EUROPEAN FORESTS AT RISK

A scoping study in support of the development of a European Forest Risk Facility

Guy Landmann, Alexander Held, Andreas Schuck, Jo Van Brusselen (Eds.)

EUROPEAN FORESTS AT RISK

A scoping study in support of the development of a European Forest Risk Facility

© tagxedo.com, 2015

Guy Landmann, Alexander Held, Andreas Schuck, Jo Van Brusselen (Eds.)

Acknowledgement

During the compilation of the scoping study we as editors experienced that it is all about people, their dedication, team work and sharing a common goal. A sincere thank you goes in particular to all chapter authors their colleagues and networks for sharing their expertise and visions with us. Further we would like to give thanks to some of our colleagues who have been instrumental during the implementation process: Verena Quadt in her tireless effort of editing, designing and developing a highly attractive lay out and thus bringing the study "into shape"; Tim Green for a fantastic job in proof-reading and making it one document despite many different authors. Last but not least, we thank all the supportive, motivating, inspiring colleagues and friends we made in the course of putting the scoping study together. The Editors

This report is available for download:

friskgo.org

Recommended citation:

Landmann, G.; Held, A.; Schuck, A.; Van Brusselen, J. (eds.) 2015: European forests at risk. A scoping study in support of the development of a European Forest Risk Facility. European Forest Institute. DOI: 10.13140/RG.2.1.1927.2169

Cover photos: 1 + 3: Daniel Kraus; 2: Verena Quadt

EFI, Freiburg 2015

CONTENT

1 Introduction

Andreas Schuck, Marc Palahi

1.1 Introduction to risks to European forests

European forests have always been exposed to various hazards with storms, wildfires, pest insects and diseases, and drought generally considered as the main agents. Wild ungulates represent another important, but more insidious and less recognized, risk to forest ecosystems. Further climatic hazards include frost, heavy snow and ice. When the protective role of forests is temporarily diminished, avalanches, landslides, soil erosion, stone/rock fallings, etc. may cause additional damage to forests and, more importantly, human properties.

Disturbances are part of natural development cycles of forests but may also be of more "catastrophic" nature and affect large forest areas. They can thus lead to disruption of forest management goals, have severe consequences for timber markets, and affect the provision of other ecosystem services

This report concentrates on three major hazards (wildfires, storms, biotic factors) and wild ungulates. Drought is not included, but as this introduction clearly highlights, it is an important risk, even more so when trends related to climate change are considered. The protective role of forests is not discussed either, but should be taken into account where this function is prominent.

Disturbances are part of natural development cycles of forests. They affect stand structures and evolutionary processes linked to succession. Their frequency, scale and intensity can vary greatly. Less intense disturbances may allow for small-scale gap dynamics which create a diversification of stand structure, stimulate natural regeneration, increase the amount of dead wood and modify micro-climate thus having positive effects on biodiversity, while economic damage stays within acceptable limits.

Disturbances can also be of a more "catastrophic" nature affecting large forest areas and whole landscapes. They can, in the case of managed forests, strongly disrupt targeted goals, have severe consequences on wood production and timber markets, and in some cases destroy the economic base of forest owners. They also may affect the provision of ecosystem services other than wood, such as, carbon storage capacities, water quality and balance, and biodiversity (Gardiner et al., 2010).

Historical reconstructions using various scientific approaches provide evidence going back hundreds of years and help to understand how historical events compare with more recent events. Observations across Europe provide indications that damage to forest, especially by storms, has markedly increased during the last decades (Schelhaas, 2008; Schelhaas et al., 2003).

It is likely that some changes of disturbance regimes have occurred, but generally long-term unbiased time series are difficult to establish. Two important factors interfere in the long-term:

- changes in forest extent, structure and composition associated with forest and land-use policies, practices and management (e.g. promotion of large afforestation programs or conversion into mixed forests) strongly influence the vulnerability of forests to events such as storms, wildfires and insect infestations (Gardiner et al. 2010; Schelhaas et al., 2010; Seidl et al., 2011);
- climate change is frequently hypothesized as an increasingly important driving force behind apparent changes in disturbance regimes (alteration of wind intensities and rain patterns, increasing flood risks, occurrence of shorter and milder winters, and changes in intensity and frequency of drought). Changing environmental conditions induced by climate change will affect the vulnerability of forests with pronounced impacts, especially on forest health and vitality.

In addition, potential interactions between hazards may become important; an example is drought, a stress factor which can severely reduce tree vitality, and thus increase vulnerability to other damaging agents, such as wildfires and insect infestations. Similar interactions occur between windthrow and bark beetles (Figure 1).

Figure 1: Example of some important hazards and their interactions

Considering the 26 main European tree species, the relative contribution of the main hazards to tree damage were in order of decreasing importance during the 1994-2005 period (Jactel et al., 2011):

- biotic agents (more than half of all occurrences) with insects representing the main cause of damage, followed by diseases;
- abiotic agents (e.g. drought, wind, snow, fire, frost, hail)) (ca. 1/5 of occurrences);
- anthropic agents (e.g. poor harvesting practices, air pollution) (ca. 1/5 of occurrences).

Thus, an increasing trend towards more disturbance-prone conditions seems likely for large parts of Europe's forests. Changing disturbance regimes would have adverse feedbacks on the sustainable provision of important forest functions and services (e.g., Ayres and Lombardero, 2000; Dale et al., 2000; EEA, 2005). This could have social and economic implications (including disruption of markets) to forest owners, public administrations and society at large. It could also have important detrimental effects on ecosystem services (e.g., carbon storage). In the longer term, the impact of adaptation measures needs to be taken into account, as they may contribute towards counteracting some of the harmful effects of hazards on forests while making them more resilient.

An important aspect of risk management is that, in addition to the intensification of threats where they already occur, the disturbances are also likely to occur beyond their traditional boundaries. Fire, biotic agents and also storm are probably the most obvious cases. Such expansions within countries and at a transnational level will require improvement in all steps towards risk management, post-disturbance and mitigation measures.

Different risks manifest themselves in a variety of ways due to their nature and occurrence. It is essential to develop tools, instruments, and strategies based on a solid information base jointly with the various actors from science, policy, practice and operational management

As the different risks manifest themselves in a variety of ways due to their nature and occurrence, it is essential to develop tools, instruments, and strategies based on the best available knowledge and information. Such tools may include, sharing of information, exchanging gained experiences, and providing training and capacity building. It also implies bringing together various actors and stakeholders from science, policy, practice and operational management and to foster such transnational exchange and capacity building. Such an approach would help prepare European countries to better cope with and mitigate the effects of the risks.

1.2 Forest Protection: a key policy issue in Europe

During recent years, several European and EU political declarations and documents have given considerable attention to risks resulting from the intensification of forest disturbance regimes within the framework of climate, forest management and land-use changes. In the following they are introduced chronologically.

EU Forest Action Plan (2007-2011)

The EU Forest Action Plan (2007-2011) provided a framework for the implementation of forest-related actions at European Union and Member State level. Its aim was to support and enhance sustainable forest management and the multifunctional role of forests. It was based on the principles and elements identified in the EU Forestry Strategy, one of which states to “improve and protect the environment” (Key Action 9).

Risks resulting from an intensification of forest disturbance regimes are given increased attention by European and EU policy processes

The activities under Key Action 9 were aimed at ‘developing the existing forest fire information system and improving the evidence base and understanding of factors affecting forest condition', at EU level and regionally. There has been further development of the European Forest Fire Information System, both on the part of the European Commission and the Member States.

The withdrawal of *Regulations 2158/92*[1] and *2152/2003*[2] and the transfer of prevention measures into a *European Agricultural Fund for Rural Development* and *LIFE*+[3] has lead towards a reduction in measures to prevent forest risks in Member States, a view echoed by the European Parliament in their 2011 report[4]. The *Advisory Group on Forestry and Cork* called for the re-establishment of independent financing for the prevention of forest fires and other forest disasters to protect the environment[5]. The process was started with help of the *Green Paper on Forest Protection and Information in the EU*.

Green Paper on Forest Protection and Information in the EU (2010)[6]

The *Green Paper on Forest Protection and Information in the EU* had as its purpose to initiate a debate on options for an EU approach to forest protection and information in the framework of the EU Forest Action Plan. It was based on the *White Paper*: *Adapting to Climate Change: towards a European Framework for Action*[7]. The EU Parliament reaffirmed its view that increased levels of funding for EU Forest protection measures and new forms of assistance to Member States are needed. The Green Paper public consultation yielded the following proposals related to forest protection and risk:

- need for more harmonized and readily available information about EU forests, with links to policies;
- strengthening of the resilience and adaptability of forest ecosystems to changing climatic conditions as well as the conservation of forest genetic resources;
- recognition that forest protection is a transnational issue, thus asking for well-coordinated cross border approaches;
- more research efforts in order to establish adequate knowledge about the nature, extent and expected effects of climatic change on forests/forest sector.

[1] Council Regulation (EEC) No 2158/92 of 23 July 1992 on protection of the Community's forests against fire

[2] Regulation (EC) No. 2152/2003 of the European Parliament and of the Council of 17 November 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus)

[3] Regulation (EC) No 614/2007 of the European Parliament and of the Council of 23 May 2007 concerning the Financial Instrument for the Environment (LIFE+)

[4] European Parliament (EP) adopted in May 2011 the Report (drafted by Kriton Arsenis) on the Commission Green Paper on forest protection and information in the EU - preparing forests for climate change

[5] Minutes AGFC meeting 29 June 2009

[6] COM(2010)66 final. Green Paper on Forest Protection and Information in the EU: Preparing forests for climate change.

[7] COM(2009)147. White Paper on Adapting to Climate Change: towards a European framework for action.

FOREST EUROPE (2011)

The FOREST EUROPE Ministerial Conference on 14-16 June 2011 in Oslo, Norway adopted the "*Oslo Ministerial Decision: European Forests 2020*"[8] with clear reference towards the action needed to address climate-driven risks:

- climate change is one of the gravest threats faced by society asking for urgent action to minimize risks of damage from events such as storms, floods, fire, drought, pests and diseases in order to protect European forests and their functions. Forest management is to be adapted to changes in climate to thus ensure healthy forests, their resilience to natural hazards and be protected against human-induced threats (…);
- the value of adequate and accessible forest information for decision making at all levels is emphasized including forest inventories, monitoring, assessing and reporting on implementation of sustainable forest management as well as science-based knowledge;
- international action is to be taken towards the elaboration of a legally binding agreement on forests in Europe [in order to] address, besides others: the maintenance and enhancement of forest resources in Europe, their health, vitality and resilience, and their adaptation to climate change; the increase of resilience of forests to natural hazards and protection against human-induced threats; the improvement of forest knowledge based on research, education, information sharing and communication.

Report to the Standing Forestry Committee by its ad-hoc Working Group VII contributing to the development of a new EU Forest Strategy (2012)

Besides the actual EU Forest Strategy, which is discussed in the following section, it is important also to remind of the report[9] (June 2012) by the "*Standing Forestry Committee ad hoc Working Group contributing to the development of a new EU Forest Strategy*". The ad-hoc working group proposed forest protection against biotic and abiotic threats as one of the EU Forest Strategy priorities. The report highlighted that these threats have increased trans-boundary effects, and suggested stronger emphasis on prevention, besides damage mitigation and restoration, and recommended that the new EU Forest Strategy should provide an appropriate framework to:

- give guidance to policy and legislative instruments at EU and national level to address risk and cope with these threats, considering the range from prevention to restoration;
- recognize the importance of, improve, make comparable and share forest information and monitoring, assessment and reporting on all the major biotic and abiotic threats building on successful experiences, such as the EU Forest Fire Information System (EFFIS);
- ensure that practitioners, Member States and the European Commission work together to share knowledge, experiences and information on restoration and prevention;
- coordinate the analysis of funding currently available for forest protection;
- reinforce response capacity in the spirit of solidarity to cope with large-scale disasters;

---

[8] http://www.foresteurope.org/filestore/foresteurope/Conferences/Oslo_2011/FORESTEUROPE_MinisterialConference_Oslo2011_EuropeanForests2020_AdoptedatMinConf14-16June2011.pdf

[9] http://ec.europa.eu/agriculture/fore/publi/sfc_wg7_2012_full_en.pdf

- enhance coordination of actions in case of large-scale trans-boundary disasters;
- enhance cooperation with neighboring countries, including for the prevention of transfer of diseases, and through enhanced coordination of disease-related research.

EU Forest Strategy

A new EU Forest Strategy was adopted in September 2013. Societal and political changes during the preceding decade have shaped society's perspective of forests and forestry. It recognizes that besides growing demands on forests, the forests are vulnerable also to increasing threats. Action is challenging due to the increasing number of forest-related policies in the EU which have led to a rather complex and fragmented forest-policy environment.

The new EU Forest Strategy constitutes a policy framework that should allow for forest-related policies to be coordinated and coherent, and for building synergies with other sectors influencing forest management. The EU Forest Strategy makes clear reference in its needs to protect forests and biodiversity from significant effects of storms and fires, increasingly scarce water resources, and pests. It is recognized that such threats do not respect national borders and are further accelerated by changes in climate.

The strategy acknowledges pressures on forests, including amongst others, fires, storms, pest and diseases, and the need for enhanced protection. Importance is placed on maintenance, restoration and enhancement of forest ecosystem resilience and its adaptive capacities. The strategy makes clear reference to building on actions proposed in the EU Strategy on Adaption for Climate Change and the Green Paper on Forest Protection and Information in the EU.

Studies commissioned by the European Commission in the field of forest protection (2007-2012)

A series of studies were commissioned since 2006 by DG ENV and DG AGRI. Most of these projects were initiated within the frame of the EU Forest Action Plan and provide valuable conclusions on how to address forest protection and meet current and future challenges. They include:

- ”Feasibility study on means of combating forest dieback in the European Union” (Requardt et al., 2007)[10]
- “Impacts of Climate Change on European Forests and Options for Adaptation” (Lindner et al., 2008)[11]
- “Implementation of the EU Forestry Strategy: How to protect EU forests against harmful impacts” (Winkel et al., 2009)[12]
- “Destructive storms in European forests: past and forthcoming impacts” (Gardiner et al., 2010)[13]
- “Disturbances of EU forests caused by biotic agents” (BIO Intelligence Service, 2012)[14]

[10] http://ec.europa.eu/environment/forests/pdf/forestdieback_technical_report.pdf
[11] http://ec.europa.eu/agriculture/analysis/external/euro_forests/full_report_en.pdf
[12] http://ec.europa.eu/environment/forests/pdf/ifp_ecologic_report.pdf
[13] http://ec.europa.eu/environment/forests/pdf/STORMS%20Final_Report.pdf

1.3 Towards a European Forest Risk Facility

Already the first of the above-listed EU launched studies (Requardt et al., 2007; Lindner et al., 2008) expressed the need for a specialized *entity*, implementing and coordinating on behalf of the European Commission a common strategy in the field of risks to forests, while other studies, and the above illustrated European forest policy processes and documents, highlighted the need for improving pan-European coordination regarding the increasing exposure of European forest towards hazards.

Therefore, this report explores the rationale of a *European forest risk facility* and how it could provide added-value information and understanding on biotic and abiotic risks affecting European forests. It further addresses the role such an entity could play in supporting collaboration and coordination of relevant national bodies for developing joint actions and measures in order to prevent, mitigate and control forest disturbances and their corresponding risks.

The scoping study explores the potential added value a European Forest Risk Facility could provide in supporting policy development towards protecting European forest against natural hazards

The report takes advantage of on-going research and monitoring activities at European and national levels, as well as the existing expertise in research, management and practice with organizations, institutions and administrations.

This initiative may act as a potential vehicle to support European and EU policy processes which address the protection of forests against biotic and abiotic threats.

[14] http://ec.europa.eu/environment/forests/pdf/FBD_report_2012.pdf

2 Scope, Objectives and Services

Guy Landmann, Alexander Held, Christophe Orazio, Andreas Schuck, Jo Van Brusselen

2.1 Scope and Overall Objective

A facility should address all major risks to European forests: storms, wildfires, pests and diseases, drought, and high ungulate densities. The first three risks affect forests suddenly, while the two others act more insidiously.

Achieve added-value in terms of preventing and mitigating risks affecting European forests

The overall objective for a European forest risk facility would be to achieve added-value in terms of preventing and mitigating risks affecting European forests and thereby to enhance sustainable forest management in the long term.

Therefore a facility ought to aim to: increase risk awareness throughout society; and improve risk management which includes prevention, mitigation, control, and crisis management.

A European forest risk facility would need to build on and facilitate between existing expertise, knowledge, data and infrastructures at local, national and European levels.

2.2 A variety of potential services

A risk facility can be characterized as a coordination tool or a platform. It should implement different approaches in order to achieve its general objective. A facility would not be in charge of implementing research or monitoring activities, but it would stimulate risk-oriented syntheses and evaluations with the actors in charge of these activities.

The following text describes some of the potential modes of action or tools that may be implemented. Further thematic consultations within an initial risk facility development stage would be required to identify detailed demands, required products and services for each disturbance.

2.2.1 Information and communication on risks

Currently available information does not allow --for most types of risks and disturbances-- to give a sound and up-to-date picture of the risk situation of the forests and its evolution. It cannot adequately inform the general public and decision makers, and cannot be used to design management and policies for the longer term, or to quickly respond in times of disaster. Therefore a facility ought to aim to:

- support the collection of up-to-date and harmonized information on forest disturbances, related risks and damage;
- give added-value to pan-European information through e.g. early warning systems, immediate maps of affected areas, harmonized information on the environmental and socio-economic

impacts of forest hazards;

- provide relevant information in a timely fashion through adequate communication and dissemination channels for different target users (media and popular dissemination outlets);
- provide training and educational events, workshops, conferences and field trips tailored toward relevant target groups (forest owners, managers, policy makers);
- provide individual forest owners and forest professionals access to practical knowledge about strategies, tools and techniques to manage forests sustainably vis-à-vis forest disturbances.

An important aspect of the FRISK concept is the provision of tools that facilitate the access to relevant information in the field of crisis management. Two tools that are seen as promising are handbooks and literature repositories.

Handbooks are frequently used tools. To date handbooks in forest crisis management focus mostly on "overcoming the direct disturbance" (e.g. Stodafor Handbook, 2004[15]; Storm Handbook – Coping with Storm Damaged Timber, 2005[16]). In the past these handbooks were produced mostly as print versions, suffering from the problem of becoming rapidly outdated, especially concerning legal aspects or issues of topical interest. Thus a main task would be the production of online handbooks which cover all phases of risk management. First successful attempts of online handbooks have proved successful in Germany (see Textbox 1). Parts of the description and advice would be similar for other areas, and therefore a supranational approach offers promising synergies.

Collection of related literature (technical papers, textbooks): A structured literature database in which relevant e-textbooks and technical papers are made available online would be a valuable means to promote knowledge and information exchange for practitioners and between practitioners and scientists.

Text box 1. Role Models – PuMa Handbook on "Forest Crisis Management" (Susanne Kaulfuß, Christoph Hartebrodt, Forest Research Institute of Baden-Württemberg)

After the "Lothar" storm in 1999 it was recognized that there was a huge need for practice orientated guidance on how to deal with the storm's aftermath. The Storm Handbook, prepared in 2004 and 2005, helped many forest owners deal with storm damage in subsequent years. Due to the great demand for practice orientated knowledge, the increase in extreme weather events and the diversity of damage causing factors, the collaborative "Prevention and Management of Forest Crises" (PuMa) project was initiated in 2008. Through the collaboration of the state forest enterprises and administrations in Baden-Württemberg, Mecklenburg-Western Pomerania, North Rhine-Westphalia, Rhineland-Palatine, Saxony and Schleswig-Holstein as well as the Austrian Chamber of Agriculture, a "Forest Crisis Management" advisory guide was developed. Along with implementation and technically orientated recommendations on how to deal with forest damage, and preventative measures which can be taken before a damaging event occurs. This online handbook became the most visible result of the PuMa project. Besides storms, damage causing events such as wildfires, insects, droughts, floods, snow and new pests are on the topics

[15] Stodafor 2004. Technical Guide on Harvesting and Conservation of Storm Damaged Timber. QLK5-CT2001-00645 STODAFOR. 113 p. http://www.stodafor.org/

[16] Original article:Odenthal-Kahabka, J. (2005): Handreichung Sturmschadensbewältigung. Hrsg. Landesforstverwaltung Baden-Württemberg und Landesforsten Rheinland-Pfalz. Online version (English) 07.04.2009: http://www.waldwissen.net/waldwirtschaft/schaden/sturm_schnee_eis/fva_sturmhandbuch/index_EN

list. Issues to do with general crisis management and communication during emergencies are discussed too. Over time the pages of the advisory guide will be filled and the range of topics expanded. The advisory guide articles appear in the relevant sections of the forestknowledge.net and can be recognized by the advisory guide logo.

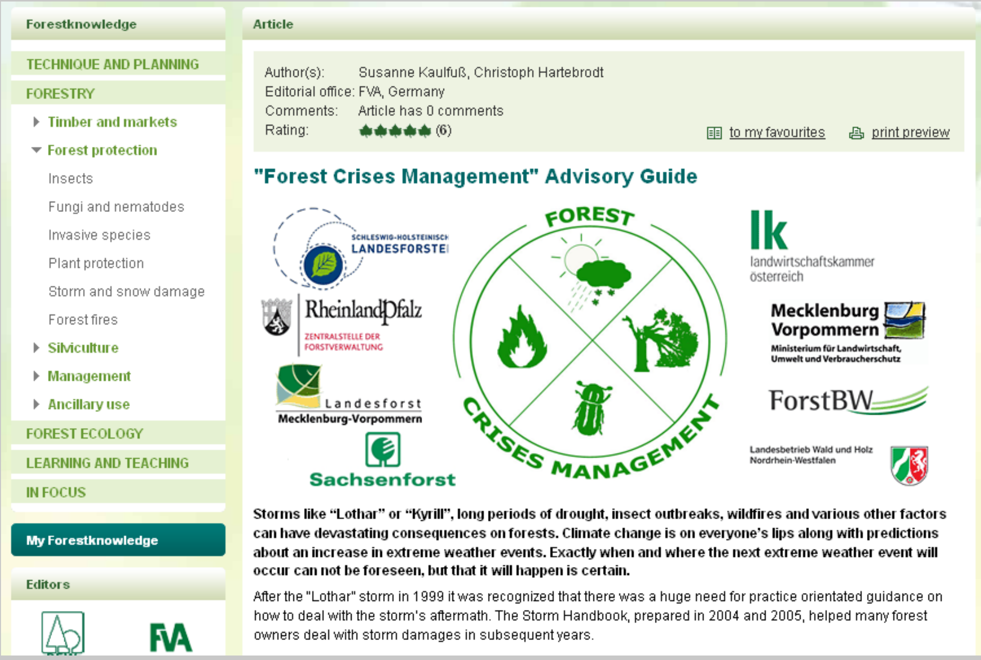

Figure 2. Front page of the Forest Crises Management Advisory Guide (available in English and German).
http://www.waldwissen.net/waldwirtschaft/schaden/fva_ratgeber_forstliches_krisenmanagement_startseite/index_EN

During the development of the handbook it became clear that general information can be combined easily with specific information, which are different in individual regions. Over time, and mostly driven by consultations, exchanges and training sessions an expert network came into existence in which a lot of information was exchanged even directly between the network members.

2.2.2 Risk analysis

Risk analysis has a prominent place within the risk management process which consists of: (1) risk analysis itself; (2) risk handling; and (3) risk control.

> A facility should help transferring research results into practice

Risk analysis itself includes risk identification where the major risk factors are detected, and risk evaluation in which the probabilities and amount of damage caused by different damaging agents are addressed.

Within this risk management process, FRISK could act as a platform on a European scale where information on hazards to European forests is gathered, categorized and distributed using a common protocol to facilitate risk handling and future research activities.

A risk facility could aim at creating synergies between different research groups dealing with risks to forests in Europe by facilitating data and model exchange, identifying research gaps and avoiding double research and thus contribute to a more efficient use of research funding. It could help transferring research results into practice and to preserve knowledge on hazards by organizing data storage and model exchange, and make data of local case studies on different risks available and facilitate the exchange between different research groups in Europe.

Furthermore, FRISK can be active in enhancing the process of integrating risk models into simulation models for forest growth (see Hanewinkel et al., 2011). At the moment, risk modellers and growth modellers often work independently from each other. There is a great potential to enhance the reliability of growth projections if major risks are included. There are already first examples of integrated growth models (see e.g. FORRISK project). A platform like FRISK can provide a long-term home for such project results and products and even ensure future funding of promising initiatives.

A facility could also aim to enhance the process of transferring the output of empirical investigations or modelling efforts into measures aiming at effectively reducing damage probabilities, by gathering and harmonizing best-practices to deal with a wide array of forest hazards.

In addition, FRISK could aim at enhancing the development of measures in support of risk transfer to insurance companies, by organizing the transformation of scientific output of risk projects to regional survival probabilities for different forest types in Europe and different hazards that can be used to develop risk premiums for insurance models.

Thus, through risk analysis, a better understanding of risks and disturbances is achieved through which policies as well as risk prevention and mitigation are improved.

2.2.3 Risk strategic planning

It is important to promote the strategic development and design of new policies, measures and instruments as well as amendments to already existing policies. The activities encompass, for example:

- developing a conceptual framework for addressing forest disturbances and their related consequences and risks;
- facilitating the design of contingency plans and stimulating know-how sharing;
- developing strategies for long-term risk mitigation in order to allow timely and efficient allocation of resources to confront risk;
- facilitating the incorporation of risk into forest policies and into management plans for decision makers and forest managers.

2.2.4 Crisis management

Practical experience of the past years shows that there is lack of applicable knowledge for forest managers in crisis situations. Even if accessible knowledge is available, a tremendous amount of "open" questions remains. Typically in the aftermath of a catastrophic event there is no time for intensive training or even reading. Thus a number of poorly informed decisions are made, resulting in waste of time and money. In addition, poor decisions negatively affect workplace safety.

Therefore a facility could aim to support its network during crisis in a manner complementary to emergency services. This requires capacity for emergency situations that are very specific:

- access to early warning system to anticipate the crisis at least shortly before it happens;
- efficient communication capacity to be able to collect information in all the countries affected by the catastrophic event even if their communication infrastructure is affected;
- contingency plans already prepared to take appropriate emergency measures;
- permanently available support system for crisis situation;
- quick access to relevant top-level experts or task forces that can support emergency and post-emergency response.

The implementation of early warning systems or the communication of existing early warning information can result in additional preparation time. Permanent risk monitoring and risk assessment teams are important components of such a system which can support the reduction of the post-disturbance monetary impact. Mass communication technology (SMS, MMS, recorded voice messages) could help on-time warning of authorities and public in endangered regions.

Finally, it is important to stress that forest risk management has up to now mostly focused on intervention, recondition and reconstruction, while proactive measures like vulnerability reduction and prevention are comparatively rare. The provision of risk-assessment teams that support administrations, forest enterprises and owners in establishing a risk management system will enhance the share of enterprises which start to cope better with natural (and also economic) disturbances. Analysing risk as well as analysing real incidents has to lead to proactive prevention measures in the long run. In the short term, risk management helps to increase preparedness levels and quality of response.

Extreme events such as storms, large fires, or pest and disease epidemics are not limited by borders; it is essential to coordinate existing national bodies involved in risk management.

FRISK could function as a gateway to a wide array of existing resources and activities belonging to various organizations and groups, taking advantage of collaboration, synergies and economies of scale. A network of European, national, local and private co-operators needs to be developed progressively. This network should be modular with the activation of modules depending on the situation and needs determined by the hazard. Needs exist at the forest risk managers level, but also at the scientific level, as research communities focused on risk are in general quite fragmented.

Within Europe the list of specialized institutions and organizations from research as well as management is long. To date there is a tremendous variation in cooperation on the national and also the supranational level. Exchange is sporadic and mostly limited to the scientific level.

There has been a lot of simultaneous work been done during the past years. It is apparent, however, that only a smaller part of the existing knowledge is already shared or at least known due to several reasons, where language barriers are just one to mention.

Text box 2. Potential network contributions by different types of partners

At a European level, there are trans-boundary tools already for extremely critical situation such as earthquakes, flooding and fire. Civil protection services already have protocols to share aerial support and emergency crews. For all issues related specifically to forests, a forest risk facility could provide support.

European regulation: A facility could support countries and the EU in the design of policies and procedures for emergency response measures such as a solidarity fund and derogative legislation not requiring negotiation case-by-case but activated after a certain level of damage. A facility could also support the Commission in establishing specific tools (insurance, funds) for forest risk management (insurance, funds).

The contribution of **national and European civil protection services** in the network could be for updating the damage assessment, providing experts to other countries and contributing to training sessions where they have specific skills. The use of the Incident Command System for international cooperation can be adapted to national systems. Lessons can also be learned in terms of procedures, protocols, insurances, etc. in the international exchange and cooperation, (the EU Exchange of Experts programme has already confirmed the will to cooperate with the FRISK initiative).

National forest administration and services: usually, they provide the first assessment of damage and support local stakeholders in the crisis management. The facility could provide access to additional temporary experts, check the best practices to make the best decision, advertise at European level the needs of countries affected by a major event, and improve their assessment methods. The facility could collect the good practices already in place, compile the data on events to characterize the risk, and map existing expertise to allow organization in other countries access the expertise when needed.

National forest inventories are already mobilized to assess the amount of damage affecting forest. They could contribute further together with research organizations to the definition and development of the more appropriate monitoring tools and contribute to data sharing. In exchange, they could access other countries' information for their own analyses.

National research organizations are required to provide up-to-date knowledge on risk monitoring, prevention and mitigation. They are key in reinforcing the scientific component of a facility in translating scientific knowledge, know-how and tools in a manner digestible and applicable to practical contexts.

National and regional training bodies: Professional training is provided by many types of organization (universities, fire services, etc.). All training organizations involved in topics related to forest risk management should be identified and approached in order to exchange best practices and share new findings. They could contribute to the development of European certificates or degrees.

National and regional bodies for forest risk management: in some regions there are already specific bodies dedicated to forest risk management. Some of them focus on monitoring, others on training or advising. In some cases they are already networked and should be considered as key partners for the European forest risk facility providing know-how and good practices to share between countries.

Existing monitoring tools and bodies that compile data on damage (such as JRC, ICP Forests, FOREST EUROPE,...) can benefit by the facility helping with outreach, communication and valorisation, and by the facility enabling more input from regional and national organizations through access to native language material and targeted analysis.

2.2.5 Capacity building

Professional exchanges between network partners can serve in speeding up the spread of best practices and risk awareness. The "fast-tracking of experience" through exchanges can help to build the required expertise and confidence for handling crisis situations quickly. An Exchange of Experts programme approach would take forest managers out of their comfort zone and expose them to more extreme scenarios. People grow with their tasks and come back home with boosted confidence and competence.

> "fast-tracking of experience" through exchanges can help to build the required expertise and confidence for handling crisis situations quickly

An approach could be to develop a unified "forest risk" training system, based on the "European Qualification Framework" (see Text box **3**) as an overarching vocational training reference system. The main objective of such an approach would be to bridge the existing weak exchange at the European level between the academic and professional communities in the fields of forest disturbances and forest risk and risk planning, and the gap between research findings and the application of research.

This could lead to the establishment of a European qualification "Forest Risk Manager" with various levels of competency based learning and a stimulation of continuous progression of development. The facility should be able to provide a general overview of who in the forest risk community is providing what kind of training. It would be important to establish a data- and knowledge-base of existing training and trained personnel, exchange programmes and visits for capacity building and capacity maintenance of the FRISK members and users.

Text box 3. European Qualification Framework EQF

The **European Qualifications Framework** (EQF) is a voluntary reference system designed to fit the multitude of qualifications across Europe into a coherent framework based on learning outcomes. The purpose of the EQF is to make qualifications more transparent and readable across sectors and countries. The EQF does this by setting qualifications into a series of reference levels (1 – 8), from basic to advanced. The eight reference levels are described in terms of learning outcomes, split into knowledge, skills and competence.
By July 2015, 25 countries had linked ('referenced') their national qualifications levels to the EQF.

The likely benefits of engagement with the EQF process are:

- improved matching of employers needs with qualifications across Europe;
- improved validation of informal learning, especially for individuals who have learned through extensive experience from work or other fields of activity;
- improved labour mobility between countries;
- to enable industries, like fire management, that are common to all EU countries to work towards common standards and qualifications.

More information about the EQF, in all EU languages, can be found at:
http://ec.europa.eu/education/lifelong-learning-policy/doc44_en.htm

3 State-of-the-Art on forest risks

3.1 Wildfire

Alexander Held, Marc Castellnou, Marco Conedera, Daniel Kraus, Cristina Montiel

3.1.1 Current situation and future developments/trends

In Europe, the last few decades have been characterized by dramatic land use changes. The abandonment of farmland and reduced grazing has led to an increase in forested areas, especially in the Mediterranean basin but also in mountainous areas. These changes in the landscape have contributed to the increased occurrence of large wildfires (FAO, 2007) such as those that occurred in Portugal in 2003 and in Galicia in 2006. This has increased the awareness of policy-makers and the public towards fires.

The reduction of low- and medium-intensity fire disturbances has, paradoxically, ensured the persistence of high-intensity wildfires: low- to medium-intensity fire disturbances have often been suppressed with the consequence of increasing fuel and fire hazards. As a result larger and more intensive wildfires with sometimes only limited chances for suppression or control are becoming more frequent.

In many ecosystems fire is an element that sooner or later will affect large parts of an area. With regard to fires, the role of forest management is to determine the degree of intensity and severity at which fire occurrence is accepted, and to carry out forest management over an entire region to create stand structures that are able to tolerate fire occurrence. In this context, the objectives change from prevention to reducing vulnerability of forest structure to wildfire and limiting the range of large wildfires.

> Most prevention strategies are based on facilitating improved capacities for firefighting. Creating a more fire resistant and long-term resilient landscape is meanwhile not high on the political agenda.

Most prevention strategies are based on facilitating improved capacities for firefighting. Meanwhile creating a more fire resistant and long-term resilient landscape is not usually high on the political agenda. This may be due to short-term political horizons, difficulties related to land ownership, legal frameworks, and in some regions an apparent increased success in fire suppression strategies. However, managing vegetation – be it forest, agricultural or fallow land – to prevent hot and intense fires is the only known way to prevent large and hot, unstoppable fires and to make these fire incidents less intense and safer to control.

Fire-prone conditions are predicted to strongly increase across Europe with climate change, and most studies suggest this will lead to a dramatic increase of area burned by the end of the century (IPCC, 2014; Flanningen et al., 2009).

3.1.2 Policy and governance context

Legislation and policies are key instruments for the introduction of innovative approaches and new recommendations. Development of effective instruments is a first step towards integrated wildland fire management in the context of sustainable forest and land use management. New policies and laws should allow firefighters and land managers to manage fire instead of only suppressing fire.

> The current trend of increasing land abandonment and land-use changes in many places in Europe leads to forests and other woodlands that are increasing in extent, fuel load and continuity, with very high densities of low-diameter trees, a situation inevitably developing towards large wildfire scenarios.

With respect to wildfire issues, forest legislation has been traditionally characterized as a punitive regime, rather than one that is motivating through incentives. There is a need for positive change within national legislation on this topic. A facility could help countries prepare such change, acknowledging that different countries are at different stages with regard to evolution of their forest policies and on the specific risk severity of wildfires. The existing multi-level governance structures in the European Union determine the competence distribution at different political and administrative levels in each country. The main policy instruments in relation to wildfires are the National and Regional Forest Programmes and specific plans concerning defence and protection against wildfires.

Meanwhile, however, the use of fire for forest management, wildfire prevention and wildfire suppression are hardly considered within the legislation of European countries. During the EU Fire Paradox project (2006-2010) a review was carried out of national and European legislation and policy instruments with reference to wildland, suppression and prescribed fires.

The European dimension of the fire issue, together with the diversity of situations in fire management and use, resulted in the recommendation of the Fire Paradox community that action would need to be taken under a global but flexible framework. A European Fire Framework Directive would ultimately help develop and reinforce e.g.: information systems (i.e. the European Forest Fire Information System, EFFIS) and intervention in emergency situations (i.e. MIC, Monitoring and Information Centre). Under the responsibility of the countries or regions there could be actions related to: evaluating risk and hazards (particularly in vulnerable wildland urban interfaces); developing fire management plans and using rural development programmes; and the restoration of areas degraded by damaging fire regimes, with all its defining elements.

3.1.3 What we know from research

Climate change is projected to increase the risk of large-scale wildfires throughout Europe. Such fires are usually caused by humans, whether accidentally or deliberately. Fire-prone conditions are predicted to increase across Europe, potentially leading to dramatic increases in area burned by the end of the century (Dury et al., 2011).

Figure **3** (Dury et al., 2011) illustrates the trend since the 1960s, forecasting into 2100:

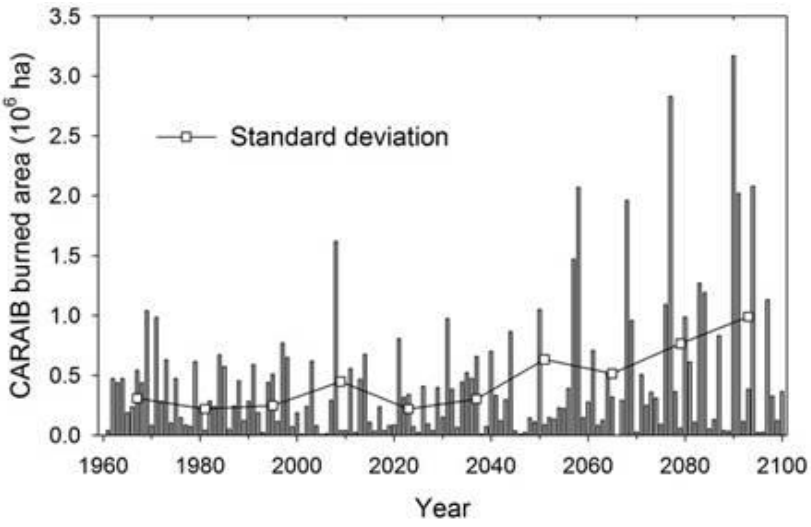

Figure 3. Forecast of Burned Area in Europe (Dury et al., 2011)

Other climate change impacts that could add damaged trees or dead wood to the forest fuel load (e.g., as a result of insect outbreaks, storms or high winds) may increase the risk of fire activity. While the effect of a changing climate on the development of large wildfires can be explained by the increasing occurrence of extreme weather episodes, it is the accumulation of vegetation fuels (i.e. biomass of an ecosystem that can be consumed by fire) that becomes the determining factor for the build-up of extreme fire behaviour. The increasing accumulation of fine fuels allows fast-moving fires to spread through the landscape with long distance spotting ahead of the fire front. The current trend of increasing land abandonment and land-use changes in many places in Europe leads to forests and other woodlands that are increasing in extent, fuel load and continuity, with very high densities of low-diameter trees, a situation inevitably developing towards large wildfire scenarios. Some areas, especially in the Mediterranean, observe a reverse trend of people moving from cities to the countryside. However, often the motivation for this move is to live in a green and peaceful rural setting, and not with the purpose of managing the land. The problem of fuel accumulation persists. Even more, where a population with an urban background is opposing land and fuel management for a lack of understanding of rural land management practices.

3.1.4 Monitoring and information availability

On a European scale, fire monitoring is provided by the Joint Research Centre (JRC) of the European Commission. Annual fire reports combine ground and remotely sensed data on area burned and number of fires. This can be considered the minimum common standard for fire monitoring and reporting. JRC is working on further developing its services to provide additional information on severity, impact, damage assessment, etc. to provide a more holistic view and understanding of the respective fire regimes. The European Forest Fire Information System (EFFIS) is described in more detail below.

Generally, the main task of a fire monitoring programme is providing basic data for characterizing regional fire regimes and possible fire regime shifts. Such information is a prerequisite for a targeted fire management approach aiming to adapt technical (e.g. firefighting facilities) and silvicultural activities, pre-suppression actions, and firefighting strategies. In view of the on-going global change, it is now even more important to collect information on forest fires, even in regions where fires at present rarely occur. The best and easiest way to characterize fire regimes is represented by the systematic collection of forest fire data based on a standardized protocol. Best should be such data collected for each wildfire event and provide a minimal catalogue of information, including geo-referenced data on fire origin and burned area perimeter, although there are difficulties in mapping surface fires under a forest canopy.

The facilitated collect-connect-exchange approach of a Risk Facility will create win-win situations both for the users and the system operators

Fire management - as with many other management activities concerned with the protection of people, property, and forest areas – is a complex task that implies additional important monitoring activities, e.g. knowledge on spatial distribution of the fire risk, probable fire effects, values-at-risk, level of forest protection required, cost of fire-related activities (structural and static factors), and on the evolving level of fire danger with time (short-term dynamic factors). Monitoring and mapping structural and very slowly changing factors such as hazardous fuel distribution, wildland-urban interface areas do not require frequent update of the data and can therefore be done in a reasonable time frame (e.g. every decade). Much more demanding in terms of time resolution is the monitoring of the dynamic factors such as the short-term evolution of the fuel moisture conditions and the related consequences in terms of ignition easiness and fire behaviour. Different approaches have been developed for estimating the current moisture of the different fuel components, ranging from direct weighing of wet and oven dry conditions of the fuel, to indirect estimation of the moisture content by empirically modelling the effects of the meteorological conditions on the fuel components (fire weather indices; e.g. Figure 4), to direct measurement of the moisture content by putting sensors in the correspondent fuel components.

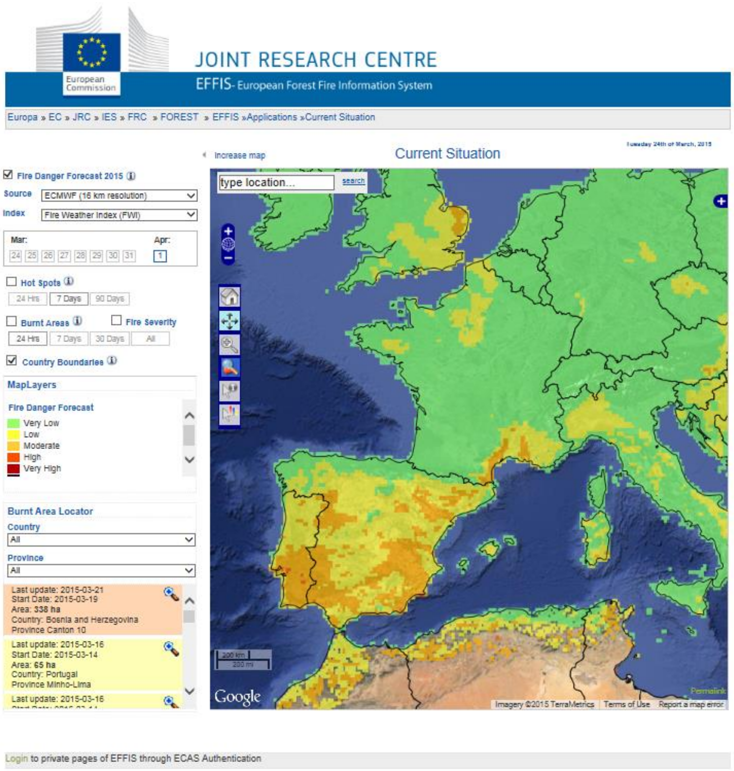

Figure 4. Example of a fire danger forecast on EC-JRC European Forest Fire Information System, which can be accessed via [http://forest.jrc.ec.europa.eu/effis.](http://forest.jrc.ec.europa.eu/effis)

There is certainly room for improvement. Monitoring outputs and products are often very useful for statistical purposes and for informing decision making on a political level. The operational side of fire management, however, does not use monitoring products to their full potential; this is partly because relevant information is not yet monitored. Of high interest in that regard is to monitor the changes that occur in hours or days, that can result in changing a 1 m flame fire into a crown fire. This change in fire behaviour may happen just because one type of fuel of a single species changed. That is what we need to monitor: what is driving the change of fire behaviour day by day, which is not dead fuel, but live fuel, about which not much is known.

Monitoring tools and services

The EFFIS has been established by the Joint Research Centre (JRC) and the Directorate General for Environment (DG ENV) of the EC to support the services in charge of the protection of forests against fires in the EU and neighbouring countries, and also to provide the EC services and the European Parliament with up-to-date and reliable information on forest fires in Europe.

EFFIS addresses forest fires in Europe in a comprehensive way, providing EU level assessments from pre-fire to post-fire phases, thus supporting fire prevention, preparedness, firefighting, and post-fire evaluations. Other than the on-line web-based system, a huge EU fire database is maintained within the EFFIS. Furthermore, annual reports on forest fires in Europe are produced. Along the main fire season (June to September), maps of forecasted fire danger are emailed daily to forest services and civil protection services of EU, fire statistics for the ongoing fire season are exchanged quarterly, and newsletters are issued monthly. In addition the EFFIS[17] team at JRC responds to ad hoc requests of specific assessments during major forest fire crisis in EU.

Similar systems are operational on other continents, such as the Canadian Wildland Fire Information System[18]. The products and services provided by such systems will play a vital role for the forest fire component within the envisaged Forest Risk Facility.

The European Forest Risk Facility aims to incorporate and use all existing initiatives for the benefits of their members and partners. It should be very clear that the Risk Facility is not intended to do things and provide services that other, often better equipped and qualified, institutions are already providing. Having systems like the EFFIS as a part of the facilitated collect-connect-exchange approach of a Risk Facility will create win-win situations both for the users and the system operators.

3.1.5 Practice

The professional fire management situation in Europe still has a rather low profile, when compared to fire management in Australia, Canada, South Africa and the USA. Nearly all countries in Europe have their own fire management organization, i.e. a fire service organization embedded in the civil protection sector with an attitude that mainly aims at improving technical fire detection and suppression measures. This symptomatic attitude is primarily effective in solving the acute fire problem of today when dealing with small and standard fire situations of 1st and 2nd generation[19] fire regimes (Castellnou, 2010), but is inexorably leading to an increased fire problem in the future: mainly low- to medium-intensity fires are controlled and their natural function in many ecosystems of clearing and removing burnable undergrowth is hindered. The vegetation keeps accumulating for large, unstoppable “megafires”.

Additionally, most European fire suppression strategies and tactics are centred on offensive direct attack and on enlarging the threshold of control of an organization. But all too often a fire service becomes overwhelmed with fire situations that are beyond this threshold of control and where initial attack is not successful anymore: fire control becomes impossible and fires develop into large wildfires or “Megafires”. It is these situations where there is no effective strategy for firefighting, management, nor is there landscape-level firefighting in place.

Land managers on the other hand are naturally mainly focused on their property or area and are therefore creating local strategies. Again, there is a lack of a comprehensive overview and guidance at the global landscape perspective, and fire ecology is often not the basis for decision making.

[17] http://forest.jrc.ec.europa.eu/effis
[18] http://cwfis.cfs.nrcan.gc.ca/home
[19] European landscapes have evolved at the pace of the socio-economic changes following the patterns of re-colonization of the cultivated land by wildland vegetation and responding to land use changes with their vegetation structure. The behaviour of wildfires has adapted to every evolutionary phase of the landscape. Costa et al. (2011) recognised as such 5 different generations of wildfires:

- 1st Generation Large Wildfires caused by Fuel Continuity
- 2nd Generation Large Wildfires caused by a high Rate of Spread
- 3rd Generation Large Wildfires caused by intensive crown fires
- 4th Generation Large Wildfires crossing the wildland-urban interface (WUI)
- 5th Generation Simultaneous Large Wildfires crossing the wildland-urban interface (WUI). Megafires

The potential spread of a wildfire is still not entirely predictable, but there is a series of tools that helps to reduce uncertainty. A key for the field of prevention in the conceptual design, planning and implementation of forest management measures (thinning, fuel reduction burning, prescribed understory burning, grazing) and infrastructure for controlling wildfires (firebreaks, forest roads) is the application of analytical tools to predict points in the landscape that have a multiplying effect on fire spread. On a landscape level planning this allows criteria for distribution of wildfire prevention and pre-suppression measures such as Strategic Management Points (SMPs), Management Priority Areas (MPAs), and access and water points. The SMPs and MPAs are identified to reduce the spread potential of large wildfires and establish opportunities for fire control and must be included in forest management planning in fire prone areas.

Prevention tends to be confused with and overlaps with preparedness or pre-firefighting measures. Management to reduce fire risk or fire behaviour that is beyond the threshold of control is not prevention in a strict sense; it is pre-suppression work. Fire prevention and mitigation in the true sense, and that does by far not exist, is ecosystem management on a landscape level that can change the fire regime itself. This will prevent fires developing into unstoppable and uncontrollable megafires. FRISK can work to support widespread adoption of this change and new landscape level approach.

3.1.6 Capacity building

In Europe there is only limited experience in dealing with the new challenge of so-called “megafires” as it is a relatively infrequent phenomenon. Large wildfire events occur only every 15 -35 years in the same areas, i.e. once or twice during the professional career of a firefighter. An institutionalized policy of learning from previous megafire events is often absent, and therefore it is difficult to accumulate experience and to maintain institutional memory, let alone let the wider community benefit from cross-institutional learning. Furthermore, fire management in almost all European countries is mandated to the civil protection sector, i.e. predominantly fire services. As a consequence, training on basic knowledge of forest fire ecology and forest fire behaviour plays a minor role compared with technical approaches to suppressing fires.

Knowledge and experience in fire management is something that takes many years for people to attain. Fire behaviour is complex and the theory needs to be understood but also observed and tested in real burning and fire suppression situations to allow a person to learn and gain confidence. However, competencies, training and equipment for fire control as well as the technical use of controlled fire are still not standardized, which hinders a European coordinated cooperation (Fire Paradox, 2010[20] and EuroFire, 2010[21]). The European Qualification Framework (EQF) provides a framework for standardized and comparable qualifications and competences that should be used for a European Fire Management Standard:

[20] http://www.fireparadox.org/
[21] http://www.euro-fire.eu/

A standardized system for the training of fire professionals, based on the "European Qualification Framework"

The main objective of this approach would be to bridge a gap that exists at the European level between the academic and professional fire-fighting communities, in the field of prescribed burning and integrated fire management planning. In the long-term, a handbook with integrated contents will be required for each level of training; the handbook will be produced as digital material to train groups of trainers from different countries within the same training system and to the same standards.

The standardized system of training for the fire professionals aims at working towards a common qualification system, based on the “European Qualification Framework”. It will be the first guidance step for organizations that want to include training for fire professionals in their courses. As large wildland fires are relatively infrequent events, the need to increase learning opportunities is realized. Therefore, it has been noted that there is an urgent need for experienced, well-trained, professionals to apply successful suppression fire operations (Fire Paradox, 2010).

There is currently a gap that at the European level, between the academic and professional firefighting communities in the field of prescribed burning and integrated fire management planning

There is currently no standardized system for the training of fire professionals. A deep knowledge of and experience with fire is a key issue so as to be capable of managing fires successfully and safely. For managing fires safely and successfully, a well-developed knowledge and experience base will be the key. Conversely, a standardized training system will attempt to:

- recommend a list of skills, competence and qualifications to be provided for each task/role;
- provide key-online training material, which will be specific to Europe;
- address past-experience during exchanges, including recognition of competence of fire managers.

In order to assemble all knowledge and competence required to use fire as a management tool, the Fire Paradox project was working on a recording system with recognized qualifications from different countries. For this purpose, specific digital training material was considered as important in Europe, and this could be in future created for training groups of trainers from various countries. Guidelines to create a network of persons for exchange of key information and mutual aid between fire managers could be established. Furthermore there is a need to define qualifications and standards of expertise for each training level within training programmes and also to develop the training material required for each level of expertise.

Figure 5. Standardized systems for the training of fire professionals. Source: Fire Paradox (http://www.fireparadox.org/)

3.1.7 Societal understanding and acceptance of risks

The concept of sustainable forest management originated in France, Germany and England in times of extreme shortage of timber supply in the 17th, 18th and 19th centuries. The traditional approach in European silvicultural thinking was focused on maximizing timber production. The approach wanted to eradicate the influence of fire as a forest disturbance, with disregard to the role of fire in the forest ecosystem cycle.

Due to this history and the focus on production as the primary forest function, disturbances such as, wind throw, bark beetles, fire etc., have been regarded as external factors disrupting the smooth running of timber production. This view has been embedded in decades of forestry education and consequently reached out to the general public. In general there is a resistance to the idea of accepting fire as a natural part of the forest ecosystem, or even using controlled fire for prevention and ecosystem management on a landscape level.

Only recently has this view been challenged, and there has been a gradual change in understanding and acceptance that disturbances are an integral part of forest ecosystems. This approach also allows research into the economic and ecological advantages and opportunities of disturbance, and into what levels of disturbance are not acceptable and how to prevent that disturbance. Only very few EU projects (e.g. Fire Paradox, 2010, Firefficient, 2015[22]) so far have investigated the economic and ecological opportunities of fire prevention.

Especially with regard to fire management, the change of mind-set will require a long and actively managed awareness raising process.

[22] http://firefficient.ctfc.cat/

3.1.8 Identification of gaps and needs for action

Research gaps

Traditionally, the majority of fire research has been aimed at understanding fire behaviour to support better decision making in fire control. Most EU calls are generally focused on reacting to the actual problem. The actual problem is just a part of a fire generation evolution and change of fire regime that are the result of decades of fire management and land management practices and policies aimed at fire control and suppression. For the most part, fire spread models, fire weather indices, fire danger calculations and fire monitoring and analysis only support the fire control and suppression approaches. Present research continues to focus on the control and suppression of large wildfires, or megafires, which are beyond the threshold of control of any firefighting force worldwide. Recent projects like EuroFire and Fire Paradox have started to move in a new direction, where the use of controlled fire as a prevention tool has played a significant role.

A facility to help manage large intensive fires before they occur

As today's society becomes more and more detached and unconnected to rural land management and at the same time as vulnerability of society increases, new fire management research is needed. The tendency of fire policies to be made within an urban environment surely does not help to improve rural fire management. Policy has become increasingly more informed regarding details and facts of fire management in general, but their understanding and comprehension of the complex fire issues in rural areas has not kept pace.

The use of controlled fire as a prevention tool

New research should be aimed at studying the effects of climate change on fire activity, and at investigating adaptation strategies and options to deal with future fire occurrence. There is growing consensus that as wildfire activity increases, fire agency suppression efforts will be increasingly strained. The objective and aim of fire research should be focused on prevention of fires through science-based land management, especially in the forest sector.

Shortcomings in Management

Prevention, early warning, adequate response and mitigation of damage will need more awareness and professional approaches in the future.

Fire services across Europe mostly work independently from one another and a European approach to fire management that would include the land-based sector does not exist. Such an organization could focus on prevention and provide leadership and guidance for an integrated common approach in fire management. Land owners and especially fire services within the civil protection environment will need to be made to understand that not all fires have to be suppressed, as long as they are burning within the prescriptions to meet the objective of creating a more resilient landscape. This will require a long-term approach to capacity development with the aim to maintain and manage a fire regime instead of a one-dimensional "never-no-fire" strategy. Once fire regimes are actively changed and adapted, the type of fire and fire scenarios can be actively changed, and the megafires can be avoided. Ignoring the underlying fire ecology would be a recipe for failure.

3.1.9 What FRISK could provide?

The role of land management, and forestry especially, in managing large intense fires before they occur will need to be strengthened through the European Forest Risk Facility. Research, operational management, capacity building and establishing a network for learning lessons from events will form core activities of the facility. The facility can be the tool to maintain steady progress in the right direction, and avoid piecemeal responses to singular fire events. It can ensure the work we do is on track to maintain right fire regime and create fire resistant and more resilient landscape.

A facility can serve the fire management community in:

- being a single independent organization to provide leadership and advice in vegetation fire management in Europe;
- providing a greatly expanded programme of fuel reduction measures to minimize the threat of fires in and around homes, farms and settlements, national parks, forests and water catchments to minimize the risk of late-fire-season infernos;
- providing a commitment and action from the state governments and local governments to protect rural communities from vegetation fire damage, and to promote and enforce appropriate fire legislation;
- providing schools and communities with education in fire science, prevention, resistance and safety, and the impacts of fires and fuel reduction tools;
- providing leadership and sound fire management to start at the top, and making sure that governments are accountable for achieving this.

A European Forest Risk Facility could actively influence the future fire management in Europe, by means of e.g. the following activities:

- provide guidance and leadership towards a stable and sustainable solution for the developing fire situation;
- work towards ensuring that no urgent quick-fix solutions are applied and advise on how to spend budgets more efficiently;
- support targeted research to focus on the key questions related to the understanding of fire ecology and fire regimes across Europe and assist with this knowledge to solve fire management questions;
- provide a platform that represents all stakeholders, from land owners and managers to firefighters, the general public and even (fire affected) tourists.

The European Forest Risk Facility and its members can advise on national and even European budget planning and spending to make available funding more effective. A broad view of fire regimes, fire ecology and fire experience is needed to create a clear strategy for the next 25 years. The added value is that a stronger land-based sector involvement in fire management issues, will increase independence from civil protection sector and at the same time greatly support the civil protection sector in wildfire management. The facility can provide guidance for prevention work based on fire ecology and based on long-term planning for future challenges, creating resilient forests for future generations.

3.2 Storms

Barry Gardiner

3.2.1 Current situation and future developments/trends

Storm damage is responsible for more than half of all damage by volume to European forests and individual storms can affect large areas of forest and many countries (Gardiner et al., 2010). There is also evidence of an increasing trend in damage levels (Schelhaas et al., 2003; Schelhaas, 2008). Part of this increase is due to greater levels of standing volume in European forests, but there is also an apparent increase due to the changing climate (Seidl et al., 2011). Forecasting developments for the rest of the century is extremely difficult but the indications are that damage levels will continue to increase. This is due to two main factors; (1) storm intensities are forecast to increase and to affect central and northern Europe and to penetrate to areas of eastern Europe previously little affected (Della-Marta and Pinto, 2009; Fink et al., 2009); and (2) warmer winters will mean a shorter period of frozen soils in northern Europe making the forests of Fenno-Scandia much more prone to wind blow during winter storms.

Storm damage is responsible for more than half of all damage by volume to European forests

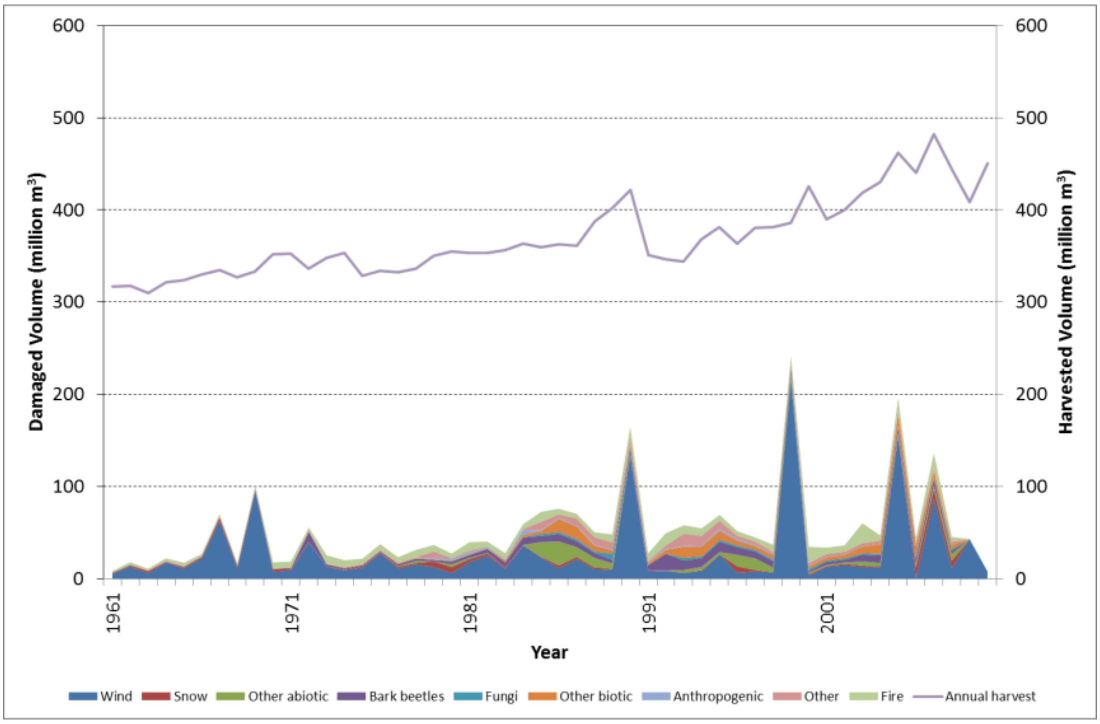

Figure 6. Volume of damage to European forests according to different hazards together with total harvested timber volume (after Schelhaas, 2008).

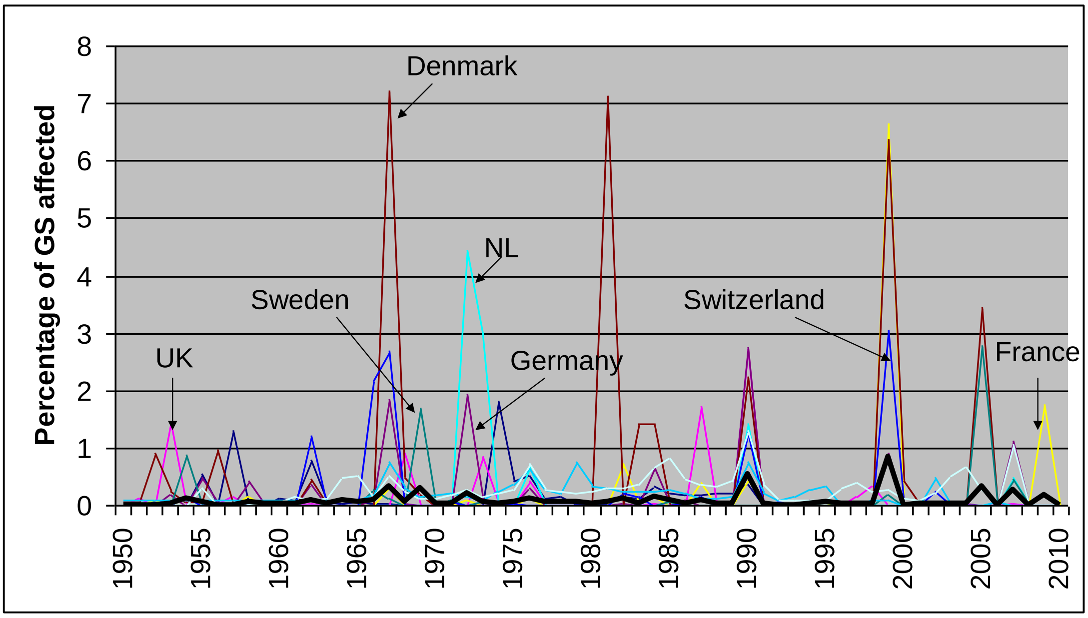

Figure 7. Storm damage as percentage of growing stock (GS) for different countries (adapted from Schelhaas, 2008).

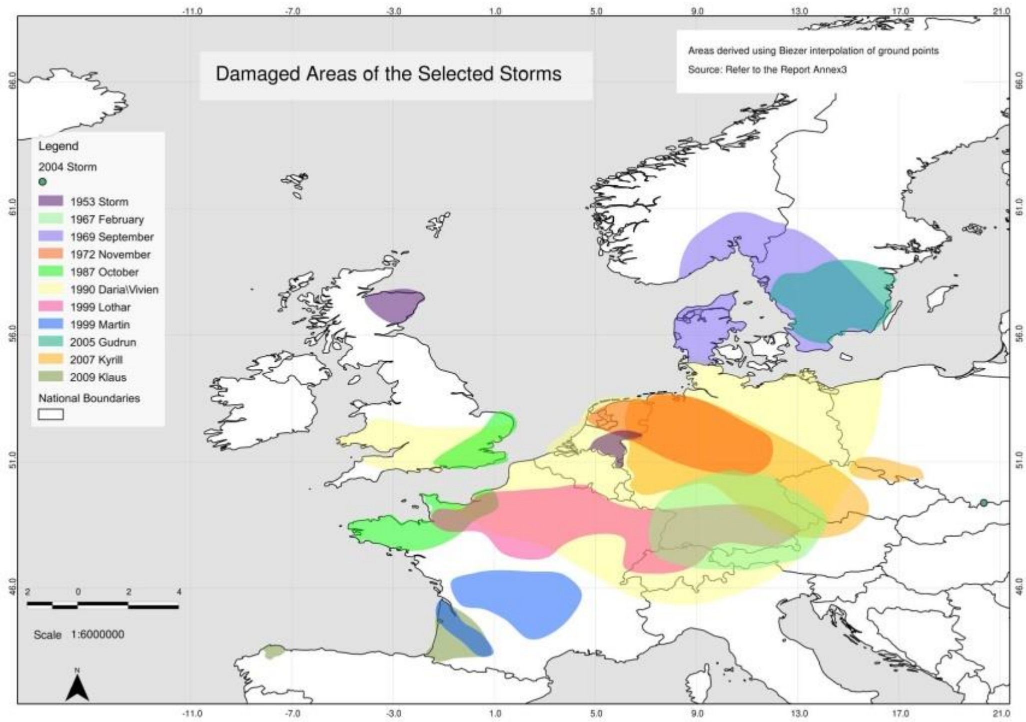

Figure 8. Estimated areas in Europe affected by major storms (Gardiner et al., 2010).

Despite the high levels of research into the factors controlling wind damage this research has been sporadic and generally poorly coordinated either at a European or global level. The first international conference on wind damage to trees organized by IUFRO was held in 1993 and has continued at approximately 3-yearly intervals and has provided one of the very few forums for international exchange of knowledge. Following the extremely severe storms of December 1999 that badly affected western and central Europe, causing more than 200 million m^3 damage (Gardiner et al., 2010), there was an upsurge in research interest particularly in Germany, Switzerland and France (e.g. Birot et al., 2009), but as time has passed that effort has diminished.

A particular difficulty with storm damage is that at any one location it is generally rare but when it occurs it can have a catastrophic impact on the forest. Therefore it is very easy for approaches to wind damage to be either very pessimistic and to believe radical action is required if there is experience of a very recent storm, or to perceive that there is no problem with wind damage and no requirement to incorporate wind damage into management plans if there has been no damage for many years. Finding a balanced middle ground in which wind damage is regarded as a natural disturbance affecting forests and which requires active and continuous management is a difficult task.

3.2.2 Policy and governance context

Some countries, particularly in central Europe, have established policies for helping to regenerate forests after wind damage but all countries respond with measures to assist forest owners following large-scale damage (Gardiner et al., 2010). Many of these policies are associated with obligations to maintain forest cover and to ensure the health of forests. However, no country in Europe has established policies for managing the risk of wind damage in all forests and for ensuring forest owners and managers comply with established guidelines. Only in the United Kingdom is there implemented policy on managing forests against wind damage and this is only within the public forest estate. This policy is based on the repetitive wind damage experienced in the United Kingdom and is predominately focused on ensuring forests are felled close to the age at which they reach "terminal height"[23] and that thinning is restricted on the windiest sites.

The highly intermittent nature of wind damage means it is difficult to persuade people of the wisdom of a policy to reduce wind damage that may only demonstrate its value once every 50 to 100 years. Furthermore, there has never been a systematic analysis of the long-term economic impact of storm damage although there is known to be quite acute short-term disruption to prices following severe storms (Statistisches Bundesamt, 2012). The policy implementation that has taken place in the UK and Ireland is only as a direct result of the relatively high levels of endemic damage that occurs every year because of the extreme wind climate of those countries relative to other parts of Europe.

It is difficult to persuade people of the wisdom of a policy that may only demonstrate its value once every 50 to 100 years

[23] Height at which wind damage is predicted to be initiated (Miller, 1985).

3.2.3 What we know from research

Systematic research on wind damage to forests has been carried out since the 1960s. The key factors controlling wind damage to forests were established at that time and remain relevant (Fraser, 1964; Gardiner et al., 2013). Research has focused on two approaches: the first has been to carry out statistical analysis of actual wind damage to determine the key factors controlling the vulnerability of forests; and the second, more recent, approach has been to develop a mechanistic understanding of the damage process including understanding the impact of forest structure and topography on the wind flow in storms (Brunet et al., 2009 and Dupont et al., 2008).

Wind damage increases with increasing tree height, recent thinning and waterlogged soils

Statistical analysis of actual wind damage has proven difficult because of the rarity of wind damage events. In addition there needs to be high quality inventory information from before and after the storm. Such data was available, for example, in France and Germany after the 1999 storms and has proved valuable in determining some of the key factors controlling the probability of wind damage in forests (e.g. Albrecht et al., 2012; Colin et al., 2009). The clearest evidence to date is that wind damage increases with increasing tree height, recent thinning and waterlogged soils. There appear to be some species differences, but the evidence can often be contradictory. Evidence for the benefits of different silvicultural systems is also difficult to determine unequivocally although recently there has been some evidence of benefits from planting more stable tree species (Valinger and Fridman, 2011).

The earliest experimental work on understanding the mechanics of wind damage was carried out in the 1960s and involved winching over trees. The experiments were designed to determine the wind speeds required to damage trees and involved measuring the forces and moments required to pull trees over in the forest as a function of species, size, soil type and cultivation (Nicoll et al., 2006). In addition measurements were made in whole trees in wind tunnels to determine the wind load on trees as a function of wind speed. One of the most important points coming from these experiments was that a purely static analysis of the wind speeds required to blow down or break forest trees gives wind speeds much greater than are measured during damaging storms. Wind loading on trees is an inherently dynamic process with wind loads due to gusts up to 10 times higher than due to the mean wind speed alone, and therefore the gusting nature of the wind is a key factor resulting in wind damage (James et al., 2006). Gusting winds can also lead to fatiguing over the winter in which the tree resistance to uprooting declines until the tree is able to restore broken roots as it grows again in the spring.

Other experiments were designed to understand the impact of forest edges and thinning on the location and level of damage. This was based on observations indicating that damage often occurred a few tree heights back from established edges and that the thinning and the creation of new edges often led to higher levels of damage (Sommervile, 1989; **Error! Reference source not found.**) uggesting that trees already exposed to the wind were acclimated and less at risk. In addition the impact of topography was studied initially through wind tunnel physical models and more recently through computer airflow models (Dupont et al., 2008).

Figure 9 Wind damage inside a stand of Sitka spruce with a long established edge (Cumbria, North-west England). Note that the edge trees are undamaged. (Photo: Graeme Prest, Forestry Commission, United Kingdom).

There are currently two wind damage risk models (ForestGALES and HWIND) available in Europe (Gardiner et al., 2008, Hale et al., 2015). These models have been used for mapping wind damage risk at local, regional and national level and even at European level (Figure 10). They are also used as management tools for forest planning. By integrating the models with GIS it is possible to build spatial planning tools that can help manage wind risk within a forest while at the same time ensuring key forest services are maintained. These tools can also be useful to look at the impacts of climate change and how adaptive forest management can reduce the levels of wind risk over the rotation length of the forest.

Although we have much more sophisticated tools and measurement techniques available there is still a large amount of uncertainty about the exact process of wind damage. Much of this is due to the difficulties of making measurements on wind damage during damaging storms and the large variability in forests due to changes in soils, water tables, topography, forest structure, etc. In addition the stochastic nature of the wind field during a storm and the exact nature of the flow above and within the forest canopy makes the possibility of predicting in which exact forest location damage will occur impossibly difficult at present. This helps to explain why statistical analysis sometimes finds it so difficult to determine exactly which factors are significant in determining forest damage unless the data sets are very large so that this variability does not dominate the analysis.

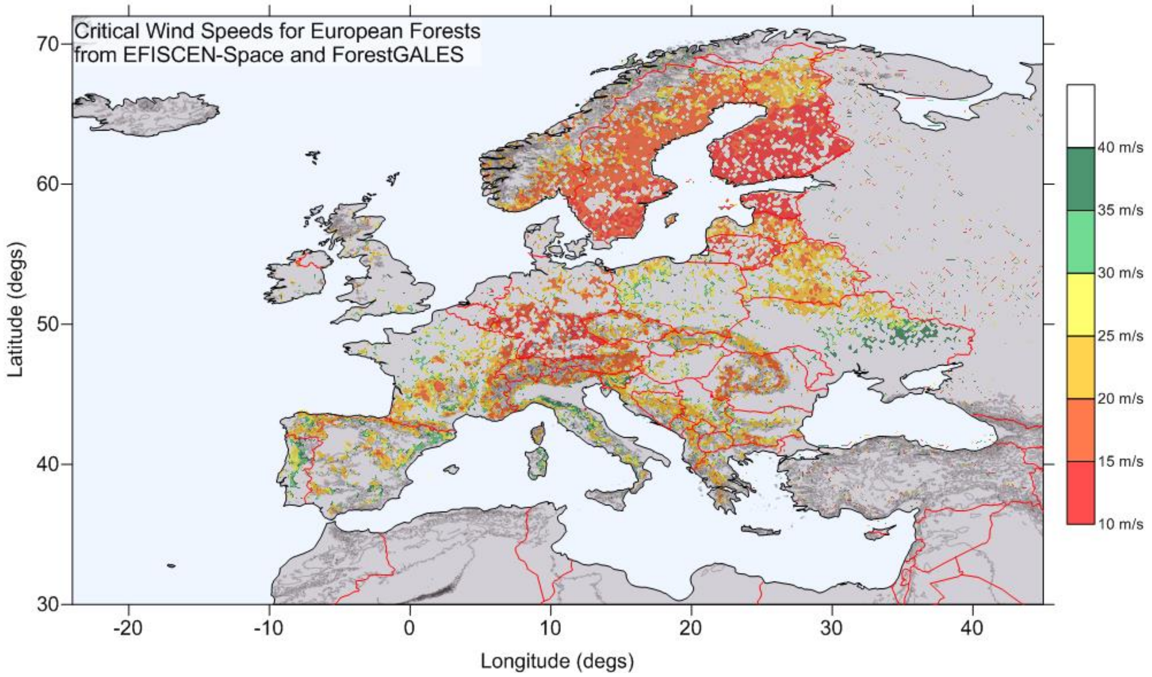

Figure 10: Preliminary calculation of critical wind speeds for all European forests (only areas with >10% forest cover shown). From Gardiner et al. (2012).

3.2.4 Monitoring and information availability (Control)

In general, forests are not monitored for wind damage although such schemes have operated in the past in a number of countries, generally through paper-based reporting systems. The best monitoring of wind damage usually comes from national forest inventories that are revisited immediately after storm damage has occurred and such data have been gathered after severe storms in a number of countries (Albrecht et al., 2012; Kamimura et al., 2015). In the past remote sensing has not had high enough resolution to show wind damage except at the scale of hectares or has been hindered by the short duration of the day and often cloudy weather that occurs during periods of winter storms. However, modern remote sensing instruments including new generations of optical satellites (e.g. QuickBird, IKONOS, WorldView) and airborne and satellite LiDAR (e.g. ICESat) are able to provide extraordinary levels of detail down to individual trees. Such data can be used to not only monitor damage but also as the input data for predictive models that could calculate risk levels at the European scale, potentially down to individual trees. If such data and risk models were coupled with growth models and national inventories it would be possible to provide wind risk maps across Europe updated on an annual basis. An example of such a possible map is shown in Figure 10. Such information could be used to trigger area-specific early warnings when wind levels are predicted to be higher than the critical wind speeds for trees (with JRC).

Past experience has shown that it is particularly important to conduct monitoring as quickly as possible after a damaging event. Such data are very important for assessing the level of damage and the response required. This effort could be aided by European level remote sensing that is constantly updating forest maps and would be able to show changes in the forest status following a storm.

3.2.5 Practice

Mitigation strategies can take two forms:

- direct mitigation is when the management of the forest is changed or various management practices are put in place in order to reduce the risk to acceptable levels;
- indirect mitigation is by sharing the risk with others through, for example, insurance schemes.

Both types of approach require good risk models in order to determine whether mitigation is possible, what are the impacts of different management strategies, and for carrying out cost–benefit analyses. Unless there is an assessment of risk one can neither calculate whether risk mitigation is possible or necessary, nor the level of insurance that would be required. Such models are available (see section above) but much more needs to be done to fully test these models across Europe and to make sure that their predictions are robust.

Good practice is rarely shared between countries and often only available in the language of the

There are many examples of how to reduce the risk of wind damage (keeping drains clear, avoiding contour ploughing, ploughing in the direction of the prevailing wind, not thinning too heavily, minimizing gap creation, avoiding creating new edges on the side of the prevailing wind, choosing the appropriate species for the site, reducing the rotation length, ensuring a mix of ages and species, etc.). Such knowledge has been made available in a number of publications (e.g. Quine et al., 1995; Jactel et al., 2009; Grigaut et al., 2010) but is often not taken into account or appears to become forgotten. The reasons for this are two-fold: (1) the primary goal of forest managers is not risk management but is usually something else such as maximizing volume production; and (2) there is a perception that it is not possible to reduce the risk of wind damage and that wind damage is a random event for which it is not possible to plan.

3.2.6 Capacity building

In general the response of all countries is similar. Following severe storms there is an effort to increase capacity to deal with storm damage and there is an increase in efforts to understand the problem and to provide advice to the sector. However, inevitably this effort then gradually declines with time and often there is little updating of information and the information and knowledge becomes out-of-date.

Furthermore, good practice is rarely shared between countries and is often only available in the language of the originating country. This means that techniques and methods that have been successfully developed in one country are often not known to other countries and everything has to be rediscovered and redeveloped. Although, there are some excellent examples of knowledge platforms (see German and French web-sites examples in Figure 11) there is no European-level platform with information available in the languages of other member states.

There also appears to be a lack of teaching of risk management as an integral part of forest management in colleges and universities. This means that generations of forest managers and policy makers are growing up with little idea of how to manage risk within their forests. This is despite the huge amount of knowledge that is available on how to reduce the risk of damage and how to respond to a damaging event.

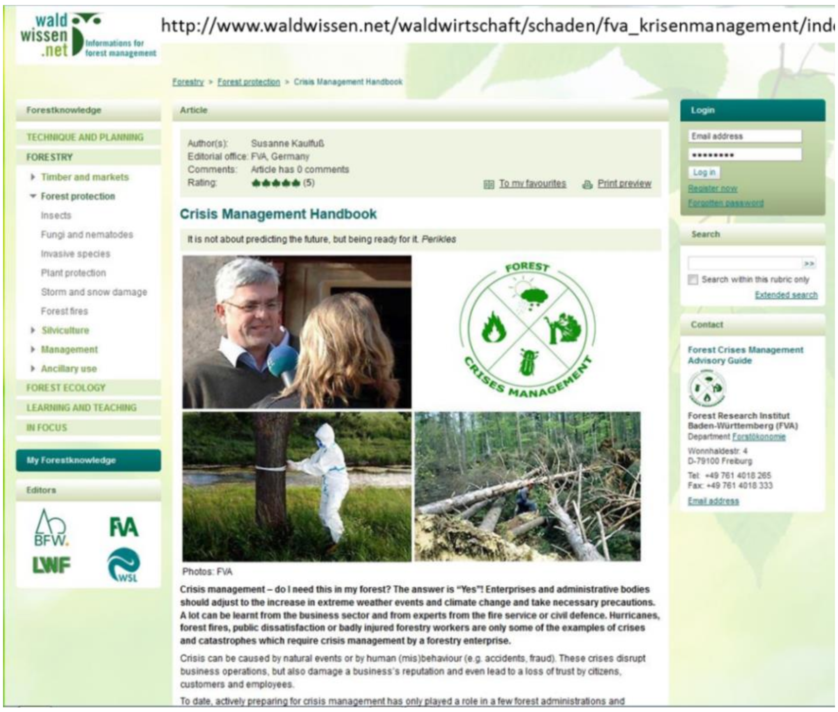

Figure 11. Examples of Web advisory pages on dealing with storms.

3.2.7 Societal understanding and acceptance of risks

Understanding of wind risk to forests is extremely variable and depends very much on how an individual values the forest and their personal experience. So far there has been little systematic use of risk assessment tools to help individuals (managers, owners, policy makers, etc.) make informed decisions about the level of risk their forest is exposed to. Much of the reason for this is probably due to perceptions of risk based on personal experience and belief in what can be controlled. We are only just beginning to understand human risk perception in forestry (Blennow, 2008; Gardiner et al., 2013) and until we have a better understanding of this subject it is extremely difficult to know the best way to encourage managers to implement risk mitigation plans. There is also a need to link this work with the way in which the insurance sector evaluate risk in order that realistic systems can be put in place for insuring European forests against the risk of wind damage.

Need to work towards realistic systems for insuring European forests against wind damage

3.2.8 Identification of gaps and needs for action

Over the last two decades there has been a rapid increase in understanding of the process of wind damage in forests and the nature of the interaction between the atmosphere and the forest canopy. However, because the problem is extremely complex and so many factors are potentially important it is still extremely difficult to give precise advice on the best ways to manage forests or to predict the exact level of wind risk.

A number of outstanding issues remain to be addressed:

- There is little knowledge of wind risk to broadleaves – for example, to date, there has been no systematic tree pulling on broadleaves or measurement of wind loading during strong winds.
- There are no risk models currently for silvicultural systems other than clearcut/replant. This means that just at the moment it is difficult to evaluate the benefits of different silvicultural systems.
- Predicting risk distributions within individual forest management units is not currently possible. At present an overall risk of damage to forest stands (typically a few hectares) is provided, but generally managers want to know the risk of different levels of damage within their management units (e.g. 10%, 20%, 40 % >50%).
- Predicting airflow over complex forested terrain is extremely difficult to do without recourse to very sophisticated airflow models such as Large Eddy Simulation (LES). However, these models are not practical tools for forest management because they require a huge effort to set up, sophisticated computer systems to run and large amounts of time (e.g. days) to complete calculations. Reliable models that are relatively quick to set up and run are urgently needed.
- There are very few measurements during actual damaging storms. At present the

assumption is made that measurements made at lower wind speeds can be directly scaled-up to provide estimates of wind loading on trees at the wind speeds that cause damage. However, there is evidence that the wind structure during severe storms is different to the wind structure at lower speeds and the loading on trees may be more severe than predicted.

- The capacity of trees to acclimate to their wind environment needs to be better understood. In particular how quickly they adjust to changes in wind loading after disturbance is not known and is probably a function of many factors including species and growth rate. Such knowledge is needed to know how quickly trees acclimate following road construction, thinning, nearby clear felling, adjacent forest damage, etc.
- Current and future wind climate over Europe at the required spatial scale (~1km) is not available and does not properly account for the presence of forest and the impact of topography. In order to make predictions of wind risk across Europe a much better assessment of the European wind climate at fine scale is needed.
- Clarifying our knowledge of forest crisis management is urgently required. We need to show people what works, what doesn't work, how we can make improvements to the way we deal with the aftermath of storms, and the economic and political decisions required.
- Develop response systems to be initiated when storms capable of severe damage are predicted. Such systems would be based on pre-planned responses by emergency services, regional bodies and forest services in order to be ready to respond both directly to the damage (clearing roads, re-establishing power, etc.) and to trigger financial and regulatory responses in order to be well positioned to quickly start restoration of the forest-based sector after the storm.
- An improved understanding of risk perception by key stakeholders is absolutely essential if mitigation plans and crisis response plans (e.g. the new Scottish Windblow Contingency Plan 2014 (Forestry Commission Scotland, 2014)) are to be successfully implemented. Such work needs to use a systems approach that sees the forest as part of a bigger societal structure in order to better understand how society responds to severe storm damage.

Improved understanding of risk perception by stakeholders is essential

3.2.9 What FRISK could provide

Depending on priorities and available means, a facility could serve the storm damage management community in promoting/providing/assisting professionals and managers as part of the main objectives of the Facility:

Understanding

- promote risk assessment by developing generic models of risk prediction shared across Europe;
- develop storm risk models for alternative silvicultural systems and broadleaf species;
- improve knowledge of wind speeds over forests during severe storms;
- provide unbiased and harmonized estimation of the damage and impact of storms on the economics of the forestry–wood sector in EU;
- support EU wind risk mapping (probability of return of critical wind speeds);
- support comparative analysis to understand economic consequences of political choices.

Informing

- act as a European centre to provide dedicated information related to storm damage to forests (e.g. forest inventory data, damage maps, levels and areas of damage, size and species mix, market conditions, etc.);
- guarantee harmonized monitoring of storm damage to forests and in particular directly after a storm event that can provide practitioners and planners with up-to-date information (with JRC);
- help coordinate early warning systems.

Strategic planning

- promote a European-wide programme of storm reduction measures to minimize the threats from large storms;
- develop a commitment and actions from state and local Governments to promote and enforce appropriate legislation on storm risk management for forests;
- support state and EU in the design of policies for emergency measures such as a solidarity fund and derogative legislation not requiring negotiation case-by-case but activated after a certain level of damage.

Capacity building and networking

- promote the exchange of professionals and researchers within partner states and within Europe;
- encourage shared experiences on risk prediction, data processing, risk analysis, forest management and mitigation;

- make available tools to monitor damage and assess risk in all partner countries;
- promote the exchange of best practice guidance between different regions of Europe;
- promote international exchanges with professionals outside of Europe with experience in forest wind damage;
- provide guidance and advise in forest risk management at stand and forest levels.

Supporting

- provide guidance and advise in integrated storm management in Europe based on expert knowledge and scientific knowledge;
- provide rapid assistance on appropriate actions in the case of national or supranational storm disaster;
- help coordinate existing national and regional networks of experts able to offer practical and operational support to European countries affected by storm damage.

Communication

- develop enhanced communication related to storm risk at all levels (local, regional, national, supranational);
- provide information to the relevant authorities for dissemination to the public and other interested parties in the period following storm damage.

3.3 Pest, Insects and Diseases

Margot Régolini, Hervé Jactel, Guy Landmann and Christophe Orazio

3.3.1 Current situation and future developments/trends

Forests in good health are essential to sustain wood production and other ecosystem services. Yet forests are exposed to a large number of threats that can cause tree growth loss and mortality, wood quality degradation as well as reduce amenity value of forest landscapes. They may also alter ecological functions of forest, such as soil protection against erosion, carbon stock, water retention, plant and animal diversity. Forest health and vitality is therefore considered as one of the main criteria for sustainable forest management (e.g. MCPFE, 2002). This chapter will focus on the main biotic hazards, i.e. pests and diseases affecting forests. Among the important sources of information is a recent report on biotic agents in European forests published by the European Commission called "Disturbances of EU Forests caused by biotic agents" (BIO Intelligence Service, 2012).The five most damaging biotic agents in Europe (Table 1) are the European spruce bark beetle (*Ips typographus)*, the common pine shoot beetle (*Tomicus piniperda)*, the European pine sawfly (*Neodiprion sertifer)*, Dutch elm disease (*Ophiostoma novo-ulmi*), and the recently introduced pine wood nematode (*Bursaphelenchus xylophilus)*. *O. novo-ulmi* and *B. xylophilus* are alien species.

A number of other agents cause severe damage in more or less large areas in Europe. Among the 30 most damaging biotic agents (see Annex 1), there are 15 fungi, 12 insects, a nematode and a bacterium. Of these 30 species, 16 are alien (BIO Intelligence Service, 2012).

Though the number of damaging biotic factors is extremely small compared to the diversity of insects and fungi in the forest ecosystems, there are quite different levels of knowledge on biotic risks: new alien agents (such as the pine wood nematode), or agents that were not harmful in the past but represent a risk now (such as *Monochamus*, which does not damage directly wood but is a nematode vector) are not yet well-known, while there is more knowledge on native, common and agents that have caused significant damage in the past.

Table 1. The five most damaging biotic agents at European scale (BIO Intelligence Service, 2012).

Common and	Taxon	Native or Alien	Type of disturbanc	Species impacted	Distribution in EU27
Dutch elm disease *Ophiostoma novo-ulmi*	Fungus	Alien (1)	Disease	Elm *Ulmus* spp.	AT, BE, BG, CZ, DK, EE, FR, DE, EL, HU, IT, LT, NL, PL, ES, RO, SE, SK, UK
Pine wood nematode *Bursaphelenchu*	Nematode	Alien	Disease	Pine *Pinus* spp.	PT and 2 outbreaks in ES under eradication
European spruce bark beetle *Ips typographus*	Insect	Native	Wood boring	Mainly Norway spruce (*Picea abies*) but sometimes pine (*Pinus* spp.)and	AT, BE, BG, CZ, DK, EE, FI, FR, DE, EL, HU, IT, LV, LT, LU,, NL, PL, RO, SK, SL, SE, UK
European pine sawfly	Insect	Native	Defoliation	Scots pine *Pinus sylvestris*	Boreal forests (SE, FI)
Common pine shoot beetle *Tomicus piniperda*	Insect	Native	Wood boring	Scots pine (*Pinus sylvestris*) and occasionally spruce (*Picea* spp.) and larch (*Larix* spp.)	AT, BE, BG, CZ, FI, FR, DE, EL, HU, IT, NL, PL, PT, RO, SE, UK

Importance of biotic damage in European forests

For the period 2001-2005, the European Commission (BIO Intelligence Service, 2012) gave an estimate of 6.4% of the total EU forest area, i.e. about 7 million hectares damaged annually by at least one type of natural disturbance. Insects and diseases were identified as the most frequent hazards (causes of damage) representing 44% of the total of abiotic and biotic natural disturbances. However, these results derive from a compilation of national estimates based on different methodologies and one-third of the countries did not provide data at all. These estimates are therefore very uncertain, and the comparison between different types of damage factors (especially biotic versus abiotic) is also problematic.

Considering the 26 main European tree species all together, the relative contribution of the main hazards to tree damage were in order of decreasing importance during the 1994-2005 period (Jactel et al., 2011):

- biotic agents (more than half of all occurrences) with insects representing the main cause of damage, followed by diseases;
- abiotic agents (e.g. drought, wind, snow, fire, frost, hail) (ca. 1/5 of occurrences);
- anthropic agents (e.g. poor harvesting practices, air pollution) (ca. 1/5 of occurrences).

There was considerable variation in the level of damage caused by the different biotic agents among tree species. The level of damage by insects ranged from only 1% in Norway spruce (*Picea abies)* to more than 20% in several deciduous broadleaved species, hornbeam (*Carpinus betulus)*, beech (*Fagus sylvatica)*, several oaks (*Quercus* spp.) and alder (*Alnus* spp.). The least damaged tree species by biotic agents was Sitka spruce (*Picea sitchensis)* (0.2%) and the most damaged was chestnut (*Castanea sativa*) (27%). Overall, broadleaved tree species experienced more frequent damage, or to accumulate more damage, than coniferous trees.

Defoliators and bark beetles or wood borers were the two main categories of insect pests while pathogens causing damage to tree roots and stems were the main categories of damage caused by fungal pathogens.

Furthermore, the analysis revealed a clear effect of climate on the prevalence of hazards, with both biotic and abiotic hazards causing more damage in biogeographical zones with harsher climates such as in mountainous and Mediterranean areas.

Thus, damage as measured in the ICP Forests gridnet provides interesting patterns and comparisons between species and types of damage. However, for methodological reasons it is not possible to derive from these data forest areas or volumes of growing stock affected by the different types of damage: the monitoring plots are usually not area representative and the grid density is probably not dense enough to capture all types of damage.

Broadleaved tree species experience more frequent damage than coniferous trees. The biotic agents were the main cause of damage in European forests for the 1994-2005 period.

For major pests, such as bark beetles, field practitioners use different approaches (including remote sensing) to provide direct estimates. As one among few European-wide examples, Table 2 gives estimates of damage caused by the top ten wood-borers in Europe between 1990 and 2001.

Table 2. Timber damage caused by the top ten wood-borers in Europe between 1990 and 2001 (after Grégoire and Evans, 2004; BAWBILT Cost project).

Species	Threatened area (million ha)	Affected area (million ha)	Cumulated Volume (million m^3)
Ips typographus	7. 6	2.8	31.6
Tomicus piniperda	14. 5	0.2	12.9
Ips acuminatus	11.1	<<0.1	12.8
Phaenops cyanea	8. 0	No data	12.8
Pityogenes chalcographus	8. 8	0.6	7.8
Scolytus mulitstriatus and *S. scolytus*	0.2	<<0.1	<<0.1
Hylobius abietis	3.4	0.1	(seedlings)
Rhyacionia buoliana	0.3	<0.1	No data

Economic losses

Data on economic losses caused by biotic hazards are scarce because it is difficult to accurately estimate the cost of biotic damage on forest production (Table 3) and it is even more challenging to give estimations of the cost of biotic damage on other ecosystems services. Usually economic calculations are done for tree mortality which results in net loss of wood production (Woodward et al., 1998; Asiegbu et al., 2005; Gren et al., 2009). Few attempts have been made to estimate the effect of defoliation on tree growth and then economic losses (Gatto et al., 2009).

Data on economic losses caused by biotic hazards are scarce

Table 3. Examples of economic losses due to some pest insects and diseases in Europe (Source: BIO Intelligence Service 2012)

Pest or disease	Scale	Losses	References
Genus *Heterobasidion*	EU forests	500-700 million €/ (includes timber losses, killing, control, remediation and diagnosis)	Woodward et al. 1998; Asiegbu et al. 2005
Thaumetopoea pityocampa	Setubal Peninsula, south of Lisbon	20% timber loss of the growing stock in the first 20 years, represents a reduction of 12% of the timber market value	Gatto et al. 2009
Dutch Elm Disease	Sweden	0.3-0.6 €/ha/yr	Gren et al. 2009
Mammals, insects and pathogens (1)	UK	37.5 €/ha/yr	BIO Intelligence Service, 2012

(1) This estimate is based on the results of several studies aimed at assessing the total costs of damage caused by mammals (Grey squirrel – *Sciurus carolinensis*) insects and pathogens in forests to the timber industry through death of trees wood quality depreciation.

In addition to the effects on wood production, biotic damage may affect other ecosystem services. For example, damage made by the Oriental chestnut gall wasp (*Dryocosmus kuriphilus*) on chestnut (*Castanea* spp.) trees reduce fruit production. Considering that forest pathogens on average can reduce the value of these services by 2.8% to 5.6%, the cost of their damage was estimated to €400–800 million per year at the country level (Sache et al., 2011). Following the same approach the cost of pest damage would range from €0.7 billion to €1.5 billion (Jactel et al., 2012b).

Evolution of biotic risks

Climate change, through increasing temperatures, is expected to benefit exothermic organisms such as insect pests which will have more generations per year (Netherer and Schopf, 2006; Robinet and Roques, 2010) and also spread towards higher latitudes or altitudes (Battisti et al., 2005). It will also result in more frequent or prolonged droughts, which make trees more vulnerable to many forest pests and pathogens as shown by a recent review (Jactel et al., 2012c). If the frequency of windstorms increases in the future, more bark beetle outbreaks are also likely to occur.

In addition, the increase in global trade has facilitated and will continue to facilitate the introduction and establishment of invasive exotic species of forest pests (Roques et al., 2010) and pathogens (Desprez-Loustau et al., 2010). In Europe there are now more than 11 000 exotics plants, insects, fungi or vertebrates (DAISIE, 2009). The frequency of exotic species introduction in Europe is often considered as exponential and though few of them are aggressive or able to survive in a new habitat, those that can survive and thrive can cause huge economic losses. Among the 700 plants fungi introduced in Europe, less than 100 are pathogenic. Most of them are phytophthoras, leaf diseases, and then bark diseases. Considering insects, around 1300 were introduced and are established in Europe; most of them are beetles (29%), aphids, scale insects and bugs (26% for these three types). However, less than 10% of them appeared to be pests of endemic plant species (Nageleisen et al., 2010).

Some trends in silviculture may also affect the vulnerability of forests. Planted forests, because they are grown as pure stands with limited genetic diversity, are in general more prone to pest damage than mixed forests (Jactel and Brockehoff, 2007). On the other hand, more frequent thinning may reduce the vulnerability to bark beetle by enhancing individual tree vigour (Jactel et al. 2009). In general, forest damage increases as growing stocks increases, and as the proportion of conifers in a forest increases; evergreen conifers are more prone to storm damage due to the higher wind resistance of evergreen species during winter, when most of the storms occur (for a European assessment see Gardiner et al., 2013 and Schelhaas et al., 2010). Lastly, it can be stressed that the impact of biotic damage increases (there are larger shortfalls) when values at stake are also more important, for example, because of a higher market demand for wood, pulp or bioenergy resources.

3.3.2 Policy and governance context

Most of the EU (and national) regulations linked to biotic risks relate to the introduction or control of alien biotic agents.

It is part of the goals of the EU 2020 biodiversity strategy[124] that "*pathways are managed to prevent the introduction and establishment of new invasive species*". The European Council established the Directive 2000/29/EC of 8 May 2000 on "*protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community*". The EU Plant Health Regime lists the harmful biotic agents that are subjected to quarantine regulations and aims at preventing organisms that are harmful to plants or plant products from being introduced into the Community and spreading within it. This Directive contains provisions about the plant passport that the nurseries must exchange plants for some species endangered by identified pests. These species have to be free from listed pests to be sold (it is the case of poplar (*Populus* spp.) with *Melampsora medusae* or chestnut (*Castanea* spp.) with *Cryphonectria parasitica*). In the same way, pine (*Pinus* spp.) seeds must be free of *Gibberella circinata* to be transported in Europe. CIRCA SANCO-EUROPHYT (2002-to date) is a notification and rapid alert system dealing with interceptions for plant health reasons. It has been implemented to protect the EU territory from introduction and spread of harmful organisms that pose phytosanitary risk.

[24] European Parliament resolution of 20 April 2012 on our life insurance, our natural capital: an EU biodiversity strategy to 2020 (2011/2307(INI)). Tighter controls on invasive alien species are one of the 6 targets.

Inside the European Commission, the Standing Committee on Plant Health is in charge of analysing reports from the Member States about biotic attacks evolution and of establishing measures related to risks management (action taken to restrict spread of the pine wood nematode is an example of this process). All states discuss and negotiate for these measures inside the Committee.

In spring 2015, the EU regulatory framework for plant health was still being revised in order to better protect the EU against intrusive and spreading pest and pathogens while combining more ambitious objectives related to biodiversity (EC, 2013). The European Commission proposed to the European parliament a new regulation, aiming at replacing the Directive 2000/29/EC.

- Proposal of 6 May 2013 for a regulation of the European Parliament and of the Council on the production and making available on the market of plant reproductive material (plant reproductive material law) (COM(2013) 262 final).
- Proposal of 6 May 2013 for a regulation of the European Parliament and of the Council on protective measures against pests of plants (COM(2013) 267 final).

There can also be some specific directives for some particular alien agents. For example, measures to combat the pine wood nematode (*Bursaphelenchus xylophilus*), which was introduced in 1999 to Portugal where it causes considerable damage on maritime pine (*Pinus pinaster*), are applied according to:

- The general Directive 2000/29/EC has incorporated the pine wood nematode in its list of harmful agents. As a consequence, measures to mitigate its spread to other European countries such as plant passports to control plant material introduction in the European member states. Border biosecurity checks are also made to prevent the introduction of contaminated wood material from non-European countries.
- The Decision 2006/133/EC of 13th February 2006 requires “Member States temporarily to take additional measures against the dissemination of Bursaphelenchus xylophilus (the pine wood nematode) as regards areas in Portugal, other than those in which it is known not to occur”. The purpose is to prevent the introduction of nematode in regions where it is unknown, and to eradicate centers of nematode infection.

Besides the reinforcement of pests and pathogens introduction and eradication control and environmental issues consideration, the new regulation will aim at sharing costs and responsibilities regarding biotic risks between the EU, the member states and professional operators.

3.3.3 What we know from research

As the diversity of forest pests and pathogens is considerable in Europe, it is extremely difficult to summarize knowledge brought by research. However, regardless of the biotic agent considered a large part of research focuses on the impact of global change on pest and pathogen range and damage for both endemic and alien species.

Climate change may affect endemic European species as it can increase an agent’s outbreaks frequency and intensity and shift their natural ranges, in particular for insects (Bale et al., 2002; Klapwijk et al., 2012 and references therein).

The European project DAISIE also showed that the rate of introduction and establishment of alien species is exponentially increasing in Europe, for both insects (Roques et al., 2010) and diseases (Desprez-Loustau et al., 2010). The main region of origin for these exotic invasive species is Asia, and globalization, through more frequent trade and passenger traffic between continents, is the main cause of invasions (Jactel et al., 2012a). Climate change, and particularly warmer conditions, may further facilitate the establishment of species originating from tropical regions. The main pathways for the introduction of exotic forest pests and pathogens are wood packaging and horticultural plants (e.g. bonsais, potted trees). This was the case for the pine wood nematode which is among the most damaging pathogens in European forests (Table 1).

The introduction and establishment of alien species is exponentially increasing in Europe

3.3.4 Monitoring and information availability

Biotic factors are relatively numerous, occur usually at local scale (though major outbreaks may cover large areas) and are difficult to assess (effects vary throughout the year and are more or less reversible). These features explain why monitoring is far from unified, and information availability very variable:

- Traditionally, monitoring activities dedicated to specific biotic factors are organized at (sub-)national level with specific protocols. This makes international evaluations difficult.
- Estimates of damage (e.g. defoliation, mortality) are often produced for major pests by local foresters, but long-term data series are only available for some pests and specific areas (e.g. mortality caused by bark beetles in public forests of some (parts of) countries).
- More recently, some (easy to observe) forest health aspects have been included in national (forest inventories) and international (forest condition) surveys, which allow new insights into large-scale patterns.

International programs deal with introduced pests considered as major threats.

We hereafter briefly list some (i) National monitoring systems contributing to the assessment of forest health, (ii) Monitoring systems at European level, and (iii) Information, communication and dissemination vectors about risks in European forests

Forest health organizations

According to a recent survey (BIO Intelligence Service, 2012), monitoring of forest pest and diseases in Europe is a concern at (sub-)national level. Less than 10 countries aim at a general survey (insects, pathogens, nematodes, mammals, plants) while most countries focus on specific agents in forests (e.g. bark beetles) or in nurseries. These monitoring systems are usually implemented by national forest authorities, research institutions or national parks on a yearly basis. Sometimes, they are used as decision support information for forest management and rely on skilled and trained staff (researchers, forest engineers, supervised volunteers). The Dutch monitoring system is the oldest in Europe. Otherwise, the longest running systems are from Central Europe (Czech Republic, Poland, Estonia and Lithuania).

National Forest Inventories (NFIs)

The increasing demand for information on productive and non-productive functions of forests has led NFIs to improve their methods and enlarge the number of recorded parameters. However, a number of NFIs provide some information on damage caused by insect pests and diseases. A main difficulty, besides the additional cost, is the fact that symptoms vary throughout the year, while inventory field activities are not necessarily carried out at the appropriate time to record the symptoms. Sampling methods and protocols are very heterogeneous throughout Europe, which makes any transnational evaluation difficult.

International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

ICP Forests is a pan-European forest condition monitoring programme using harmonized methods and criteria[25]. ICP Forests operates under the UNECE Convention on Long-range Transboundary Air Pollution, and was jointly implemented with – and supported by – EC between 1986 and 2006. It is organized at two monitoring intensity levels:

- Level 1: a systematic network of ca. 6000 plots (16x16 km gridnet, ca. 135 000 trees) in Europe is assessed annually since mid- to end- (depending on country) 1980s; a visual crown condition assessment provides a general estimate of forest condition.

- Level 2: a set of selected (ca. 800) intensive plots has operated since 1992/1995, with the objective to establish cause–effect relationships.

The role of biotic factors was not one of greatest concern at the beginning of ICP Forests, and a specific working group was only set put in the early 2000s with the aim to improve the protocols which were considered as weak. The lack of skilled observers (and associated costs) was identified as a problem with regard to improved/intensified observations.

Since the end of the Forest Focus Regulation (2006), the EU has not funded the network anymore and the Member States are no longer committed to conducting regular surveys on the conditions of their forests. Some countries have stopped forest condition monitoring on Level 1 and 2, and it will become more difficult to detect changes in forest condition at the European scale in the future.

EPPO, the European and Mediterranean Plant Protection Organization[26]

Founded in 1951 by 15 European countries, the EPPO is an organization for decision-making and sharing which gathers around 50 countries concerned with plants pests and pathogens. Its main objectives are to protect plants (including trees), to develop international strategies against the introduction and spread of dangerous pests, and to promote safe and effective control methods. As a Regional Plant Protection Organization, EPPO also participates in global discussions on plant health organized by FAO and the International Plant Protection Convention (IPPC) Secretariat[27]. The EPPO

[25] http://icp-forests.net/
[26] http://www.eppo.int/
[27] The International Plant Protection Convention (IPPC) is an international agreement on plant health to which 179 signatories currently adhere. It aims to protect cultivated and wild plants by preventing the introduction and spread of pests. The Secretariat of the IPPC is provided by the Food and Agriculture Organization of the United Nations.

maintains two lists of organisms that have to be regulated as quarantine pests: List A1 quarantine pests that are not present in the EPPO region; and List A2 quarantine pests that are present in the EPPO region but not widely distributed there and are being officially controlled.

At the European level, this organization provides some measures including regulation of wood packaging material, guidelines for pest eradication, and integrated pest management.

Information, communication and dissemination vectors about risks in European forests

There are several European level databases on biotic disturbances and some of them are related to monitoring systems:

- ICP Forests: database on forest conditions in Level I monitoring plots, for different categories of damage (i.e. percentage of trees affected by pest and diseases), but information on causing agents is limited to a few countries.
- DFDE (Database on Forest Disturbances in Europe): hosted by the European Forest Institute (EFI). It provides pan-European historical data on biotic (mainly insects and diseases) and abiotic disturbances in the forests of Europe. Data goes back to 1449 and provides estimates of the intensity of damage (in terms of information for permanent, endemic pests' volume or area affected). However, these trends are biased towards the larger disturbances (those more likely to be reported, such as windstorm, fire and some types of pest damage, like bark beetle outbreaks).
- The Forest Pest and Disease database, hosted by EFIATLANTIC, was funded first to collect information about main endemic pests and pathogens of South-West Europe (France, Spain and Portugal). It has been recently extended to the whole Europe and provides informative sheets on agents.
- DAISIE database: database on alien species found in the EU covering all taxa including those damaging trees (inventory, species description, ecology and habitat, distribution, impact and management, experts).
- EPPO: its two Alert Lists on quarantine pests, and Pest Risk Assessment on several pest and diseases relevant to EU forests.

At the national level, a number of information systems in the EU provide information on forest biotic agents: the Protection of Slovenian Forests, the Spanish Forest Damage Inventory, the Skogs Skada database in Sweden, and the Path News [pathology bulletin] and the Quarantine identification cards in the UK. These information systems make available information on the main biotic agents of their country.

3.3.5 Practice (prevention and mitigation)

Biotic risk mitigation and prevention strategies are divided into preventive and curative types.

The preventive methods are either linked to stand management or based on biodiversity conservation. A review made by Jactel et al. (2009) showed that every single silvicultural option may have an impact on forest stand vulnerability to biotic hazards. Therefore, these options, from soil preparation to harvest can be optimized to manage targeted biotic risk. On the other hand, biodiversity conservation, and in particular the use of tree diversity have been proved to be efficient to manage some biotic attacks: for example, the scale insect (*Matsucoccus feytaudi)* show higher infestation in pure maritime pine (*Pinus pinaster*) stands than in maritime pine stands mixed with Corsican pine (*Pinus nigra* subsp. *laricio*) (Jactel et al., 2006). However, the degree of exposure to biotic risks is determined by the qualitative and quantitative composition of the mixture of stands rather than the stand species-richness itself (Battisti and Jactel, 2010).

The curative methods aim at controlling insect populations once they are already in the stands or damaging trees. The use of insecticide is a curative method, but it possibly has serious drawbacks such as: lack of effectiveness, the selection of resistance, the cost, and the negative effects on non-target species (Battisti and Jactel, 2010). Other curative methods are used to reduce population levels below the economic threshold (Wainhouse, 2005). These include: mechanical methods such as pruning of attacked branches or burning of infected trees; biological methods such as the use of pest enemies through the release of predator or parasitoid species; and biochemical methods such as using chemical insecticides made from biological pathogens (Battisti and Jactel, 2010). Using pheromones such as sex-pheromones for mass trapping (e.g. of gypsy moth (*Lymantria dispar*) populations control in isolated oak (*Quercus* spp.) woods in the US) or antiaggregation pheromones as repellents (in particular to control bark beetle outbreaks in pine (*Pinus* spp.)) are also curative options (Battisti and Jactel, 2010). These methods may be difficult to implement on large scales and remain restricted to protect the most valuable stands or trees (Battisti and Jactel, 2010).

Despite all these measures and directives adopted to control the spread of biotic agents, the issues of plants exchanges and transportation regulations remain crucial for preventing new damage of pests and pathogens. Plant material exchanges remain a main cause of pest introduction inside the European Union, or pest spreading through the European Union.

Curative methods aim at controlling already established insect populations mechanically, biologically or biochemically.

3.3.6 Capacity building

Training on biotic risks is usually supplied by three types of organizations:

- Forest schools, faculties and universities sometimes include forest protection courses into their curricula.
- Forest research institutes play a key role in many countries in disseminating outcomes of their scientific projects (e.g. publications, leaflets and other means) to professionals, other researchers, students, and public organizations.
- Ministries and public organizations provide general information to a larger public, including private forests owners and managers.

Among these organizations, the example of the French Department of Forest Health is of interest. It relies on about 220 part-time field observers employed by public and private forest organizations. They continuously report the damage caused by pests and diseases they observe during their usual professional activities. They have been trained to identify the causes (biotic agents) of forest damage.

3.3.7 Societal understanding and acceptance of risks

The societal understanding of biotic risk (risk perception /aversion) depends on social groups. The public is generally concerned by large-scale disturbances, such as windstorms, fire, and bark beetles outbreaks that are reported in the press and may also directly affect their well-being, e.g. by damaging their properties, disturbing road and railway transport, or affecting the aesthetics of landscapes. A few biotic agents are also noxious to people or domestic animals. These include the caterpillars of the pine processionary moth (*Thaumetopoea pityocampa*) which have urticating hairs which can cause extreme irritation, thus raising concern in the general population living close to forests or forested parks and questioning sometimes silvicultural work in forests.

Another social group to consider is the group of forest professionals. They are more aware of forest risks but again they often underestimate the impact of non-epidemic pests or diseases, for example those that do not kill trees but reduce their growth.

However, one should acknowledge that the information is scarce about the impact of biotic damage on the economy of the forestry sector and even less abundant on their consequences for the well-being of the public. This lack of information prevents raising awareness on forest risks.

Forest professionals often underestimate the impact of non-epidemic pests or diseases.

3.3.8 Identification of gaps and needs for action

Understanding the process of biotic damage is increasing thanks to research and forest management progress. However gaps remaine due to the high diversity and complexity of the agents. This is a research topic in itself, which sometimes does not take the consequences on forest and possible mitigation into consideration. Moreover climate change and the introduction of new agents increase difficulties and are the cause of new gaps in biotic risk knowledge.

Therefore a number of gaps and needs for action remain to be addressed:

- Long-term analyses are still needed for endemic biotic agents.
- Transnational analyses using data from current monitoring of different countries in order to get European perspectives are largely missing. Among potential sources of data, those from systematic and intensive monitoring networks tend to be less collected since the end of the Forest Focus Regulation in 2006.
- The combination of several biotic agents may cause increasing damage; however, interactions between pests and pathogens are not well-studied. By extension interactions between biotic and abiotic risk has been shown to be very damaging (such as storm and bark beetles; Stadelmann et al., 2013; drought and bark beetles; etc.) but are far from being understood. These aspects are very important with regard to long-term changes in climate and forest management (Seidl et al., 2011).
- Risks models for biotic agents are still rare: they could allow the identification of impacts of pests and pathogens causing losses throughout the forest rotation.

- The integration of biotic risks management is being increasingly studied but still needs to be commonly put into practice.
- Despite all the measures and directives adopted to control the spread of biotic agents, plant material exchanges remain a main cause of pests' introduction inside the EU or pest spreading through the EU. Cooperation on invasive pests and pathogens, especially on knowledge and mitigation techniques could be enhanced. The pathways for the introduction of alien agents' introduction need to be clarified and methods to block them still need to be implemented.

3.3.9 What FRISK could provide

Depending on priorities and available means, a risk facility could help the biotic risks communities on the following topics

Information and communication

The facility would aim at developing a sound and accessible picture of the risk situation of the forests related to biotic agents by, among other actions:

- Providing dedicated information related to biotic damage to forests at different levels (regional to supranational);
- Making accessible information from scientific papers:
- Helping raising the awareness of the relevant authorities and the public, especially young people through the production of educational material in relation to existing initiatives.

Understanding

The facility could be a place for collection and analysis of data at the European scale. Therefore the following activities could be accomplished in this framework:

- Gathering and analyzing data on long-term series and spatial data to reveal the importance of specific agents;
- Establishing online tools to enhance geographic mapping of pests and monitoring including organisms that are not (or not anymore) listed on national quarantine pests lists;
- Sharing of methods of analyses and diagnosis, especially for pathogens;
- Combining social science and biological science to link scientific work and forest management through vulnerability and full risk assessment.

Strategic planning

The risk facility could help developing conceptual frameworks and strategies for long-term mitigation and facilitate the incorporation of risks into forest policies use the following actions:

- To help identifying any specificity to address forest risks and biotic risk through the comparison of the approaches from different European countries and case studies;
- To share information between countries on strategic planning;

- To assess biotic vulnerability associated to forest management options for mitigation;
- To exchange knowledge on how risk is incorporated in different countries regulation, laws management through the review and the constant survey of existing laws and practice;

Networking

The facility could provide the opportunity of information and transboundary exchange between practitioners, scientists and policy makers through:

- The establishment of a list of key-contacts of stakeholders and their field of expertise;
- The identification and diffusion of stakeholders needs in order to initiate transnational dialogues;

Supporting

The facility could provide "in time" support service, mainly by identifying and linking people willing to contribute to:

- Establish and maintain experts, institution and accessible knowledge available for quick mobilization on demand;
- Support post-disturbances coordination actions between countries;
- Facilitate the access and the use of the best available technique and build a technical documentation, focusing on complex diagnosis and monitoring tools and on lesson-learnt from the major events.

Capacity building

The risk facility could support capacity building in Europe by:

- Organizing training and knowledge transfer on request and advertising on existing training and internships;
- Supporting the introduction of risks in forest education; by preparing material for training bodies

3.4 Wild Ungulates and their effects on forest ecosystems

Michael Müller, Philippe Ballon, Alexander Held

3.4.1 Current situation and future development/trends

Over the past decades, some threatened ungulate species – e.g. Alpine ibex (*Capra ibex*), mouflon (*Ovis orientalis musimon*), Sardinian red deer (*Cervus elaphus corsicanus*), European bison (*Bison bonasus*) – have been effectively protected, and their populations have increased and stabilized. At the same time, populations of the the well-established species – especially red deer (*Cervus elaphus)*, roe deer (*Capreolus capreolus*), and wild boar (*Sus scrofa*) – have increased dramatically in European forests and the wider landscape in spite of increasing hunting quotas (Apollonio et al., 2010). The total number of large ungulates in Europe is estimated to be more than 15 million and more than 5 million animals are harvested each year, which has left room for populations to increase (Figure 12).

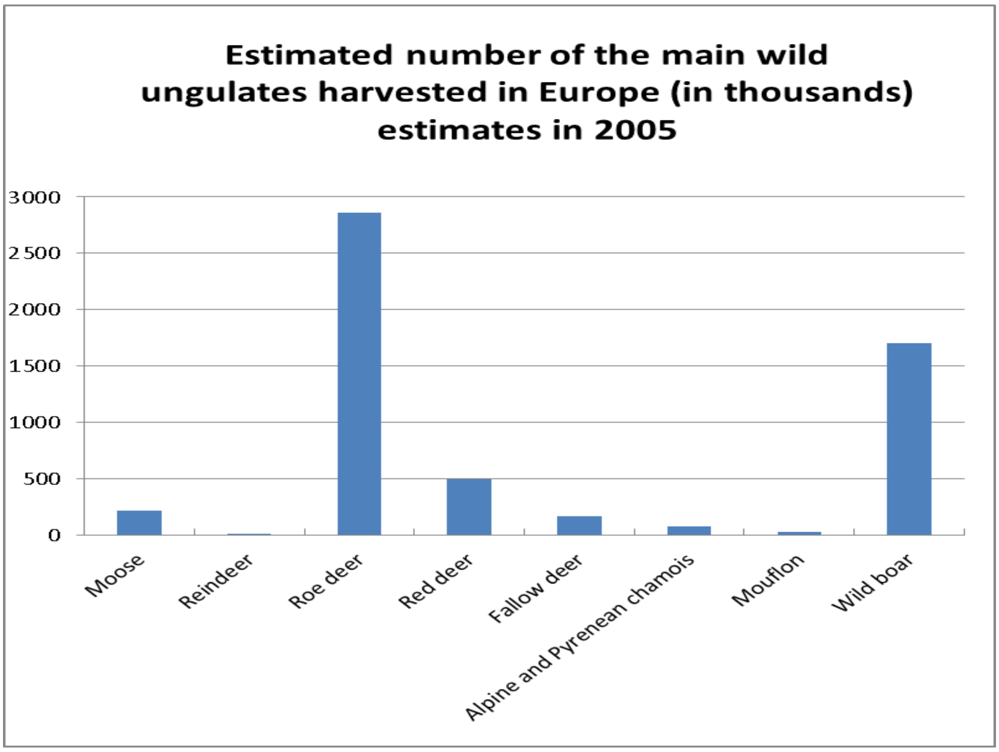

Figure 12. Estimated number of the main wild ungulates harvested in Europe (in 28 European countries). Data 2005 from (Apollonio et al., 2010)

As a consequence of high ungulate densities, the negative selecting influence of deer species on tree regeneration through browsing and bark stripping has become prominent on the forestry agenda in most European countries. The latest report on the State of Europe’s Forests (2011) lists “wildlife and grazing” as one of the most important causes of forestry damage in Europe. A prominent example is the the complete lack of regeneration of silver fir (*Abies alba*) in some places in the Swiss and Austrian mountain protection forests (Schodterer, 2011). However, the relevant information is based on inquiries among forest institutes and forest damage are not regularly surveyed in Europe.

Therefore, it is not easy to make statements about the actual severity of damage in most countries. The way in which the ungulate browsing effect is perceived varies with the forest management objectives (e.g. energy wood plantations vs. recreational forests). Focusing on population control as the only solution, ignores other underlying factors which may affect the wildlife–forestry interaction.

One of the new challenges is the management of a guild of ungulate species rather than the management of single species in a given area.

The current wildlife carrying capacity in most parts of Europe is now higher than that of a primeval forest situation. However, the primeval forest often serves as the standard model against which browsing damage on tree regeneration is measured. This is one reason for the contentious debates surrounding ungulates and forestry interests.

The interactions of silviculture, agriculture, legislation, tourism, hunting, herbivores and carnivores need innovative research and management approaches. A strong focus should be placed on mitigation of conflicting interests within all stakeholders. Interests of particular groups, however, need to be weighted. For instance, the interest of the forest owner tends to hold more weight than the interest of the private (but paying) hunter, which in turn tends to hold more weight than the interest of the local horse riding club. If interests are not weighted, it is impossible to find solutions. All actors, however, will have to subscribe to actively supporting the continuity of resilient forest ecosystems.

In forestry and silviculture the complex ecological interrelations and influences have been known for quite a while. They are researched intensively, and are respected and applied in silviculture (i.e. soil and climate conditions, tree species characteristics, biotic and abiotic influences, anthropogenic influences, etc.). In wildlife management on the other hand, all too often the “management” is reduced to a simplified approach: hunting of endangered species is banned and populations of species that cause damage are regulated.

Wild ungulates in a broader sense refer also to complex interactions within the forest (i.e. interactions between and with other animals and plants) and the connection with other ecosystems (e.g. agriculture), and also interactions with humans (e.g. possible transmission of diseases). In any case, the issue should not be simplified only to culling of game, though this is seen as the most important reason for strong conflicts among stakeholders.

Wildlife managers operate in the overlap of ecology, nature conservation, hunting, forestry and agriculture, and tourism

Management of wild ungulates is far more complicated than just reducing numbers of game, i.e. hunting. It is the integrated management of wildlife and wildlife habitats, serving the interests of the wider society, and not one-sided interests of only foresters, or only hunters, or only nature conservationists. Wildlife managers consequently operate in the overlap of ecology, nature conservation, hunting, forestry and agriculture, and tourism in the rural areas and the green economy (Putman, 2011). Recent research has shown that browsing severity of tree regeneration by ungulates is not only influenced by size of ungulate populations, but also byfactors such as tree species composition, plant and site quality, habitat quality and silviculture practices in the predisposition of trees to damage. For a successful management approach and resolution of the conflicting interests a number of measures need to be used: hunting, based on the forest management objectives, meaning local reduction of deer numbers possibly with reduced hunting stress and pressure as far as possible; habitat management; and creation of quiet and undisturbed wildlife refuge areas inside and outside forests (Müller et al., 2012).

European wildlife species and populations are diverse and so are the influences and effects of high population densities on forests and forest regeneration. In the same way, forest types and silvicultural treatments differ greatly between forest ecosystems in Europe, and so obviously the incidence of browsing will be variable too.

Deer species are managed by the forest owners in some parts of Europe. In most countries, however, wildlife and forests are managed by different actors, and conflicts of interests between different lobby groups (forestry vs. hunting) but also between landowners with different goals (e.g. forestry vs. agriculture, income from forestry vs. income from hunting) can make sustainable management of both resources problematic (see e.g. Herzog, 2013).

Top predators have been strictly protected all over Europe in recent years. Consequently in many countries there has been a recovery of wolf (*Canis lupus*) and lynx (*Lynx lynx*) populations and the increase of their geographical range; however, it is an open question as to what effect these large carnivores will have on ungulate-plant interactions in the European context. Wildlife management by humans will remain the only option for years to come.

Ungulates are generally forest dwelling animals but due to their mobility utilize food sources also in the agricultural landscape. However, in winter they move back into the forest with generally lower carrying capacity. The attractiveness of forest habitats for wild ungulates depends not only on food supply but also on food independent habitat factors such as terrain conditions, climate, edge effect, disturbance, competition, and cover availability. Areas where the clear.cut system is used are attractive for deer because of the abundance of food supply. However, this system is very susceptible to game damage, because of selective browsing of young trees and saplings and bark stripping. A more natural forest on the contrary results in a higher resilience to game damage and an improved wildlife habitat with greater wildlife species diversity (Reimoser, 1996). Thus, ungulates may have a different function and effect in a “human-made” forest compared with a more natural forest.

3.4.2 Policy and governance context

Ungulate management is influenced at pan-European level by the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), and in the European Union by the Habitats Directive (92/43/EEC). Neither of these contains any specific provisions on hunting or ungulate management, but they both maintain lists of strictly protected species: "strictly protected fauna species" for the Bern Convention, and "animal and plant species of community interest in need of strict protection" for the Habitats Directive. The EU Habitats Directive forms together with the EU Birds Directive the foundation for the NATURA2000 network of sites that are managed for the protection of both species and habitats.

In 2001 the EC DG Environment started the Sustainable Hunting Initiative, which in 2004 resulted into a Sustainable Hunting Agreement between BirdLife International and the FACE (European Federation of Associations for Hunting and Conservation) foundation. While this agreement refers to the Birds Directive and not explicitly to the Habitat Directive, it does refer in more general terms to the "importance of effective habitat protection and active management for biodiversity conservation" and that this is not incompatible with hunting.

Ungulate management is directed mostly by national and regional legislation and regulation, however not always without problems. Apollonio et al. (2010) report that problems with ungulate management in Europe can be caused by inappropriate or inconsistent legislation (e.g. without regard for biological cycles and juvenile dependency; national and regional differences in length of hunting season), problems enforcing laws (e.g. related to illegal hunting), lack of coordination of management objectives from local to transboundary levels, and inadequacy of systems to monitor ungulate numbers and their impact.

3.4.3 What we know from research

During the last three decades, numerous studies have been conducted that have led to improvements in our understanding of the biology of the forest deer species: e.g. see Andersen et al. (1999) for a review on roe Deer (*Capreolus capreolus*).

Causes of browsing damage by deer species on forest regeneration have also been investigated. It is now known that damage is influenced by many factors that vary temporally and spatially, e.g. tree age, ground vegetation, tree species, stand types, fertility, snow depth, human disturbance.

Problems with ungulate management in Europe can be caused by inappropriate or inconsistent legislation and law enforcement, amongst many other contributing factors

Forest structure and species composition are especially important; broadleaved trees like maples (*Acer* spp.), oaks (*Quercus* spp.) and others experience a negative selection compared to pines (*Pinus* spp.) and Norway spruce (*Picea abies*). In the same way, selective browsing is favours the less attractive spruce (*P. abies*) and beech (*Fagus sylvatica*) components of the mixed fir-spruce-beech forests in many European mountain areas; these forestsare turning towards pure stands of spruce and beech. Browsing by wild ungulates increases mortality in young trees, especially when it occurs on very young seedlings. Thereby forest structure is affected and the protective function of mountain forests or especially the desired conversion to mixed forests is compromised. In that context, it is important to differentiate between different feeding types of ungulates. For example, in mixed stands of beech and silver fir (*Abies alba*), red deer (*Cervus elaphus*) seems to show a preference especially for established beech seedlings, whereas roe deer prefer very young silver fir seedlings. Especially the differentiation between the consequences of browsing and of other factors, such as e.g. light, frost, insects, or drought remains an open question in many cases. Additionally, forest management practices have promoted Norway spruce and Scots pine (*Pinus sylvestris*) over vast areas at the expense of species like silver fir during the last decades. As many ungulate species coexist in the same area, we need to better understand the feeding selection of forest tree species in that context.

Intensive tourism, with leisure activities like mountain biking, paragliding, snow-shoeing, cross-country skiing and geo-caching have in some areas led to a reduction of wildlife habitat and refuge areas and are causing major problems with regard to food supply during winter, i.e. leading to localised and higher browsing pressure in other areas.

To conclude, damage to forestry varies greatly in time and space, and yet there is no quantitative model available for the prediction of browsing damage, its severity and occurrence. Numerous methods to assess ungulate damage exist, but there are no nationwide monitoring systems to record the extent of damage in each country.

A forest risk facility could play a role especially in reinforcing the link between research and practical information and management.

3.4.4 Monitoring and information availability (control)

Estimating roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) population numbers is hardly ever accurate and the error margins are so broad that any further calculations, models based on such data are not a sound basis for making management decisions. However, monitoring of wildlife and its feeding impacts on forests follow two different concepts in most European countries.

- Sustainability in wildlife harvests has to be monitored by regular estimations of species abundance. The impact on forest ecosystems is estimated by different sampling procedures, taking into consideration the proportions of browsed and not-browsed plants in a given regeneration plot. Although impacts of ungulates are described as a major threat to forest regeneration in many European countries, much of these appeared subjective. There are few monitoring systems to record these impacts.
- In contrast, there is a set of different methods for abundance monitoring that allow applications for the specific questions to be solved. For instance the trends of harvest statistics of European ungulates in each country are well recorded. Abundance monitoring of wildlife is much more imprecise and time-consuming. New methods based on the monitoring of indicators of ecological changes can provide reliable information to achieve management objectives (Morellet et al., 2007).

Estimating browsing impact on forest stands in the long-term scale of forest planning is more challenging. Managers have to estimate today how a stand will look in 60 or 100 or 200 years. This might be possible in artificial regenerations of monocultures (with the experience of the last 200 years of forestry) but it would be very resource intensive to implement this for all of the different types of mixed and naturally regenerated stands to be grown the future.

3.4.5 Practice (mitigation and prevention)

In contrast with other disturbances considered in this report, which result in sudden damage, wild ungulates trigger slow-onset, incremental and cumulative changes in forests which are not discernible in the short term. Only after an extended period of time – depending on the specific characteristics of the forest system considered – and when the changes have accumulated to a visible level and considerable damage has been done, does society usually seek to address the changes.

There is no quantitative model available for the prediction of browsing damage, its severity and occurrence

These changes can be classified together with other so-called Creeping Environmental Problems or Changes (CEPs), which were selected as one of the emerging environmental issues to be presented at RIO +20. The CEPs are for instance erosion of the quality of soil, water and the atmosphere. In the forest and forestry environment of Europe they deserve attention and new approaches to deal with the resulting changes. Dealing with CEPs is normally delayed until a threshold of change has been crossed. At that time, the seemingly minor changes have accumulated into a major crisis. Those thresholds are not usually identified until the threshold has been crossed, even though it is easier and less expensive to deal with CEP early in its process rather than waiting until the threshold of change has been crossed (Glantz, 1994). The similarities in dealing with ungulate effects on forests are obvious. CEPs are a relevant approach to show that it is better to deal with the causes rather than the impacts.

Selective browsing of young saplings and trees and bark stripping by wild ungulates is considered as one of the most severe silvicultural challenges in European forests and even more so in European mountain forests. In most European legislative settings hunting must be conducted in a way that forestry operations are not adversely affected. In particular, the regeneration of the main forest tree species should be possible without the need for protective measures like fencing. Lack of tree regeneration, loss of quality of forest products as well as of forest biodiversity, and in a long-term perspective, restricted possibilities for adaptation to climate change, and interference with different ecosystem services have to be considered when discussing wildlife management in forests. On the other hand, the positive effects of wildlife management in relation to its cultural and socio-economic importance need to be taken into account when striving for sustainability of forest resources.

Thus, problems related to ungulates are complex and far reaching. It is, therefore, proposed that the Forest Risk Facility should also deal with this source of disturbance, especially by reinforcing the link between research and practical information and management. In this issue, the forest ungulate species implied are: Roe deer (*Capreolus capreolus*), Red deer (*Cervus elaphus*), and to a lesser extent moose (*Alces alces*), reindeer (*Rangifer tarandus*), fallow deer (*Dama dama*), European bison

(*Bison bonasus*), Alpine chamois (*Rupicapra rupicapra*), Pyrenean chamois (*Rupicapra pyrenaica*), mouflon (*Ovis orientalis musimon*), Alpine ibex (*Capra ibex*), and wild boar (*Sus scrofa*).

In many countries, domestic ungulates no longer represent an issue with respect to the management of European forests, with the exception of local incidences. Grazing effects of domestic animals are therefore not , considered as relevant in this context.

3.4.6 Capacity building

Education, with respect to wildlife/hunting and forestry is based on traditions, historic and socio-cultural customs. In most forestry schools wildlife biology and wildlife management are part of the curriculum. In many cases, the focus is still on reduction and avoidance of damage with regard to the primary forest use, i.e. timber production.

Hunting education in some European countries is also quite advanced, covering a wide range of biology, although here there is a focus on how to best have diverse and healthy populations of wildlife. Hunting laws traditionally focus on sustainability of yield and nature (species) conservation. The education is influenced by tradition, often ignoring changing environmental conditions. This is also relevant for forestry education.

Still some countries in Europe do not require hunters to do a test in wildlife ecology.

There are also still countries in Europe where a hunting license does not require knowledge of wildlife ecology, let alone forest ecology.

Both forestry and hunting education could be viewed as not up-to-date in certain aspects, resulting in discussions that are often too biased, un-informed and, therefore, not helpful in resolving conflicts.

Statements on acceptable and on desired wildlife densities differ within Europe and change in space and time.

Innovative approaches should be encouraged by the well-established stakeholders, in order to deal with a changing environment and changing conditions for forest as well as wildlife management.

Building capacity for all stakeholders in the rural setting around forests and wildlife management, biodiversity and conflict management is a tool that has not been used to its full potential.

A change of mind-set from the approach of trying to exclude the disturbance (this applies to all disturbance types) towards an accepted level of disturbance as part of ecosystems and biodiversity is required, but will need time and very sensitive approaches.

3.4.7 Societal understanding and acceptance of risks

Management approaches concerning wildlife in forest ecosystems show significant differences throughout European countries. In many cases the primary focus is on regulating wildlife numbers, neglecting the complete set of management tools. As silviculture is more than clear-cutting and planting spruce, wildlife management is much more than regulating animal populations.

Static wildlife density recommendations are not helpful, as the local conditions, land management objectives and natural influences are extremely diverse and also change over time. Similarly, the estimation of the size of a population provides no information on the relationship between the population and its habitat and on the underlying demographic processes.

The usual discussion about acceptable wildlife densities should be substituted by a discussion about goals and adequate management tools. Reducing population densities can be one such tool.

Wildlife management is mostly discussed though with regard to forestry damage. Other wildlife and forest ecosystem services remain excluded from the discussion.

The current discussion is limited to forestry versus wildlife, often only looking at the negative effects of wildlife on timber production. A more comprehensive view on an ecosystem level and with a greater understanding of ecosystem services is needed. The value of wild ungulates must be explicitly recognized as a natural resource both in terms of their value as living organisms and as part of the biodiversity. Wild ungulates are also a resource that can be managed to improve conditions for the people living in the area.

The conflict lies in differing human interests within the same forest area (in Germany, Austria and similar systems with a strong connection between hunting rights and land ownership) or between different stakeholders (in systems with no such close connection between land ownership and hunting rights, such as in the Baltic states).

Defining the goals and interests of the landowners and of other more or less relevant stakeholders, balancing these interests and defining common management objectives for the ecosystem forest is a constructive way to mitigate the existing conflicts and to define what level of risk or disturbance is accepted by society. It is not clear whether that should be done using a bottom-up approach, ideally in a participatory process, or using a top-down approach.

Reasons for failing ungulate management are plenty: lack of clear management objectives, lack of coordination, inadequate monitoring systems, inadequate quotas and control…

3.4.8 Identification of gaps and needs for action

As a result of the, sometimes, very emotional discussion it is difficult to deal with the issue objectively and to challenge the current perceptions. In addition, the numerous differences on local levels of forest type, management type, forest products, hunting traditions and regulations make it very difficult to express a European view or European status. The increase of ungulate populations and their effects are often considered as a demonstration of failure of the current management to control ungulate populations and their impacts. Apollonio et al. (2010) listed the main reasons for the situation. These are: lack of clear definition of precise management objectives, lack of coordination of management over a larger geographical scale and inadequate scale of management units, inadequacy of monitoring systems for estimating animal abundance and their impact, failure to set adequate hunting quotas and control, and the need for holistic, multi-objective and adaptive management. With respect of this analysis, the future needs are explored through the following points.

Definition of precise management objectives

Too often, the management objectives are not shared between the landowners (state and private) and the public. The following questions must be resolved: How are the management objectives of a specific forest area defined? Is it based on ownership? Or based on type of land use type? Or is the set of objectives based on spatial planning?

Better coordination of management over a larger geographical scale and adequate scale of management units

For effective management, harvest efforts must be coordinated over the entire population range, covering different administrative units within countries and also different countries. The average forest district/unit/company size is often too small to manage populations and evaluate impacts that should be evaluated on larger scales based on ecological conditions and natural dynamics. Can large-scale effects be measured against small-scale objectives?

Improved monitoring systems for estimating animal abundance and their impact

Accurate estimations of population size are extremely difficult and time consuming. Whatever the methods that are to be adopted, consistent programmes of monitoring are needed in order to evaluate the effectiveness of the management options. A fact-based scientific discussion is needed on the different factors influencing the impact of wildlife on forest trees and forest ecosystems. For that purpose, one possible approach should be to look at the different factors disturbing a balanced situation. Such balances could exist between mortality and birth rates (the traditional forestry viewpoint), but also between abundance and forage supply, between the need for summer and winter habitats, or between the disturbance situation (especially in winter times) and the internal energy regulation to mention only some aspects. This approach naturally does not focus only on wildlife management, but also on silvicultural management. Wildlife damage should be assessed and measured against the remaining tree regeneration and not only for the disappearing tree individuals. The remaining tree regeneration that will form the future stand is the standard against which the browsing should be measured (Reimoser, 1999; Hamard and Ballon, 2009). However, new assessment methods with much longer time scales, i.e. fencing of representative model areas, adequate indicators, biodiversity, etc. are needed.

> *The economic significance of game damage is poorly documented.*

Model- , Trial- , and Demonstration areas with a long-term perspective as well as applied research programmes are needed to develop decision support tools for integrated land use and wildlife management. We have to deal with the following challenges. To understand where the forest–wildlife conflict situation has come from, where it is at the moment, and in which direction it will likely develop and how best to manage wildlife and forests. Sound historical data and current data are a prerequisite for this understanding. Over the decades, methodologies and sometimes silvicultural practices were changed, and looking at a larger area, like central Europe, there have never been comparable methodologies used. The comparison and use of historical data for the understanding of the current situations and future trends is therefore difficult. Sound data and information need to be developed for a better understanding and discussion between the various stakeholders.

The economic significance of game damage is poorly documented. There is a lack of a comparison of damage and benefits from wildlife and its management in the context of sustainable use of the forest resource by all stakeholders. The existence of contradicting forest resource management objectives, the lack of compromise between stakeholders with contradicting objectives, and the lack of objective information explains why it is impossible to develop appropriate management policies in Europe. Research on integrated, ungulate management is crucial for the future. It is more and more apparent that managers need to adopt new approaches, taking into account the inputs of all stakeholders (foresters, hunters, farmers, tourists, conservationists and administrative authorities). And last, but not least, the possible positive effects of ungulates on vegetation structure are poorly investigated in contrast to the well documented negative impacts.

The need for multi-objective and adaptive management

Management of ungulates needs to be considered and integrated within a wide framework and related to all land management uses. It is a very challenging goal to overcome the emotional dimension and bring stakeholders from forestry, nature conservation, hunting, industry and even tourism together to engage in a process where a set of common objectives can be developed and agreed to preserve forest ecosystem services for the future. The management of both forest and wildlife will gain from a European approach with larger scale management options.

3.4.9 What FRISK could provide

A Wildlife Component within the European Forest Risk Facility

Within the FRISK network and with cooperating partners from forest and wildlife science and practice the above described gaps and challenges can be addressed.

New approaches should be given a chance. In a professional, participative and transparent approach FRISK can facilitate movement towards commonly agreed forest ecosystem management objectives, where all stakeholders cooperate in the form of partnership contracts with the objective to maintain and develop resilient forest ecosystems with all its services for future generations. Developing guidelines and role models for decision support for land owners can be a further FRISK role.

An underlying principle is, of course, the condition that natural tree regeneration without fencing should be the norm.

Hosting inclusive workshops with stakeholders for development of a wildlife component within the Forest Risk Facility, including potential donors and sponsors, is an initial important step to:

- Describe the structure of a wildlife component within FRISK;
- Describe needed products and services;
- Identify partnerships for development of case studies, demonstration and trial areas;
- Create early ownership of all actors, e.g. land owners, forestry, agriculture, hunting, nature conservation, industry, etc.).

Future Challenges

Land-use change, climate change and effects from population dynamics of large carnivores, represent the key main future challenges to ungulate management. Apollonia et al. (2010) suggest that ungulate management in the 21st century needs the development of a more holistic and responsive management system, which:

- attempts to integrate management of ungulates in relation to all land-use interests where ungulates themselves may have an impact. This means the management of the ungulate populations themselves, whether objectives are control, exploitation or conservation, but also management of their impacts on other land-use interests: agriculture, forestry, habitat conservation, recreation, access to the countryside;
- properly declares and defines management objectives (transparency);
- includes more extensive (and science-based) monitoring systems which record trends in ungulate populations and impacts in order to assess effectiveness of management strategies in the short or medium term and allow refinement or adjustment of management policy so that it better delivers the declared objectives of that management;
- explicitly recognizes the value of wild ungulates as a natural resource both in terms of their value as living organisms and part of the wider biodiversity of an area, but also as a resource that can be managed in order to provide better living conditions for the people living in the same area, and ensures greater coordination of management both within and between countries.

Development of a European policy framework directed to regulate the use of this important natural resource should be considered (Apollonio et al., 2010).

4 Concluding remarks

Jo Van Brusselen, Andreas Schuck, Guy Landman

All types of forest disturbances are on the rise in Europe and therefore it is justifiable that they gain political attention. Forest disturbance events cause considerable harm to Europe's bio-economy and biodiversity, and ultimately they threaten the resilience and sustainability of the forest ecosystem. This is easily understood for large-scale devastating events such as forest fires, but often underestimated, even by professionals, for less detectable impacts from, for example, damaging biotic agents.

Important deficiencies need to be addressed in terms of coordination, exchange of information, know-how and technology. This would help to increase effectiveness and efficiency when addressing forest disturbances that do not stop at borders, whether they are regional or national. While they may differ in nature, cause and effect, this conclusion is valid for all of the presented forest disturbances.

Capacity building should address stakeholders at various levels in the forest and environment domain, which currently often have to come by relatively unprepared, with ad-hoc experience that needs to build up on-the-go.

Information and communication, increased understanding and risk analysis, mitigation strategies and risk readiness planning, crisis management, supporting, networking and building capacities, are all types of activities that would help those responsible for managing the forest, from stand scale to the national level, in order to be as well informed as possible and manage forests in the best possible manner.

Taking the above into account, it could be seen as a very positive development that discussions are on-going towards initiating an entity that could facilitate these activities. Therefore the authors of this report consider it timely and highly welcome that the common ground that is opening up for potentially increased regional and European cooperation is explored in a start-up project named FRISK-GO (http://www.friskgo.org/).

5 References

Albrecht, A., Hanewinkel, M., Bauhus, J. and Kohnle, U. 2012. How does silviculture affect storm damage in forests of south-western Germany? Results from empirical modelling based on long-term observations. European Journal of Forest Research, 131>229/247. doi:10.1007/s10342-010-0432-x

Andersen R., Duncan P., Linnel J. 1999. The European Roe Deer: The biology of success. Oslo, Scandinavian University Press, 376 p.

Apollonio, M., Andersen, R., Putmann, R. 2010. European Ungulates and their Management in the 21st Century. Cambridge, UK: Cambridge University Press, 602 p.

Asiegbu F.O., Adomas A., Stenlid J. 2005. Conifer root and butt rot caused by Heterobasidion annosum (Fr.) Bref. s.l. Molecular Plant Pathology 6(4):395-409. doi:10.1111/j.1364-3703.2005.00295.x

Ayres, M.P. and Lombardero, M.J. 2000. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. Science of the Total Environment 262:263-286. doi:10.1016/S0048-9697(00)00528-3

Bale J.S., Masters G.J., Hodkinson I.D., Awmack C., Martijn Bezemer T., Brown V.K., Butterfield J., Buse A., Coulson J.C., Farrar J., Good J.E.G., Harrigton R., Hartley S., Hefin Jones T., Lindroth R.L., Press M.C., Symrnioudis I., Watt A.D., Whittaker J.B. 2002. Herbivory in global climate change research: direct effects of rising temperatures on insect herbivores. Global Change Biology, 8, 1-16. doi:10.1046/j.1365-2486.2002.00451.x

Battisti A., Jactel H., 2010. Pest insect populations in relation to climate change in forests of the Mediterranean basin. Forêts méditerrannéennes, XXXI(4):385-392.

Battisti A., Stastny M., Netherer S., Robinet C., Schopf A., Roques A., Larsson S. 2005. Expansion of geographic range in the pine processionary moth caused by increased winter temperatures. Ecological Applications, 15(6)2084-2096. doi:10.1890/04-1903

BIO Intelligence Service, 2012. Disturbances of EU forests caused by biotic agents. Final Report. European Commission (DG ENV). Contract 070307/2010/574341/ETU/ENV.B.1. 271 p.

Birot, Y., (ed.) 2009. Living with Wildfires. What Science can tell us. A contribution to the Science-Policy dialogue. EFI Discussion Paper 15. Joensuu, European Forest Institute, 82 p.

Birot, Y., Landmann, G., Bonhême, I. (eds). 2009. La forêt face aux tempêtes. Editions Quæ. ISBN: 978-2-7592-0330-7. Versailles Cedex, France.

Blennow, K. 2008. Risk management in Swedish forestry – Policy formation and fulfilment of goals. Journal of Risk Research 11:237-254. doi:10.1080/13669870801939415

Brunet, Y., Dupont, S., Sellier, D. and Fourcaud, T. 2009. Les interactions vent-arbre, de l'échelle locale à celle du paysage : vers des approches déterministes. In: Birot, Y., Landmann, G., Bonhême, I. (eds.). La forêt face aux tempêtes. Editions Quæ. ISBN: 978-2-7592-0330-7. Versailles Cedex, France. Pp. 229-259.

Castellnou, M, Kraus, D, Miralles, M, Delogu, G. 2010. Suppression fire use in learning organizations. In: Sande Silva, J., Rego, F., Fernandes, P., Rigolot, E. (eds). Towards Integrated Fire Management –

Outcomes of the European Project Fire Paradox. EFI Research Report 23. European Forest Institute, Joensuu, Finland. Pp 189-201.

Costa, P., Castellnou, M., Larrañaga, A., Miralles, M. and Kraus, P.D. 2011. Prevention of Large Wildfires using the Fire Types Concept. Unitat Tècnica del GRAF, Divisió de Grups Operatius Especials. Direcció General de Prevenció, Extinció d'Incendis i Salvaments. Departament d'Interior. Generalitat de Catalunya. ISBN: 978-84-694-1457-6. 88 p.

Colin, F., Vinkler, I., Riou-Nivert, P., Renaud, J.-P., Hervé, J.-C., Bock, J., Piton, B. 2009. Facteurs de risques de chablis dans les peuplements forestiers: les leçons tirées des tempêtes de 1999. In: Birot, Y., Landmann, G. and Bonhême, I. (eds.). La forêt face aux tempêtes. Editions Quæ. ISBN: 978-2-7592-0330-7. Versailles Cedex, France. Pp. 177-227.

DAISIE, 2009. Handbook of Alien Species in Europe. Invading Nature - Springer Series in Invasion Ecology, Vol. 3. Dordrecht, Springer. 93-104

DAISIE European Invasive Alien Species Gateway http://www.europe-aliens.org/aboutDAISIE.do

Dale, V.H., Joyce, L.A., McNulty, S. and Neilson, R.P. 2000. The interplay between climate change, forests, and disturbances. Science of the Total Environment, 262(3): 201-204. doi:10.1016/S0048-9697(00)00522-2

Della-Marta, P.M., Pinto, J.G. 2009. Statistical uncertainty of changes in winter storms over the North Atlantic and Europe in an ensemble of transient climate simulations. Geophysical Research Letters 36, L14703. doi:10.1029/2009GL038557

Desprez-Loustau M.L. 2009. The alien fungi of Europe. In: DAISIE (ed.) Handbook of alien species in Europe. Invading Nature - Springer Series in Invasion Ecology, Vol. 3. Dordrecht, Netherlands: Springer. Pp. 15–28.

Desprez-Loustau M.L., Courtecuisse R., Robin C., Husson C., Moreau P.A., Blancard D., Selosse M.A., Lung-Escarmant B., Piou D., Sache I. 2010. Species diversity and drivers of spread of alien fungi (sensu lato) in Europe with a particular focus on France. Biological Invasions, 12(1):157-172. doi:10.1007/s10530-009-9439-y

Dupont, S., Brunet, Y., Finnigan, J.J. 2008. Large-eddy simulation of turbulent flow over a forested hill: validation and coherent structure identification. Quarterly Journal of the Royal Meteorological Society 134:1911-1929. doi:10.1002/qj.328

Dury, M., Hambuckers, A., Warnant, P., Henrot, A., Favre, E.,Ouberdous, M., François, L. 2011. Responses of European forest ecosystems to 21st century climate: assessing changes in interannual variability and fire intensity. iForest, 4: 82–99. doi:10.3832/ifor0572-004

EC, 2013. Proposal for a regulation of the European Parliament and of the council on protective measures against pests of plants. COM(2013) 267 final. Brussels, European Commission. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2013:0267:FIN

EC, 2010. Green Paper on Forest Protection and Information in the EU: Preparing forests for climate change. COM(2010)66 final. Brussels, European Commission. http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1442210383982&uri=CELEX:52010DC0066

EEA, 2005. Vulnerability and adaptation to climate change in Europe. European Environmental Agency, Technical Report 7/2005, 79 p.

FAO, 2007. Fire management global assessment 2006 A thematic study prepared in the framework of the Global Forest Resources Assessment 2005. FAO Forestry Paper 151.

Fink, A.H., Brücher, T., Ermert, V., Krüger, A., Pinto, J.G. 2009. The European storm Kyrill in January 2007: Synoptic evolution, meteorological impacts and some considerations with respect to climate change. Natural Hazards and Earth System Science 9, 405-423. doi:10.5194/nhess-9-405-2009

Flannigan et al. 2009. Implications of changing climate for global wildland fire. International Journal of Wildland Fire 2009, 18, 483–507

FOREST EUROPE, UNECE, FAO, 2011. State of Europe's Forests 2011 Status and Trends in Sustainable Forest Management in Europe Ministerial Conference on the Protection of Forests in Europe. FOREST EUROPE Liaison Unit Oslo Ås, Norway.

Forestry Commission Scotland, 2014. Scottish Windblow Contingency Plan. A strategy for dealing with catastrophic windblow events in Scottish forests. http://scotland.forestry.gov.uk/images/corporate/pdf/windblow-contingency-plan.pdf

Fraser, A.I. 1964 Wind tunnel and other related studies on coniferous trees and tree crops. Scottish Forestry 18: 84-92

Gardiner B., Schuck A., Schelhaas M.J., Orazio C., Blennow K., Nicoll B. (eds) 2013. Living with Storm Damage to Forests. What Science Can Tell Us 3. Joensuu, European Forest Institute, 129 p.

Gardiner, B., Schelhaas, M.-J., Nicoll, B., 2012. Mapping current and projected key European forest risks. Report FP7-226544-MOTIVE / D4.1B. http://motive-project.net/deliverables.php?P=35&SP=45

Gardiner, B., Blennow, K., Carnus, J-M, Fleischer, P., Ingemarson, F., Landmann, G., Lindner, M., Marzano, M., Nicoll, B., Orazio, C., Peyron, J-L., Reviron, M-P., Schelhaas, M.J., Schuck, A., Spielmann, M., Usbeck, T. 2010. Destructive Storms in European Forests: Past and Forthcoming Impacts. Final Report to EC DG Environment. (07.0307/2009/SI2.540092/ETU/B.1), 113p.
http://ec.europa.eu/environment/forests/studies.htm

Gardiner, B., Byrne, K., Hale, S., Kamimura, K., Mitchell, S.J., Peltola, H., Ruel, J.-C. 2008. A review of mechanistic modelling of wind damage risk to forests. Forestry 81, 447–563. doi:10.1093/forestry/cpn022

Gatto, P., Zocca, A., Battisti, A., Barrento, M.J., Branco, M., Paiva, M.R. 2009. Economic assessment of managing processionary moth in pine forests: A case-study in Portugal. Journal of Environmental Management, 90(2): 683-691. doi:10.1016/j.jenvman.2008.01.007

Glantz, M.H., 1994. Creeping Environmental Problems. The World & I, June 1994 Issue 6:218-225.

Grégoire J.C., Evans H.F., 2004. Damage and control of BAWBILT organisms, an overview. In: F. Lieutier F, Day K, Battisti A, Grégoire JC, Evans HF (Eds.), Bark and wood boring insects in living trees in Europe, a synthesis. Kluwer Academic Publisher, Dordrecht, The Netherlands. Pp. 19-38.

Gren, I.M., Isacs, L., Carlsson, M. 2009. Costs of Alien Invasive Species in Sweden. Ambio, 38(3) (May, 2009):135-140. doi:10.1579/0044-7447-38.3.135

Grigaut, G. Deuffic, P., Orazio, C. 2010. Expertise sur l'avenir du massif des landes de Gascogne, rapport de synthèse du groupe de travail 1 : retour sur la gestion de crise suite à la tempête Klaus et éléments d'anticipation. Gip-ECOFOR. 48 p. http://landes.gip-ecofor.org/data/RFSortieCrise0310.pdf

Hale, S., Gardiner, B., Peace, A., Nicoll, B., Taylor, P., Pizzirani, S. 2015. Comparison and validation of three versions of a forest wind risk model. Environmental Modelling & Software, 68:27–41. doi:10.1016/j.envsoft.2015.01.016

Hamard, J.P., Ballon P. 2009. Guide pratique d'évaluation des dégâts en milieu forestier, 32 p.

Hanewinkel, M., Hummel, S., Albrecht, A. 2011. Assessing natural hazards in forestry for risk management: a review. European Journal of Forest Research 130: 329–351. doi:10.1007/s10342-010-0392-1

Herzog, S. 2013. Wildlife Management in Protected Areas: Goals and Concepts. Conference Volume, 5th Symposium for Research in Protected Areas. Mittersill 10-12 June, 2013. ISBN: 978-3-200-03106-7. Pp. 295-298.

IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jactel, H., Brockerhoff, E.G. 2007. Tree diversity reduces herbivory by forest insects. Ecology Letters. Ecology Letters (2007) 10(9):835–848. doi:10.1111/j.1461-0248.2007.01073.x

Jactel, H., Branco, M., Duncker, P., Gardiner, B., Grodzki, W., Langstrom, B., Moreira, F., Netherer, S., Nicoll, B., Orazio, C., Piou, D., Schelhaas, M.-J., Tojic, K.. 2012a. A multicriteria risk analysis to evaluate impacts of forest management alternatives on forest health in Europe. Ecology and Society 17(4):52. doi:10.5751/ES-04897-170452

Jactel, H., Desprez-Loustau, M.L., Marçais, B., Piou, D., Robinet, C., Roques, A. 2012b. Evolution des risques biotiques en forêt. Innovations agronomiques, INRA, 18, 87-94.

Jactel, H., Petit, J., Desprez-Loustau, M.-L., Delzon, S., Piou, D., Battisti, A., Koricheva, J. 2012c. Drought effects on damage by forest insects and pathogens: a meta-analysis. Global Change Biology, 18(1):267–276, doi:10.1111/j.1365-2486.2011.02512.x

Jactel, H., Vodde, F., Branco, M., Carnus, J.M., Gonzalez, J.R., Groszki, W., Langstrom, B., Moreira, F., Netherer, S., Nicoll, B., Orazio, C., Piou, D., Santos, H., Schelhaas, M.-J., Tojic, K. 2011. Prevalence of Biotic and abiotic hazards in European forests. Deliverable PD 2.4.2 EFORWOOD Tools for sustainability impact assessment, EFI Technical Report 66. Joensuu, European Forest Institute, 30 p.

Jactel, H., Nicoll, B.C., Branco, M., Gonzalez-Olabarria, J.R., Grodzki, W., Långström, B., Moreira, F., Netherer, S., Orazio, C., Piou, D., Santos, H., Schelhaas, M.J., Tojic, K., Vodde, F., 2009. The influences of forest stand management on biotic and abiotic risks of damage. Annals of Forest Science, 66(7):701. doi:10.1051/forest/2009054

Jactel, H., Menassieu, P., Vétillard, F., Gaulier, A., Samalens, J.C., Brockerhoff, E.G. 2006. Tree species diversity reduces the invasibility of maritime pine stands by the bast scale, Matsucoccus feytaudi (Homoptera: Margarodidae). Canadian Journal of Forest Research, 36(2):314–323. doi:10.1139/x05-251

James, K., Haritos, N., Ades, P. 2006. Mechanical stability of trees under dynamic loads. American Journal of Botany, 93:1522–1530. doi:10.3732/ajb.93.10.1522

Kamimura, K., Gardiner, B., Dupont, S., et al. 2015. Mechanistic and statistical approaches to predicting wind damage to maritime pine trees. Canadian Journal of Forest Research. In Press.

Klapwijk, M.J., Battisti, A., Ayres, M.P., Larsson, S.. 2012. Assessing the impact of climate change on outbreak potential. In: Barbosa P, Schultz JC, Letourneau D, (eds). Insect outbreaks revisited. Oxford, UK: Blackwell Publishing Ltd. Pp. 429-450.

Lindner, M., Garcia-Gonzalo, J., Kolström, M., Green, T., Reguera, R., Maroschek, M., Seidl, R., Lexer, M. J., Netherer, S., Schopf, A., Kremer, A., Delzon, S., Barbati, A., Marchetti, M., Corona, P. 2008. Impacts of Climate Change on European Forests and Options for Adaptation. DG Agriculture and Rural Development, 173 p.

MCPFE, 2002. Improved Pan-European Indicators for Sustainable Forest Management as adopted by the MCPFE Expert Level Meeting 7-8 October 2002, Vienna, Austria, 6 p.

Miller, K.F. 1985. Windthrow Hazard Classification, Forestry Commission Leaflet 85. HMSO, London.

Morellet N., Gaillard J. M., Hewison A.J.M., Ballon P., Boscardin Y., Duncan P., Klein F., Maillard D., 2007. Indicators of ecological change: new tools for managing populations of large herbivores. Journal of Applied Ecology, 44:634-643. doi:10.1111/j.1365-2664.2007.01307.x

Müller, M., Müller, T., Möhring, A., 2012. Waldbesitzerinteressen – Wildeinflüsse – Zielorientierte Jagd. AFZ-Der Wald, 67(9):22-25.

Nageleisen, L.M., Piou, D., Saintonge, F.X., Riou-Nivert, P. 2010. La santé des forêts. CNPF/IDF, Paris, France, 608 p.

Netherer, S., Schopf, A. 2010. Potential effects of climate change on insect herbivores in European forests-General aspects and the pine processionary moth as specific example. Forest Ecology and Management, 259(4):831-838. doi:10.1016/j.foreco.2009.07.034

Nicoll, B.C., Gardiner, B.A., Rayner, B., Peace, A.J. 2006. Anchorage of coniferous trees in relation to species, soil type, and rooting depth. Canadian Journal of Forest Research 36(7):1871–1883. doi:10.1139/x06-072

Putman, R., Andersen, R., Apollonio, M. 2011. Ungulate Management in Europe: problems and practices. Cambridge, UK: Cambridge University Press, 398 p.

Quine, C.P., Coutts, M.P., Gardiner, B.A., Pyatt, D.G. 1995. Forests and wind: Management to minimise damage. Forestry Commission Bulletin 114. London, HMSO.

Reimoser F., Gossow H. 1996. Impact of ungulates on forest vegetation and its dependence on the sylvicultural system. Forest Ecology and Management 88(1-2):107-119. doi:10.1016/S0378-1127(96)03816-9

Reimoser F., Armstrong H., Suchant R. 1999. Measuring forest damage of ungulates: what should be considered. Forest Ecology and Management 120:47-58. doi:10.1016/S0378-1127(98)00542-8

Requardt, A., Köhl, M., Schuck, A., Poker, J., Janse, G., Mavsar, R., Päivinen, R. 2007. Feasibility Study on means of combating forest dieback in the European Union. EC DG ENV Contract, Brussels, 79 p. + Annexes.

Robinet, C., Roques, A. 2010. Direct impacts of recent climate warming on insect populations. Integrative Zoology, 5(2):132-142. doi:10.1111/j.1749-4877.2010.00196.x

Roques, A., Kenis, M., Lees, D., Lopez-Vaamonde, C., Rabitsch, W., Rasplus, J.Y., Roy, D. 2010. Alien terrestrial arthropods of Europe. BIORISK - Biodiversity and Ecosystem Risk Assessment, No. 4 (Special Issue), 1038 p. http://biorisk.pensoft.net/browse_journal_issue_documents.php?issue_id=148

Sache, I., Roy, A.S., Suffert, F., Desprez-Loustau, M.L. 2011. Invasive Plant Pathogens in Europe. In: Pimentel, D. (ed.). Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal, and Microbe Species. CRC Press. Pp. 227-242. doi:10.1201/b10938-14

Schelhaas, M.J. 2008. Impacts of natural disturbances on the development of European forest resources: application of model approaches from tree and stand levels to large-scale scenarios. Dissertationes Forestales 56, University of Joensuu, Finland. Alterra scientific contributions 23, Wageningen, The Netherlands, 168 p.

Schelhaas, M.J., Hengeveld, G., Moriondo, M., Reinds, G.J., Kundzewicz, Z.W., ter Maat, H., Bindi, M. 2010. Assessing risk and adaptation options to fire and windstorms in European forestry. Mitigation and Adaptation Strategies for Global Change, 15(7):681-701. doi:10.1007/s11027-010-9243-0

Schelhaas, M.J., Nabuurs, G.J., Schuck, A. 2003. Natural disturbances in the European forests in the 19th and 20th centuries. Global Change Biology 9(11), 1620-1633. doi:10.1046/j.1365-2486.2003.00684.x

Schodterer, H. 2011. Verjüngung im österreichischen Wald: Defizite im Schutzwald. BFW-Praxisinformation. 24/2011.

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

Somerville, A. 1989. Tree wind stability and forest management practices. In: Somerville, A., Wakelin, S., Whitehouse, L. (eds). Workshop on wind damage in New Zealand exotic forests. FRI Bulletin 146. Forest Research Institute, Rotorua, New Zealand. Pp. 38-58.

Stadelmann, G., Bugmann, H., Meier, F., Wermelinger, B., Bigler, C. 2013. Effects of salvage logging and sanitation felling on bark beetle (*Ips typographus* L.) infestations. Forest Ecology and Management, 305:273-281. doi:10.1016/j.foreco.2013.06.003

Statistisches Bundesamt, 2012. Erzeugerpreisindizes Staatsforsten Deutschland (.in German) [Producer-price index, State Forest Germany]. Statistical Office, Wiesbaden.

Valinger, E., Fridman, J. 2011. Factors affecting the probability of windthrow at stand level as a result of Gudrun winter storm in southern Sweden. Forest Ecology and Management 262(3):398-403. doi:10.1016/j.foreco.2011.04.004

Wainhouse, D. 2005. Ecological methods in forest pest management. Oxford, UK, Oxford University Press.

Winkel, G., Kaphengst, T., Herbert, S., Robaey, Z., Rosenkranz, L., Sotirov, M. 2009. Final Report EU policy options for the protection of European forests against harmful impacts. EU DG ENV.B.1/ETU/2008/0049. 146 p.

Woodward, S., Stenlid, J., Karjalainen, R., Hütterman, A.A. (eds) 1998. Heterobasidion annosum, Biology, Ecology, Impact and Control. Wallingford, UK: CAB International. 589 p.

Annex 1 - Top-30 biotic agents in EU forests classified by category

(Classification from most to less damaging; Source: BIO Intelligence Service 2012 – corrections indicated with (*))

Category	**Scientific and common name**	**Taxon**	**Native/ Alien**	**Type of disturbance**	**Distribution in EU27**	**Trees impacted**
Top 1-5	*Ophiostoma novo-ulmi* (Dutch elm disease)	Fungus	Alien (evolution)	Disease	AT, BE, BG, CZ, DK, EE, FR, DE, EL, HU, IT, LT, NL, PL, ES, RO, SE, SK, UK	Elm (*Ulmus minor, U. glabra, U. laevis, U. americana, U. rubra, U. thomasii* and *U. crassifolia*)
Top 1-5	*Bursaphelenchus xylophilus* (pine wood nematode)	Nematode	Alien	Disease	PT and 2 outbreaks in ES under eradication	Pine (*Pinus pinaster, P. sylvestris* and *P. nigra*)
Top 1-5	*Ips typographus* (European spruce bark beetle)	Insect	Native	Wood boring	AT, BE, BG, CZ, DK, EE, FI, FR, DE, EL, HU, IT, LV, LT, LU,, NL, PL, RO, SK, SL, SE, UK	Mainly Norway spruce (*Picea abies*) but sometimes pine (*Pinus* spp.) and larch (*Larix* spp.)
Top 1-5	*Neodiprion sertifer* (European pine sawfly)	Insect	Native	Defoliation	Boreal forests (SE, FI)	Scots pine(*Pinus sylvestris*)
Top 1-5	*Tomicus piniperda* (common pine shoot beetle)	Insect	Native	Wood Boring	AT, BE, BG, CZ, FI, FR, DE, EL, HU, IT, NL, PL, PT, RO, SE, UK	Scots pine (*Pinus sylvestris*) and occasionally spruce (*Picea* spp.) (*) and larch (*Larix* spp.)
Top 6-10	*Chalara fraxinea* (ash dieback)	Fungus	Unknown	Disease	AT, CZ, FI, FR, DE, HU, IT, LI, NL, PL, SL, SE and observed on the basis of the symptoms: DK, EE and LV	Ash (*Fraxinus excelsior* and *F. angustifolia*)
Top 6-10	*Heterobasidion annosum*	Fungus	Native	Disease	AT, DE, EE, FR, IE, FI, LI, LV, PL, SE, UK	Norway spruce (*Picea abies*) and fir (*Abies alba*)

Category	Scientific and common name	Taxon	Native/ Alien	Type of disturbance	Distribution in EU27	Trees impacted
Top	*Phytophthora*	Fungus	Alien	Defoliation	Found only in nursery in: BE, DK, FR, DE, IE,	Beech family tree (*Lithocarpus densiflorus*,
6-10	*ramorum* (sudden oak death)				NL, PL, SL, ES, SE, UK In the wild: DE, DK, IE, LU, NL and UK In the wild now eradicated BE and SL	*Quercus agrifolia, Q. parvula* and Q. *kelloggii*) and shrub species (*Rhododendron* spp. and *Viburnum* spp.). Bleeding canker due to *P. ramorum* reported on *Querus rubra* (in NL) as well as *Q. ilex, Q. acuta, Q. falcata* and *Q.* cerris (in UK). Bleeding canker due to *P. ramorum* reported on *Fagus sylvatica* (in NL) and *Nothofagus obliqua* (in UK).
Top 6-10	*Lymantria dispar* (gypsy moth)	Insect	Native	Defoliation	AT, BG, CZ, DE, EL, FR, HU, IT, PL, PT, RO, SK, SL, ES	Deciduous trees, notably oak (*Quercus* spp.)
Top 6-10	Large herbivores	Mammal	Native	Browsing	Found in all EU27	Deciduous notably oak (*Quercus* spp.), hornbeam trees (*Carpinus* spp.)
Top 11-15	*Phytophthora cinnamomi*	Fungus	Alien	Disease	FR, IT, PT, RO, SL, ES, UK	Cork oak (*Quercus suber*), but wide range of hosts like chestnut (*Castanea* spp.) and conifers (*Chamaecyparis lawsoniana, Juniperus conferta*)
Top 11-15	*Biscogniauxia mediterranea* (charcoal disease)	Fungus	Native	Disease	Mediterranean MS (ES, FR, IT, PT) and reported in SL	Oak (*Quercus* spp.)
Top 11-15	*Dothistroma septospora* (red band needle blight)	Fungus	Alien	Disease	AT, BG, DE, ES, EL, FR, IT, PT, RO, UK	Pine (*Pinus* spp.)
Top 11-15	*Diplodia pinea* (diplodia blight)	Fungus	Native	Disease	From Southern Europe to the north (FR, BE, IT, UK), reported in EE	Pine (*P. nigra, P. pinaster* and *P. sylvestris*)
Top 11-15	*Thaumetopoea pityocampa* (pine processionary moth)	Insect	Native	Defoliation	Central and Southern Europe (AT, BG, CY, FR, EL, HU, IT, PO, ES)	Pine (*P. nigra* var. *austriaca, P. sylvestris; P. pinaster, P. pinea, P. canariensis, P. halepensis*)

Category	Scientific and common name	Taxon	Native/ Alien	Type of disturbance	Distribution in EU27	Trees impacted
Top 16-20	*Cryphonectria parasitica* (chestnut blight)	Fungus	Alien	Disease	AT, BE, FR, DE, EL, HU, IT, PL, PT, SL, SK, ES	Chestnut (*Castanea* spp.) (*)
Top 16-20	*Ceratocystis fagacearum* (oak wilt)	Fungus	Alien	Disease	Wide distribution in North America, not in Europe yet.	Oak (*Quercus* spp.)
Top 16-20	*Gremmeniella abietina* (Brunchorstia disease)	Fungus	Native	Disease	AT, BE, BG, CZ, DK, EE, FI, FR, DE, EL, IT, LI, NL, PL, RO, ES, SE, UK	Spruce (mainly *Picea abies*) and pine (mainly*P. contorta* and *Pinus sylvestris*)
Top 16-20	*Anoplophora glabripennis* (Asian Longhorned Beetle)	Insect	Alien	Wood boring	AT, DE, FR	Deciduous (*Populus* spp., *Salix* spp., *Ulmus* spp. And *Acer* spp.)
Top 16-20	*Anoplophora chinensis* (citrus longhorned beetle)	Insect	Alien	Wood boring	Infestation detected mainly in IT where it is spread (Rome, within Milan: mainly in West and North West of the city, and in 30 municipalities North West, West, and South of Milan). In isolation, A. chinensis was detected in FR (but declared eradicated since 2006), in DE in 2008 (but now eradicated) and in NL	Broadleaved trees and shrubs – major concern for *Citrus* spp.
Top 21-25	*Erwinia nimipressuralis* and *E. amylovora* (fire blight)	Bacteria	Alien	Disease	AT, BE, BG, CY, CZ, DK, FR, DE, EL, HU, IE, IT, LU, NL, PL, RO, SK, ES, SE, UK	Rose family (*Crataegus* spp) .and chestnut (*Castanea* spp.)

Category	**Scientific and common name**	**Taxon**	**Native/ Alien**	**Type of disturbance**	**Distribution in EU27**	**Trees impacted**
Top 21-25	*Fusarium circinatum* (pitch canker)	Fungus	Native	Disease	ES, IT, FR, PT	Pine (*Pinus* spp.)
Top 21-25	*Melampsora allii-populina* and other *Melampsora* spp. (European rust)	Fungus	Native	Disease	BE, ES, FR, PT	Poplar (*Populus balsamifera, P. deltoides, P. nigra* var. *italica* and *P. tremuloides*)
Top 21-25	*Armillaria* spp. (armillaria root disease)	Fungus	Native	Disease	FR, HU, DE, BG, EL, ES, IT, UK, BE	Wide range of hosts - mainly larch (*Larix* spp.), spruce (*Picea* spp.) and pine (*Pinus* spp.))
Top 21-25	*Dryocosmus kuriphilus* (Oriental chestnut gall wasp)	Insect	Alien	Disease	IT, FR, SL	Chestnut especially *Castanea sativa*
Top 26-30	*Phytophthora alni*	Fungus	Alien	Disease	BE, DE, FR, UK	Alder trees (*Alnus glutinosa*)
Top 26-30	*Odontota dorsalis* (locust leafminer)	Insect	Alien	Defoliation		Robinia (*Robinia* spp.)
Top 26-30	*Ips sexdentatus* (six-toothed bark beetle)	Insect	Alien	Wood boring	AU, BG, CZ, FR, DE, GR, HU, IT, LI, PO, PT, RO, ES, SE, SO, CH, UK	Pine (*P. sylvestris, P. pinaster, P. heldreichii* and *P. nigra*)
Top 26-30	*Phoracantha semipunctata* (eucalyptus longhorned borer)	Insect	Alien	Wood boring	FR, IT, NL, PR, ES	Eucalypts (*Eucalyptus* spp.)
Top 26-30	*Rhynchophorus ferrugineus* (red palm weevil)	Insect	Alien	Wood boring	CY, FR, ES, EL, IT, MT, PT, SL	Palm (*Phoenix dactylifera* and *P. canariensis*)

Annex 2 - International information systems on forests pests and diseases

(Source: BIO Intelligence, 2012)

General information websites	
Global Forest Information Service	Provides the framework to share forest-related data and information through a single gateway. It promotes the dissemination and sharing of forest and tree-related information and knowledge among the global forestry community by developing common information exchange standards, building capacity and enhancing partnerships among forestry information providers and users. It also provides links to collections of forest databases including forest pests http://www.gfis.net/
IUFRO	Promotes global cooperation in forest-related research and enhances the understanding of the ecological, economic and social aspects of forests and trees. It disseminates scientific knowledge to stakeholders and decision-makers and contributes to forest policy and on-the-ground forest management. http://www.iufro.org/
Forest Europe	Forest Europe (The Ministerial Conference on the Protection of Forests in Europe) develops common strategies for its 46 member countries and the EU on how to protect and sustainably manage forests. It provides general information and publications on forest health and management. http://www.foresteurope.org/
Euroforest Portal	The EuroForest portal is an entry point to information about forests in Europe. It provides links to maps and information about forest resources, forest policy and legislation, forest ecology and ecosystems, forest management and planning, forest protection, research, forest products industries, wood science, wood preservation, bioenergy, and non- wood forest products. http://forestportal.efi.int/
Forest Data and Information System (led by the JRC)	A European Forest Data Centre which is the central point of forest information at European level in support of relevant EU policies, and as the basis of the European Forest Monitoring System proposed in the EU Forest Action Plan. http://http://forest.jrc.ec.europa.eu/
Databases covering forest biotic agents	
BAWBILT Cost Action E 16 (1998-2002)	Database on existing knowledge about bark and wood boring insects in living trees in Europe.
DFDE (2003-to date)	Database providing historical information about natural disturbances in the forests of Europe http://www.efi.int/portal/virtual_library/databases/
DAISIE database	On the alien species found in the EU covering all taxa (inventory, species description, ecology and habitat, distribution, impact and management, experts) http://www.europe-aliens.org/
FAO-country pest overviews	Includes information about the pests and diseases found in naturally regenerating and planted forests in the country, and also methods of forest production http://www.fao.org/forestry/38536/en/
Global Invasive Species Database	Database on alien invasive species that threaten native biodiversity, covering all taxonomic groups Species information is either supplied by expert contributors from around the world. and by the Invasive Species Specialist Group (ISSG) of the IUCN Species Survival Commission http://www.issg.org/database/welcome/
EPPO database on quarantine pests	Quarantine lists and species information to draw the attention of EPPO member countries to certain pests possibly presenting a risk to them and achieve early warning. http://www.eppo.int/DATABASES/pqr/pqr.htm
Identification tools	

EPPO database on diagnostic expertise	Provides an inventory of the diagnostic expertise available in the EPPO region. Its aim is to cover the expertise on regulated pests, pests possibly presenting a risk to EPPO member countries and plants of the EPPO List of invasive alien plants. This database does not include common pests which are widely distributed in the EPPO region http://www.eppo.int/DATABASES/diagnostics/diag_quest.htm
ICP Forest manual part IV - Visual assessments of Crown Condition and Damaging Agents	Aims at providing a consistent methodology to collect high quality, harmonized and comparable tree condition data about crow condition (biotic and abiotic damage). http://www.icp-forests.org/pdf/FINAL_Crown.pdf
Forestry images	Provides image of forestry pests (insects, diseases and other damage agents). http://www.forestryimages.org/
CABI Distribution Maps of Plant Diseases	Covers important disease affecting agriculture, horticulture and forestry. http://www.cabi.org/dmpd/
Forest and shade tree pathology	Contains information about major diseases that affect trees and provides an aid to learn forest and shade tree pathology. http://www.forestpathology.org/
Information repositories	
NOBANIS-European Network on Invasive Alien Species	Provides database on species introduced in the region, a literature database and factsheets on the most invasive aliens. This network mainly acts in North and central Europe. https://www.nobanis.org/
CIRCA SANCO-EUROPHYT (2002- to date)	Has been implemented to protect the EU territory from introduction and spread of harmful organisms that pose phytosanitary risk. http://ec.europa.eu/food/plant/plant_health_biosecurity/europhyt/index_en.htm

The scoping study presents the current situation and future trends for different forest disturbance regimes and explores knowledge gaps and needs for action. It thus provides valuable input for developing the framework of a European Forest Risk Facility.

With support from

Federal Ministry of Food and Agriculture

by decision of the German Bundestag