

Environmental crises as drivers of the state and use of Swedish forests

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*Future Forests analyzes conflicting demands on forests systems
to enable sustainable strategies under uncertainty and risk*

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Abstract

An analysis is made on environmental crises and how they may impact on Swedish forests' ability to provide ecosystem services. I review the definition of crisis and related terms, and discuss them mainly from an ecological perspective but also relate to perceptions in the social sciences. The crises are classified regarding different characteristics, and three examples are described: one fire, one storm, and one nuclear power plant breakdown. I conclude that environmental crises, although important, might not be the strongest drivers of the future state and use of Swedish forests. My examples show that the crises mostly act on local and regional scale and not profoundly affect national finances based on forest ecosystem goods or fundamentally change policies. There are important interactions with other drivers and for the future, most significantly with climate change.

1. Introduction

This paper has been initiated within the scenario analysis of the interdisciplinary research programme “Future Forest”, starting January 1, 2009 and with a likely duration of 8 years. The scenario analysis forms the initial step, in which a number of drivers with more or less strong potential impact on the future state and use of Swedish forests will be analysed. Thus, the driver “environmental crises” is among several that will be addressed. The largest future potential environmental crises are closely linked to climate change but “climate change and climate politics” are analysed as drivers of their own, and thus are not a main focus here. For all driver analyses in the programme, a starting point is that the driver should be external, i.e. emanate from outside the Swedish forest ecosystem. I focus on the terrestrial parts of the forest ecosystem, and thus put less emphasis on lakes and running waters.

The presentation is made from a natural science perspective, written by an ecologist. I have chosen to highlight the forests themselves, and more specifically on their ability to produce ecosystem services under impact of various hazards. I fully acknowledge that crises research is part of the social science arena with a strong anthropocentric perspective, and that, consequently, I might have an unorthodox angle. I have attempted to, at least superficially, orient myself about paradigms, nomenclatures and approaches within the social sciences, through reading of literature and discussions with social scientists. In order to achieve clarity, I have tried to be distinct in delimiting my scope, and in defining terms used. Since the Future Forest programme is multidisciplinary I have strived to express also complex phenomena in a simple way. A challenge has also been to conceptualize my view on how crises and related processes and mechanisms relate to ecological systems.

Aim of the paper

The main aim with the paper has been to conclude whether environmental crises are such strong drivers of change for Swedish forests that they warrant further processing within the scenario analysis. Additional aims have been to:

- define the term “crisis” and how it is used in my context, but also to elaborate on how it and related terms are applied in the social sciences
- describe types of environmental events that have acted, and are likely to act in the future on Swedish forests

- assess the type and degree of impact that environmental events might cause on the capacity Swedish forest to produce ecosystem services
- evaluate whether environmental crises are main drivers of change for Swedish forests

Definitions

Ecosystem services

The term “ecosystem services” has become established and extensively used during the last decade in academia but also increasingly in environmental assessment and monitoring. It relates to the capacity of ecosystems to provide goods for the benefit of man. For forests, the services span from values that can be expressed in monetary terms, such as supply of pulp and timber to the forest industry, to collective goods which are hard or impossible to express in traditional economic terms, such as the capacity to maintain a good water quality within forested watersheds and in recipient areas, and aesthetic values like the ability to experience beauty of intact, natural forest landscapes. I here use the definition of the Millennium Ecosystem Assessment: “Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling that maintain the conditions for life on Earth” (Millennium_Ecosystem_Assessment 2003). In the context of Swedish forests, production of timber, pulp, bioenergy (biomass production), availability of mushrooms, berries and game (non-tree forest products), possibility to use the forests for recreation, water quality and capacity to contribute to a positive carbon balance are especially important ecosystem services. UN:s International Strategy for Disaster Reduction highlights the link between natural disasters and ecosystems services in their Global Assessment Report on Disaster Risk Reduction (ISDR 2009).

Crisis and related terms

There are several important considerations to be made before analyzing specific environmental crises that have acted, and possibly will act in the future on Swedish forests. The first is how to define the term. According to Cambridge Advanced Learner's Dictionary

8<http://dictionary.cambridge.org/define.asp?key=18339&dict=CALD>; May 19 2009) a crisis is

“a situation that has reached an extremely difficult or dangerous point; a time of great disagreement, uncertainty or suffering”.

This leads to several different properties that need to be further elaborated: the type of event (what is “situation”), the strength of the pressure (what is “dangerous”), the time-frame (what is “time”), and the one that is exposed to the crisis (who is experiencing “uncertainty or suffering”).

In the social science crisis research there, not surprisingly, are numerous definition of the term crisis. The term has also been analysed in reviews, e.g. by (Gundel 2005). In their book “The politics of crisis management” (Boin et al. 2005) use the following: “when policy makers experience a serious threat to the basic structures or the fundamental values and norms of a system, which under time pressure and highly uncertain circumstances necessitates making vital decisions”. Thus, crisis in this interpretation is a social process, related to institutional changes. Another, closely related definition but broader since the agent of making critical decisions is not defined, is “a serious threat to the basic structures or the fundamental values and norms of a social system, which – under time pressure and highly uncertain circumstances – necessitates making critical decisions” (Rosenthal et al. 1989). Crisis researchers are a heterogeneous group with a background in e.g. political science, international relations and political psychology (Boin 2005).

There are several closely related terms, varying in application depending on scientific discipline. The meaning of disaster has been extensively debated within the scientific community, which in this case is dominated by US sociologists and geologists. This is clearly demonstrated by the many diverging views put forward in the two books “What is a disaster? Perspectives on the question” (Quarantelli 1998), and “What is a disaster? New answers to old questions” (Perry & Quarantelli 2005). A general agreement is that disasters are inherently social phenomena, i.e. they are constructions that depend on social context and human values. Accordingly, if there are no social consequences, there is no disaster. Disaster studies, which started about 40 years ago and which have largely focused on behavior of people and organizations, are now in a phase of re-orientation towards more theoretical discussions and multidisciplinary approaches (Quarantelli 2005). Disaster sociologists and crisis researchers agree in the social construction but a dividing point is the causes for social response, for which there are few restrictions for crisis researchers, while disaster research, at least traditionally, have focused on natural, physical events. Obviously, “crisis” and “disaster” are related terms, and (Boin 2005) has suggested that “disasters are crises with bad endings”, i.e. that disasters is a sub-group of the crisis concept. (Boin 2005) also advocates integration between the two perspectives as well as more cooperation between the two research fields.

Other terms often used in relation to crises and disasters are event (an observable occurrence), risk (uncertainty of outcome of an event), and hazard (a potentially harmful event). They are interrelated; for instance (Cottle 2009) considers environmental crises that are induced by man’s action as failures to deal with environmental hazards. Thus risk reduction is central to crisis development and management. In fact, it can be questioned if there are today any true “natural disasters” or if not all are mediated by man and thus are “un-natural”. Climate change, industrialization, new technologies, changed land-use are examples of human action that affect the environment profoundly, and reinforce ecologically change (Cottle 2009). (Cutter 2005) suggests that less emphasis should be put on discussing and trying to agree on definitions, and more effort should instead be devoted to analyzing the vulnerability and resilience (see below) of human, environmental and technological systems, to threats and extreme events.

In this context, I define an **environmental crisis** as:

a change in the Swedish forest ecosystem caused by an external driver (originating outside Swedish forests) with large negative impact on the ability to provide ecosystem services on local, regional or national level

According to this definition, the focus is on the reaction of the ecosystem itself, without specifically emphasizing the response of the social systems. It certainly might be questioned if the ecosystem can be viewed as being under crisis, since it is man that observes, measures and analyses its state, and thus is its interpreter. But, my perspective is ecocentric as well as anthropocentric since it is man that is the user of the ecosystem services. The ecosystem focus rests on a massive scientific body of knowledge on ecosystem properties and dynamics that can be expressed in quantitative as well as qualitative terms. Thus, the degree to which the ecosystem is under crisis can be described by comparing different characteristics, like soil properties, biomass volumes, number of species, and also more specifically on the monetary value of different ecosystem services, before and after an event. It surely rests on the observer to assess whether the ecosystem changes warrant to be classified as a crisis, but this approach is transparent and possible for others to scrutinize. Despite the focus on the forest ecosystem itself, I also pay regard to reactions of institutions and policies, although much more briefly.

Different aspects of crisis in the current study

Based on the different properties of the definition of crisis, I have in this paper made a number of demarcations. Table 1.

Table 1. Delimitation of different aspects of the term “crisis” used in the paper.

Aspect	Delimitation applied in the paper
Origin	Outside of Swedish forests
Cause	Either natural or man-induced
Strength	Serious enough to harm the ability to produce ecosystem services
Extent	From local to national
Initiation	Quick or gradual
Duration	Extending from a few years up to ca. 100 years
Object	Ecological, social and economic values

For environmental crises, the causes can be either natural, like climatic events, or man-made, like various kinds of pollution. The strength of the impact to be classified as a crisis is hard to delimit in exact quantitative terms but it should be strong enough to seriously harm the ability of the forests to produce one or several ecological, economical or social goods from the forest. An environmental crisis can act on widely different scales, from local strong pressure of e.g. flooding in a watershed to factors that impact on all Swedish forestland, like climate change. The speed at which the crisis initiates is vital to notice in demarcations of an environmental crisis study. It can be instant like the radioactive fallout from a nuclear plant disaster or be a more slow process like acidification linked to successively progressing industrialization. The time duration of an environmental crisis is one of the most difficult factors to define, and it is by necessity rather arbitrary. A storm might cause serious impacts for only a few years while radioactive fallout can lasts in the ecosystem for centuries before it decreases to un-harmful levels. Here, I have set the time range from about a decade up to a century. The longest rotation time in a clearcut cycle (the prevailing logging method in Sweden is clearcutting) presently is about 100 years and thus this was chosen as the upper level. The object (“victim”) that the crisis acts upon can vary tremendously depending on context. Ecological objects can be e.g. the trees in the forests, subjected to an insect outbreak, or repeated and severe spring frosts that drastically decrease the flowering rate of blueberry *Vaccinium myrtillus*, which in turn affects pollinators negatively. Objects of crises can also be economic, since some of the ecosystem services are monetary, e.g. production of timber, pulp, and bioenergy. There are strong social values linked to forests like outdoor recreation, berry and mushroom picking, and also assets like the possibility to experience beauty and quietness.

Disturbance, succession, resilience

In natural states, forests are shaped by disturbances that heavily affect their structure and composition, like fires and wind-storms. Thus, forests as other ecosystems are highly dynamic and subjected to constant change. A natural forest landscape is composed of a mix of areas of different sizes in different stages after disturbance. Depending on climate, topography, hydrology and geology the disturbance patterns vary greatly between different geographic areas. In N Sweden, which belongs to the boreal region, fires have been the dominating disturbance agent in the natural coniferous forest landscape, and areas of thousands of ha formerly regularly could be deforested after severe events. In the deciduous forests of S Sweden, which is part of the temperate region, wind and flooding were more important when the forest landscape was in a more natural state, and affected much smaller areas. In Sweden as in many other countries on the globe, man-induced disturbances have become increasingly common since a large proportion of forested landscapes is managed for the purpose of

biomass extraction. A forest affected by fire, wind or flooding differs largely from that after logging. For instance, there are few above-ground structures left, in contrast to after most natural disturbances where such usually are very abundant (Franklin et al. 2002).

Ecologists started to study succession, i.e. the development after a disturbance, early in the 20th century (Clements 1904 ; Clements 1916). Succession processes are affected by disturbance type, disturbance strength, ecological conditions at the site, ecological conditions in the surroundings, and climate. The first stage in a typical succession after a severe “stand-replacing” fire in Sweden is an open stage with herbs and grasses, followed by deciduous shrubs, then a mix of deciduous trees and coniferous trees, and finally a forest dominated by old coniferous trees. To a certain degree succession patterns can be predicted, but the complexities of the systems are very large and there are also always elements of randomness. Succession theory is one of the foundations of modern ecology and is essential for the understanding of how an ecosystem responds to environmental events. From the early 1970s, the field has broadened considerably and many mutually non-exclusive hypotheses have developed (Glenn Lewin et al. 1992).

In a discourse on environmental crises it is inevitable to approach basic concepts on the capacity of ecosystems to resist and recover from natural or human disturbances. During the last decade studies centered round the term resilience have been rapidly evolving in research. Resilience is a complex term that has two broad meanings (which, incidentally, is a drawback in its present wide use). The most commonly referred to is *ecosystem resilience* which is the capacity of an ecosystem to experience disturbance and still maintain its ongoing functions and controls, measured as the magnitude of disturbance that can be absorbed before the system changes to another state. The other is *engineering resilience* which is the resistance to disturbance and a measure of the speed of return to a stable state (Holling & Gunderson 2002). These two terms reflect widely different views on ecosystem dynamics, stability and equilibrium. For ecosystem resilience the emphasis is put on the strong dynamic character of ecological systems and that there is no stable, equilibrium state but instead a continuum of stages. It also stresses the possibility that the system can flip into another, irreversible and often degraded state, for instance if variability and diversity is decreased. The *engineering resilience* concept, which more adheres to early ecological theory, focuses on the stability of ecosystems near an equilibrium state, and stresses the ability to maintain stability. Critics of this view claim that it is wrong to assume 1) that ecological systems can be controlled, 2) that the consequences are predictable and 3) that maximum production is a sustainable goal. Instead they (i.e. the followers of ecological resilience) advocate that management of ecosystems should be dynamic and adjust to the non-equilibrium states and to the inherent large variability in functions and processes. The common view is also that natural ecological systems have a high resilience (Holling & Gunderson 2002).

In parallel to the development of the resilience concept within the science of ecology, there has also been a recent development to link it to human systems, and put it in a social science context. There are both divergences and convergences between natural and social systems. One fundamental difference is that social systems usually strive towards stability, i.e. maintenance of control and order is viewed as preferential, while there is no goal or preference in ecological systems, instead they are inherently under constant disturbance, instability and change. This is assuming short time-scale (in ecology named “ecological time”), i.e. at the span of decades or slightly more. On an evolutionary time-scale (centuries or more), it can be argued that social systems evolve and change. Evolutionary processes are increasingly noticed in social science research, and might also affect crisis research since it modifies the often implicitly expressed value that crises are negative (Quarantelli 2005). Further, human systems have (at least) three unique features: foresight (ability to make forecasts), communication, and technology (Holling et al. 2002). For ecological as well as social systems, scale is important, i.e. if processes and actions operate at local, regional, national or global scale (Pritchard Jr & Sanderson 2002).

The take-home message from ecological science is that nature is in a constant dynamic, changing state but yet that ecosystems, in a short time perspective, are entities that are distinct enough to be described

quantitatively and qualitatively. The landscape perspective is crucial since the ecosystems are always in different succession phases after disturbance and form spatial mosaics. Central to resilience theory is that ecosystems can be subjected to such strong pressures, natural or man-induced, that they are transferred to a different state, i.e. they are subjected to a regime shift.

2. Method for literature review

As a first step literature searches were made in Google Scholar and the first 50 hits were analysed for relevance, with the criteria that they should contribute to fulfilling the aims of the paper. Table 2. Very few relevant publications (7) were found this way.

Table 2. Number of hits in Google Scholar searches for different search strings, made May 19, 2009. All six search strings were combined with the word "forest".

FOREST	Crisis	Disaster	Catastrophe
Ecological	59 900	31 500	20 800
Environmental	134 000	68 800	26 100

Apart from finding literature, the searches were also made to decide on which term to use, i.e. which combination of ecological-environmental and crisis-disaster-catastrophe to apply in the writing. "Environmental crisis" was chosen since it was linked to the highest number of hits in the searches. During the subsequent acquiring of literature, cross-reference retrievals were common. For the specific crisis identified and described, further searches in Google Scholar and Web of Science were made, and own knowledge on publications was also important. Valuable advice on literature was also given through discussions with social scientists. Significant empirical information was retrieved from the web-page of Räddningsverket (Swedish Rescue Services Agency), from January 1, 2009 part of Myndigheten för samhällsskydd och beredskap (The Swedish Civil Contingencies Agency).

3. Conceptual and empirical overview of environmental crises in Swedish forests

Types of external environmental events that can trigger crises in Swedish forest

Some of the types of events are natural like fire, wind and storm, i.e. related to climate, and such can also be affected by human activity, like fire-prevention, forest management systems that decrease or increase wind vulnerability, hydrological changes that reinforce effects of flooding. Other events are fully man-induced, like air pollution and nuclear power plant breakdowns. Climatic events have high probability, i.e. it is certain that they will occur sooner or later, although their predictability in time is low. Due to future industrial activity and also new industrial processes, it is rather likely that air pollution will continue to affect Swedish forests but it is not easy to predict how and when. The likelihood that nuclear power plants break down is low, and it is impossible to forecast when it will happen. Invasive pest species are likely to colonize Swedish forests in the future, not the least due to climate change, which will enable species from warmer climates to survive. To a certain extent, it will be possible to predict which species will enter, since the international distribution of the most serious ones is fairly well known. Table 3.

All types of events listed in Table 3 affect several ecosystem services. All except nuclear power plant breakdown affect biomass production. Storms cause large volumes of trees to be instantly available for industry processing or for use as bioenergy, while the biomass supply, at least regionally will be lowered in a longer time perspective. Strong fires result in very large tree die-offs while flooding is less detrimental since many trees usually survive. Invasive species induce tree death but also reduce vitality which decreases biomass production.

Air pollution has mixed effects depending on type. High content of SO₂ in the air and associated acid rain acidifies soil and water which may cause large impacts on aquatic life, like fish. At very large decreases of pH in the soil tree growth may be negatively affected. Nitrogen fall-out on the other hand increases available nitrogen in the soil, and enhances tree production. Air emissions of heavy metals from industries may have large impact, causing decreased tree vitality and die-off. The possibility to harvest non-tree forest products like berries and mushrooms is probably most strongly negatively affected by fall-out from a nuclear power plant breakdown, due to the long half-life of the radioactivity. Disturbances that create open spaces and re-growth with deciduous shrubs and trees, e.g. storms and fires promote game like moose, i.e. result in an increased supply of this ecosystem service. The ability for people to use forests for recreation is negatively affected some time after fires and storms, due to often large accumulation of dead wood and the strong deciduous re-growth. Uncertainty and fear make people avoid using forests for recreation after a nuclear power plant breakdown. There is risk for negative impact on water quality from large flooding events due to transport of large amounts of organic material. Nitrogen fall-out in regions with nitrogen-rich forest soils might cause leaching of nitrate. When trees are removed and open spaces are created, like after a fire or storm, soil respiration exceeds carbon uptake in vegetation, a phase that can last for several decades, creating a negative carbon budget. Such soil disturbances might also lead to leaching of mercury.

Table 3. Environmental events that can trigger environmental crises in Swedish forests, and different characteristics of their effects. All events are external, i.e. they originate from outside the Swedish forest ecosystem. (* The possibility to hinder ignition by lightning is almost non-existent. The possibility to reduce the size of a fire on the other hand is large, through fire prevention and fire fighting.)

	Frequency in Sweden, (during the last 100 years)	Probability of occurrence	Predictability in time	Ecosystem services affected	Consequences for provision of ecosystem services	Scale level	Reversibility (during a 100 year period)	Influence possibility (prevention by man)
Storm	Medium	High	Low	Biomass production, berries, mushrooms, game, recreation, water quality, carbon balance	Small-Large	Local and regional	High	Low
Fire	High	High	Low	Biomass production, berries, mushrooms, game, recreation, carbon balance	Small-large	Local	High	Low/High*
Flood	Low	Medium	Low	Biomass production, recreation, water quality	Small	Local	High	Low
Invasive pest species	Medium	High	Medium	Biomass production	Small-large	Local-national	Varying	Medium
Air pollution	High	Medium	Medium	Biomass production, water quality, carbon balance	Small-large	Local-national	Varying	High
Nuclear power plant breakdown	Low	Low	Low	Berries, mushrooms, game, recreation	Small	Regional	Low	High

Cases

I describe three cases of environmental crises in Swedish forests, one storm, one fire, and one breakdown of a nuclear power plant. The qualification as “crisis” is my own but the climatically induced events (the storm and the fire) are listed in the database on natural casualties (naturolycksfallsdatabas) of the Swedish Civil Contingencies Agency (Myndigheten för samhällsskydd och beredskap, MSB), under the keyword “forest”. The intention is to describe the event and why it lead to a crisis, and also to evaluate how the crisis impacted on the provision of different ecosystem services. The response of policies and institutions is also touched upon.

1. Bodträskfors fire
2. Gudrun storm
3. Chernobyl nuclear power plant breakdown

The fire at Bodträskfors 2006

On August 11 2006, the largest forest fire in recent history started in the forests around the village Bodträskfors, municipality Boden, county Norrbotten, northernmost Sweden. The fire was initiated by a spark caused by a forest machine. An area of 1900 ha, equivalent to 3000 football pitches, had been burnt when the fire had finally been put out, 29 days later, causing heavy losses for forest owners in the affected area. When the fire began, several other forest fires were already raging in the country, and it proved difficult to bring firefighters, helicopters and equipment into the area quickly.

The costs to the municipality, landowners, central government and insurance companies were estimated at SEK 70-75 million. Nine of the fourteen landowners were insured with the Länsförsäkringar insurance group, which paid out a sum of around SEK 25 million to them. The MSB states that the forest owners have the greatest obligation to prevent forest fires, but the municipality has a responsibility to make it easier for the landowner, both in terms of prevention and afterwards. The county administrative board considers that it is not possible to halt forestry during drier periods, but that preventive efforts and forecasting and reconnaissance must take place and that the forestry industry must help pay for this.

According to MSB several lessons were learnt and actions taken from the incident. For example, the information centre that was opened by the municipality of Boden could have started earlier than it did. The firefighters and fire and rescue services from southern Sweden whose assistance was urgently requested were delayed as they were unable to obtain tickets for flights in the evening, either at travel agencies or at Arlanda Airport. This has lead MSB to take the initiative to create a resource bank of equipment and personnel. The voluntary resource group, according to several parties involved, made a very valuable contribution in evacuating the affected villages, and now has a self-evident position in all major rescue operations and incidents in the Municipality of Boden. Contact routes and who does what in different situations with a view to ensuring faster and more effective cooperation between different parties in emergencies have been clarified in a folder from the fire and rescue services, the county administrative board and the forest industry. The government decided to reintroduce the fire airborne fire-fighting units in 2007.

The fire affected several ecosystem services, in a short time-perspective (up to a few decades). The volume of trees declined drastically, which caused loss of income to the forest owners. Although not investigated, it can be assumed that the yield of berries and mushrooms decreased in stands that before the fire hosted mature forest. Forest fires also cause large emissions of carbon dioxide, creating a negative carbon balance. Within a decade after a fire there is often a strong re-growth of deciduous shrubs, which promotes moose, and thus can increase hunting possibilities.

Source: The database on natural casualties (naturolycksfallsdatabas) of the Swedish Civil Contingencies Agency (Myndigheten för samhällsskydd och beredskap, MSB), http://www.srv.se/templates/SRV_ExternalPage_22396.aspx

The storm Gudrun 2005

In January 2005, a very severe storm struck southern Sweden. In total 18 persons died; 7 in accidents on the night of the storm, most as a result of falling trees, and another 11 in connection with clear-up operations. There were serious damages to the road network, railroads, and power supplies. On the evening of the storm 730 000 customers were without electric power.

About 75 million m³ (or around 250 million trees) were felled, which is almost equivalent to the combined volume felled by storms in the whole of the 20th century, and also almost the whole logged volume during a normal year in Sweden. The storm felled three times more forest than the 1969 storm which had previously been regarded as having caused the greatest damage to forests in recent times. Spruce forest was most badly affected, particularly forest more than 30-40 years old. The Swedish Forest Agency estimates the cost of forest damage to about SEK 18.4 billion. The total cost to Sweden's four largest insurance companies was around SEK 4 billion. When Sweden applied for EU-grants to cover costs of the storm, SEK 15.8 billion were assigned to costs for damage to the forest.

MSB states that the high proportion of spruce and pure spruce stands with a minimum deciduous element is regarded as one of the reasons for the large volumes of storm-felled forest, partly because of the shallow root system of spruce and because the proportion of forest damaged by rot is high. In addition, temperatures since the Christmas holiday period had been above zero, so that the ground had thawed.

Many forest owners in the storm area were not insured and thus suffered large economic losses caused by damage to the trees. Forestry owners affected by the storm were given the chance to get tax relief from the Swedish Parliament, to provide an incentive to remove the storm-felled timber from the forest. The Government also provided SEK 450 million in subsidies to encourage replanting with a variety of tree species, and not just spruce.

The Swedish Forest Agency in an analysis of the impacts of the storm concluded that there was no reason to change current forest policy since the restoration activities had been successful. But, they suggested certain measures like monitoring of bark beetle populations (pest insects causing damage to spruce), monitoring of leaching of nitrogen and mercury, and that the forest owners should be better informed on risks associated with different forest management methods (National_Board_of_Forestry 2006).

A high number of ecosystem services were affected. On a larger scale, the supply of timber and pulp was suddenly raised sharply in south Sweden, causing a disturbance to the otherwise rather steady flow of wood to the industry. Nevertheless, in the summer of 2009, four and a half years after the storm, most cleared areas had been replanted, and the stocks of trees had almost vanished, causing normal logging activities to be re-initiated (Hallands Nyheter 22 August, 2009). According to MSB, The Forest Industries Federation claims that severe storms have a quite limited impact on logging possibilities in a long-term, since they occur so infrequently. The storm created large open areas which in about a decade later will be covered by a more or less dense deciduous shrub layer, which will benefit the moose population for which deciduous shrubs is a main food source. Leakage of nitrogen from the forest soils to run-off waters has been estimated to increase with 70% (National_Board_of_Forestry 2006), and large leakage of methylmercury, mainly caused by soil damage from forest machines in the cleared areas, has been observed (Munthe et al. 2007). The reduction in the carbon sink in the storm-felled area has been estimated at 3 million tons carbon the year after the storm which is about 1/6 of the total yearly carbon sink (Lindroth et al. 2009). Although

not investigated, it can be assumed that the possibilities for picking of mushrooms and berries, and recreational activities were decreased in the 270 000 ha large storm-felled area.

Main source: The database on natural casualties (naturolycksfallsdatabas) of the Swedish Civil Contingencies Agency (Myndigheten för samhällsskydd och beredskap, MSB),
http://www.srv.se/templates/SRV_ExternalPage_22396.aspx

The nuclear power plant breakdown at Chernobyl 1986

The Chernobyl breakdown in Ukraine 1986 is the largest nuclear power plant accident so far on the globe. One of the reactors exploded and a nuclear cloud spread by winds over large parts of Europe. Although most radioactivity was deposited in Ukraine, Belarus and Russia, as much as 10% fell over Sweden (Persson et al. 1987), with a mean total fallout of radiocesium 50-75% higher than at nuclear weapon testing (Jones 1989). The highest concentrations of Cesium-137 were found in the counties of Gävleborg, Västernorrland and Västerbotten. More than 90% of the Cesium-137 in Swedish forests originates from the Chernobyl accident with more than 85% found in soils, and less than 10% in trees (McGee et al. 2000). Since the half-life of Cesium-137 is about 30 years, the impact will last for generations. The Cesium-137 in the edible produce from the forest is much higher compared to agricultural crops since fungi through their mycelia extract nutrients from the top soil organic layer where most of the Cesium 137 is stored, and dwarf forest shrubs that produce berries have shallow root systems. The concentrations in fungi often exceed the limit of 1500 Bq kg⁻¹ for consumption of wild produce, although there are large variations depending on species. The concentrations are lower in berries than in fungi but the variations are large also for these, with mean levels of about 300 Bq kg⁻¹ for blueberry and lingonberry *Vaccinium vitis-idaea*, and 1000 Bq kg⁻¹ for cloudberry *Rubus chamaemorus* (Johansson 2006). Moose eats fungi to a certain extent, and enough for their Becquerel concentrations to vary according to fungi availability. In a study area in Heby, Uppsala county, the concentration was about 750 Bq kg⁻¹ per year during the first 10-year period after the accident (Johansson 2006). Roe deer is a large consumer of fungi, which often constitute 20-30% of the rumen (first stomach) volume. In the autumn of 1988 the highest concentrations so far were found with, for instance, 12 000 Bq kg⁻¹ on average in the municipality of Gävle. In other seasons the concentrations were at least five times lower. This seasonal variation caused the hunting period for bucks to be extended, to also include spring (Johansson 2006). A general conclusion regarding human health risks, for provisions of different kinds of food originating from different types of land-use in Sweden, is that there is no risk of increased frequency of cancer diseases (Räaf 2006). Another strong negative impact from the Chernobyl accident was the contamination of reindeer meat, caused by high cesium levels in lichens, their main food source (Åhman & Åhman 1994).

The main ecosystem services from forests that are affected by the Chernobyl fall-out are production of fungi, berry, reindeer, moose and roe deer, safe for consumption. There most likely was also an initial resistance to using forests for recreation in areas with high cesium concentrations but there are no studies addressing this. Attempts have been made to estimate the economic loss of reduced ability to hunt. The decreased value for moose hunters in Västerbotten county was calculated to be 3 million SEK in a contingent valuation study performed one year after the accident (Mattsson & Kriström 1987). A national estimate suggested the loss to be 45 million SEK per year (Hanemann et al. 1992).

As a response to the accident, the government policy-makers specified the time-line for phaseout of nuclear energy production in Sweden, and issued a bill that prohibits preparations for new reaction construction. But taken as a whole, the Chernobyl accident did not result in any substantial action for change of Swedish nuclear energy policy (Nohrstedt 2008).

4. Reflections

The list of examples on environmental crises given here is not meant to be complete; there have been and will be other types in the future. One evident hazard that has not been given special attention is pest species (insects, fungi etc) that might cause large damage and also die-off of trees. There are a number of pest species in the country that belong to the natural flora and fauna, like root rot, bark beetles and pine weevils. In the scenario analysis of the programme Future Forests, one assumption has been that the drivers should be external, i.e. emanate from outside the Swedish forests, and thus indigenous species should not be considered. In the future, there is an evident risk of immigration of new aggressive pest species to the country, due to climate change. In a more whole-covering exposition of environmental crises it would be motivated to make a deeper description of such potential, exotic pests. Another important expansion would be to more thoroughly reflect on the classification of ecosystem services and also in more detail analyse how they might be affected by environmental events. Not all effects are negative, the reaction might be opposite for different ecosystem services. For instance, carbon will be released when trees fall and decompose in a storm, which is negative for the ecosystem service of carbon stock. But, this disturbance will lead to vigorous re-growth of deciduous shrubs, which will benefit the ecosystem service of moose and raw deer production.

Media is a key actor in the communication of environmental events, and can be decisive for how crises are perceived and reacted upon, and even for an event to be viewed as a crisis. In fact, it can be claimed that environmental events need media attention, otherwise they will not be experienced as crises (Cottle 2009). In media research, it is debated how much media influences, and perhaps also manufactures, information flow, with the “control” model claiming a strong impact, while the “chaos” model states the opposite; that news is shaped by a combination of many factors and forces that act independently of one another (McNair 2006). Further, there are opposing paradigms on the mechanisms behind crises, with the social constructionist approach advocating human perception and communication as driving forces, while supporters of “crisis realism” believe that today’s crises are so strong that they themselves are superimposed over social factors, and thus are drivers of change in their own (Cottle 2009).

Studies of news and crises have found e.g. that 1) news media tend to focus on a few stories at any one time, 2) TV puts more emphasis on disasters than radio (dramatic images), 3) the human causes for the disaster (pollution, poor land-use practices etc) are not given much attention (Cottle 2009). Different actors have different narratives (interpretation of stories), shaped by their values, interests and experiences. Since media possesses large power on policy making, it becomes important for interest groups to communicate their narratives and communicate their messages in a way that they get large media coverage. Interaction with news media is becoming increasingly important for e.g. environmentalists and protest groups, and has become target of recent media research (e.g. (DeLuca 1999; Lester 2007)).

One Swedish example of how strong narratives transferred by media may affect perception of crises and also policy making is the case of acidification or “acid rain”, which was a prominent environmental forest issue in Sweden but also in the rest of Europe and in N. America in the 1980s and 1990s. In the beginning of the 1980s there was large media attention on severe forest decline in Central Europe, believed to be caused by acidification which in turn was due to air pollution from industries. The Swedish National Board of Forestry made inventories and found signs of decreased tree vitality also in Sweden. The fear for acidification was enhanced by earlier observed fish death and change in water quality in lakes and rivers caused by acid rain (Tunlid 2007). The researchers were divided into two polarized groups, with one side, partly through modeling, claiming that the acid rain would severely jeopardize forest production. The other side, which gained increasing credibility over time, on the contrary, and basically based on evidence from experiments argued that forest growth was more vigorous than ever, and that the change in soil status observed would not affect tree vitality or

production (Johansson 1993). When the debate faded out in the late 1990s, it was clear that the risks with acid rain for forest production had been heavily overestimated. Media had a strong role in initially forwarding the narrative prevailing among certain actors, like NGOs, some researchers, and also policy makers that needed arguments for international negotiations on reduction of emissions. As the risks were toned down, the critics of the disaster narrative were given increasing attention, and instead forest die-back due to acid rain was described as a myth. (Tunlid 2007) suggest that studies of how media affected the public's view of acid rain and forest die-back as well as policy making is worthy of further analysis.

Although I have not targeted how environmental crises relate to policy reforms, it seems clear that it is not only the actual events and their impacts, as measured in quantitative terms, e.g. reduced value of ecosystems services, that are decisive. For instance, the perception of fear and risk might strongly affect the behavior of different actors. According to a study recently performed in Sweden, people fear most seriously illnesses, traffic accidents, climate change and stress/burnouts. Of 16 listed risk factors, "natural catastrophes" were ranked as number 10 regarding personal fear (Dagens Nyheter May 14, 2009, p. 15-17). Should natural disasters become more frequent in the future they might be up-graded in this ranking. Perception of fear might also cause the public and different interest groups to demand action. To exemplify, it might be claimed that the effects of severe storms need to be softened through new management measure. One such could be to abandon monocultures with spruce, which are storm-sensitive, and instead increase the proportion of deciduous trees, which was claimed after the storm Gudrun (e.g. Ecosensus 2/2006 p. 1), and also to increasingly apply selective logging. On the whole, Swedish forest owners' risk awareness and risk management seem rather low (Blennow & Eriksson 2006).

Some researchers consider that the Swedish forests have gone through a regime shift, i.e. that the forest ecosystem has changed to another (unwanted) state, through the large transformations caused by the industrial, clearcutting system (Jonsson 2008). Implicit in this view is that the resilience of the Swedish forests is low. The criteria for a regime shift and the degree of resilience of Swedish forests need further analysis, theoretically as well as empirically. In a crisis perspective, this preferably should be done in relation to different environmental events, to elaborate on how large such can be before the forests are subjected to irreversible changes.

Future analyses of environmental crises related to forests would gain from widening the scope from the strong focus applied here on effects on the ecosystem itself, to integrating human aspects of uncertainty (reaction to events, importance of awareness and access to information), and people's and institution's possibilities and time to counteract effects. Also, there is reason to problemize if it is possible to objectively assess ecosystem effects. For certain, there are different ways to quantify ecosystem response, and there are numerous ways to interpret and also distribute data. Thus, it is not always straightforward to estimate when negative effects have occurred, for instance as here, on the ability to produce ecosystem services. Deepened reasoning on such matters would necessitate a more pronounced social science perspective.

In reading of social science literature I have noted a surprising lack of ecologists in the often multidisciplinary teams that approach the issue of environmental crises. By including ecologists in such teams, valuable insights could be added regarding the ability of ecosystems to resist changes, and also to predict responses, like capacity to supply ecosystem services. The importance of fundamental ecosystems processes like the need for disturbance and succession to maintain ecosystem properties could stimulate discussions on differences and similarities between ecological and social systems (for which strive towards stability often, implicitly, seem to be a desired characteristic).

It is hard to study environmental crises as drivers of change in isolation from other potential drivers; there are often strong interactions. The most evident link is with climate change but there are also other complex relations. One example is the link to governance through EU policies on use of renewable energy and emission rights, which will increase the conversion from timber and pulp

production towards bioenergy production. Another is the age distribution of the Swedish population, i.e. demographic aspects, which impacts on the interest in using the forests for different types of outdoor activities. A further example is norms and values, which affect the attitudes towards non-monetary ecosystems services, like preservation of cultural heritage and biodiversity conservation.

5. Conclusions

Environmental crises no doubt are frequent phenomena globally, for instance the Red Cross estimates that on average 220 natural catastrophes occur on average per year, as compared with 70 technological disasters and three armed conflicts

(International_Federation_of_Red_Cross_and_Red_Crescent_Societies 2002). The environmental crises most likely will increase in frequency, with the largest negative impacts in low-income countries with poor governance (ISDR 2009). But, also in high-income countries like Sweden environmental crises are likely to become considerably more common and severe in the future, since climate change will increase the frequency and severity of events like hurricanes and floods. But, new industrial processes and technical applications can also pose types of threats that are yet un-known, like new types of pollutants that affect the forests' function and vitality.

My analysis has identified various environmental events that have impacted negatively on the ability of Swedish forests to provide ecosystem services. Some of these are related to climate, like fires initiated by lightnings and storms. But there are also technologically-driven ones, like fires triggered by forest machines, the Chernobyl breakdown, and air pollution. Most crises have so far had only local extension but there are also examples of strong effects on regional scale, e.g. the storm Gudrun, and the nuclear power plant breakdown at Chernobyl. The time duration of the negative impacts vary largely from a few years, e.g. reduced availability for recreation after a fire, to centuries (Chernobyl).

My overall judgment is that environmental crises, although important, might not be the most crucial drivers for the future state and use of Swedish forests. My empirical examples show that their effects are often local, and sometimes regional, and their strengths are not so large that they fundamentally affect business economics or national finances based on forest ecosystem goods or profoundly change policies. But, I safeguard myself and add a reservation: there might be future surprises in the form of man-induced impacts, for instance through climate change and technological developments, that unleash so far unsurpassed environmental effects on the Swedish forests.

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Appendix 1. How environmental crises affect other drivers

Climate change and climate politics	Fires and storms cause raised CO ₂ - levels which contribute to global warming. High levels of nitrogen fallout increases biomass production, which leads to higher carbon uptake in vegetation and higher carbon stock in soils which counteracts global warming.
Competing land-use	At very high pollution and nuclear emission levels (dangerous to man), some forestland might be left without management.
Demography	Extreme environmental, long-lasting crises that make forest regions unhospital, might force human migration.
Energy	Large storms, pollutants, invasive pest outbreaks may create pulses of increased energy wood availability.
Forest governance	Repeated and strong environmental crises that have national and international effects, may lead to change in national and international policies.
Forest products markets	Large storms, pollutants, invasive pest outbreaks may create pulses of increased wood supply which might affect the local forest products market.
Geopolitics and conflicts	Swedish forestland is only 0.5% of the total global forestland, and only 10% of Europe's (excluding Russia). Thus, environmental crises in Swedish forests are unlikely to trigger international conflicts.
Scientific and technological developments	Environmental crises that decrease supply of ecosystem services from forests might stimulate scientific and technological developments to decrease risks and increase resilience in the future.
Values, attitudes and norms	Repeated environmental crises in forests that affect people's daily life may change the opinion on how to use and manage forests.

Appendix 2. How other drivers affect environmental crises

Climate change and climate politics	Increased temperature increase risk for fire, especially in SE Sweden. Increased precipitation increase risk of flooding in the western part. A warmer climate implies invasion of pest species which may cause great harm to trees. Higher frequency of high wind speeds may cause storm fellings.
Competing land-use	Use of forestland for nature conservation, reindeer husbandary, hunting and cultural heritage instead of for forestry most likely would decrease environmental risks (less intensive use, less disturbance)
Demography	Increased human population size (national and international) might cause higher pollution loads.
Energy	Expansion of nuclear energy increases risk for nuclear fall-out.
Forest governance	National and international politics might lead to increased air pollution levels, risks for nuclear power plant breakdowns and other environmental hazards.
Forest products markets	Large demand for fast-growing wood may intensify forestry (intense fertilization, exotic tree species = plantation forestry) which might increase sensitivity to storms and pest species.
Geopolitics and conflicts	Armed conflicts may increase pollution risks.
Scientific and technological developments	New forest production techniques and other innovative use of forests might affect biodiversity, soil, water in unforeseen ways.
Values, attitudes and norms	If people value high production and put low weight on environmental concern, environmental hazards may increase (higher pollution levels, higher leaching of N, mercury etc).