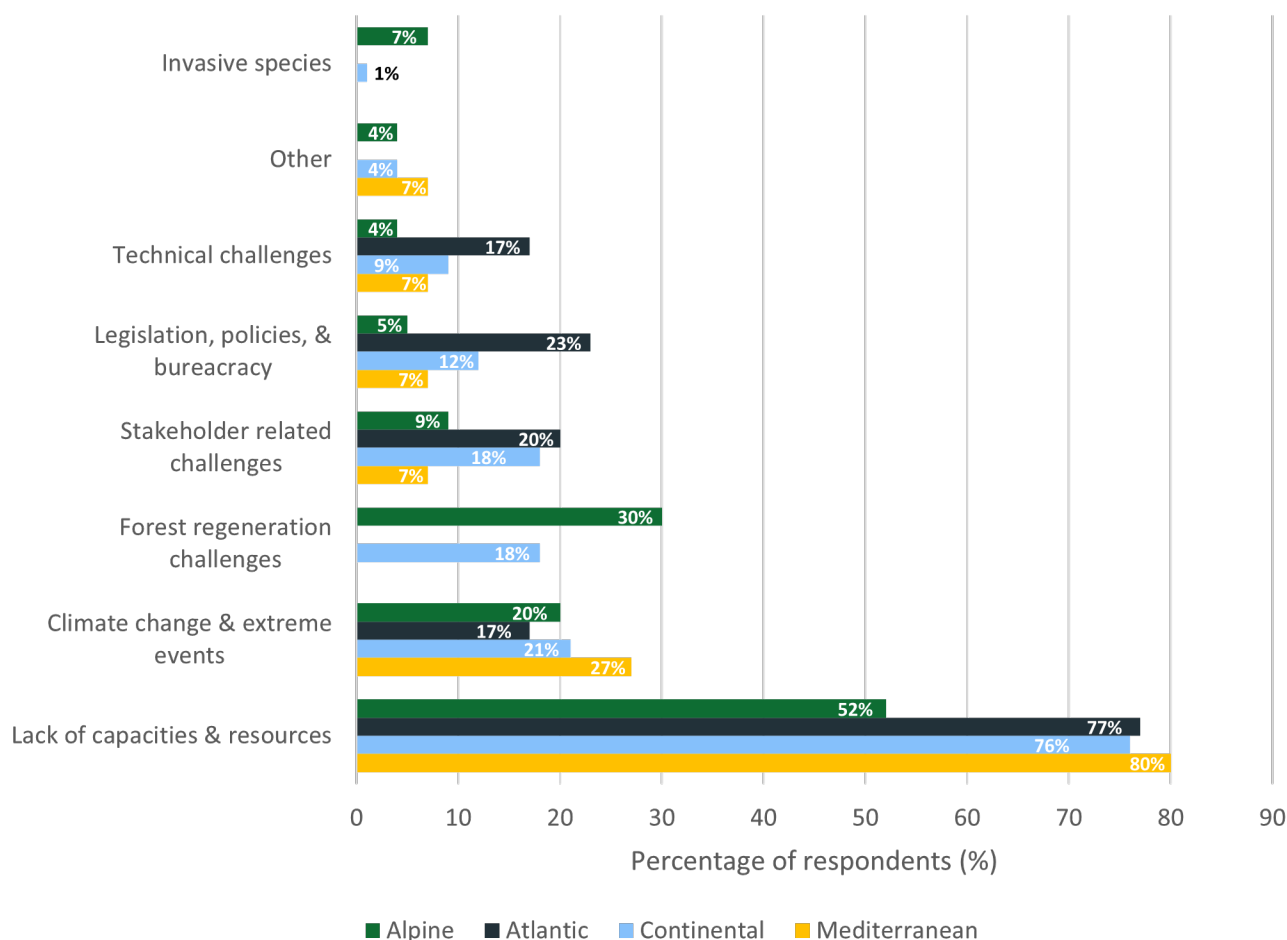


Figure 10: Challenges implementing CCA measures by biogeographical region

4.3. Compatibility and importance of CCA and biodiversity conservation

4.3.1. Synergies between CCA and biodiversity conservation measures

The majority of respondents saw synergies between the CCA measures they currently implement and biodiversity conservation measures (79 %, n=258), while 10 % saw no synergies (n=32) and 11 % (n=36) did not know if there were synergies or not (Figure 11). The exact synergies described by respondents were diverse. We summarise five of the most prominently mentioned synergies below which were found across all biogeographical regions:

- Increased tree species diversity enhances overall forest biodiversity**
 Respondents found that increasing tree species diversity, giving emphasis especially to certain tree species types (e.g., deciduous, rich litter, and fruit producing species), enhances overall forest biodiversity. However, some respondents found that this synergy is only true if native tree species are used.

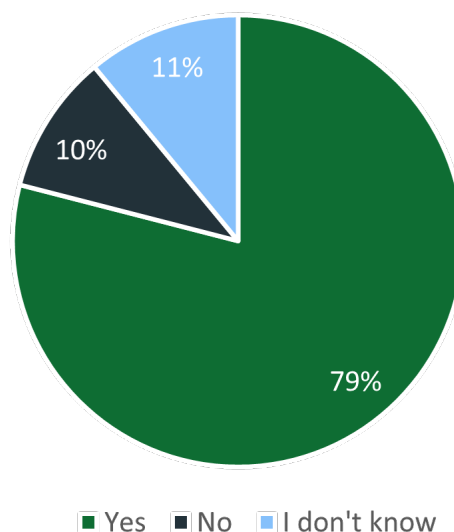


Figure 11: Synergies between CCA and biodiversity measures according to respondents (in %)

- **Increased structural diversity enhances overall forest biodiversity**

Respondents saw several synergies between increased structural diversity and biodiversity. For example, they noted that increasing quantity and types of deadwood (e.g., lying and standing) supports the availability and development of (micro) habitats for saproxylic species, nesting birds, and soil microfauna. Creating different age classes and increasing vertical diversity were also associated with the creation of more habitats for different species.

- **Water retention creates habitats for certain species**

Respondents saw synergies between water retention and the creation of new habitats. For example, restoring formally drained wetlands and removing ditches to lower groundwater levels can be beneficial for amphibious and other aquatic species.

- **A greater focus on natural regeneration and natural processes increases overall forest biodiversity**

Respondents found that putting a greater focus on natural regeneration allowed them to transition from planted stands of mostly spruce to more mixed tree species stands. In addition, focusing on restoring natural processes in forests were seen to be compatible with biodiversity conservation.



Placing a greater emphasis on natural regeneration can have positive benefits for biodiversity. Photo: Andreas Schuck

- **Thinning and low impact harvesting techniques improve and create habitats for certain species**

Thinning and low impact harvesting techniques were reported by some respondents as having direct synergies with biodiversity conservation.

For example, canopy gaps created by thinning operations were seen to create habitats for light dependent species and accelerate the development of old-growth elements. Low impact harvesting techniques were also thought to improve soil conditions for soil microfauna.

4.3.2. Conflicts between CCA and biodiversity conservation measures

Compared to the high percentage of respondents that saw synergies between CCA measures and biodiversity, only 26 % (n=86) saw conflicts between the two (Figure 12). The exact conflicts described by respondents were diverse. We summarise five of the most prominently mentioned conflicts below which were found across all biogeographical regions:

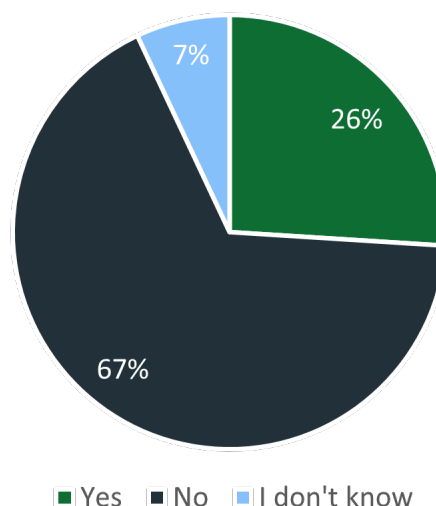


Figure 12: Conflicts between CCA and biodiversity measures according to respondents (in %)

- **Conflicting policies and goals between biodiversity conservation and CCA**

While not specifically related to technical measures, several respondents saw trade-offs between policies and goals for biodiversity conservation and CCA. For example, some respondents thought that some management goals of Natura 2000 areas restrict the choice of certain climate adapted tree species. Strict management regulations for certain habitat types was also mentioned on a more local level. In addition, a number of respondents noted that some biodiversity goals promote the use historical types of forest management which sometimes conflict with CCA measures, i.e., natural regeneration.

- **Increased deadwood quantities can lead to higher fire and bark beetle risks**

Respondents referred to trade-offs between increased levels of deadwood in the forest and increased risk of forest fires and bark beetle outbreaks. Respondents elaborated that this increased risk makes it difficult to decide if they should increase deadwood to enhance biodiversity in their forests or not.



Increasing deadwood in the forest creates habitats for a variety of species but may have risks. Photo: Andreas Schuck

- **Use of climate adapted, non-native tree species**

Respondents reported trade-offs between using tree species that may be considered to be more climate adapted, but are non-native. For example, tree species such as black locust (*Robinia pseudoacacia*), black cherry (*Prunus serotina*), and Sitka spruce (*Picea sitchensis*) were seen to be promising climate adapted species in the Continental region, but with negative effects for biodiversity.

- **Introduction of new tree species may change or decrease biodiversity in the long-term**

Several respondents thought that there may be negative effects from the introduction of new tree species on biodiversity in the long-term, although the exact impacts were thought to be uncertain. At the same time, other respondents thought that the introduction of new tree species may not be enough to increase biodiversity.

- **Reduced rotation times can lead to reduction of valuable old trees**

Some respondents saw conflicts between biodiversity conservation and reduced rotation times aimed at mitigating the risk of disturbance impacts, because doing so may negatively affect the number of old trees which have a

higher probability of displaying valuable tree microhabitats.

4.3.3. Importance of CCA vs biodiversity conservation

When asked if CCA or biodiversity conservation is more important, the majority of respondents thought they were equally important (74 %, n=244), as compared to those that thought CCA or biodiversity measures were more important (17 %, n=55 and 7 % , n=22, respectively) (Figure 13). Responses were similar across biogeographical regions with a few exceptions. The percentage of respondents that thought both types of CCA measures were equally important was highest in the Atlantic, Continental, and Mediterranean regions (around 70-80 %) but lower in the Alpine region (62 %). Additionally, in the Alpine region, 31 % of respondents thought CCA measures were more important than biodiversity conservation measures as compared to around 12-16 % in the other three regions.

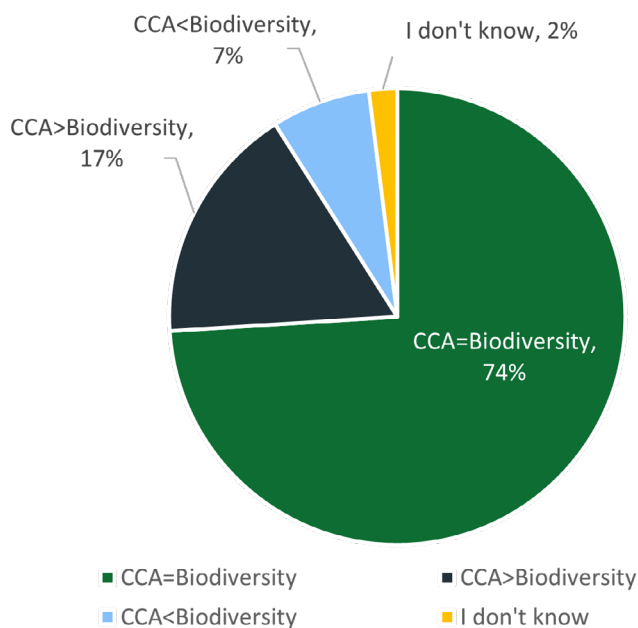


Figure 13: Respondents' answers on whether CCA or biodiversity conservation is more important

4.4. Types of knowledge sources used in decision-making

Respondents were asked to select what types of knowledge sources they use to support decision-making in implementing CCA measures. This was a multiple-choice question (with multiple answers allowed) including an "other" category that allowed for specification. All types of knowledge sources were

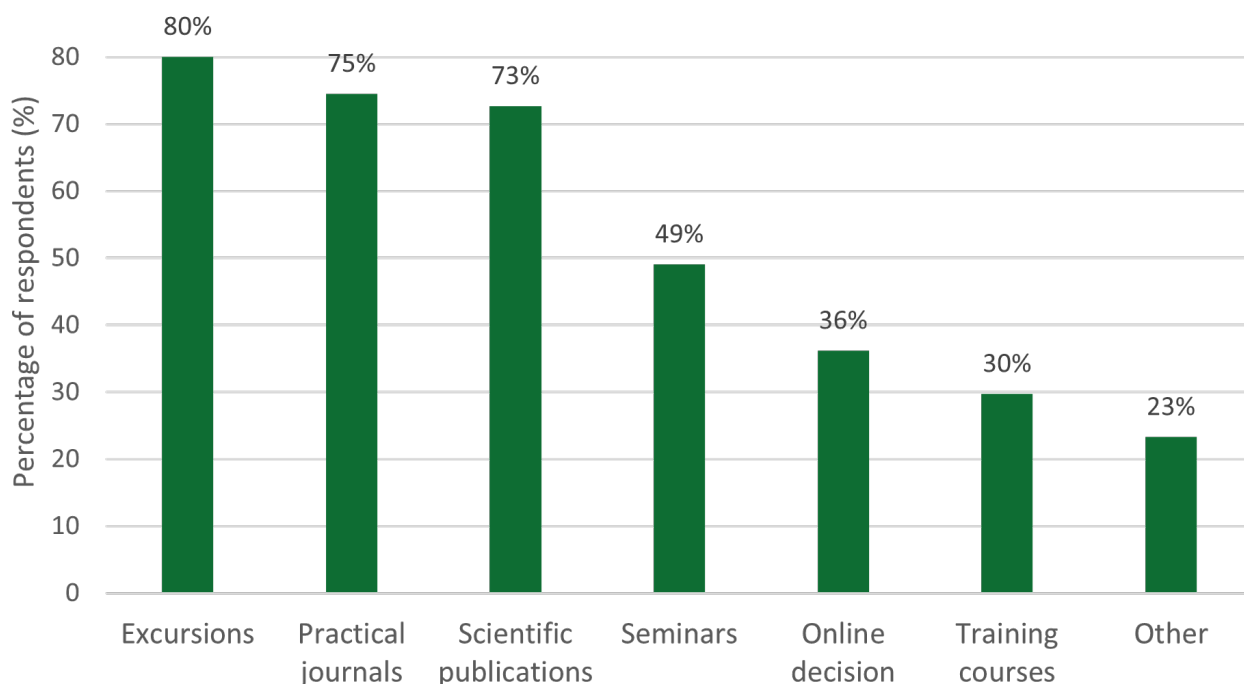


Figure 14: Types of knowledge sources respondents use to inform their decision-making on implementing CCA measures

used by respondents. ‘Excursions and field-trips’ was the most popular source of information (n=261), followed by practical oriented journals (n=243) and scientific publications/reports (n=237). Seminars (n=160), online support & decision tools (n=118), training courses (n=97), and other knowledge sources (n=76) were less frequently mentioned (Figure 14). Other sources included for example respondents’ own experiences and observations, advice from forest associations or advisory services, and exchanges among colleagues.

With regards to knowledge sources to inform biodiversity conservation measures, 96 % of respondents reported that they use the same knowledge sources as for implementing CCA measures. However, only 56 % thought that these types of knowledge sources are sufficient to inform decision-making when it comes biodiversity conservation and CCA measures.

4.5. Impact of CCA measures on the day-to-day functioning of forest enterprises

The majority of respondents thought that implementing CCA measures impacted day-to-day functioning of the forest enterprise (48 %, n=157), compared to 43 % (n=137) that experienced no changes and 9 % (n=32) that did not know (Figure 15).

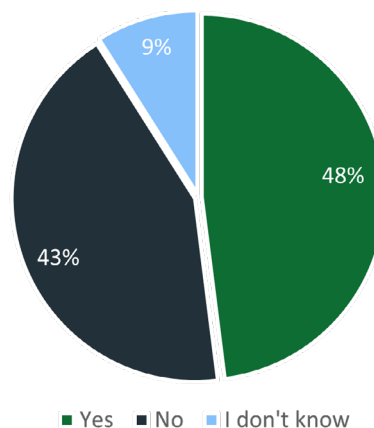


Figure 15: Overview of responses to whether implementing CCA measures impacts day-to-day functioning of the forest enterprise

Specific changes were aggregated into the following six categories (ordered by frequency of responses): Change in forest management (n=78); Time management and effort (n=34); Education/training/communication (n=28); Disturbance management and safety (n=26); Change of income and costs (n=24); and Administration and bureaucracy (n=17) (Figure 16).

Changes in forest management included answers related to the selection of tree species, changes in forest structure, regeneration practices, biodiversity conservation measures, harvesting practices, and game management. The category also included

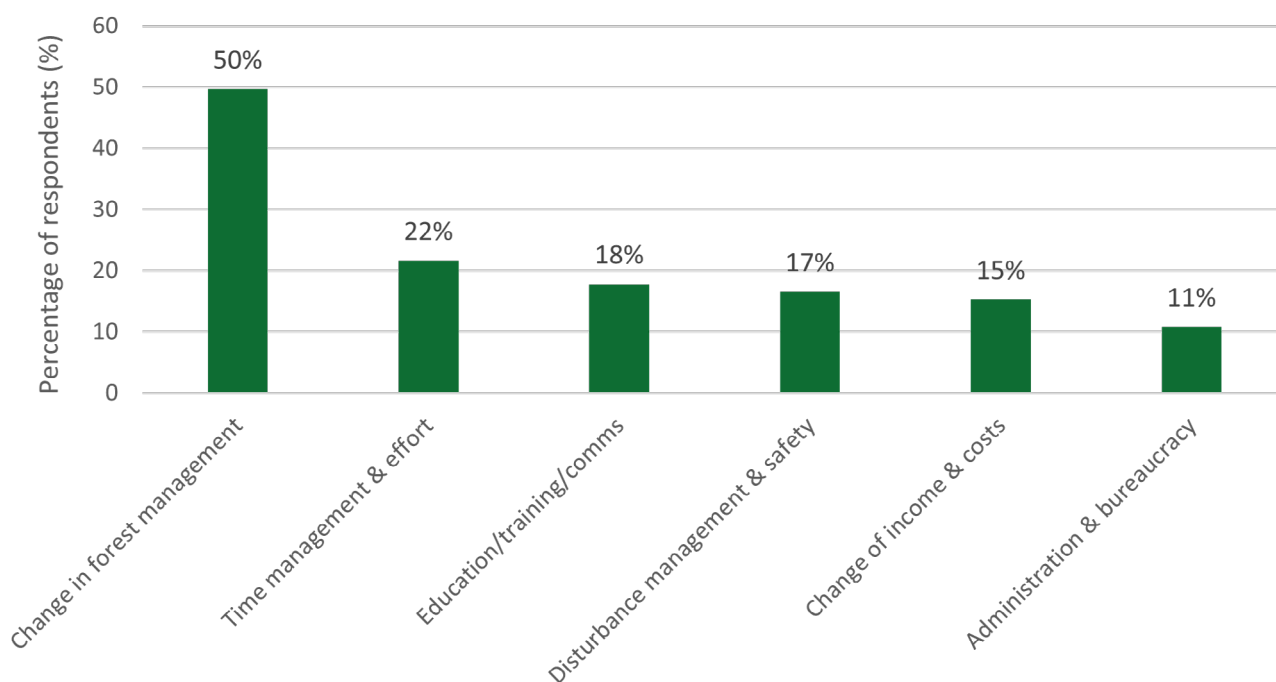


Figure 16: Changes to the day-to-day functioning of forest enterprises as a result of implementing CCA measures

answers related to changes in forestry planning and goals, e.g., a greater focus on biodiversity conservation as opposed to timber production. Time management and effort grouped together answers that referred to changes in the workload and time management of forest practitioners as a result of implementing CCA measures. For example, respondents frequently mentioned that implementing CCA measures was time consuming and required more planning, especially in the long-term. Education, training and communication included for example, training staff to implement CCA measures, communication with forest owners, and communication with the public on biodiversity and CCA measures. Disturbance management and safety included answers that gave reference to changes in the monitoring and management of disturbances, pest and diseases, and other calamities. This category also included answers that described the increasing need for safety for forest visitors post forest disturbances (e.g., after bark beetle outbreak or windstorm). Change of income and costs included responses that referred to increased costs as a result of implementing CCA measures, as well as changes to develop new sources of income besides timber production (e.g., through payments for ecosystem services), reduction of income, and increased financial investments within the forest enterprise (e.g., for stand conversion).

“ We take advantage of the enormous potential of the forest ecosystem and the human-made infrastructure within the forest. Especially as an increasing part of society lives in cities, time spent in nature becomes more valuable. Thus, quite a number of forest ecosystem services could be given a market value. Providing trails for bike rides, accommodations in the forest, visits to extraordinary viewpoints, marketing forest spring water, promoting wedding ceremonies in the forest or guided tours are just a few examples.
– A Hungarian forest enterprise on how they develop alternative sources of income from ecotourism

Finally, administration and bureaucracy referred to changes in administration, work processes and procedures, for example the need for more staff, as well as changes to decision-making processes.

Types of changes to day-to-day functioning varied across biogeographical regions. Changes related to administration and bureaucracy were highest in the Mediterranean compared to other regions whereas change in forest management and time management and effort was notably higher in the Atlantic and Continental regions, respectively. Furthermore, changes related to disturbance management and safety were not experienced by respondents in the Atlantic region.

5. Summary and outlook

By directly communicating with practitioners, this study was able to shed insight on how forest enterprises deal with the impacts of climate change across different biogeographical regions, as well as the related challenges they face. Such information is vital to spread practical information on CCA as well as develop potential solutions to challenges. Most forest enterprises that responded to our questionnaire were impacted by climate change, whether it be from drought, increased pests and diseases, or changes in tree species. However, a sizeable portion of 12% believed that their forest enterprise was unaffected by climate change and also do not implement climate change adaptation measures. For the majority that believed they were affected by climate change, most already implement CCA measures to address these various impacts. The diversity of practical measures implemented by respondents was very high, however most types of measures were implemented in all biogeographical regions with varying popularity. This suggests that a wide variety of CCA measures may be suitable for adapting forests to climate change regardless of the biogeographical region. However, some measures may be more successful in some regions compared to others, which highlights the importance of the regional context. Future research could further investigate the patterns among different regions in Europe, as well as other drivers for implementing CCA measures.

The high proportion of questionnaire respondents that implement measures suggests many forest enterprises are willing or find it necessary to make changes to adapt their forests to climate change.

However, the large majority of forest enterprises face multiple challenges to implement these measures. The most common challenge faced by respondents was a lack of capacities and resources, particularly lack of funding and incentives. In order to increase and encourage the uptake of CCA measures and increase forest resilience to climate change, it’s imperative that these challenges are addressed by decision-makers. Ideally, solutions should ideally be developed jointly by decision-makers and practitioners.

When it comes to jointly addressing the dual crises of biodiversity loss and climate change, the results of this questionnaire provide an optimistic perspective. Most respondents thought CCA and biodiversity conservation are equally important and that there are more synergies than conflicts between CCA and biodiversity conservation measures. However, it is still vital to address conflicts and explore how they can best be mitigated, as well as investigate how to maximise synergies. Networks such as the Integrate Network and Pro Silva can act as knowledge multipliers and are well poised to further these discussions on how to integrate biodiversity conservation into forest management and the associated trade-offs and synergies with CCA.

Understanding how practitioners inform their decision-making in regard to CCA is crucial for disseminating information and knowledge-sharing on potentially new or useful measures. Respondents used a variety of complimentary knowledge sources to guide their decision-making. Excursions and field-trips, practical journals, and scientific publications were especially popular among questionnaire respondents. However, many respondents thought that these knowledge sources are not sufficient for informing decision-making, especially given the uncertainty of climate change in the long-term. New ways of communicating and disseminating information related to CCA in forest enterprises should be explored with practitioners to facilitate further uptake.

When implementing CCA measures, the most prominent impact on day-to-day functioning of respondents’ forest enterprises was the change to forest management itself. This suggests that other factors such as reduced income from reduction of timber harvesting and increased time management and effort, may not serve as strong deterrents for implementing CCA measures. However, alternative sources of income, such as payments for ecosystem services schemes, should be given more attention,

especially in policies, to help practitioners overcome impacts related to the shifting sources of income in the forest enterprise as result of implementing these measures.

When furthering discussions on how to increase forest resilience to climate change, it is important to directly communicate with practitioners to see how such efforts are being achieved on-the-ground. This study represents one of a few that examines this issue at this level. However, while the results presented here aim to answer our main research questions, they represent the answers to most, but not all, of the questions in our questionnaire (see Annex 1 for full list of questions). Due to time capacities, questions related to the importance of different forest ecosystem

services in individual forest enterprises, anticipated future changes to CCA measures and challenges, as well the impacts of implementing CCA on different forest ecosystem services were not analysed. Analysis of this data could help to further understanding of challenges and impacts related to implementation of CCA. In addition, further studies could investigate the success and failures of such measures, and how challenges related to implementation could be overcome. However, we do hope this study is able to both initiate and further discussions among practice and decision-making alike on how adapting managed forests to climate change is taking place on-the-ground across Europe from the valuable perspective of the forest practitioner.



More studies are needed that investigate CCA from the perspective of the forest practitioner. Photo: Andreas Schuck

6. References

- Blennow, K., Persson, J., Tomé, M., & Hanewinkel, M. (2012). Climate Change: Believing and Seeing Implies Adapting. *PLoS ONE*, 7(11). <https://doi.org/10.1371/journal.pone.0050182>
- Bolte, A., Ammer, C., Löf, M., Madsen, P., Nabuurs, G. J., Schall, P., Spathelf, P., & Rock, J. (2009). Adaptive forest management in central Europe: Climate change impacts, strategies and integrative concept. In *Scandinavian Journal of Forest Research* (Vol. 24, Issue 6, pp. 473–482). <https://doi.org/10.1080/02827580903418224>
- Brang, P., Spathelf, P., Larsen, J. B., Bauhus, J., Bončina, A., Chauvin, C., Drössler, L., García-Güemes, C., Heiri, C., Kerr, G., Lexer, M. J., Mason, B., Mohren, F., Mühlethaler, U., Nocentini, S., & Svoboda, M. (2014). Suitability of close-to-nature silviculture for adapting temperate European forests to climate change. In *Forestry* (Vol. 87, Issue 4, pp. 492–503). Oxford University Press. <https://doi.org/10.1093/forestry/cpu018>
- Carpio, A. J., Apollonio, M., & Acevedo, P. (2021). Wild ungulate overabundance in Europe: contexts, causes, monitoring and management recommendations. In *Mammal Review* (Vol. 51, Issue 1, pp. 95–108). Blackwell Publishing Ltd. <https://doi.org/10.1111/mam.12221>
- de Groot, M., Diaci, J., & Ogris, N. (2019). Forest management history is an important factor in bark beetle outbreaks: Lessons for the future. *Forest Ecology and Management*, 433, 467–474. <https://doi.org/10.1016/j.foreco.2018.11.025>
- de Koning, J., Lindner, M., Spathelf, P., Espelta, M., Schwarz, M., & Vančo, M. (2020). Integrated forest management and climate change adaptation in European forestry-A policy and practice review Joost de Koning.
- Duncker, P. S., Barreiro, S. M., Hengeveld, G. M., Lind, T., Mason, W. L., Ambrozy, S., & Spiecker, H. (2012). Classification of forest management approaches: A new conceptual framework and its applicability to European forestry. *Ecology and Society*, 17(4). <https://doi.org/10.5751/ES-05262-170451EU>
- EEA (2019) Biogeographical Region in Europe. Available at <https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2>
- European Commission, 2020. Biodiversity Strategy for 2030 Bringing nature back into our lives. European Commission, Brussels, Belgium, 1-22.
- Jandl, R., Spathelf, P., Bolte, A., & Prescott, C. E. (2019). Forest adaptation to climate change—is non-management an option? *Annals of Forest Science*, 76(2). <https://doi.org/10.1007/s13595-019-0827-x>
- 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. In *Forests* (Vol. 2, Issue 4, pp. 961–982). <https://doi.org/10.3390/f2040961>
- Konczal, A. A., Derks, J., de Koning, J. H. C., & Winkel, G. (2023). Integrating nature conservation measures in european forest management – An exploratory study of barriers and drivers in 9 european countries. *Journal of Environmental Management*, 325. <https://doi.org/10.1016/j.jenvman.2022.116619>
- Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M., Lexer, M. J., & Marchetti, M. (2010). Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *Forest Ecology and Management*, 259(4), 698–709. <https://doi.org/10.1016/j.foreco.2009.09.023>
- MEA. (2005). *Ecosystems and human well-being: synthesis*. Island Press.
- Millar, C. (2008). *Natural Resource Management; Reframing Strategies for Climate Change*.
- Patacca, M., Lindner, M., Lucas-Borja, M. E., Cordonnier, T., Fidej, G., Gardiner, B., Hauf, Y., Jasinevičius, G., Labonne, S., Linkevičius, E., Mahnken, M., Milanovic, S., Nabuurs, G. J., Nagel, T. A., Nikinmaa, L., Panyatov, M., Bercak, R., Seidl, R., Ostrogović Sever, M. Z., ... Schelhaas, M. J. (2023). Significant increase in natural disturbance impacts on European forests since 1950. *Global Change Biology*, 29(5), 1359–1376. <https://doi.org/10.1111/gcb.16531>
- Pfeffer, S. E., Singh, N. J., Cromsigt, J. P. G. M., Kalén, C., & Widemo, F. (2021). Predictors of browsing damage on commercial forests – A study linking nationwide management data. *Forest Ecology and Management*, 479. <https://doi.org/10.1016/j.foreco.2020.118597>

Roitsch, D., Abruscato, S., Lovrić, M., Lindner, M., Orazio, C., & Winkel, G. (2023). Close-to-nature forestry and intensive forestry – Two response patterns of forestry professionals towards climate change adaptation. *Forest Policy and Economics*, 154. <https://doi.org/10.1016/j.forpol.2023.103035>

Seidl, R., Schelhaas, M. J., & Lexer, M. J. (2011). Unraveling the drivers of intensifying forest disturbance regimes in Europe. *Global Change Biology*, 17(9), 2842–2852. <https://doi.org/10.1111/j.1365-2486.2011.02452.x>

Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., Wild, J., Ascoli, D., Petr, M., Honkaniemi, J., Lexer, M. J., Trotsiuk, V., Mairota, P., Svoboda, M., Fabrika, M., Nagel, T. A., & Reyer, C. P. O. (2017). Forest disturbances under climate change. *Nature Climate Change*, 7(6), 395–402. <https://doi.org/10.1038/nclimate3303>

Sousa-Silva, R., Verbist, B., Lomba, Â., 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. *Forest Policy and Economics*, 90, 22–30. <https://doi.org/10.1016/j.forpol.2018.01.004>

Spiecker, H., Hansen, J., Klimo, E., Skovsgaard, J. P., Sterba, H., & von Teuffel, K. (2004). *Norway Spruce Conversion* (Eds).

IPCC. (2021). Summary for Policymakers. In *Climate Change 2021 – The Physical Science Basis*. Cambridge University Press. <https://doi.org/10.1017/9781009157896.001>

7. Annex

7.1. Annex 1: Questionnaire: Practitioner's challenges and experiences in adapting forest management to a changing climate

Brief introduction to study

As part of our short-term study "Challenges and experiences in adapting forest management to a changing climate – a practitioner's view", EFI is seeking to gather insight of what practical climate adaptation measures are already being implemented in forest enterprises in different parts of Europe, how these measures relate to biodiversity conservation, what knowledge sources inform their implementation, and any impacts they may have on ecosystem services and the forest enterprise in general. Specifically, this questionnaire seeks to answer these questions by asking practitioners in forest enterprises.

It is likely to take 15-20 minutes to complete. We also encourage you to distribute the questionnaire further to other practitioners you may know! Based on the survey outcomes, we plan to contact a number of enterprises to collect more detailed information in the form of an interview. We thank you for your time and look forward to hearing from you!

1. General information

- a. Name (first, last)
- b. Name of forest enterprise and location (place, country)
- c. Contact information, so we may follow up with additional questions if needed (email)
- d. Forest enterprise ecosystem service rating (Likert Scale – not at all important to very important; will use same ES as 1.5a): Please rate the following ecosystem services according to their importance in your forest enterprise.
 - Please list and rate the importance of any ecosystem services that are relevant for your enterprise but are missing from the previous question

2. Current climate adaptation measures in your enterprise and future changes

- a. Is your forest enterprise impacted by climate change (e.g., forest or species dieback,

increase in forest fires, etc.)? (yes, no)

- If yes, how?
- b. Have you implemented climate change adaptation measures in your forest enterprise? (yes, no)
 - If yes, what measures? (open ended, please provide your answer in bullet point list)
 - If no, why? (after answering this question, their response would be submitted as the rest of the questions are not relevant)
 - c. Do you plan on changing or adding any measures in the future?
 - If yes, what type of measures and why?
 - d. Do you face any challenges implementing climate change adaptation measures in your forest enterprise? (yes, no, I don't know)
 - If yes, what challenges? (open ended)
 - e. Do you expect any additional challenges managing climate change in the future? (yes, no, I don't know)
 - If yes, what challenges? (open ended)
 - f. Do you implement any other measures in your enterprise to increase forest resilience?

3. Compatibility of biodiversity and climate change adaptation measures in your enterprise

- a. For the climate change adaptation measures you currently implement, do you see any synergies with biodiversity conservation measures? (yes, no, I don't know)
 - If yes, what synergies? (open ended)
- b. For the climate change adaptation measures you currently implement, do you see any conflicts with biodiversity conservation? (yes, no, I don't know)
 - If yes, how do they conflict? (open ended)
- c. Do you see climate change adaptation or biodiversity conservation measures as more important for your forest enterprise? (Multiple choice: Biodiversity is more important, climate is more important, they are both equally important, I don't know)

4. Types of knowledge sources used in decision-making

- What types of knowledge sources inform your decisions to implement climate adaptation measures (multiple choice: practice oriented journals, scientific publications/reports, seminars, professional training courses, field trips, online support/decision tools (e.g., TreeApp, Climassences, FORSITE) other: please describe)
- Do you use the same knowledge sources to inform your decisions to implement biodiversity conservation measures (Yes, no)
 - If no, how do they differ?
- Are these knowledge sources sufficient for making decisions about climate change adaptation and biodiversity conservation measures?
 - If no, why?

5. Impact of climate change adaptation measures on ecosystem services and day-to-day functioning of the forest enterprise

- a. How do the climate change adaptation measures you currently implement in your forest enterprise impact other forest ecosystem services? Please note that biodiversity conservation has not been included as it has been covered in the previous section 1.4: (Potential Likert scale with multiple ES listed: timber production, provision of non-timber forest products, water regulation, erosion regulation, protection from natural hazards, recreation, other: please list)
 - Please list and rate the impact on any ecosystem services that are relevant for your enterprise but are missing from question (optional)
 - For any significant negative or positive impacts please provide additional details or any other relevant comments (optional)

- b. Has the implementation of climate change adaptation measures in your enterprise lead to any changes in its day-to-day business? (Multiple choice: yes, no, I don't know)
 - If yes, what changes and why? (open ended)
 - Do you anticipate that there will be any changes in the future?
 - If yes, what changes and why?

Thank you for contributing to this study!

7.2. Annex 2: Table of questionnaire responses by country

Country	Number of questionnaire responses
Austria	38
Belgium	23
Croatia	1
Czech Republic	55
Denmark	26
Finland	7
France	5
Germany	47
Hungary	9
Ireland	5
Italy	6
Liechtenstein	5
Netherlands	3
Portugal	3
Romania	1
Slovakia	2
Spain	27
Switzerland	102
United Kingdom	3
Total	368