Integrated and systemic management of storm damage by the forest-based sector and public authorities

Key message

Integrated and systemic management of wind damage risk can help to address decision-making requirements, mitigate economic impacts of storms and improve collective well-being of the forest sector. In this context, public authorities should actively act to enable flexible decision-making and strengthen the resilience of the forest sector facing destructive storms.

Abstract

- **Context:** Destructive storms are among the major threats for forest-based economies in Europe. Over three decades, the topic has gradually moved to the top of the forest community's agenda but with little coordination among stakeholders and limited response from public authorities.
- **Aims:** The paper's goals are to identify key challenges in the current windthrow management framework and present a blueprint for how to progress in the settlement of regional strategies. SWOT analyses are used to highlight relevant issues and opportunities in classical approaches from both the forest-based sector and public authorities' perspectives.
- **Results:** Despite the large body of knowledge that allows decision-makers to react promptly after huge storms, strategic responses still suffer from too individual and fragmented decisions and a lack of holistic economic assessments. To tackle these issues, the paper suggests using systemic and integrated risk management approaches. It also presents the ways to enhance the forest-based sector's resistance and resilience towards economic shock and supports decision-making with the help of systemic analysis.
- **Conclusion:** This shift of paradigm is one of the key requirements in optimizing the way of dealing with storm damage, but public authorities should concur with it more actively by improving decisional and administrative frameworks.

Keywords: windthrow; risk management; decision-making

1. Introduction

Worldwide, windstorms are among the major abiotic threats for planted forests (Payn et al. 2015), and in Europe they have contributed to more than the half of the total damage to forest resources since 1950 (Schelhaas et al. 2003). Even though wind hazards are natural drivers of forest ecosystems (Mitchell 2013), destructive storms that occur over large areas in managed forests lead to severe economic losses for the forest-based sector (Björheden 2007) and offset benefits resulting from higher forest productivity (Fares et al. 2015). For example, the total insured losses, including forestry, due to the storm series of 1999 exceeded €10 billion (Munich Re 2002). The total economic losses resulting from those events were estimated at around twice as much (Pinto et al. 2007). From an industrial angle, destructive storms are usually defined as hazards that blow down 100% or more of the average annual harvest at the scale of industrial supply (Forestry Commission Scotland 2014). This sudden amount of timber to cope with threatens the normal functioning of forest-based activities (Valinger et al. 2014), disrupts the classical management and decision-making processes (Angst and Volz 2002; Broman et al. 2009), and consequently causes critical situations within public and private organizations (Drouineau et al. 2000; Birot et al. 2009). Regarding timber markets, prices and supply may be heavily impacted over the long run when several supply areas are experiencing severe damage at the same time (Costa and Ibanez 2005). From an environmental perspective, wind disturbances may cause a huge reduction of forest carbon sinks (Lindroth et al. 2009), lead to pest outbreaks (Wermelinger et al. 2013), or weaken the production of goods and services of forests in damaged areas (Lindner et al. 2010). In addition, society is also affected by the consequences of storms, i.e. occurrence of civil casualties, alteration of landscapes, and of living conditions (Blennow and Persson 2013).

In light of those potential impacts, active management of storm damage risk should appear logical. Paradoxically, even though destructive storms have been part of the history of European forests for a long time (Corvol 2005), this only became obvious in the 1990s, after a succession of shock events that led to questions regarding major changes in forest management (Birot 2002; Veenman et al. 2009). As a result, literature on risk management in forestry exponentially increased in the 2000s (Yousefpour et al. 2012), and a large body of knowledge in now available. This new paradigm within the forest community is also driven by several external factors. One of them is the macro-economic context, particularly the need to stay competitive in a globalized timber market and thus to limit the costs related to natural hazards (Meyer et al. 2013). Other impulses ensued from uncertainties linked to expected impacts of climate change on forest storm damage (Spathelf et al. 2014; Keenan 2015; Schou et al. 2015). Among others, the potential shift in winter storm frequency and severity (Fink et al. 2009; Schwierz et al. 2010), the continuous increase of the economic value at risk owing to the capitalization of growing stock (Nabuurs et al. 2007), and the higher vulnerability of forest stands (Campioli et al. 2012) are expected to increase the risk of damage. Societal changes also generate increasing economic losses from natural disasters (Barredo 2010). Therefore, in accordance with the "*Risk Society*" concept (Beck 1992), the management of hazards and insecurities in our modern societies tends to be one of the main preoccupations of public decision-makers (Brunet 2007). Nowadays, in this new perspective of modernity, politics are more prone to deal with the after-effects of huge storms and actively take part in the process (Barthod and Barrillon 2002). Whatever the initial motivation, it is now clear that both the forest-based sector and the public authorities cannot avoid addressing storm damage risk. The question is how to do this soundly and effectively?

Through the years, a methodological framework to address storm damage risk in forestry was gradually formalized on the basis of the classical theory of risk management (Haimes 2011) and international standards (ISO 31000), and was used in several papers (Gardiner and Quine 2000; Kamimura and Shiraishi 2007; Schelhaas et al. 2010; Hanewinkel et al. 2011). This framework consists of an iterative assessment process that allow decision-makers to quantify risk —where the term *risk* encompasses the large variety of risks resulting from destructive storms—and implement mitigation strategies in order to reach the desired level of residual risk. For this latter purpose, decision-makers have to know what the options are, what the costs and benefits are, and know the residual risk associated with policy options (Kaplan and Garrick 1981). In a second step, if the residual risk remains too high to be acceptable, tools and procedures to support crisis management may be developed, such as decision-support systems, contingency plans, trainings, and exercises. Finally, if the destructive storm occurs, the response phase will be activated. It first consists of an immediate crisis response period with a special focus on emergency and rescue operations, timber damage assessment, and safeguarding measures. After the emergency phase, a public strategy should be implemented to support the forest-based sector. Again, public decision-makers will have to choose between a set of strategies encompassing the particular interests of stakeholders, and public constraints. The more efficient the strategy is, the quicker the forest-based sector will recover from the shock and stabilize to a new equilibrium.

Despite the methodological improvements and the large body of literature addressing specific storm-related issues in forestry over the last fifteen years, several papers recently reported the need to improve decision-making and management of storm damage at the strategic level (Gardiner et al. 2010; Gardiner et al. 2013; Landmann et al. 2015). However, as indicated previously, storm damage management is a highly complex, uncertain and ambiguous process, because of the multiplicity of risks, stakeholders, goals, and beliefs. As it is impossible to eliminate those elements from the risk management process, new approaches to address them effectively must be provided to the forest-based sector and the public authorities. Furthermore, the role of public authorities has to be clarified in regards to the forest community’s expectations. Indeed, in the past, initiatives from the forest community did not always receive the expected responses from public authorities (Birot et al. 2009). In this context, it seemed relevant to re-open the debate on how windthrow crisis management may be improved at the strategic level and what the role and interactions of the forest community and public authorities should be in this effort. The target of this paper is thus to provide a blueprint for how to progress in the future, identify where the priorities are, and suggest how some of them should be addressed. The first step is to identify issues and opportunities for stakeholders, using SWOT analyses based on recent storm experiences and the relevant literature. The second is to present a holistic approach for addressing storm damage risk at the regional (or national) level, and describe the way to mitigate risk and support decision-making according to this framework. A focus on the specific role of public authorities is presented in a third step.

2. Strategic issues and opportunities

2.1. Methodology

SWOT methodology was chosen to identify current strengths, weaknesses, opportunities, and threats in the storm damage management process from both the forest-based sector and public authorities' perspectives. This allows the internal factors that can be handled directly by decision-makers from both groups to be distinguished, and identifies the external elements they need to address to build their risk management strategy. It also contributes to highlighting common features and reveals the inherent relationships between these two types of stakeholders. A broad literature search focusing on "risk and crisis management in forestry" was done using different search engines. This resulted in a list of approximately 250 relevant papers. However, few of them provided a global analysis of storm damage crisis approaches. Therefore, several ex-post crisis evaluations—either governmental reports or publications by public bodies and private institutions (see Table 1)—were also reviewed. Analyses of recent storm crises in European countries are indeed good entryways to identifying limits and failures in classical approaches (Trauman 2002).

[Table 1]

2.2. SWOT analyses

Table 2 presents the outputs of the two SWOT analyses. Only the most significant topics regarding strategic decision-making and crisis management were retained after the review process. Tactical and operational issues are not considered, except as they arose because of strategic concerns. The results are briefly discussed below.

[Table 2]

Forest managers usually have a good perception of the exceptional nature of destructive storm events, and thus are prone to react quickly after calamities (Direction des Forêts 1987; Swedish Forest Agency 2006). The downside to this strong empirical knowledge may be a reluctance to manage actively the risk of storm damage, as stakeholders generally consider windstorms from a fatalistic perspective (Peyron et al. 1999). At the same time, knowledge about the operational management of windthrows has strongly increased in the last decades because of former crisis experiences and an increasing scientific focus on this topic. Numerous technical handbooks—sometimes released in emergency just after a storm—support decision-makers and managers (Forest Windblow Action Committee 1988; FAO/ECE/ILO 1996; Pischedda 2004; Odenthal-Kahabka 2005; OFEV 2008; Oosterbaan et al. 2009). However, the sharing of knowledge between scientists and practitioners can be problematic. The *Storm Handbook* (Odenthal-Kahabka 2005; Chtioui et al. 2015), which evolved progressively from a print to an on-line version, is a good illustration of how information policy about windstorms has changed over the years to address the lack of accessibility and applicability of information (Hartebrodt 2014).

As for disaster risk management in general (Gopalakrishnan and Okada 2007), the main flaw results from the diversity of stakeholders' beliefs, interests, and goals which complicate the post-storm crisis response. The high fragmentation of forest estates and the multitude of owners, in both private and public forests, also make it difficult to settle on a common strategy. As an illustration, the fragmentation of forest estates and the rights of ownership were considered major hindrances to timber salvage during previous crises (Lesbats 2002). The recurring lack of liquidity also exacerbates the stakeholders' dependence on public compensation. Therefore, the competition for public subsidies in the aftermath of windstorms may enhance individualistic behaviour (Brunette and Couture 2008). As a result, the forest-based sector often implements uncoordinated and fragmented strategies, which is a major source of inefficiency. Insurance issues also lead to ambiguous behaviours. For instance, too high premiums compared to forest investments often deter owners from subscribing to insurance (Brunette et al. 2015) and make them dependent on state aid in case of storm damage. Furthermore, when insurance does exist, it compensates primary damage on the forest resource, but rarely subsequent damage resulting from complications (Holecy and Hanewinkel 2006).

In the past, diverging interests between stakeholders have also weakened the sector's credibility vis-à-vis the public authorities, and complicated negotiations with them (Lesbats 2002). Individual and sometimes antagonistic strategies contributed to slowing down recovery from storm crises (GIP ECOFOR 2010), while fragmented approaches have led to a dispersion of financial resources without knowing whether individual measures are cost-effective (Caurla et al. 2015). Consequently, public mitigation measures may cause competitive distortion between stakeholders if the global economic welfare of the forest-based sector is ignored during the decision-making process (Ananda and Herath 2009). Former experiences revealed that even if public authorities hold the strategic levers, they lack supporting tools and information to build integrated strategies (Gardiner et al. 2010). Usually, forest policymaking follows its own logic, based on diverging interests and values (Winkel and Sotirov 2015). Even though risk awareness is increasing, significant gaps remain in public risk governance, and public policies do not often encompass risk as the driver of decision-making processes (Blennow 2008). In a storm crisis context, it results in unpreparedness, overhasty strategies, and the spread of all possible grants (i.e. harvesting, storage, replanting, and marketing subsidies) without cost-efficiency assessments. Owing to the emergency context, crisis management measures are often disconnected from the prevailing macro-economic context (Bavard et al. 2013) although they are determinants of the forest sector's resistance and resilience. In fact, without appropriate economic analyses, the pros and cons of mitigation strategies are not easy to predict. The restricted availability of country-level information on disturbances can make implementing multi-risk strategies even more difficult (van Lierop et al. 2015).

Fortunately, new conditions for storm damage management are emerging. The accessibility to advanced decision support systems (Diaz-Balteiro and Romero 2008; Reynolds et al. 2008; Marques et al. 2013b; Segura et al. 2014), and the development of powerful Information and Communications Technology (ICT) solutions (Reynolds et al. 2005) should ease the strategic management of storm damage by both the forest-based sector and public authorities. Innovation capacity in the timber industry will open new market opportunities for windblown timber, and provide favourable market and policy conditions (Buttoud et al. 2011). However, as stated by Nilsson (2015), forest policy-making is not yet an affair between the sector and the public authorities, as manifold stakeholders claim interests and rights associated with the forest. Societal requirements are double-edged elements because even if they increase the role of forest ecosystems, they also force the public authorities and the forest sector to cope with ideological expectations (Ananda and Herath 2009). Therefore, storm calamities and associated casualties are likely to cause overreactions and political claims (Raetz 2004).

From an economic angle, a slump in market conditions associated with lower financial public support may threaten the effectiveness of risk management approaches when windstorms occur. Uncertainties relative to market behaviour and long-term wood procurement (Schwarzbauer and Rauch 2013) are among those economic issues. From the perspective of decision-making, rigid administrative and decisional frameworks, as well as uncontrolled ideological issues (Raetz 2004) may jeopardize rapid support to the forest sector. Finally, the loss of experienced people (Hartebrodt 2014) and fading memories (Harmer 2012) could make the risk management process less obvious and urgent for forest-based sector stakeholders. Indeed, although damaging windstorms occurred on average twice a year at the European scale during the last 60 years (Gardiner et al. 2010), their frequency is not equally shared at the regional scale. For countries that did not experience destructive storms for decades, such as Belgium, it could be a major hindrance to actively manage the risk (Riguelle et al. 2011). Uncertainties linked to climate change will require flexible and priority-setting approaches on the one hand (Millar et al. 2007), and on the other hand will require a mixed strategy, including adaptation and mitigation measures (Seidl and Lexer 2013). Even though uncertainties linked to future climate tend to push risk management issues to the top of the forestry agenda, they remain potentially a major source of inertia (Petr et al. 2014).

3. Integrated and systemic storm damage management

3.1. Advocacy for integrated storm damage management

Integrated management of risks in forestry is an emerging trend that aims to consider simultaneously, at each level of decision, every component of the risk management process together with external constraints, and the expectations and beliefs of various stakeholders (Orazio et al. 2014). This definition implies that decision-makers must ideally handle together the large variety of risks that face forests in order to reduce the global threat for the forest sector (Drouineau et al. 2000). Interactions between risks are crucial to consider because a particular response to a specific risk may enhance resistance to one damaging agent while increasing susceptibility to other causes of damage (Jactel et al. 2009). A global vision also allows diversification of the portfolio of mitigation measures and reduction of the overall residual risk for forest economies (Birot 2002). Furthermore, one of the key outputs of such integrated risk management approaches is to understand and combine the desires and beliefs from all stakeholders under external constraints (Yousefpour et al. 2013; Blennow et al. 2014). As highlighted by previous SWOT analyses, storm damage management is characterized by a high level of complexity, which is exacerbated by the manifold stakeholders, economic goals and personal beliefs. Agreeing on a common strategy for storm damage management is thus very tricky. To tackle this major challenge, we suggest forest policy and decision-makers should take the plunge and turn from an individual to an integrated management of storm damage risk.

Integrated approaches aim to combine several disciplines and involve different stakeholders operating in their own sphere (or *subsystems*, see below) across different spatial and temporal scales (Figure 1). Within this framework, storm damage risk can be addressed specifically, provided interactions with other risks (i.e. risk of pest outbreaks, fire or game damage) are kept in mind (Fermet-Quinet 2013). By analogy with the Integrated Natural Resources Management (INRM) concept (see e.g. Lal et al. 2002; Sayer and Campbell 2002), an Integrated Storm Damage Management (ISDM) methodology should thus be built. Nevertheless, because integrated approaches embrace, by definition, many topics at the same time, decision-makers need methodological supports to handle this complexity. The main requirements for applying an integrated framework are generally considered twofold: on the one hand to incorporate stakeholders requirements; on the other hand to provide decision-support methodologies (Lal et al. 2002).

[Figure 1]

Regarding stakeholders targets, there is no simple method for balancing different concerns when facing complex situations (Aven 2009). The holistic approach proposed by Aven and Kristensen (2005) considers risk in its full dimension, taking into account possible consequences and associated uncertainties. An output-oriented approach (Greiving et al. 2012) could also help to determine "agreements on objectives" among stakeholders. In this latter approach, dialogue among experts, stakeholders, and decision-makers is fundamental in order to guarantee inclusion of all perspectives (values, opinions, and claims) in the risk analysis process. According to Greiving et al. (2012), a win-win situation among involved stakeholders could emerge with regard to reaching an agreement on common goals, and actions to achieve them in due course. Furthermore, participatory approaches could facilitate stakeholders' involvement in the decision-making processes (Ananda and Herath 2003), and increase the quality of decisions (Beierle 2002). This is mainly relevant to multi-stakeholder decision-making processes (Garcia-Gonzalo et al. 2013) in which the willingness to share strategic information is a key factor of success (Marques et al. 2013a). For natural risks, when uncertainty in the decisions made is coupled with a high degree of conflict among the affected interest groups, combining participatory planning and structuring instruments like multi-criteria decision analysis methods (Mendoza and Martins 2006) could serve to incorporate the risk preferences of stakeholders for policy-building (Gamper and Turcanu 2009). Previous approaches to reaching common goals about risk management are promising and should be applied in integrated storm damage management. However, the success of an integrated storm damage management strategy will also lie in the ability to identify balanced strategies at an aggregated level of decision-making.

3.2. Towards systemic approaches

In order to support the ISDM process and identify, in the portfolio of potential crisis measures, the most efficient way to reach mid and long term collective targets, we suggest a systemic approach should be used. Indeed, the complexity of storm damage management can be handled by using *Systems Theory*, since it can be conceptualized in a systemic way. In *Systems Theory* – also known as *Systems Thinking* – the complexity of these kind of systems can be considered and their dynamics – the interaction between elements – can be observed through simulations (de Rosnay 1997). According to that, systemic analysis can be used to identify, optimize and control the system, while taking in account multiple objectives, constraints and resources (Heylighen and Joslyn 1992). Systemic analysis is thus a powerful tool for specifying different storm damage mitigation scenarios, together with their associated risks, costs and benefits. However, it requests to determine first the scale, boundaries, inputs, outputs, and internal processes of the system in stake.

Scaling issues are crucial as the strategy might be assessed as being negative at one scale but positive at another (Sayer et al. 2001). The analytic scale could also restrict the generality and utility of findings (Lovell et al. 2002). Regarding storm damage management, there is no unique appropriate level to judge the overall benefits of a strategy; therefore several systemic scales can be considered, according to the decisional level (supranational, national or regional) or management level (strategic, tactical or operational). Whatever the scale considered, it is fundamental to conceptualize the system and its relationships with sub- or meta-systems and remind that decisions at this specific scale can also influence those other systems. Example of a basic system including a succession of forest operations (salvage logging, transport, storage, processing), partially bound up with and affected by up- and downstream decisions as well as by the external context is given in Figure 2. In this example, the system encompasses successive steps of regional forest-wood chains and is thus composed by several sub-systems (Riguelle et al. 2015). Its behaviour is influenced by regional, national and supranational (European) factors. Those external constraints may include political, institutional, financial, environmental, ideological, or social considerations that directly influence the state of the system.

[Figure 2]

The systemic approach was already suggested by Blennow and Sallnäs (2005) for active risk management in forestry. In their view, the forest-based sector is a wide system whose functioning is influenced by individual behaviours, and which interacts with elements outside of the system (Blennow and Sallnäs 2005). Systemic approaches were also used to analyze the impacts of policy reforms on the forest-based sector (Rametsteiner and Weiss 2006a) or to study innovation in the forest sector (Rametsteiner and Weiss 2006b). Regarding storm damage management, the *Systems Thinking* concept is also partially applied nowadays. In fact, the first reaction after the storm is to determine if the event is expected to have critical (regional) or limited (localized) impacts on the forest-based sector. Experience usually helps to determine threshold values, expressed in terms of resources impacted by the storm, beyond which the functioning of the forest-based sector will be disrupted (Nieuwenhuis and O'connor 2001) and crisis management should be activated. Traditionally, the initial amount of damage is associated with an expected impact on the timber market and mobilization by comparison to previous windthrow crises.

This kind of systemic reasoning is valuable but oversimplified because it does not take into account the ability of the system to withstand the shockwave. In fact, damage threshold values could evolve between two critical events, due to internal changes within the system resulting from active risk mitigation processes, or external constraints. Thus in a second phase, deeper systemic analysis would still be needed to depict how the functioning of forest-wood chains will change according to a brutal disruption, where the bottlenecks are, and what the consequences will be of strategic action or inaction. Another premise is that within this system, which is a connected network, any individual element will not be able to reach its optimum state if others struggle with the crisis consequences. In other words, the global result is curbed by the weakest link in the chain. From that assumption, it follows that managing storm damage with a systemic approach will improve well-being at the aggregate level, and then could be profitable for each individual. While it does not exclude taking tailored measures with a limited scope to improve the functioning of a specific sub-system (i.e. logging or transport operations) or supporting stakeholders experiencing heavier storm impacts, it compels decision-holders to think globally. Even though the emergence of lone-rangers, who will acquire huge benefits from a crisis situation at the expense of others, is not excluded with this approach, it can be minimized if the crisis management strategy is balanced and the cooperation thereby enhanced (Fischbacher and Gächter 2010).

3.3. Risk mitigation at the systemic level

Dealing actively with storm damage risk implies the definition of mitigation strategies based on the level of risk and the risk preference of decision-makers (Gardiner and Quine 2000). At the individual level, each actor can choose between a set of measures to reduce, spread or manage the consequences of windstorms on his/her business (see Figure 3). Adaptation and mitigation strategies are well described, especially in regards to forest management (Heinonen et al. 2009; Schelhaas et al. 2010; Lagergren et al. 2012; O'Hara and Ramage 2013; Subramanian et al. 2015). However, the sum of individual strategies does not guarantee the effectiveness of the global strategy, and systemic mitigation measures should be taken as complementary to them. Figure 3 presents some of the most relevant ways to increase both systemic resistance and resilience according to the risk-acceptance level of decision-makers.

The resistance of the system can be defined as its ability to function at close to its normal capacity and to carry on normal operations with minimal disruption after the storm. Resistance could be improved by reducing either the vulnerability or the exposure of the forest-based sector (FBS) at the regional scale (Figure 3). As mentioned in the previous sections, cohesion among stakeholders is a priority to reduce vulnerability. Another major opportunity to improve systemic resistance is to identify bottlenecks and find the way to address or avoid them before the next crisis. Bottlenecks are the weakest links of a system, therefore they are good indicators of its viability (Bossel 2002). Practically, legislative, technical or financial hindrances may be the cause of systemic dysfunctions. However, advanced modelling tools are necessary to lead systemic analysis and identify bottlenecks. From a systemic perspective, increasing the local demand for wood products could facilitate the absorption of damaged timber and lower the pressure on timber markets. It could also contribute partially to a better regulation of the forest growing stock at the regional level, which is a major determinant of the level of damage (Usbeck et al. 2010). More generally, integrating risks in forest policies will have a positive impact on national resistance towards unexpected events (Blennow 2008).

[Figure 3]

The resilience of the system is its ability to absorb a shock wave in such a way that it can return to a normal state with the least possible delay and with the least possible dysfunction (IPPC 2012; Dymond et al. 2015). Ensuring decision-makers have a high level of information and preparedness corresponds with the enhancement of this systemic resilience. For these purposes, technical handbooks and contingency plans are key elements. Contingency plans are required to quicken and coordinate the operational and strategic response. Contingency plans developed in recent years for the public authorities (Bartet and Mortier 2002; OFEV 2008; Riguelle 2010; Forestry Commission Scotland 2014; Chtioui et al. 2015) or by the forest-based sector (Lesgourgues and Drouineau 2009; FIBOIS 2010a) illustrate how windthrow crises management may be optimized. Technical guides also facilitate decision-making after the storm. Another option to increase resilience is to improve the flexibility of the system. Past events have shown that too rigid decisional frameworks and administrative procedures (Lesbats 2002) as well as uncontrolled ideological issues (Raetz 2004), may slow down the recovery after destructive storms. Yet this must not be underestimated in the systemic approach. The development of timber storage facilities which can contribute to softening the stumpage prices' variation (Costa and Ibanez 2005) is also a main option for improving systemic resilience.

Between these two options, a possible middle path is to spread the risk. A possibility is to transfer the financial consequences of storms from one party to another. Compensating losses through insurance is an option for the forest-based sector (Birot and Gollier) but its implementation is slowed down by several issues (Brunette et al. 2015), including the belief that public subsidies will always compensate the losses (Brunette and Couture 2008). Indeed, public authorities used to build rescue funds to pool the risk or mobilize extra budgets to provide financial compensation for storm damage, and these safety nets may have reduced the sector's willingness to purchase insurance or invest in risk reduction (Brunette and Couture 2008). Insurability of natural hazards in forestry has already been identified as a prerequisite for risk mitigation (Birot and Gollier) but with limited response from both public authorities and insurers in some countries. Nowadays, the forest-based sector needs clear public commitment about assurance premiums, incentive programs, and self-insurability (Sauter et al.).

3.4. Assessing systemic impacts of storms

Taking decisions according to this integrated and systemic framework is not easy for decision-makers, as they have to consider simultaneously internal interactions between stakeholders, and external influences. It implies continuously gathering information during the decision-making process and identifying barriers or distortions that arise from decisions or the absence of decisions. To a certain extent, technical handbooks already bring knowledge-based decisional support to decision-makers and can drive decision-making processes. In addition, decision-makers may request aggregated information and calibrate mitigation strategies at the global level. A main requirement to address systemic issues is to provide to decision-makers a deeper understanding about economic knock-on effects of storms. In order to identify expected changes and key levers before windthrow crises, it is recommended that the long-term effects of policy options and the economic context on the forest-based sector are assessed as, for instance, Schwarzbauer et al. (2013) did with a dynamic system model for the Austrian forest sector. Outside the crisis period, mapping the wood harvesting changes, which result from the salvage harvesting that follows destructive storms at an aggregated level (Verkerk et al. 2015), could serve to assess potential economic losses. During the crisis period, from a purely economic angle, the challenge will be to manage stocks in order to smooth fluctuations and, for this purpose, it is necessary to understand how the wood markets react to disturbances (Baur et al. 2004). A model of timber market dynamics after natural catastrophes was also used by Prestemon and Holmes (2004) to explore how U.S. government spending to mitigate economic losses through timber salvage is related to the costs of intervention This simulation model illustrates how such an approach could, in time, support crisis response and a cash-constrained context (Prestemon and Holmes 2004).

Including the economic dimensions of disturbances in the decision-making processes is a core requirement (Holmes et al. 2008). First, a thorough understanding of overall economic impacts of wind hazards, including damage and risk mitigation costs is required (Meyer et al. 2013). Assessment of storm economic impacts begins with sound damage assessment procedures at the regional or national level, which is mandatory within the first days to support decision-making (Honkavaara et al. 2013). Whatever the methodology chosen at regional scale (field inventory, aerial, or satellite imagery) estimates, which imply a trade-off between accuracy and swiftness, must only be used to calibrate the crisis response (Riguelle et al. 2011). Indeed, inferring systemic economic impacts from the initial amount of damage is misleading as secondary and tertiary damage are not taken in account, nor are the benefits of mitigation strategies. For example, secondary damage resulting from bark beetles outbreaks in the follow-up to large disturbances

(Wermelinger et al. 2002) are responsible, on average, for extra damage of between 10 and 25% of initial wind damage (Stadelmann et al. 2013). Thom et al. (2013) demonstrated that for every cubic meter of bark beetle damage in the current year, 0.56 m^3 of additional bark beetle damage is expected in the following year. This not only means that sanitary concerns must be integrated as soon as possible in the decision-making scheme (Wermelinger et al. 2013), but it emphasizes the need for an advanced cost-benefit analysis to inform decisions. For example, it could be useful to assess the need to make salvage cuttings in partially damage stands in regards to the potential secondary losses (Bouget and Duelli 2004).

Economic assessments also implies quantifying in monetary terms the public benefits and externalities generated from forests' goods and services (Buttoud 2000). As an illustration, destructive storms in forests can cause a huge reduction of carbon sinks (Lindroth et al. 2009) that would have been far more costly if created in other ways (Canadell and Raupach 2008). Therefore, they can cause additional losses for owners if they have to repay emissions units (Moore et al. 2013). Such considerations must be included in decision-making processes. Nonetheless, assessing the economic effects of disturbances requires models with a considerable scope (Toppinen and Kuuluvainen 2010). For example, modelling the forest-based sector as a group of interacting autonomous economic agents would make possible the analysis of the effects of forest-based disturbances on market dynamics (Schwab et al. 2009). In the ex-post evaluation of the French state's compensation plan after hurricane Klaus (Bavard et al. 2013), a bio-economic partial equilibrium model (Caurla et al. 2010) was used to compare a set of alternative management scenarios through varying output variables, such as prices and timber volume. This approach is very promising for supporting strategic decision-making, for example, to assess alternative strategies for timber export and storage (Caurla et al. 2015). In this context, a main challenge is to improve the reporting of economic data to help ex-post assessments and build models to predict the economic impact of storms on both individual agents and the forest-based sector as a whole.

3.5. Supporting systemic decision-making

Those challenges also emphasize the need for a portfolio of decision support systems (DSS) where decision-makers can find appropriate tips. An illustration of how system analysis can drive the strategic management of storm damage is presented below. In this example, taking place in Wallonia (Belgium), a decision-support system based on System Dynamics principle, the WIND-STORM software (Riguelle et al. 2015), is used to predict how transport capacity and timber storage may influence the amount of timber lying in forests and industrial log yards during a five-year period after a destructive storm. Four scenarios have been simulated, on the basis of an overall damage of 8 million cubic meters: a baseline scenario, for which no specific measure is taken after the storm (BASE); a second scenario where only the harvesting capacity is boosted by 20 % (SC1); a third in which both harvesting and transport capacities are increased by 20 % (SC2); and a fourth where 2 million cubic meters of damaged timber are stored for 24 months (SC3).

[Figure 4]

Simulations show that transport capacity is lacking even in the baseline scenario and is therefore a systemic bottleneck (Figure 4a – BASE). As transport capacity is a limiting factor, efforts to improve salvage logging have a limited impact as the harvested timber is progressively accumulating in the forest areas (Figure 4a – SC1), which increases the risk of secondary damage. Doubling the transport capacity can nullify the stock in forests, but it causes accumulation of timber in log yards (Figure 4 – SC2). Timber storage is able to alleviate the accumulation of harvested wood in forests and preserve it from decay; however, as seen in Figure 4b, too rapid destocking can cause an excessive supply if no measures to limit the upstream offer are taken. Interested readers should refer to Riguelle et al. (2015) for a thorough description of this type of DSS and its contribution to systemic analysis.

4. Recommendations to public authorities

This paper also offers an opportunity to highlight some of the main challenges for public authorities in supporting the forest-based sector in the context of integrated storm damage management. According to Figure 2, public authorities could play an active role and beyond, they should be the catalysts of this process. Five key challenges are briefly discussed:

- Improving public risk governance and awareness;
- Developing an integrated policy for forests risk management;
- Enhancing systemic resilience of the forest-based sector;
- Facilitating the implementation of decisions;
- Playing an active role in windthrow crisis management.

Improving public risk governance and crisis management awareness is a prerequisite to be ready to cope with exceptional events (Mortier and Bartet 2004). Solutions to promote a risk awareness culture within public organizations could involve making knowledge of risk management issues a selection criterion when recruiting high-level officials, conducting risk surveys and audits, providing trainings and workshops to the staff, and organizing frequent crisis exercises. Moreover, the need for integrated policy of forest risk management is not only a challenge for the forest-based sector, but also for the public authorities. They must provide the guidelines according to which the forest sector develops its own strategy. For example, they must clearly indicate what losses the policy will cover in case of damage. The challenge is to find the optimal share between public and private compensation (Nicolas 2009). Some governments used to undertake large interventions; nowadays, direct financial support to the forest-based sector is likely to be restricted by the EU's competition law. In addition, public compensation after windstorms may be counterproductive assuming it curbs stakeholders investing in risk-reducing options at the individual level (Brunette and Couture 2008). On the other hand, insurance that could help to alleviate pressures for public compensation in the aftermath of natural disasters

(European Commission 2013b) are not widespread in the forest sector. Whether there is any ideal framework to share the economic risk due to various forest ownership patterns and habits, the forest-based sector requires a clear view on what they can expect back from public authorities if they subscribe to insurance or self-insurance programs.

Public authorities should also take initiatives to improve the systemic resistance and resilience of the forest-based sector. Whether they have any direct influence on the macro-economic context, they can act locally by alleviating the constraints with which the forest-based sector struggles. In parallel, they should identify institutional bottlenecks and try to resolve them in advance by leading on prospective systemic analyses (Riguelle et al. 2015). The continuous improvement of the system also requires consistent and systematic ex-post evaluations of public policies (Bisang and Zimmermann 2006).

In addition, public authorities should act to facilitate the effective implementation of decisions. This begins with a flexible decision-making context that can be adapted throughout the crisis period. It also means simplifying administrative processes and ensuring that all the stakeholders within the decision-making chains, not only the forest agencies, are aware of their role (Raetz 2004). For instance, ministerial orders or authorizations that are not issued on time have slowed down recovery in the past (Lesbats 2002; Nicolas 2009). The public authorities must also communicate on their strategy, the choices made, and the underlying long-term vision to facilitate the acceptance and the implementation of their strategy (Bavard et al. 2013).

Finally, public authorities should invest money and human resources actively in windthrow crises management in order to ease the implementation of strategic decisions. On the one hand, they should set up contingency plans and improve then continuously following “Plan-Do-Check-Act” principle. On the other hand, public authorities could play a crucial role in regulating the timber market, for instance by mutualizing timber sales to stabilize stumpage prices. To be effective, forest agencies should be first in line to support market facilities, by reducing the public timber offer or postponing payment delays, for instance. The main operational challenge for public authorities is to anticipate and prepare timber storage operations (Bavard et al. 2013; Birot and Gardiner 2013). This implies, among other things, identifying potential storage areas and developing a mutualized management framework to pool the costs and limit the fees for public and private owners.

5. Conclusion

In this paper, several sources of information were combined to draw a global picture of current issues and opportunities concerning strategic decision-making and management of forest storm damage. We reached a conclusion that the forest-based sector has quite often a good perception of the windthrow phenomenon and is able to handle rapidly its consequences, owing to a strong empirical knowledge. Saving and sharing this knowledge, through contingency plans for instance, is essential, even more in countries that did not experience storm damage for decades. However, storm damage risk management cannot rely only on former crises, since the decisional context is changing and uncertain. Upcoming threats and opportunities arising from this uncertain context must be considered in the decisional process, as they will influence the way to deal with storm-related issues in the future. A way to reduce uncertainty in the aftermath of storms is to strengthen the resilience and resistance of the forest-base sector towards destructive storms, by addressing the main issues highlighted in this paper. Although some of these issues have already been addressed in some countries, this review can contribute to re-open the debate in order to foster the implementation of good practices and bridge remaining gaps at regional and national levels. Nevertheless, insofar as it is unrealistic to deliver a tailored solution for storm damage management, new approaches that could help to reduce the global impact of storm crises are also needed.

One way to deal with complexity and uncertainty throughout the risk management process would be to change perspectives and adopt an integrated management of storm risks, ideally as part of a wider analysis of forests' risks that could help to handle the multiplicity of risks coherently. However, because integrated approaches embrace many concepts, two prerequisites are highlighted: firstly, the forest community needs to develop advanced methodologies to deal with such complex issues and, on the other hand, dialogue among and outside the forest community must be enhanced. According to that, a systemic approach for storm damage management is also suggested in this paper to deal with the forest-based sector as a dynamic system. This holistic approach assumes that the strategy will not be optimal if some individuals are suffering from crisis conditions within the system. In contrast, a balanced solution for the whole sector will likely benefit all stakeholders individually. The resulting idea is to evaluate all possible mitigation scenarios through a systemic perspective, with the help of appropriate decision support systems. This approach requires, however, identifying the scope (regional, national or supranational) and the internal and external drivers of the system at stake.

Finally, we insist on the role of public authorities in supporting windthrow crisis management at the European, national and regional levels. On the one hand, public decision-makers should foster the development of an integrated policy about forest risks and take part more actively in the storm damage management process. Nevertheless, such active involvement requires enhancing risk culture within politics and public bodies. Furthermore, it is also crucial to ensure the mobilization of decision-holders (ministers and high-level officials), and not only the institutional players. On the other hand, high transparency in public policy- and decision-making processes is needed to build confidence between the forest community and public authorities. Public authorities should also be the drivers for enhancing cooperation and reducing competition between bordering countries, which remains a major impediment in post-storm crisis periods. In regards to this challenge, the European Forest Strategy (European Commission 2013a) targets enhanced cooperation between member states and facilitates the coherence of forest-related policies in Europe, whereas the building of an European Forest Risk Facility (Landmann et al. 2015) illustrates that the forest community actively concurs with the need for a better collaboration between stakeholders inside the forest sector and with decision-makers.

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Tables

Tab. 1 Selection of ex-post evaluations of storm crisis management strategies in Europe

Scope	Storm (Year)	References
United Kingdom	The Great Storm (1987)	MAFF (1988); Grayson (1989); Harmer (2012)
Europe	Selection of storms	Gardiner et al. (2010, 2013)
France	Lothar - Martin (1999)	Drouineau et al. (2000); Barthod and Barrillon (2002)
		Lesbats (2002); Birot et al. (2009); FIBOIS (2010b)
	Klaus (2009)	Nicolas (2009); Laffite and Lerat (2009)
		GIP ECOFOR (2010); Bavard et al. (2013)
Germany	Lothar (1999)	Hänsli et al. (2003)
Sweden	Gudrun (2005)	Swedish Forest Agency (2006)
Switzerland	Lothar (1999)	Bründl and Rickli (2002); Hammer et al. (2003)
		Hänsli et al. (2003) ; Raetz (2004).

Tab. 2 Overview of most frequent strengths, weaknesses, opportunities and threats regarding strategic decision-making and management of storm damage by the forest-based sector (FBS) and public authorities (PA)

	Forest-based sector (FBS)	**Public authorities (PA)**
STRENGTHS	• Strong operational know-how • Strong empirical knowledge • Large body of scientific knowledge	• Financial capacity • Legislative power • Regulatory levers
WEAKNESSESS	• Reluctance to manage risks • Limited common strategy • Short *versus* long-term goals • Private *versus* public behaviours • Lack of financial liquidity • Few long-term impact assessments • Share of knowledge (all levels)	• Lack of public risk governance • No integrated policy for forest risks • Unclear storm management strategy • Fragmented and unbalanced approach • Complexity of cost-efficiency analyses • Poor cooperation with other regions/states • Staff, structures and facilities
OPPORTUNITIES	• Advanced decision support systems • Innovation capacity • Development of ICT solutions • Higher expectations towards forest • Coordination initiatives • Increasing scientific knowledge • Emergence of new markets	• Advanced decision support systems • Innovation capacity in the FBS • Development of ICT solutions • Societal expectations towards forests • Increase of societal risk-awareness • Advanced economic impact assessments • Role of forests in climate mitigation
THREATS	• Macro-economic context • Climatic and market uncertainties • Change resistance • Timber market disruption • Reduction of financial support • Inappropriate legislation • Rigid decisional framework • Loss of experienced people • Lack of solidarity	• Macro-economic context • Public expectations • Change resistance • Shrinkage of financial resources • Globalization of timber market • EU competition rules • Uncontrolled ideological issues • Emotional management • Uncertain impacts of climate change

Captions of figures

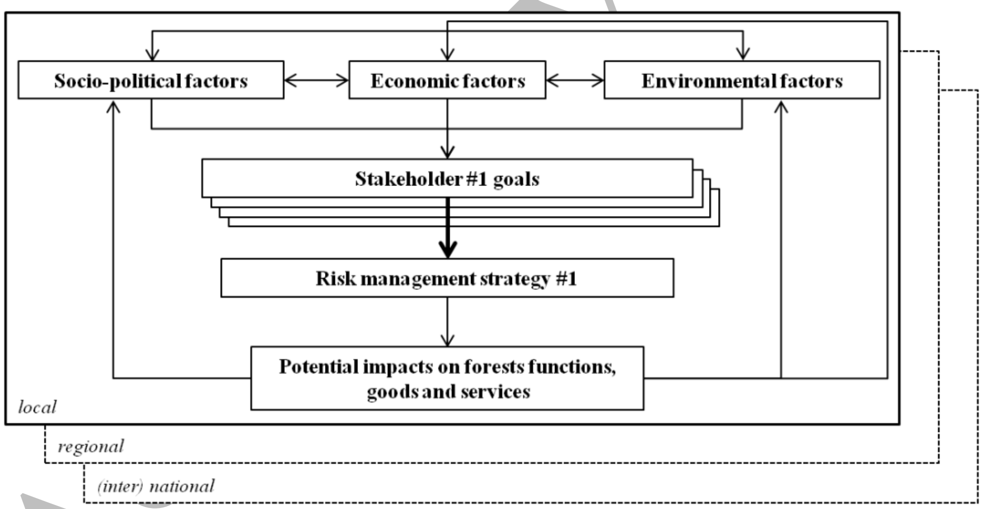
Fig. 1 Generic framework for implementing integrated storm damage management (ISDM) approach (adapted from Campbell et al. 2002)

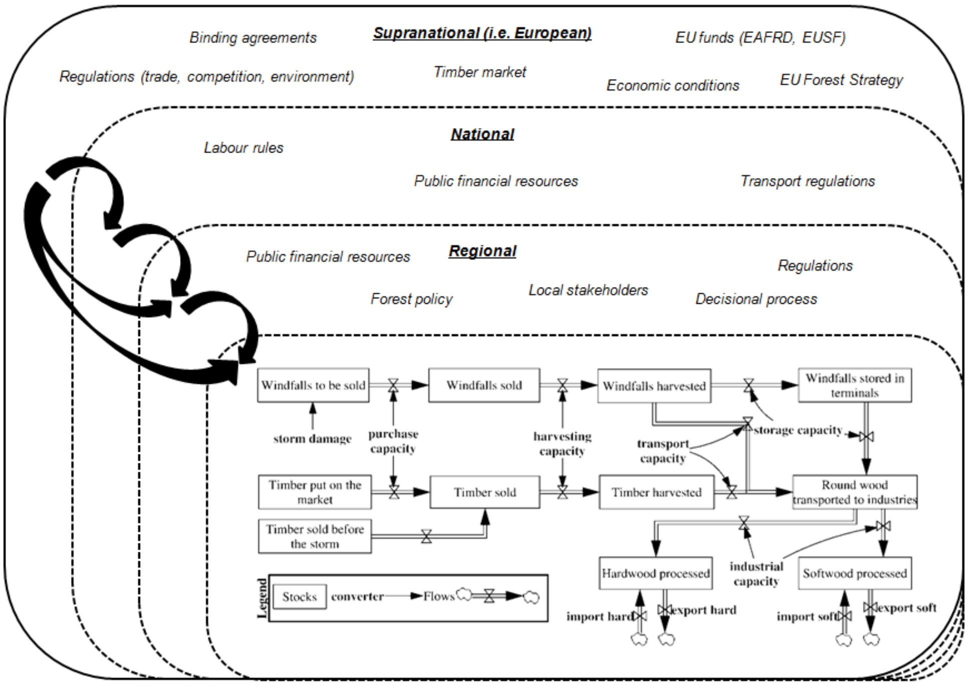
Fig. 2 Systemic representation of a regional forest-wood chain. In this example, scale, boundaries (dash lines), inputs, outputs, internal processes and external drivers of the system are represented

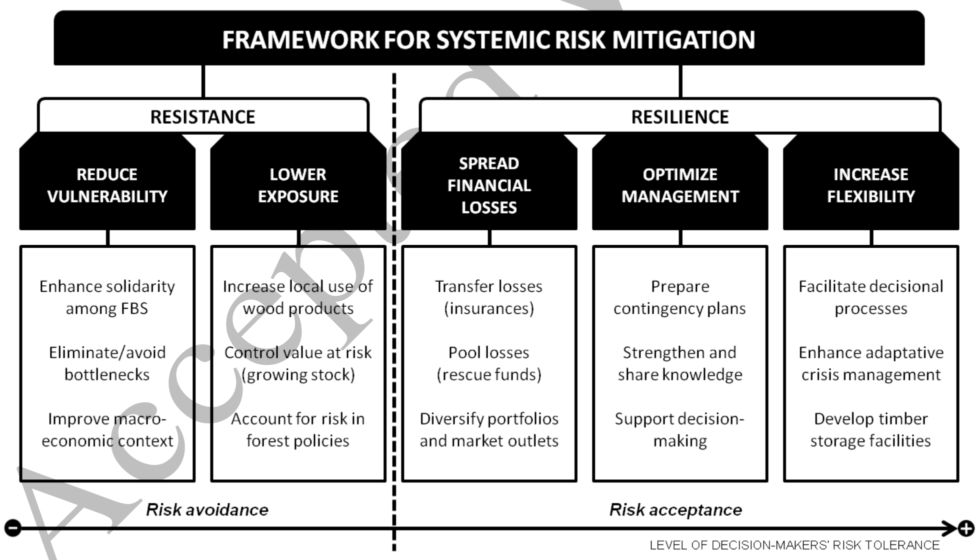
Fig. 3 Set of strategies to mitigate impacts of storms on the forest sector at the systemic level

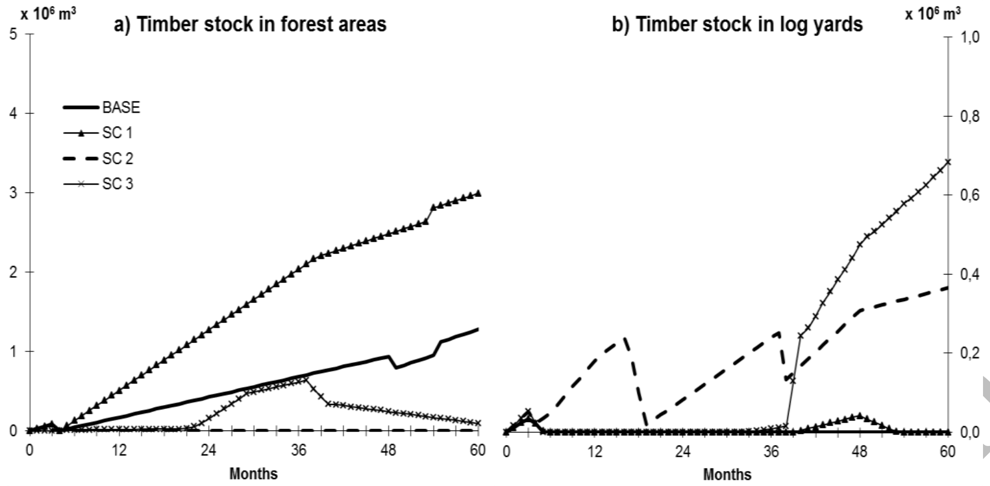
Fig. 4 Example of systemic analysis supporting strategic decision after windstorms. (a) Stock of timber in forest areas; (b) Stock of timber in forest areas

Figures




Supranational (i.e. European)
Binding agreements
EU funds (EAFRD, EUSF)
Regulations (trade, competition, environment)
Timber market
Economic conditions
EU Forest Strategy
National
Labour rules
Public financial resources
Transport regulations
Regional
Public financial resources
Regulations
Forest policy
Local stakeholders
Decisional process
Windfalls to be sold
Windfalls sold
Windfalls harvested
Windfalls stored in terminals
storm damage
purchase capacity
harvesting capacity
transport capacity
storage capacity
Timber put on the market
Timber sold
Timber harvested
Round wood transported to industries
Timber sold before the storm
Hardwood processed
industrial capacity
Softwood processed
Legend
Stocks
converter
Flows
import hard
export hard
import soft
export soft


FRAMEWORK FOR SYSTEMIC RISK MITIGATION
RESISTANCE
RESILIENCE
REDUCE VULNERABILITY
LOWER EXPOSURE
SPREAD FINANCIAL LOSSES
OPTIMIZE MANAGEMENT
INCREASE FLEXIBILITY
Enhance solidarity among FBS
Eliminate/avoid bottlenecks
Improve macro-economic context
Increase local use of wood products
Control value at risk (growing stock)
Account for risk in forest policies
Transfer losses (insurances)
Pool losses (rescue funds)
Diversify portfolios and market outlets
Prepare contingency plans
Strengthen and share knowledge
Support decision-making
Facilitate decisional processes
Enhance adaptative crisis management
Develop timber storage facilities
Risk avoidance
Risk acceptance
LEVEL OF DECISION-MAKERS' RISK TOLERANCE



The final publication is available at www.link.springer.com/article/10.1007/s13595-016-0566-1