Role of computer tools in risk management – applications in forestry

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Abstract

Risk management is about handling uncertainty. Decisions are always preceded by assessments of outcome and analyses of risk. For complex systems, such as the forestry system, it may be difficult to make reliable assessments of outcome in one's head. This is where computer tools could provide useful information. In this paper, the Gärdenfors & Sahlin decision theory is used as an analytical framework for describing non-industrial private forest owner's perception of risk and identifying hazards for which decision support is needed. A system of models for calculating the probability of windthrow in forestry is used as an example of a computer tool that could provide useful decision support to forest owners if the results are communicated wisely.

1 Introduction

Risk management is about handling uncertainty. In a decision situation, the decision maker chooses between different alternatives. The choice is made after making a risk analysis. To make a risk analysis, assessments of outcome are required for each alternative in the decision situation. In a complex system, such as the forestry system, it may be difficult to make such assessments. This is where computer models could provide decision makers with more reliable assessments than can be made without the models. This paper presents the role of computer tools for risk management in forestry.
2 The decision situation

According to fundamental decision theory, a decision is preceded by a risk analysis. In technological terminology, risk means the uncertainty in terms of the probability times the extent of an adverse outcome (hazard) (e.g. [1]). In decision theory terminology, risk usually means uncertainty for which the probability distribution is known. According to the Gärdenfors & Sahlin decision theory, the decision maker also evaluates the epistemic (knowledge related) reliability of each probability distribution [2]. Here it is of importance what the probability distributions are based on as this determines their epistemic reliability. The decision maker’s attitude towards risk taking sets a level of epistemic reliability that can be accepted. A risk averse decision maker considers more alternatives than a risk-liking decision maker. After estimating the minimal expected utility of each sufficiently reliable alternative, a risk averse decision maker decides on the alternative with the largest minimal utility. In this way the probability of a highly adverse outcome is reduced. In the extreme case where a decision maker has no knowledge, the decisions have to be based solely on the decision maker’s ethical values and his or her belief in society, including science [3,4]. In conclusion, it is the decision maker’s perception of risk that guides in the decision-making process [5,6]. The Gärdenfors & Sahlin decision theory [2] has been used as an analytical framework when analysing the perception of risk among non-industrial private forest (NIPF) owners [7].

A rational decision maker who wants to avoid taking risk should always try to learn more about the system he or she is operating in. In this way more reliable assessments of probability and extent of adverse outcome can be made. This information can be used to make reasonable decisions, i.e. decisions that are put in a wider, holistic perspective [8].

3 Computer tools for risk management in forestry

The forest system is complex. Its management often calls for handling processes over close and distant time spans as well as in space, which, furthermore, has to be done simultaneously. According to [9], NIPF owners are risk averse. In a decision situation, the decision maker has to make assessments of outcome for each available alternative. Such assessments are based on the decision maker’s experience and his or her information gained from various sources.

The assessments may be difficult to make for irregularly occurring events such as windfalls or outbreaks of insect attacks as well as for features previously not experienced such as effects of a changing climate. Either our distant memory fails us or the available information is not enough. Here, the forest research community can provide useful decision support. Current contributions made are to a large extent in the form of reductionist information that typically has to be synthesised in order to be useful in a decision situation. This means that a lot of information may be available that can be used to provide useful decision support, e.g. in relation to irregularly occurring events such as hazards. For example, if information on the mechanical properties of the tree stem is available, this
information can be used together with additional information to model the resistance of the stem to snapping from wind load. By linking together a series of such sub-models that each contributes significant pieces of information for the understanding of the whole, a computer-based system of models can be developed for making simulations on a complex system [10]. For this to be successful, a conceptual view of the system functioning is essential. Ideally, the individual sub-models to be linked together are already available. GIS (geographical information systems) furthermore provide means of modelling the spatial processes. The temporal dimension, however, often requires tailor-made solutions. For example, a model that projects the state of the forest into the future may be useful [11]. Computers may thus be used for providing forest managers with tools for making decision support in relation to hazards.

4 Hazard identification in production forestry

The management objectives determine which hazards need to be handled. In a forest production perspective, hazards may be related to financial transactions or to the growing of the trees. Hazards related to the working environment in the forest and additional aspects further down the line towards end-users of forestry products are not covered in this paper.

Based on an enquiry, [7] identified the hazards that non-industrial private forest (NIPF) owners perceived as most risky in a forest production perspective. The forest owners were asked to pick out hazards from a given set and rank them according to their recent experience of costly damage, and their willingness to invest money in risk-reducing measures. They were, furthermore, asked to assess the risk associated with each hazard in four classes ranging from very high to negligible risk. The results show that the same six hazards were considered most problematic in all three aspects. These were browsing by large herbivores on plants in regeneration, falling timber prices, damage by wind, spruce bark beetle, root rot and pine-ewevel. A majority of the respondents, furthermore, claimed to take action to reduce risk. But, only 33–60% of the respondents claimed to take action to reduce the risk associated with the six hazards for which the respondents were the most willing to invest capital to reduce risk. One explanation for this could be that the decision maker has forestry goals in addition to production [12]. Another explanation could be that the optimum choice of action in relation to one hazard is perceived to increase the risk in relation to another hazard. Furthermore, it could also indicate a need for information on existing risk-reducing methods and/or that new efficient methods are needed. Indeed, there was a substantial lack of knowledge in relation to risk reducing measures. Four to thirteen percent of the respondents claimed not to know whether or not they take risk-reducing action in relation to the top-ranked most problematic hazards. Even if this possibly can be explained by the forest owners managing their forests based on recommendations for which the effects are not explicitly described in relation to each hazard, information about risk-reducing measures could help reduce risk. The level of ignorance was highest for the hazard damage by wind. It was concluded that the need of decision support
was largest in relation to the hazard damage by wind due to a combination of perceived high risk and high level of ignorance in relation to whether or not risk-reducing action was taken [7].

5 Modelling the probability of windthrow

Several models for estimating effects of strong winds on forests have been presented, e.g. [13–18]. These models have in common that the probability of windthrow is affected by silvicultural treatments and forestry planning activities. Consequently, the probability of windthrow differs between forest management alternatives available to a forest owner.

In technology terminology an assessment of probability is called a risk assessment. A formal risk assessment includes handling the exposure and the response to this exposure [19]. We have constructed a system of models for assessing the probability of windthrow at a landscape level under conditions such as those found in the south of Sweden [10]. Here, the exposure corresponds to the frequency of occurrence and magnitudes of strong winds and the response depends on the stability of the trees (Figure 1).

In the south of Sweden, the topography is gentle and the forest stands are small (a few to some tens of ha). Norway spruce, Scots pine and birch are the main species for production of forest raw material. Strong winds mainly occur in association with the passage of cyclones, i.e. in association with large-scale weather systems. The model is made at a landscape level. By a landscape we mean an area of a few km$^2$ to a few tens of km$^2$. Within such an area, we assume the weather to be the same, i.e. caused by the same weather system.

Our approach to model the risk of windthrow makes it possible assess the probability of windthrow under a different climate than that of today.

![Diagram of factors affecting the risk (probability) of windthrow. (From [10].)](image-url)
Input data to the system are forest inventory data and a digital terrain model (DEM) stored in a geographical information system (GIS) for the area of interest and surroundings, and wind climate data from a nearby meteorological observing station (Figure 2).

The Finnish model HWIND is used to calculate the stability of the forest stands [17]. This model calculates the critical wind speed for stem breakage and up-rooting at the stand edge. The model takes account of the gustiness of the wind, using empirical relationships established from wind tunnel experiments [18, 20]. The model is fed with forest inventory data regarding tree species, tree height, stem diameter at breast height, the number of stems per ha, and the wind fetch in front of the forest stand. Currently, parameter values for the shape of the trees, the mechanical properties of the wood and the rooting conditions for the tree species Norway spruce (Picea abies (L.) Karst.), Scots pine (Pinus sylvestris L.) and birch (Betula spp.) are available.

Topographic variation and variation in land-use and forest development stages make the surroundings differ between forest stands in a landscape. In combination with effects of the wind direction, this results in a large variation in wind exposure to different stands in a landscape. HWIND has been modified to handle as variables the parameterised aerodynamic properties (roughness length and zero plane displacement height) of the terrain up-wind exposed forest edges. Furthermore, to make it possible to use HWIND for all stands in such a heterogeneous landscape, a model has been constructed that identifies wind exposed forest edges, and calculates parameter values for aerodynamic properties of forest stands and areas up-wind exposed edges. In its present configuration, the system of models calculates the probability of windthrow at wind exposed forest edges of at least 10 m in height. The calculation of aerodynamic parameter
values is based on the GALES model presented in [18]. In addition, the height above the ground for which the critical wind speeds are calculated has been made into a variable in HWIND to make it possible to compare the calculated critical windspeeds with the results of the wind exposure model.

Our system of models includes the Danish model Wind Atlas Analysis and Application Program (WASP) [21] for distributing the wind climate over the terrain. This exposure model is fed with wind climate data from a nearby meteorological observing station, information about the topography and the aerodynamic properties of the study area and its surroundings (Figure 3). For the area of interest and for each stand, the aerodynamic properties are parameterised as described above. After estimating the regional wind, the model gives correction factors that enable the calculated critical windspeed at a specific point in the landscape to be linked to a corresponding regional wind [22]. Calculated using extreme-value statistics, the risk of windthrow is the probability of the calculated critical regional windspeed being exceeded.

Figure 3: Bottom: Block diagram of the terrain in Asa Experimental Forest, Sweden, and immediate surroundings, draped with modelled values of the zero plane displacement height, d. d is used as a zero plane for modelling of the wind field over rough surfaces, such as the forest terrain, and is dependent on the aerodynamical properties of the ground. Stacked on top of the block diagram: Two contour maps of the generalised modelled windspeed at 10 m above d for two windthrow occurrences in January, 1993. (From [10].)
6 Risk communication

Model output in terms of probability values for a particular outcome can be useful in a decision situation. However, both technical and communicative criteria need to be fulfilled for a risk (probability) assessment to be reliable and useful [23]. The decision maker needs information about what the assessment is based on in order to be able to estimate its epistemic reliability. Here it is important to show in what ways the model has been evaluated (Figure 4).

![Figure 4: Preliminary results of evaluation of the system of models for the hazard windthrow. Distribution of forest stands in Asa Experimental Forest, Sweden, with the number of windthrown trees marked, as observed in a ground-based field survey after two windthrow events in January, 1993. Additionally, those forest stands are marked out for which windthrow was predicted by the system of models, as are those with no wind exposed edges identified. (From [10].)
Furthermore, information on potential changes (internally or externally), and information about the relevant management options, their cost and effect on the probability are also requested [23]. To achieve this, the system of models above, together with a landscape projection model, can be used for simulations in relation to the hazard windthrow in order to evaluate silvicultural programs and other planning options over time and in space. (From [10].)

7 Acknowledgements

This work has funded by MISTRA under the research programme Sustainable Forestry in Southern Sweden (SUFOR) and by FORMAS under the research project Decision Support for the Management of the Risk of Windthrow in South Swedish Forestry. Magnus Mossberg, Southern Swedish Forest Research Centre and Dag Åstrand, Computing Unit, both at the Swedish University of Agricultural Sciences (SUAS) are acknowledged for programming assistance, Dr. Heli Peltola and Professor Seppo Kellomäki, Joensuu University, Finland, for making the HWIND model available to us and for modifying the model according to our needs, Dr. Barry Gardiner for giving us access to the GALES model.

8 References


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