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Risk aversion and optimal management of an uneven-aged forest under risk of windthrow: A Markov decision process approach

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ABSTRACT

Forests are increasingly threatened by windthrows but those composed of uneven-aged stand plots are generally less impacted by their effects. As a consequence, the management of such forests should be based on a joint management of all their different uneven-aged stand plots. This article determines the optimal management regime of uneven-aged forests under risk of windthrow and furthermore takes the risk preferences of the forest owner into account. This study analyzes optimal harvesting of uneven-aged stand plots by applying a Markov decision process (MDP) framework using an economic description of uneven-aged forestry. Two management types are considered: the joint uneven-aged forest management model in which the forest owner jointly manages all the different stand plots, and the independent uneven-aged forest management model that assumes that the forest owner independently manages each plot of the forest. The MDP framework is applied to a non-industrial private forest owner located in northeastern France. First, we show that the forest owner tends to converge toward a forest structure that is close to a normal forest in the joint uneven-aged forest management model. Second, we find that the independent uneven-aged forest management model poorly approximates the optimal multi-stand harvesting policy. Third, and more surprisingly, the levels of windthrow probability

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changes considered have little influence on the optimal harvesting strategies of the forest owner. Lastly, in contrast, the forest owner's risk aversion is shown to have a strong influence on the optimal policy.

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Introduction

Uneven-aged forests are generally more resistant to natural disasters such as windthrow because of a higher stability against storm damage (Mason, 2002; Hanewinkel et al., 2014) in comparison with even-aged forests. Furthermore, the frequency and intensity of windthrows are projected to increase due to climate change (Haarsma et al., 2013), requiring changes in forest management plans and practices (FAO, 2013). This supports the application of uneven-aged forest management. The uneven-aged forest system has a long tradition in Central Europe (Rollin et al., 2005; O'Hara et al., 2007; Puettmann et al., 2015) but has always been applied to just a small portion of the total forest area (Boncina, 2011). This type of forest management can be difficult to carry out for many private forest owners. It is therefore important to study to what extent uneven-aged forest management can be adapted to respond to the increase in windthrow risk. While forest management under windthrow, mainly dealing with even-aged forests, has received considerable attention in the literature over the last decades (Loisel, 2014), empirical analysis and modeling studies on windthrow damage in uneven-aged forests are less frequent (Hanewinkel et al., 2014).

Before analyzing uneven-aged forest management, it can be difficult to assess precisely windthrow risk and its potential variation due to climate change. Future climate evolution and its impact on forest ecosystems are not easily evaluated in terms of standard probability concepts (Schou et al., 2015). Since the probabilities of catastrophic events might increase, exploring the consequences of different values of probabilities allows us to investigate how the forest owner's optimal decision concerning forest management is affected by uncertain climate change. Although risks of extreme events have a large impact on forest management, forest owners' decisions also depend on their risk attitudes. Indeed, behavior under risk typically results from the interplay of the risk level faced by forest owners (level of probability) and their perception of risk. Forest owners' risk preferences are key factors in explaining variability in behavior between decision-makers. Risk attitude is the stance a forest owner has towards the content and the consequences of risk (attitudes towards risk can be risk-averse, risk-neutral or risk-seeking). It is the interaction between risk perception and risk attitudes that matters in decision-making. There is no doubt that many forest owners are not risk-neutral but risk-averse instead, and forest owners' risk preferences have a significant impact on forest management (Andersson and Gong, 2010; Brunette et al., 2014). It is therefore essential to consider risk and risk aversion when addressing the problem of forest management.

As indicated by Schou et al. (2015), reviews of decision-making under climate change (Yousefpour et al., 2012) and of the modeling of natural hazards in forest management (Hanewinkel et al., 2011) present a comprehensive overview of the literature on decision making under uncertainty. In the same way, Pasalodos-Tato et al. (2013) reviewed and classified methods and approaches to deal with risk and uncertainty in forest planning. They classified methods including risk and uncertainty models into different categories depending on the spatial scale of the planning problem addressed (stand level, forest/landscape level and regional level). In contrast we only focus on studies based on Markov chains in order to describe the similarities and differences with our study. Since forest management can be modeled as a controlled Markov process (Lohmander, 2011), the Markov decision process[1] is a technique commonly used to deal with risk and uncertainty at the stand level (Hool, 1966; Lembersky

[1] Williams (2009) presents a general review of MDP applications in natural resources management.

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