Natural risk modelling in silvicultural decision models: A survival function approach

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1. Introduction and problem outline

Natural hazards, caused by storms, droughts and insects, are – to different extent – an integral part of forest ecosystems (OTTO 1994, pp. 322). However, to forest managers they constitute considerable risks, since they interfere with scheduled operating procedures and objectives, cause additional costs for salvage-harvesting and replanting and decrease revenues from timber sales. As a result of climate change, a considerable increase of risks is expected, especially caused by lower levels of precipitation during the vegetation periods and more frequent droughts and storms (FEDERAL ENVIRONMENT AGENCY 2008). Since the end of the 1980s, scientific publications dealing with the causes and scope (e.g. KÖNIG 1996) as well as with economic implications of natural hazards in forest management were correspondingly numerous.

Accordingly, in his review article NEWMAN (2002) refers to publications, which address the integration of risks into the FAUSTMANN model, in order to determine the optimal rotation age. BUONGIORNO (2001), for example, describes the stochastic influenced development of a forest using a Markov Decision Process (MDP) model, which implicates discrete transition probabilities. The objective is to determine the best decision policy, which maximises the soil expectation value. Numerical solutions for this purpose are found using either successive approximation or linear programming. KUBOYAMA and OKA (2000) analysed long term data to climate induced forest damages from the national forest insurance of Japan, in order to derive empirical, age class dependent damage probabilities. By means of Monte Carlo simulations (cf. METROPOLIS and ULAM 1949) and using these probabilities they determine the optimal rotation age. HOLECY and HANEWINKEL (2006) as well derived empirical probability functions for the occurrence of forest calamities, based on the analysis of times series of forest maps, and modelled these probabilities with the Weibull function (cf. also PIENAAR and SHIVER 1981). DIETER (2001) calculated risk influenced soil expectation values, using Monte Carlo simulations like KUBOYAMA and OKA (ibid.), and determined the risk adopted optimal rotation age for beech and spruce in southern Germany. He describes the risk by means of survival functions, which model the chronological sequence of survival probabilities depending on tree species and site conditions. Similar approaches were pursued by KNOKE and WURM (2006) and BEINHOFER (2007), e. g. First considerations of these findings in the forest practice were proposed by KURTH et al. (1987), KÖNIG (1999) and KOHNLE et al. (2008a, 2008b). However, standardized forms of quantification of natural risks and risk management systems have yet to be established in Germany (cf. GADOW 2000, GAUTSCHI 2002). Considering the large economical impact of natural risks on forest management, namely on the selection of tree species, thinning practices and rotation cycles, this seems surprising.

This is the essential starting point of the present article. The objective is to develop an applicable "standard" method for quantifying calamity influenced survival probabilities of forest stands. Therefore the authors use the so called survival function, whose theoretical fundamentals are described briefly in the context of the survival analysis. In this article the survival function follows the Weibull distribution, described by the correspondent function. However, it is modified in a way that makes it easy to interpret the coefficients. Thus, they indicate the level and chronological sequence of risk. Furthermore a method is shown, that allows the immediate calculation of the "annuity under risk". It supersedes the application of iterative or numerical methods like the Monte Carlo technique or linear programming. Finally it is shown, by means of calculations with different survival functions, how the costs of risks and the risk-adjusted optimal rotation age can be determined. This approach, the authors hope, will contribute to the enhancement of decision-making in forestry (cf. DEEGEN 1994) and will promote the integration of risks into practical forest planning and evaluation.

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