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Understanding risk in forest ecosystem services: implications for effective risk management, communication and planning

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Uncertainty, insufficient information or information of poor quality, limited cognitive capacity and time, along with value conflicts and ethical considerations, are all aspects that make risk management and risk communication difficult. This paper provides a review of different risk concepts and describes how these influence risk management, communication and planning in relation to forest ecosystem services. Based on the review and results of empirical studies, we suggest that personal assessment of risk is decisive in the management of forest ecosystem services. The results are used together with a review of different principles of the distribution of risk to propose an approach to risk communication that is effective as well as ethically sound. Knowledge of heuristics and mutual information on both beliefs and desires are important in the proposed risk communication approach. Such knowledge provides an opportunity for relevant information exchange, so that gaps in personal knowledge maps can be filled in and effective risk communication can be promoted.

Introduction

Uncertainty, insufficient information or information of poor quality, limited cognitive capacity and time, along with value conflicts and ethical considerations, are all aspects that make decision-making difficult.

By way of example, Swedish private forest owners consider damage by wind to represent one of the greatest risks to their forestry from the perspective of their individual income; however, according to a questionnaire, only one-third of Swedish private forest owners reported that they had actively taken measures to reduce the risk of wind damage (Blennow and Sallnäs, 2002). The lack of action to reduce this risk may be because the owner does not perceive the risk to be high enough, but there are other possible explanations. Not taking measures to reduce the risk of wind damage might very well make sense, even to a forest owner who perceives a high risk and also knows how to reduce it. For example, the forest owners may value the plant twinflower (*Linnaea borealis*) and thus would wish to preserve its habitat – the dense canopy of old-growth coniferous forest – at the expense of lighter forests in which the risk of wind damage has been reduced by a shorter rotation cycle. In this case, it makes sense to run the risk of wind damage, because the measures required to reduce that risk would increase the risk of losing twinflowers from the forest. However, for researchers who have exerted substantial effort trying to find ways to reduce the likelihood of wind damage, the fact that relatively few forest owners have taken such measures may be difficult to understand.

The aim of this study is to provide a review of risk concepts and risk communication research, to illustrate the significance of the choice of conceptual approach for the management and planning of forest ecosystem services and to provide an approach to risk communication that is effective as well as ethically sound.

Risk and risk communication

Like all risks, forest-related risks vary with respect to magnitude, seriousness, etc. In general, it is taken for granted that the language of risk is a way of describing uncertain negative *outcomes*. Outcome risk is often seen as a combination of probability and severity of the negative effect. For instance, Aven and Renn (2009, p. 1) suggested that: 'Risk refers to uncertainty about and severity of the consequences (or outcomes) of an activity with respect to something that humans value'. They partly base their suggestion on similar definitions of outcome risk in the literature, such as: 'Risk is the probability of an adverse outcome' (Graham and Weiner, 1995) and 'risk is a measure of the probability and severity of adverse effects' (Lowrance, 1976). This way of defining risk is also prevalent in relation to forestry. For instance, Guthrie (2009) reported that in landslide studies linked to forestry operations, risk is broadly defined as: 'The likelihood of specified adverse consequences arising from an event, circumstance or action within a stated period and area' (Lee and Jones, 2004).

Outcome risk as an objective attribute

In the early years of risk communication research, it was believed that clear, understandable information was all that was needed to make people see that the (outcome) risks were in accordance with the assessments of experts (see Fischoff, 1995) (Table 1). One concept of risk that might lead to such a situation is where both experts and laymen understand a risk as being identical to probability and where scientific research has produced a base from which to monitor the relative frequency of the type of risk in question. For example, according to Törnqvist (1995), in its early days, Swedish forestry was treated as an enterprise that was guided by scientific results and unaffected by personal values. Thus, there was essentially one 'right' way of conducting forestry. Over the years, the view of risk in terms of objective probability has been strongly criticized.

Outcome risk as part of decision-making

In the 1970s, emphasis was increasingly placed on a conceptualization of risk as part of the decision-making situation. The decision-making situation, as such, has properties that make it – or the risk that is part of it – appear less 'objective' than the simple measure of relative frequency of a type of event. It typically involves personal beliefs and preferences as well as theoretical models (along with explicit and implicit assumptions about their application). The decision-maker also often takes several types of potential effect into account. It is unlikely that the expert and other stakeholders would be in such complete agreement about these features that it becomes possible to talk about one 'right' way of conducting forestry. It is more likely that the interested parties disagree about some of these features. Moreover, it is not given that the opinion of a particular expert should be given priority, particularly because differences may emerge between the risk perceptions of two informed experts. Experts may have the same risk concept, but their risk judgment may differ widely.

In decision theory, potential effects are often expressed as expected utility: the average utility of all possible outcomes under certain circumstances, weighted according to the probability that any particular event will occur. After estimating the expected utility of different alternatives, the best one can be selected. To determine the best alternative, a decision rule is needed. The fundamental decision rule says that, in a given decision situation, we should choose the alternative with maximum expected utility. In forestry, the utility is sometimes measured as the net present value. To maximize the expected utility, then, means to choose the decision alternative with the maximum expected net present value.

Simple expected utility theory, however, may not be the effective tool for risk assessment that it is sometimes proposed to be. The probabilities forming part of the calculation of expected utilities can be seen as either objective, as entities about which we may have better or poorer knowledge, or subjective, or personal, as a measure of the degree to which a person believes a proposition. They differ in their consequences for decision-making. Objective probabilities, such as frequencies, can be unknown to us. There may be situations where we simply do not know how probable certain consequences are. In these cases, expected utility calculations break down and we need some other decision rule, one that is not dependent on probabilities. The choice of rule depends on how cautious one wants to be. One possible cautious rule is to maximize the minimal (maximin) utility so that the alternative action that has the least

Table 1 Overview of outcome and knowledge risk concepts

Risk is:	Determinants	References	Examples
Objective	Attributes in the world	(Starr, 1969)	(Outcome) Risks are relative frequencies of physical harm.
Subjective (decision theoretic)	Beliefs and preferences concerning events	(Savage, 1954; Ramsey, 1990)	(Outcome) Risks are personal (Bayesian) probabilities for an unwanted event, or expert opinion on plausibility and value of an unwanted event.
Socially constructed	Social setting	(Wynne, 1980, 2001)	Our perceptions of (outcome) risk reflect shared values and beliefs, such as 'This is not normal', 'Life is a lottery' and 'We do not trust this institution'.
Perceived	Contextual and personal factors	(Slovic, 1999)	Catastrophic potential, involuntariness and unfamiliarity affect what we perceive as risky (outcome risk)
Felt (risk-as-feelings)	Feelings, emotions and the related response known in psychology as 'affect'	(Loewenstein *et al*., 2001; Slovic *et al*. 2004)	Potential consequences that give rise to emotions (or 'affect'), such as fear, have extra weight in risky decisions (outcome risk).
Part of culture	Cultural context	(Douglas and Wildavsky, 1983)	Phenomena that are regarded as dangerous in the particular culture to which one belongs are conceived as (outcome) risks.
About knowledge (knowledge risk)	Amount and quality of information used in decision-making	(Gärdenfors and Sahlin, 1982; Gärdenfors and Sahlin, 1983; Sahlin and Persson, 1994)	Decisions based on unreliable information yield (knowledge) risk. Disregarding additional predictions or explanations in decision-making generates (knowledge) risk.

negative outcome is chosen (a classic review of decision rules under uncertainty is presented in Savage (1954), which also contains an elaborate theory of statistics based on personal probabilities).

An example of how different decision rules lead to different decisions is provided in a Monte Carlo simulation study by Knoke and Wurm (2006). They estimated the effects of wind damage, snow breakage and insect attacks on the utility as net present value of forests of Norway spruce (*Picea abies* L. Karst.) and European beech (*Fagus sylvatica* L.) in southern Germany when the timing of harvest depended on a simulated timber price. Whilst the Norway spruce forest maximized the expected utility, the utility for single rotation periods fell within a wide range. The tree species alternative that maximized the minimal utility was European beech with or without an admixture of 20 per cent Norway spruce. Applying a decision rule based on maximum expected utility may then lead to recommended actions that are far from what the risk manager (the forest owner) is prepared to do, based on a maximin decision rule.

Subjective probabilities are measures of degrees of belief (Ramsey, 1926). As we believe any conceivable proposition to some degree (it could even be to zero degrees), every proposition that we can think of can, on this basis, be allocated a probability. Given that a utility function exists, that is, a measure of how consequences of a decision are valued, it is always possible to make decisions according to the principle of maximizing expected utility.

An obvious drawback of this simple view of decisions using personal probabilities is that there is no difference in decision-making between decisions with well-informed degrees of belief and decisions where the degrees of belief are based on poor (either in quality or in quantity) information. This can be solved by allowing people to assign sets, or intervals of probabilities, when they are unsure of how strong their belief is. This approach requires new decision rules. Several rules have been proposed in the literature (Levi, 1980; Gärdenfors and Sahlin, 1982; Wally, 1991): one example is the maximum minimal expected utility rule, where minimal expected utilities are calculated for each alternative among the different probability distributions and the alternative with the highest resulting expected utility is chosen. This is also a cautious type of rule.

Just as with objective probabilities, a demand for a single probability distribution to be used in risk assessment may lead to risk decisions that are not in accordance with what a seemingly rational forest owner chooses to do.

Risk perception

Psychologists often focus on people's perceptions of risk, which seems to imply two related things (Table 1). First, that there is something – a risk – that can be perceived, a risk that presumably can be observed and might also exist external to the observer (see Brehmer, 1994). Second, that there is some objective reality that we can measure perceptions of risk against. It is, perhaps, not the risk *per se* that exists independently of our perceptions of it, but that risky behaviour can be better or worse according to some objective standards. Among researchers in psychology, rational decision-making is often equated with maximizing expected utility (see Sahlin *et al.*, 2010). From this viewpoint, it is tempting to see experts as supplying risk assessments that are objective, analytical, wise and rational, whereas the public's perceptions of risk are subjective, often hypothetical, emotional, foolish and irrational (Slovic, 1999).

Within psychological research, much effort has been devoted to identifying biases, patterns of irrationality that occur in particular situations (for example, see Kahneman and Tversky, 1972) and heuristic principles (simple decision rules that people use to reduce complexity in a given decision situation) (Tversky and Kahneman, 1974). Some of these are of immediate relevance to risk communication (for example, see Table 2 and Kahneman and Tversky, 1979). The irrationality of heuristics and biases has been discussed ever since they were introduced in the 1970s and the controversy remains (see, for instance, Cohen, 1981; Lopes, 1991; Todd and Gigerenzer, 2000; Holtug, 2002; Kuntz-Duriseti, 2004; Brinck, 2005).

The plural nature of risk

Slovic and his colleagues suggested that the factors we take into account when dealing with risk differ. They found, for instance, that a small number of factors accounted for the difference in risk perception that had been identified between experts and laymen (Slovic *et al.*, 1981). These factors suggest that experts and laymen have different concepts of risk. Slovic (1994, p. 94) expressed the point in the following way: 'Although many observers have labelled public perceptions of risk irrational, the research [. . .] paints a much different picture. First, whereas experts define risk in a narrow, quantitative way, the public has a wider view, qualitative and complex, incorporating legitimate considerations such as uncertainty, dread, catastrophic potential, and controllability into the risk–benefit equation'.

From this perspective, risk does not appear to be one thing (or concept) but many. At the very least, we cannot rely on a common understanding of risk. The interested parties need to define and play 'the risk game' (Slovic, 1998). By using this term, Slovic suggested that the risk concept has similarities to a game. Games have rules, time limits, criteria for winning and losing and so on, but no rule, time limit, etc. is common to all games. The general concept of a game – if there is one – cannot be defined by listing necessary conditions for all games. The concept of risk, Slovic claimed, is like the concept of a game. There are many kinds of risk, and nothing relevant is common to all of them (cf. Wittgenstein, 2009). For some time now, it has been popular to categorize positions such as Slovic's as social constructivist. For instance, Bradbury (1989, p. 391) wrote that if acceptance and acceptability of risk cannot be 'analytically determined', they 'must be negotiated, that is, socially constructed'. We fear that this view rests on a simplistic division between 'risk as a physically given attribute' and 'risk as a socially constructed attribute'. This may not be problematic for Bradbury, who only discussed societal risks, but the distinction is potentially harmful when generalized to personal risk assessments and local 'risk games'. Slovic's position does not presuppose social constructivism but follows quite naturally from differences in the individuals' decision-making situations. However, it is clear that cultural and societal values and perspectives have a role to play in shaping the way individuals understand risk as well as which risks we accept. There are social dimensions as well as other dimensions that need to be taken into account if we want a more complete understanding of risk.

Risk as feeling – the emotional nature of risk

The emergence and contemporary popularity of dual process theories in theories of judgment and decision-making are connected both to the idea that rational decision-makers conform to

Table 2 Examples of biases and heuristics

Bias or heuristic	Description	Reference	Example
Availability heuristic	When people judge an event that immediately comes to mind as more probable than events that are less readily recalled	(Tversky and Kahneman, 1973)	A higher proportion of Swedish private forest owners believed in global warming in 2004 than after the cold winter in Sweden in 2010 (Blennow *et al.*, 2012)
Confirmation effect	When people tend to search for or interpret information in a way that confirms their preconceptions	(Bacon, 1620/2000), for a review of modern psychological studies, see (Nickerson, 1998)	The public debate about container seedlings has, according to (Hagner, 2005), focused on the fact that damaged trees often have root deformations. What has not been in focus is whether healthy trees have root deformations as well.
Certainty effect	When people tend to discount uncertain future outcomes in comparison with the certain and immediate costs of action now	(Kahneman and Tversky, 1979)	People would be reluctant to take measures to reduce possible wind damage when compared with the certain loss of production caused by a reduction in the length of the rotation period.
Framing effect	When people are influenced by the way equivalent decision problems are presented (framed), i.e. whether they are presented using positive words (gains) or negative words (losses). This is known to affect how risk-seeking people make choices (risky choice framing), but also how attractive an option is taken to be (attribute framing).	(Tversky and Kahneman, 1981; Levin and Gaeth, 1988)	The Finnish rural public's willingness to pay for a hypothetical policy regulating regeneration cutting was higher when the forest management was described as involving uncertainty as opposed to when framed as a clearly defined management scenario (Rekola and Pouta, 2005).

something like the principle of maximizing expected utility and to the fact that we often deploy heuristics and are prone to biased judgments in ordinary life (for an overview, see Evans, 2008) (Table 1). The basic idea is that decisions can be reached either through a fast and intuitive system (resulting in heuristic decision-making which, on occasion, gives rise to biases) or through a slower, deliberate system essentially acting in accordance with rationality norms. Sometimes, this is connected to ideas that the fast intuitive system is governed more by emotions (e.g. Finucane *et al.*, 2000; Loewenstein *et al.* 2001). Dual process theories are relatively popular at the moment, but they produce few novel predictions related to risk perceptions. Their role is, rather, to integrate previous research into a more complex framework (it is, however, not certain how successful this integration is, see Sahlin *et al.*, 2010). There are approaches to risk perception that may be seen as potentially more productive.

Feelings and emotions can clearly be a problem in the context of risk assessment and communication. However, a lack of these sentiments can be an even more important problem. Feelings and emotion can make us take action. Mere statistical information, claimed Slovic (2007), sometimes paralyses us into inaction. Roeser (2012) argued that communication about the risks of climate change is often conducted in terms that are too abstract, with the result that it does not motivate us; it should trigger emotions. Recent findings show that personal experience of climate change motivates individuals to take action (Blennow *et al.*, 2012). It is possible that this phenomenon occurs because emotions are triggered by personal experience, but it might also be the case that personal experience has an impact on our behaviour in other ways – personal experience may change the strength of belief the person has in climate change (cf. Blennow and Persson, 2009) or their preferences (without giving rise to emotions) and this might be sufficient to instigate action.

The values at risk

Forests are important not only to their owners but also to the general public. They provide wood and timber, they are important for the global climate through their role in carbon sequestration, water evaporation and condensation and oxygen production, plus they provide opportunities to experience nature and for recreation. Studies show differences in the value placed on forests by different groups of people (Edwards *et al.*, 2012). For example, a high value placed on the forest as a resource for timber and wood has been found to be more common among forest owners than among the Swedish general public (Eriksson, 2012). On average, the Swedish public ascribes a higher value to biodiversity and recreational benefits from the forest than forest owners do, although only small differences have been found between the groups with respect to the value of recreation in terms of fishing and hunting activities (Eriksson, 2012). In spite of the differences found between the general public and the forest owners, both groups show considerable variation in attitudes and people often put a high value on deriving multiple benefits from the forest (Eriksson, 2012). Nevertheless, among private individual forest owners, the financial return from the forest is often not the sole motivation to own a forest. In Sweden, forestry on average contributes only 12 per cent to the average private individual forest owner's household income (Mattsson *et al*., 2003).

The way that we deal with a risk is also influenced by how we analyse and deal with the values at stake. To claim that something has value can, in fact, mean many different things. In practical decision-making, it is important, as far as possible, to be able to measure and compare values on the same scale. This is usually achieved by expressing all values in monetary terms. Doing so also has its drawbacks, however. Monetary value is normally decided by the market, but it is not the case that everything is, or can be, bought and sold within a market. Take, for example, the relationship a forest owner has with a forest he planted with his grandfather, which he has followed throughout his life and is now managing together with his granddaughter (Blennow and Persson, 2013). In situations like this, we have to use more or less artificial means of assigning monetary value. That the methods for assigning value differ (market versus contingent valuation methods) means that it is not obvious that different values can be measured and compared along the same scale even when measured using the same unit.

Another problem with translating all types of values into monetary terms is that we lose information in the process. There can be many different reasons why someone wants to buy or sell something within the market. It might be because they value it as an end in itself, because they see a value in it as a tool for achieving some other value, or because they expect other people to value it and plan to sell it to them. All these motives can be transformed into a demand within a market and measured in monetary terms (Blennow and Persson, 2013). This, in turn, means that the price in money of, for instance, a forest depends on many things other than the value of the forest in itself (the end value of the forest) (Persson, 2008).

Knowledge risk and trust

Outcome risk is not the only kind of risk we have to consider in forestry. Epistemic risk – or knowledge risk, as we prefer to call the type of epistemic risk we are interested in here – is the risk we take or run when our decisions rest on an uncertain foundation – decisions that are based on information that is insufficient or of poor quality (Sahlin and Persson, 1994). In forestry, there always seems to be the possibility that decisions may be associated with adverse effects (outcome risk) and decisions involving outcome risks normally also involve knowledge risks: we act on beliefs as if we know they are true, or base our decisions on one of two rival hypotheses, disregarding the other possible hypothesis (knowledge risk: see Gärdenfors and Sahlin, 1982 for a definition of this type of epistemic risk). Sometimes, when we take knowledge risks, we end up taking unwanted outcome risks simply because we have not spotted them. We might decide on a particular course of action because we think that we know more than we do. Our beliefs may be likened to a map with which we navigate our way through life (the idea originates from Ramsey (1929), who held that a belief is 'a map of neighbouring space by which we steer'). Some continents on the map are sketched in the smallest detail; others have blank spaces and others are perhaps a bit blurry around their edges. Seeking knowledge means filling in the blank spaces and sharpening the contours. In this analogy, you take a knowledge risk when you only use a part of your map to lead you forward, or if you take your incomplete map to be a true picture of the whole world.

Knowledge risk is only indirectly about outcomes (Table 1). However, the outcomes it is indirectly concerned with are the same types of outcome that risk managers in forestry typically worry about. One example of a knowledge risk situation in forestry occurred when containers for growing and planting seedlings at low cost were introduced on a large scale to Sweden to overcome the difficulties of sowing and using bare-rooted seedlings (see Sahlin and Persson, 1994; Hagner, 2005; Persson, 2007). The introduction of containerized seedlings was a direct response to a quest for a more 'rational forestry'. The first container that was introduced by Svenska Cellulosa Aktiebolaget (SCA) in Sweden in the early 1970s was a paper pot. SCA bought the entire planting system from Lännen Sokeri, the Finnish sugar refinery. Other Swedish forest owners also decided to use this or similar systems. The system had originally been invented in Japan and was designed so that the roots would be able to penetrate the container walls and/or so that the containers would decompose after some time in the soil. Hagner (2005, p. 212) reported that SCA produced 12 million plants in paper pots between 1971 and 1974. One of the primary reasons why SCA decided to use the paper pot was that they could buy the entire system and start production at once. The idea seems to have been to evaluate the paper pot system whilst developing their own system. In 1973, the decision was made to use plastic containers instead. 'Kopparforssystemet', a smooth-walled conical container was introduced. Neither the paper pot nor SCA's own container was optimal. They have now long since been replaced by other kinds of containers, such as the JackPot that, 'assisted by air canals, guiding rails, and copper-containing paint, results in a root system that is very similar to that of a naturally rooted seedling' (Hagner, 2005, p. 213: authors' translation). The paper pots were also used in northern Sweden and at high elevations, where the climate is colder and the decomposition process slower than in the region where they were originally designed to be used. Here, the system did not function well. Roots did not emerge from the cell and continued to grow, in spirals, affecting tree stability and the timber quality in mature forests (Lindström and Rune, 1999). Spiralling roots were a problem with SCA's own container, too. However, the crucial difference was thought to be that the seedling only had to spend a few months in the Kopparfors container (Hagner, 2005, p. 213). The knowledge risk in this example arose when decision-makers decided to act on the knowledge they had, knowledge that did not, in fact, rule out the possibility that the paper pot system would not function satisfactorily. Rather, the idea was to replace it quickly with a better system, if needed. There was a problem with this strategy, of course. How was it possible, quickly, to determine whether one system was better than another without first knowing, for instance, how to monitor the outcome risks of spiralling roots? In Sweden, there was a division between 'the concerned' (for an example, see Bergman and Häggström, 1973) and 'the optimistic' (Hagner, 2005, p. 221) about the consequences of early root deformations (in pine especially). According to Hagner (2005, p. 223), SCA founded their optimism and initial decision to proceed on the basis of a single paper – a student's master's thesis.

Clearly, the decision to use the containerized seedlings was made on the basis of insufficient information and hence the decision-maker took a knowledge risk. Even in 1999, the economic consequences of the widespread use of containerized seedlings in

Sweden could not be estimated (Lindström and Rune, 1999). To circumvent some of these knowledge risks, it would have been necessary to use information that was as robust as possible, as well as to be aware of the limits of knowledge (Sahlin and Persson, 1994). (This is where alternative concepts of epistemic risk may differ from the one presented. Sometimes, epistemic risk is simply understood as the risk of believing falsely or in failing to believe truly, irrespective of what 'practical' outcome risks this may lead to.)

We seldom have a full set of accurate information (in the sense of exact information that is correct in every detail) that we perhaps would like to have for practical decision-making, but it is clear that some contexts are more problematic than others. Certain factors produce knowledge risks. Social scientists usefully distinguish between internal and external validity (Campbell, 1957). Researchers aim to make correct inferences both about that which is actually studied (internal validity), for instance in an experiment, and about what the results 'generalise to' (external validity). In the container seedling example, the limited internal and external validity are two reasons why the knowledge risks were considerable. At the time, SCA and the other Swedish forest owners knew relatively little about the consequences of the root deformations that they studied (lack of internal validity) and about how the results could be generalized (lack of external validity). Both problems were generated – no doubt – by the perceived time-pressure to rationalize Swedish forestry and – perhaps – also by a strong preference to mechanize it. Knowledge risks are easily generated by such factors. The decision-makers may be well aware that the evidence they have is not sufficient for an inference that one of their rival hypotheses is true and the others false; nevertheless, lack of internal and external validity may prevent them from obtaining complete information when deciding how to act. Other factors can be relevant in other cases. Viswanath *et al*. (2012) examined the experiences of scientists and practitioners working with transgenic trees. It is widely accepted that field trials are crucial for understanding the value and adaptability of transgenic trees. In their study, different kinds of regulations and bureaucratic procedures turned out to be the major knowledge risk-producing factors. The authors did not use the language of knowledge risk, but their conclusions contain – according to our perspective – a list of factors generating knowledge risks that may discourage scientists and practitioners from conducting field trials: '[...] uncertainties in approvals and the time period to obtain permission; several years of monitoring following harvest to detect root sprouts or seedlings; added costs of molecular characterization and permit preparation even for familiar types of genetic modifications; special disposal procedures for large amounts of tree biomass [...] It follows that many scientific studies are likely to never be undertaken, and the quality of studies that are done will frequently be of reduced quality due to reduced size and scope. These conditions clearly impede science and technology development'. (Viswanath *et al*., 2012, p. 224)

The transgenic tree example is particularly interesting in that it shows how attempts to manage the outcome risks involved in transgenic tree growth and field trials can contribute to increased knowledge risks in (future) decisions about such growth and field trials. The regulations seem to lead to reduced quality in the information we need to monitor the outcome risks. In sum, the regulations hinder researchers from assessing both the external and the internal validity of preliminary results. Knowledge risk has, so far, been largely overlooked in risk communication research.

Over the years, the role of trust – defined as a willingness to depend – in the 'sender' (for instance, the risk-management professional) has been proposed as a fundamental component in all risk communication (Slovic 1999). Persson (2004) argued that analysis of the mechanisms behind trust can provide new opportunities for risk communication. As we have seen, the knowledge risks depend on the reliability of the processes used when assessing the risk (Sahlin and Persson, 1994). Persson (2004) argued that the 'receiver' (for instance, the public or the private forest-owner) needs to be able to assess the knowledge risks involved to have trust in the sender of the information. To be able to map the knowledge risk, the receiver needs to be able to grasp the state of knowledge in a wider sense to help combine fragments into a map of the whole (Persson, 2004). Not only is this approach promising with respect to the efficacy of risk communication, it also provides an approach that is ethically appealing because the individuals' autonomy and reflective capacity is respected. It furthermore provides an opportunity for learning and for generalizations that probably have a more lasting effect on an individual's decision-making than when the receiver is expected to accept an assessment that is provided to them acritically. Given the general complexity of a decision situation and the subjective components involved, ideally a risk communication situation would be a situation in which parties exchange valuations and assessments, resulting in some kind of management of risk (see Persson, 2004).

There are more sources communicating risk than just experts or governments, however. Forest owners may gain information about potential risks and their consequences from family members, other forest owners, the media and so on. It is interesting to note that these sources will be more or less similar to the forest owner in important respects. We can speculate that family members will share attitudes and values with respect to many aspects of the forest, not only economic and environmental concerns, but also the value of a beautiful landscape, or an interest in hunting. When taking advice from others, we are more influenced by those who express greater confidence in their decisions or recommendations (e.g. Sniezek and Buckley, 1995; Sniezek and Van Swol, 2001), who are experienced rather than inexperienced (e.g. Harvey and Fischer, 1997), have good reputations rather than bad (e.g. Yaniv and Kleinberger, 2000; Yaniv and Milyavski, 2007) and who have a track record of being accurate rather than inaccurate (e.g. Harries *et al*. 2004). When preferences are likely to differ, advisors with similar preferences are preferred to those with less similar ones (e.g. Feick and Higie, 1992; Gershoff *et al*., 2001) and such advice also appears to lead to better decisions (e.g. Aksoy *et al*., 2006).

Distribution of risks

With respect to planning, risks and benefits can be assessed in different ways. An approach in which our aim is only to maximize the total number of good effects and minimize the total number of bad ones for the whole population is called a utilitarian approach. If we include other aspects, such as a fair distribution, respect for individual rights or the dignity of our acts among our aims, our approach can be referred to as a rights-based or deontological.

Considering that it is very common that one person or group of people make decisions about risks that affect others, it might be a good idea to consider not just the size but also the distribution of risks. The distribution of risks needs to be seen in relation to the distribution of benefits. In many cases, risks and benefits go together but it is common that the benefits and the risks resulting from a decision fall on different groups. To have a clear idea of their distribution is, therefore, important for both the communication and the handling of risks.

The basic answers to what constitutes a fair distribution can be divided into three groups (Frankena, 1963):

- equal distribution,
- distribution according to merit and
- distribution according to need.

Equal distribution means that risks and benefits should be distributed so that the risk is equally high for everyone. If applied to the whole population, it means, for instance, that it is not acceptable to manage a forest in a way that increases the profit for the forest owner whilst imposing far-reaching risks on the whole of society by destroying important ecosystem services. Neither is it, according to this view, acceptable to demand that the forest owners take on high economic risks for managing the forest in a way that mainly benefits the general public. Biodiversity protection has been shown to be in higher demand by the general public than by forest owners in Sweden (Eriksson, 2012). At the same time, protecting biodiversity can, in some instances, hamper timber production. Sometimes, therefore, forest owners consider the presence of a rare species in their forest to represent a risk to their freedom to manage their forest according to their own aims. Forest owners may not be prepared to take this risk (see Drake and Jones, 2002, for example, from North America).

Distribution according to merit means that everyone should get what they deserve. This can, for instance, mean that the person who creates the risk should take on more of the risk than people who were not involved in the decision. Applying this line of reasoning to forest insurance would mean that forest owners who exhibit more risk-prone behaviour, which exposes the insurance company to a higher risk, should be charged higher premiums. It can also mean that if you take on a higher risk, you should also receive more of the benefit. For example, when there is a conflict of interests between a forest owner who has invested work and money in the forest and the general public, the interests of the forest owner should be given priority according to this view of fair distribution.

Distribution according to need means that, for things like food or medical attention, those who lack food or are more badly hurt should receive more help quicker. When it comes to risk, it can be interpreted as meaning that lower risks should be conferred on those who are most vulnerable. For instance, those who live close to a forest may be more vulnerable to what happens to the forest, not just economically, but also in terms of aesthetic, health and cultural values than those who own stocks in the timber industry but who live far away from the forest.

To these three basic ideas about distribution, we can add many different versions and combinations. Identifying the distribution that is most ethically sound is a matter of controversy everywhere, from the playground to the UN and the perspective that one selects in this controversy obviously also affects how the distribution of risks and benefits are handled. We are not advocating any particular distribution of risk but we do want to stress the importance of considering this question, not just as an exercise in political and ethical theory, but as a very important practical consideration with far-reaching consequences for all decisions regarding risks and forestry.

The significance of the choice of conceptual approach for ecosystem management

The choice of how to conceive and define risk is not merely a case of semantics. The result of an assessment depends on one's ideas of risk, and different assessment methods imply different opportunities for risk management, with strong implications for the management of ecosystem services. For example, an influential study that applied a model based on structures in society, such as economic welfare, level of education and institutions, predicted the adaptation of forest management to climate change among private forest owners to be more common in northern Europe than in southern Europe, where the intensity of forest management in general is lower (Lindner *et al*., 2010). However, Blennow *et al*., (2012) reported that not only do private forest owners in southern Europe undertake measures to adapt to climate change but that a model of adaptation to climate change based on two personal variables had significantly higher explanatory and predictive power than a model based on several variables related to structural information. The two personal variables, strength of belief in local effects of climate change and strength of belief in having experienced climate change, almost completely explained measures taken to adapt forest management to climate change. The different underlying theoretical approaches of the two studies by Lindner *et al*. (2010) and Blennow *et al*. (2012) lead to distinctly different conclusions. As a consequence, fundamentally different solutions are suggested to the same problem. The authors of the study relying on the general structural model concluded that small and fragmented privately owned forests in southern Europe are often poorly managed and constitute a barrier to efficient wood resource utilization and adaptive management practices (Lindner *et al*., 2010). The opportunities suggested for alleviating the constraints are the formation of forest co-operatives and active support from public forestry administration (Lindner *et al*., 2010). In contrast, Blennow *et al*. (2012) concluded that when forest owners believe in, and see the effects of, climate change, they are more likely to take adaptive measures. The opportunities to influence adaptation to climate change implied by this result are through gathering and disseminating evidence of climate change and its effects on increasing peoples' perceptions of having experienced it, and hence to consider the need to take adaptive measures (Blennow *et al*., 2012).

The study by Blennow *et al*. (2012) reflects an approach in which risk is seen as something that, at least partly, does exist in the physical world. The strong emphasis on the belief in the risk and personal experience of the risk points towards a conception of risks as something that we can experience and observe in a clearer manner than either the decision-analytic or constructivist accounts of risk can achieve. However, it shares with the decision-analytic approach the basic idea that the outcome of a risk cannot be judged as undesirable without somebody making the valuation; both the probability of the undesired thing happening and the determination of whether the risk is big or small. With respect to the management of risk (adaptation), the point of departure is that our beliefs and desires influence action. Hence, the approach is different from both purely objective and purely decision-analytic and constructivist approaches to risk.

Opportunities for effective risk communication

To be able to take account of the contribution of forest ecosystem services to human well-being, we need information on the beliefs and desires of the general public, including forest owners, as a basis for risk communication as well as for planning and the formulation of forest policies. To avoid the potential problem of interpreting the risk concept too narrowly, in this article we prefer the term *personal risk assessment* to *risk perception*. The psychological research on heuristics and biases, with its focus on how risks are perceived and distorted, might help us understand how decision-makers respond to risk, regardless of whether we regard these responses as being irrational or not. Recent research has focused on how information environments affect personal assessments of risk and how the performance of various heuristics is affected by different environments. In one version of this research, the claim is for *ecological rationality*, that is, the idea that we should see heuristics, not as sources of biases, but rather as practical tools that lead to good (and sometimes even superior) decisions in the environments to which they are adapted (Gigerenzer *et al*., 1999). For instance, heuristics that ignore a large part of the available information can sometimes lead to better predictions than decision strategies tailored according to statistical and decision theoretic norms, such as versions of linear regressions (cf. Gigerenzer *et al*., 2011).

More importantly in this context, there is now a growing body of knowledge about how different information environments affect aspects related to personal assessments of risk. For instance, for choices where the outcome(s) of the decision is (are) not known, but the probabilities for the various outcomes are known, there may be differences in how outcomes are assessed depending on how the likelihood of an event is determined. Participants respond differently when the likelihood of the event is *described*, that is, given in terms of numerical probabilities (such as a gamble where the probability of each outcome is described to participants), compared with when it is *experienced*, that is, when participants are given information sequentially, so that they experience occurrences over time. Risky choices with respect to relatively rare events such as wind throw differ dramatically in these two cases: in the first case, rare events are known to have more impact on decisions than they are expected to given the norm, whereas in the second case, rare events are instead given *less* weight. This is known as the description–experience gap in risky choices (cf. Hertwig and Erev, 2009). Research such as this can help us to explain differences between the response of forest owners and researchers, as in the introductory example, to statistical information handed out by authorities or resulting from research (encouraging decisions from description). It also helps to explain differences in the responses to real events (deciding from experience).

It is important that forest advisors appreciate the values and beliefs of their clients to give advice that facilitates the clients' ability to reach their goals. However, Kindstrand *et al*. (2008) reported that Swedish forest advisors, in general, significantly overestimate the value private forest owners put on timber production, both in the recent past and in the future, and they significantly underestimate the value that forest owners put on the forest as a source of opportunities for recreation and habitats for plants and animals.

Even the format in which information is given influences the types of errors that are made. For instance, the base rate fallacy occurs when the prior probability of an event is ignored, in cases when its conditional probability, given some evidence, is determined. A hypothetical example is given by the situation where a device for unintrusively monitoring stem rot has been used to help estimate the probability of stem rot infection in a certain tree. The base rate fallacy occurs if the base rate of positive indication from uninfected stems is ignored when determining how likely it is that a particular tree for which the device signals stem rot is infected. The base rate fallacy is known to decrease when likelihoods are presented as natural frequencies (X cases out of 100) rather than as single event probabilities (X%) (cf. Gigerenzer and Hoffrage, 1995). Note that these phenomena not only have implications for how communicated risks are interpreted by forest owners, forest managers and advisors, they are also a key to how risks are perceived and acted upon in everyday life.

To provide an environment that promotes learning, we need to create a situation characterized by openness, in which parties exchange valuations and assessments, thereby enabling the filling in of gaps in their respective personal knowledge maps. We need information about the preferences of the forest owner who assigns a higher value to the flora than to avoiding wind damage to the trees, members of the public who prioritize the opportunity for recreation over timber production, the big forest company that prioritizes the opportunity to 'rationalise' forest management over having a fully functioning system for regeneration and the old forest owner who manages the forest together with his grandchild. All are examples of how risk communication can fail unless information on the preferences of the communicating parties is provided. Communication also provides an opportunity to fill in gaps in individuals' knowledge maps. The forest owner who assigns a high value to the flora might be unaware of the risk of wind damage and how it will affect that flora, or whether there is an alternative way to reduce the risk of wind damage that also leaves the flora unaffected. Members of the public might be unaware that a production forest could be more suitable for many recreational activities than an unmanaged forest. The big forest company might believe that it is easy to know when the plants have been improved. We expect that this can lead to a direction of integrating assessments that enable effective risk communication, even though the objective is not to make parties change their goals. Hence, we need knowledge about the beliefs and desires of the parties to be able to provide information that is relevant to the decision-maker. That the communication works in both ways helps avoid myopic views of a decision situation (see Sahlin and Persson, 1994).

Conclusions

Risk management, communication and planning of forest ecosystem services are complicated by uncertainty, insufficient information or information of poor quality, limited cognitive capacity and time, along with value conflicts and ethical considerations. Based on a review of different interpretations of risk and results of empirical studies, we suggest that risk has both subjective and objective components and that the personal assessment of risk is decisive for the management of ecosystem services. Risk management, communication and planning are sometimes facilitated by heuristics. They also help us to understand how people make decisions which, together with mutual information about beliefs and desires, are important in all risk communications and help to fill in gaps in personal knowledge maps. To have a clear idea of the distribution of risk is, furthermore, important for risk management, communication and planning in relation to forest ecosystem services.

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