Received 20 July 2009
Revised 7 August 2009
Accepted 10 September 2009

Adapting production forests in southern Sweden to climate change

Constraints and opportunities for risk spreading

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Abstract

Purpose – Recent climate scenarios indicate that Sweden's southern region, Götaland, will experience significant climate change over the coming century. Swedish forestry policy guidelines emphasize the need for risk spreading to reduce the potential adverse impacts of these changes. Risk spreading is defined here as reducing the vulnerability of a social-ecological system by increasing the heterogeneity of its ecological components. Risk spreading may be achieved through the diversification of tree species currently relied upon by the forestry sector. The purpose of this paper is to consider the capacity of the socio-ecological forest system to adapt to climate change through the use of risk spreading.

Design/methodology/approach – A variety of disciplines contribute to the understanding of the rate at which risk spreading is likely to take place in a system. A synthesis is conducted to unite these insights.

Findings – Five key constraints on the rate at which risk spreading can take place are identified. These include constraints imposed by the silvicultural system itself, voluntary policy measures, forest-owner perceptions of climate change, motivation among forest owners to respond to risk, and forestry consultants. Potential future directions are discussed and include the need for specifying the goal of risk spreading policy, and the need to evaluate the motivations of those forest owners already altering adopting risk spreading approaches.

Originality/value – Conceptual equivalents of the "risk spreading" approach are international, due to the need for many societies to adapt social-ecological systems to climate change. The issues raised from this case study/synthesis provide value insights regarding the breadth of systemic constraints which can thwart attempts at rapid adjustment to climate change, and where solutions to these constraints may be found.

Keywords Forests, Global warming, Land, Ecology, Risk management, Sweden

Paper type Research paper

The authors thank Mattias Boman, Jörg Brunet, Per Magnus Ekö, Annika Felton, Nils Fahlvik, Matts Lindbladh, Magnus Löf, Leif Mattson, and Rolf Övergaard, for helpful comments and contributions to this research. The authors also thank Svante Claesson, Göran Kempe, and Jan-Olaf Loman for their advice regarding forestry statistics. This research would not be possible without financial and logistical support from the Southern Swedish Forest Research Centre, SLU, Alnarp. Two anonymous reviewers improved an earlier draft of this paper.

International Journal of Climate
Change Strategies and Management
Vol. 2 No. 1, 2010
pp. 84-97

1756-8692
DOI 10.1108/17568691011020274

1. Introduction

Globally, the emission of greenhouse gases is increasing at an increasing rate (Raupach *et al.*, 2007; Pielke *et al.*, 2008). Over recent decades natural ocean and land-based CO_2 sinks appear to have declined in efficiency, thus enabling a larger airborne fraction of greenhouse gas emissions to occur (Canadell *et al.*, 2007; Raupach *et al.*, 2007). Owing to systemic time-lags, even if immediate and substantial cuts to greenhouse gas emissions were to occur, they could not prevent at least some further warming of the atmosphere over the coming century (Corell, 2006; IPCC, 2007; Kerr, 2007). Therefore, many social-ecological systems (sensu Berkes and Folke, 1998) will need to adapt to the regional and international repercussions of climate change despite global mitigation efforts.

Adaptation refers to the adjustment of natural or human systems in response to actual or expected stimuli and their effects, which reduces harm or exploits beneficial opportunities (IPCC, 2007). Instigating effective adaptation strategies requires the identification of sensitive systems, assessment of the risk and consequences of impacts, and the identification and evaluation of adaptation options (Hulme, 2005). Once sensitive systems are identified, feasible options for adaptation are not unlimited and may be constrained by both societal and ecological resistance to change. Understanding the extent to which societal or ecological constraints limit the capacity of a system to adapt, or limit the time periods under which adaptation could take place, is a fundamental step in evaluating the feasibility and potential effectiveness of adaptation options.

In this paper, the capacity of the social-ecological forest system of southern Sweden (Götaland, approximately defined as south of 59°N) to adapt to climate change over coming decades through the use of "risk spreading" strategies is considered. Temporal constraints on the rate at which the tree species composition of production forests currently change are estimated, and the current effectiveness of informative policy instruments as a catalyst for change are discussed. Private individuals own approximately 78 percent of the total forest area in Götaland (SFA, 2008). For this reason, this research specifically aims to synthesize the impact private individual forest owner beliefs, desires and responses to climate change may have on the rate at which this change could take place, and the importance of forest consultancy agencies in the process of instigating change. The results highlight some aspects of this social-ecological system which are likely to facilitate or constrain efforts to adapt to climatic change. Potential future directions are discussed and include the need for specifying the goal of risk spreading policy, and the need to evaluate the motivations of those forest owners already altering adopting risk spreading approaches.

2. Background

Sweden is a northern European nation, 450,000 square kilometers in area, with a population of just over 9 million and a gross domestic product (purchasing power parity) of almost US$350 billion (Figure 1). Sweden's forests have important economic, social, and ecological values, and are considered to be an important part of the Swedish national identity (Fredman *et al.*, 2008a, b). In 2007, the total export value of forestry and forest products was valued at 127 billion SEK, or 11 percent of the total value of products exported from Sweden (SFA, 2008). Forest management in Sweden is primarily based on clear-cutting even aged stands of mostly coniferous timber tree species on a rotational basis. Forest area is more than 60 percent of land area

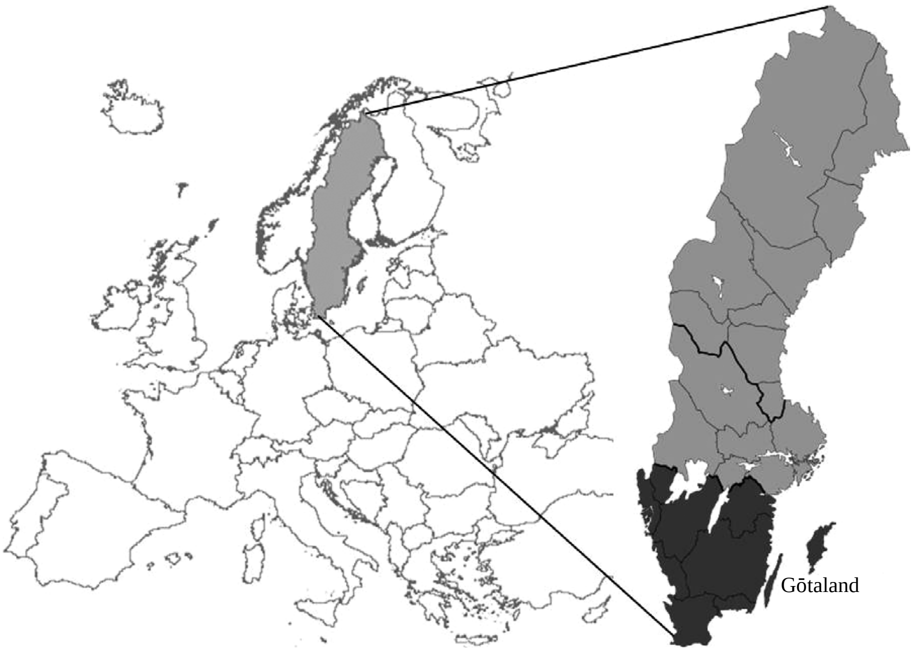

Figure 1.
Map identifying the location Sweden relative to Europe, with the region of Götaland indicated

and the current annual growth is close to 100 million cubic meters. The final felling age varies from 60 years to over 100 years. Despite human disturbances, Sweden's production forests provide habitat for a significant proportion of the country's biodiversity (Fridman, 2000).

The maritime climate of southern Götaland gradually changes to a cool temperate climate in the north and centre of the region. Without human intervention, current climate conditions would favor deciduous trees on the central and western landscape, with pine forests more dominant in the east of Götaland (Lindbladh *et al.*, 2000). However, human activities have fundamentally shifted this balance over approximately the last 850 years, with the rate of change escalating 150 years ago (Lindbladh *et al.*, 2000). Over 93 percent of the forest area in Götaland is now managed for production forestry and associated goals, for example, the maintenance of biodiversity (SFA, 2008). Approximately, 1.7 percent of the total forest area in Götaland is set aside as protected forest land through the use of national parks, nature reserves, habitat protection areas or through nature conservation agreements (SFA, 2008). The remainder of forest land has uses including recreation, military exercises, forest grazing, and game protection (SFA, 2008). The forests of Götaland are currently dominated by conifers, with 49 percent of standing volume consisting of Norway spruce (*Picea abies*) and 28 percent consisting of Scots pine (*Pinus sylvestris*) with the remaining 23 percent consisting primarily of deciduous trees (SFA, 2008).

Climate change in Sweden is predicted to be larger than the global average (SCCV, 2007; IPCC, 2007). By 2020, mean temperatures are expected to increase by approximately 2°C, with the largest temperature increases experienced during winter (SCCV, 2007).

This is likely to result in a general trend of vegetation regions shifting northward due to warmer conditions (SCCV, 2007). Some scenarios indicate that temperatures during January (mid-winter) in Götaland could increase by as much as 5-6°C by 2080 (SCCV, 2007). Summer temperatures are also predicted to increase, with potentially lower precipitation resulting in drier summers for parts of southern Sweden over coming decades. In addition to gradual and directed patterns of climate change there is also the possibility of an increase in the frequency and intensity of extreme disturbance events. These events, such as storms or insect plagues, can disturb large areas of forest over brief time periods (SFA, 2006).

Because of the widespread occurrence of conifers in Götaland, aspects of climate change which can pose a potential threat to the viability of spruce and pine may be of particular concern to forest owners and managers. A range of climate simulation models suggest that by the end of this century the ecological suitability of spruce may be reduced in Götaland (Sykes and Prentice, 1996; Sykes *et al.*, 1996; Bradshaw *et al.*, 2000; Koca *et al.*, 2006), due in part to reduced summer precipitation, the susceptibility of spruce to wind damage, and the ability of warmer climatic conditions to favor the reproductive capacity of the pests bracket fungus (SCCV, 2007) and spruce bark beetle (Jonsson *et al.*, 2007). However, studies indicating potential problems associated with growing spruce in Götaland under some climate change simulations (Koca *et al.*, 2006) may be juxtaposed against arguments that spruce forests are associated with relatively simple management, early returns from thinning, high-wood production, short rotation periods and relatively low susceptibility to browsing pressure from ungulates.

Although greatly reduced in area, nemoral tree species continue to make up an important component of the managed forests of Götaland, primarily in the southern portion of the region. Currently, 10 percent of the standing forest volume consists of birch, with another 11 percent consisting of other broadleaved species, with a large proportion of this volume occurring within what are referred to as coniferous forest monocultures. In recent years, some nemoral tree species have experienced dramatic declines due to species specific diseases (e.g. Dutch elm disease, ash disease). In contrast, other nemoral tree species, such as oak (*Quercus* spp.) and beech (*Fagus sylvatica*), are expected to be favoured by the changing climate conditions. In addition to these native coniferous and nemoral tree species, several exotic tree species (e.g. hybrid species of aspen *Populus* spp., larch *larix* spp., and sitka spruce *Picea sitchensis*) are also commercially grown to a limited extent in the region.

Recent trends in tree species composition can be considered by assessing whether there have been any changes in the youngest cohorts of different tree species in Götaland from the mid-1990s (1993-1997) to early this century (2001-2005). The result of comparing the standing volume of different tree species under 15 centimeter diameter breast height, with the total standing volume in this size category, is that the tree species composition of the youngest categories of trees in the forest landscape have experienced only small changes over this decade (NFI, 2007). The standing volume of spruce and pine in these younger size categories are currently 1.5 percent less than they were in the mid-1990s (NFI, 2007). Concurrently, birch has increased in standing volume for this size category by a similar percentage over the same time period. Aspen, oak, and beech, the predominant deciduous broadleaved trees in Götaland, have varied by less than half a percent (NFI, 2007).

3. "Risk spreading" as adaptation

The effective adaptation of managed forests to climate change will, by necessity, be a site specific task. However, this does not prevent the formulation of general guidelines for Sweden. One guideline that permeates Swedish literature (Eriksson, 2007; SCCV, 2007) and public discourse on this topic (Skogskonferensen, 2008) is the principle of risk spreading. To our knowledge, the term risk spreading has not been specifically defined in the Swedish context; instead it is often accompanied by examples which serve as a means of providing guidance as to the author's or institution's intended meaning. In addition to diversifying silvicultural methods, one adaptation which is frequently included as a representative risk spreading strategy is increasing the proportion of productive forest dedicated to growing tree species or combinations of tree species which are relatively underrepresented in the landscape (Ask, 2002; Fransila *et al.*, 2005; Eriksson, 2007; SCCV, 2007; Sveaskog, 2007). Reliance on relatively few tree species, often grown as high-production monocultures, has homogenized the managed forests of Sweden to a point of making the system vulnerable to climate change (Chapin *et al.*, 2007). Increasing the amount of forest allocated to a range of tree species (i.e. risk spreading) is thought to reduce the vulnerability of the entire system. This strategy could involve the increased growing of hardy provenances of native, exotic, and hybrid taxa, increasing the proportion of area dedicated to growing other tree species (such as native broadleaves), and the increased use of mixed species stands. Notably, such a strategy does not imply that change in tree species composition is the appropriate goal for all locations, only that diversification of tree species composition at larger regional scales is consistent with the goal of spreading risk. Thus, risk spreading is defined here as reducing the vulnerability of a social-ecological system by increasing the heterogeneity of its ecological component.

Risk spreading could involve fundamental changes to the forest environment and forestry. For instance, replacing forests once dominated by coniferous tree species with nemoral or exotic tree species, or monocultures with mixed species stands, involves decisions at the time of planting or thinning that could theoretically alter large tracts of Götaland's forest landscape. Such changes, if enacted, would also alter the composition of forest dependent taxa, and alter the relationship the people have with the land.

4. Constraints or opportunities

Annual area available for adaptation using current forest management

Over 93 percent of forest area in Götaland is managed for production forestry and associated goals (SFA, 2008). Approximately, 47,000 hectare of this forest land is planted or naturally regenerated in Götaland annually, which represents slightly less than 1 percent of total forest area (SFA, 2008). If alternative tree species, or combinations of tree species, are to be planted as part of a risk spreading strategy, then this is the readily achievable means by which tree species composition in the landscape cover could be altered under the current silvicultural system.

In addition, changes to tree species composition could also occur subsequent to the time of planting or initial regeneration, such as in the case of mixed species stands. The decision to create a mixed species stand generally occurs at the time of planting. However, the ratio of tree species in a forest compartment alters naturally over the years and can be regulated during thinning operations or, to a varying extent at different stages of the rotation cycle. In addition, approximately 10 percent of the timber volume contained in monocultures consists of other tree species. Theoretically, these forests could be thinned to promote tree species alternatives as part of a risk spreading strategy by the time of first thinning. The area of forest that is readily available for the growth of alternative tree species as part of a risk spreading strategy amounts to approximately 1.1 percent per annum of the total forest area of Götaland (calculated from SFA, 2008).

It is important to note that such figures do not take into account the potential for exceptionally strong wind events to damage large areas of forest land, and thus open up large areas for regeneration. Over the last century, Götaland has experienced greater forest losses to such events than northern Sweden (Nilsson *et al.*, 2004). In January of 2005 a storm (Gudrun) fell almost 75 million cubic meter of timber, amounting to almost a year's harvest for the entire country. In total, approximately 270,000 hectare of forest were damaged (SFA, 2006). Although it is difficult to determine whether climate change will increase the frequency of such storms, some models (HadAM3H and Echam4) and emissions scenarios indicate the potential for an increase in strong wind events in southern Götaland over coming decades (SCCV, 2007). Therefore, it is possible that strong wind events could increase the rate at which changes in tree species composition take place in Götaland over coming decades.

Any attempt at arriving at an estimated rate of change for a complex system (i.e. 1.1 percent per annum) is inherently based on a series of assumptions and a somewhat arbitrary decision for where to draw the line at what is "readily available." For instance, it is certainly possible for the rate of change in tree species composition in this landscape to exceed this estimate; although for this system to experience a higher rate of change may first require more dramatic environmental impacts from climate change – such as Gudrun-like wind storms or severe infestations by pest species (Kurz *et al.*, 2008). In either regard, in order to dramatically increase the rate at which tree species composition could be changed, would require larger areas of forest to be cut and regenerated and thus be of a similar age, and necessitate a decrease in the evenness of the forest's age class distribution (Ask, 2002). To adopt such an approach could neglect the ecological and economic benefits of maintaining a stable age distribution in the forest landscape and would require a fundamental change in the current silvicultural system.

Voluntary policy instruments

For 30 years (1960-1990) forestry law required that forest owners utilized their land to achieve a high and valuable timber production (Stjernqvist, 2001). This shifted the system towards extensive conifer production and directed funding to research that helped to achieve production targets (Ekelund and Hamilton, 2001). In the early 1980s, state funds were made available for an extensive system of subsidies necessary to ensure that the infrastructure, forest inventories and regenerative measures were in place to match what was expected in the forestry legislation (Ekelund and Hamilton, 2001). This approach was very successful in creating a system designed to meet state and industry requirements for timber products.

Sweden's 1994 revised Forestry Act brought into law the need for forest managers to "preserve biodiversity" and "provide a valuable yield", thereby equating the importance of wood production and biodiversity. Concurrent with this shift in forest goals was an increased reliance by the government on voluntary measures (Hysing and Olsson, 2005). These voluntary measures were primarily composed of informative, and to only some extent economic, rather than regulatory instruments (Vedung, 1998). Götmark *et al.* (2009) used the Swedish National Forest Inventory to assess the effectiveness of these "soft" policy approaches at increasing the density of broadleaved trees in Götaland, and parts of Svealand, in southern Sweden. The authors conclude that although these initiatives appear to have been somewhat successful at increasing broadleaved trees, there has not been any marked changes in the densities of broadleaved saplings (in part due to ungulate browsing pressure) over the course of a fifteen year period (Götmark *et al.*, 2009). The authors conclude that in order to motivate further change in this system will require more economic-based incentives; thereby indicating that the current reliance on voluntary measures is not sufficient for attaining the conservation goals considered. Blennow (2008) raises similar questions regarding the ability of relaxed regulatory approaches to instigating effective risk management amongst private individual forest owners. Together, these results raise some question as to whether current policy approaches will be effective at instigating more than limited change in the management of these forest systems in the current environment.

Owner perceptions of climate change

In 2007, there were 138,014 private forest owners in Götaland, who managed almost 3.7 million hectares of forest land (SFA, 2008). These land holdings represent approximately 78 percent of the total forest area in Götaland. Owing to the dominance of these holdings in the landscape, the beliefs, desires, and responses of private forest owners to climate change are a good indication of the extent to which risk spreading strategies are likely to be voluntarily adopted in the managed forests of Götaland.

In 2004, a survey was conducted which assessed attitudes towards climate change among non-industrial private forest owners. The survey results show that 8 percent of respondents did not believe the climate was changing, and 14 percent of respondents thought that climate change was probably not occurring (Blennow and Persson, 2009). The authors found that compared to the results of a survey made by the Swedish Environmental Protection Board in the same year, the strength of belief in climate change was lower among private forest owners than among Swedish citizens in general.

Boyden (1989) suggests that an often overlooked but vital prerequisite for successful adaptation is the recognition that an undesirable state exists. The disbelief in climate change amongst private individual forest owners (Blennow and Persson, 2009) seems to occur at four times the frequency than exhibited in the general Swedish populace (Reiner *et al.*, 2006). Unless there has been a subsequent shift (a possibility, considering the increasing media coverage concerning this issue), approximately 22 percent of private production forest in Götaland is controlled by individuals who do not acknowledge climate change and are presumably unlikely to consider adaptive measures.

Private forest owner responses to other risks

Previous survey results suggest that the private individual forest owners of Götaland are aware of the risk of wind damage to their forests (Blennow and Sallnas, 2002; Blennow, 2008). Several years prior to the Gudrun storm, forest owners from one of the most affected regions by the storm (Småland) ranked wind damage as one of the worst financial risks to their own forestry, and indicated they were prepared to invest time and effort in order to reduce the risk of wind damage to their forest holdings. Furthermore, 87 percent of respondents indicated that they were aware of what actions to take in order to reduce these risks, and yet, only one third of forest owners indicated in surveys that they had taken any action.

Blennow (2008) highlights the potential for discrepancy to exist between the concern expressed by private individual forest owners regarding wind damage risk, and the extent to which they take measures to reduce this risk. Of spruce-growing private individual forest owners in Småland (a central province of Götaland), 83 percent indicated they would not modify their choice of tree species grown, even if their holdings were substantially damaged by high-wind events (Blennow, 2008). This is despite the relatively high sensitivity of spruce to strong winds (SCCV, 2007). If the eventuation of a risk does not motivate a desire for change, then some questions must be raised regarding how effective arguments for pre-emptive risk aversion are likely to be at motivating change. Further research is needed to assess the length of planning horizons of forest owners and managers. Recent research elsewhere in Europe suggests that the planning horizons of private foresters are 15 years or less rather than operating at the decadal horizons normally assumed by researchers (Hoogstra and Heiner, 2009).

One contributing factor to how forest owners decide to respond to risks may reside within the motivation private individual forest owners have to be involved in forestry (for further discussion see Blennow (2008)). Two surveys (Törnqvist, 1995; Mattsson *et al.*, 2003) suggest that only a small percentage of forest owners ($\sim$10 percent) rely on the income derived from forestry. Rather than private forest owners being characterized by a financial dependence on forestry, multiple investigations (Törnqvist, 1995; Mattsson *et al.*, 2003; Blennow, 2008) suggest that more normative values, such as perceptions of independence, a wish to be a part of forestry culture, and inter-generational tradition, may be important to forest owners. This view is supported by Hugosson and Ingemarson (2004) who state that owning a forest is not primarily an economic institution, but an institution to maintain social structures, culture, and lifestyles.

Adopting risk spreading strategies make sense if, the respective forest owner is convinced that by so doing so may reduce the risk of financial loss, or allow them to achieve a greater financial gain. If for most forest owners the impact of forest disturbance primarily involves more normative than financial issues, then changing tree species composition may itself be seen as inflicting a cost, rather than reducing a risk. Under these circumstances, the incentives necessary to instigate the adoption of alternative tree species compositions by small-scale private forest owners may be significantly higher than indicated by previous analyses which does not take into account the importance of non-financial motivations.

Consulting organizations

In Sweden, a vital interface for the implementation of forest policies occurs through contact between forest owners and forest consultants from regional forest agencies, forest owner associations, and various other interested parties (Kindstrand *et al.*, 2008). The consultants assist forest owners through education, information, and counselling, as well as conducting inventories and providing practical assistance. In a survey conducted in 2004, over 70 percent of non-industrial private forest owners sought advice from forest consultancy agencies, and 80 percent trusted the advice they received from such consultations with respect to risk management (Blennow, 2008). The extent of trust in forest consultancy agencies was such that it appeared to be relatively unaffected by the Gudrun storm (Ingemarsson *et al.*, 2006). This is despite the extensive damage that resulted, and the fact that less than half of surveyed respondents indicated that they received advice on the risk of wind damage from forest consultants (Blennow, 2008).

For high levels of trust to be warranted, presumably the advice given by forest consultants should match the goals and interests of the forest owners. However, research by Mattsson *et al.* (2003) indicates that forest consultants overestimate the value that forest owners place on production and underestimate the importance they place on recreation and biodiversity. Furthermore, Blennow (2008) provides evidence to suggest that the advice given by forest consultants emphasizes risk management strategies which are not necessarily in keeping with the best interests of individual private forest owners.

There are several possible causes for an incongruity between forest owner values and consultants. Forest owners may be shifting in the extent that they value different aspects of their forests, such as biodiversity, relative to what is readily apparent to some forest consultants (Hugosson and Ingemarson, 2004; Kindstrand *et al.*, 2008). After decades of reinforcement of the value of production it is not unlikely that some consultants retain these values well past the date of policy change initiatives (Hysing and Olsson, 2005).

It is also possible that the incongruity between advice being provided by forest consultants and the values of forest owners is a product of an inherent conflict of interest. Some forest consultants represent organizations which are often linked directly or indirectly through investments or ownership to the forest product industry. If conflict of interest results in the "omission" of alternative possibilities that may be favourable to the forest owner, but unfavourable to the organizations providing consultants, then a further barrier may exist to the effective instigation of risk spreading approaches in Götaland. Therefore, there is a need for a deeper understanding of the motivations behind the behaviour and relationship between forest owners and forest consultants, especially in relation to adapting to climate change.

5. Conclusion

The purpose of this research is not to determine whether the current tree species composition of forest land in Götaland is adapted or maladapted to climate change. The answer to such a question depends on the scale of inquiry, the forest site in question, the extent and way in which climate change manifests itself, the desires of forest owners and society in general. However, if we accept that the goal is to spread the risk, and that altering the tree species composition of this landscape is a component of this goal, then the likely rate of change is curtailed by multiple aspects of this system. This raises the core questions as to what would be a sufficient degree of change in tree species composition and over what time period, to adequately spread the risk.

Currently the policy of risk spreading lacks a spatial and temporal goal. For risk spreading to be effective as policy, and to enable some assessment of its advance, requires that guidelines are put in place regarding the extent, rate, and form to which change is desirable. Without such guidelines we are flying blind without an odometer. To rectify this situation requires several issues need to be addressed which should help begin to elucidate which obstacles need to be overcome and which trajectory might be appropriate for achieving sufficient risk spreading for this system. This draws us to four main conclusions.

First, spruce and pine continue to dominate the forests of Götaland. Is the goal to drop the relative dominance of either tree species, or just one, by how much, and over what time period? Would the increased cultivation of some exotic tree species decrease the economic risk of climate change but increase the ecological risk? If reforestation occurs in Götaland, what ratio of tree species composition is desirable on these converted lands, and should these areas be included in a risk spreading agenda? If the principle means of change takes place through the independent decisions of over 130,000 private forest owners, what are the spatial patterns of forest tree species that are likely to eventuate, and is this spatial pattern suited to a risk spreading agenda and favorable economically, environmentally, or socially? Without the answers to these and similar questions we have no way of evaluating whether the current forest system or its trajectory is on a course perceived to be compatible with a changing climate. Poorly defined or un-quantified goals are unlikely to be achieved when they stray far from a system's current trajectory.

Second, reliance by respective government agencies on informative policy measures continues to place the onus of instigating change onto forest owners. As such, the forest system of Götaland is unlikely to be altered in tree species composition without a concomitant change in the beliefs, desires, values, and preferences of these forest owners. It is vital that individual forest owners who currently grow tree species which conflict with a goal of risk spreading are provided with guidelines regarding alternatives tree species or compositions that are most suitable to their circumstance. They will require information regarding the potential costs and benefits of maintaining the status quo, and some understanding of the inherent uncertainties of predicting climate change and its associated impacts on forest systems. Without such information, it is unlikely that informed decisions can take place, and therefore it is unlikely that appropriate change will take place.

Third, for risk spreading to occur requires the participation of forest consulting organizations. However, at present we are unaware of any strong public or private sector incentives for these organizations on mass to motivate forest owners to alter tree species composition in this forest system. Therefore, if there is a perceived benefit in altering the tree species composition of Götaland as a "risk spreading" response to climate change, it is unlikely that the rate of such changes will increase if the present incentives for the respective parties go unchanged.

Fourth, we need to seek answers from those who are already adopting new trajectories. Despite the dominance of Götaland's forest system by small-scale individual forest owners, it is important to consider the actions of other forest owners. For example, the industrial forest owners, Skåneskogens Utbecklings AB ($>2,000$ hectare) and Högesta and Christinehofs Förvaltnings AB ($\sim 7,000$ hectare), are both in the process of altering tree species composition of their properties as part of a risk spreading strategy (personal communication E.M. Madsen and Matts Karlsson, respectively). The question that needs to be addressed is what motivations or opportunities were behind their decisions. Altering tree species composition and similar initiatives among small-scale private forest owners deserves more attention from the scientific community. They represent the implementation of risk spreading initiatives at the local scale. Understanding the motivations and circumstances of the individuals involved should offer valuable insights regarding which policies are likely to be effective at instigating the adoption of risk spreading strategies in the forestry sector over appropriate time periods and at larger spatial scales.

References

Ask, P. (2002), "Biodiversity and deciduous forest in landscape management", doctoral dissertation, Southern Swedish Forest Research Centre, Swedish University of Agricutlural Sciences, Alnarp.

Berkes, F. and Folke, C. (1998), *Linking Sociological and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*, Cambridge University Press, New York, NY.

Blennow, K. (2008), "Risk management in Swedish forestry – policy formation and fulfilment of goals", *Journal of Risk Research*, Vol. 11, pp. 237-54.

Blennow, K. and Persson, J. (2009), "Climate change: motivation for taking measures to adapt", *Global Environmental Change*, Vol. 19 No. 1, pp. 100-4.

Blennow, K. and Sallnas, O. (2002), "Risk percept ion among non-industrial private forest owners", *Scandinavian Journal of Forest Research*, Vol. 17, pp. 472-9.

Boyden, S. (1989), *Western Civilization in Biological Perspective*, Oxford University Press, Oxford.

Bradshaw, R.H.W., Holmqvist, B.H., Cowling, S.A. and Sykes, M.T. (2000), "The effects of climate change on the distribution and management of *Picea abies* in southern Scandinavia", *Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere*, Vol. 30, pp. 1992-8.

Canadell, J.G., Le Quéré, C., Raupach, M.R., Field, C.B., Buitenhuis, E.T., Ciais, P., Conway, T.J., Gillett, N.P., Houghton, R.A. and Marland, G. (2007), "Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks", *Proceedings of the National Academy of Sciences*, Vol. 104, pp. 18866-70.

Chapin, F.S., Danell, K., Elmqvist, T., Folke, C. and Fresco, N. (2007), "Managing climate change impacts to enhance the resilience and sustainability of Fennoscandian forests", *Ambio*, Vol. 36, pp. 528-33.

Corell, R.W. (2006), "Challenges of climate change: an Arctic perspective", *Ambio*, Vol. 35, pp. 148-52.

Ekelund, H. and Hamilton, G. (2001), *Skogspolitisk historia*, Swedish Forest Agency, Jönköping, pp. 45-78.

Eriksson, H. (2007), *Svenskt skogsbruk möter klimatförändringar*, Skogsstyrelsen, Stockholm, p. 49.

Fransila, J., Malmhäll, J. and Eriksson, H. (2005), *Klimatförändringar och deras inverkan på skogbruket*, Skogstyrrelsen, Jönköping, pp. 1-19.

Fredman, P., Karlsson, S.E., Romild, U. and Sandell, K. (Eds) (2008a), "Besöka naturen – hemma eller borta? Delresultat från en nationell enkät om friluftsliv och naturturism i Sverige", Report No. 3, Forskningsprogrammet: Friluftsliv i Förändring, Östersund.

Fredman, P., Karlsson, S.E., Romild, U. and Sandell, K. (Eds) (2008b), "Vilka är ute i naturen? Delresultat från en nationell enkät om friluftsliv och naturturism i Sverige", Report No. 1, Forskningsprogrammet: Friluftsliv i Förändring, Östersund.

Fridman, J. (2000), "Conservation of forest in Sweden: a strategic ecological analysis", *Biological Conservation*, Vol. 96, pp. 95-103.

Götmark, F., Fridman, J. and Kempe, G. (2009), "Education and advice contribute to increased density of broadleaved conservation trees, but not saplings, in young forest in Sweden", *Journal of Environmental Management*, Vol. 90, pp. 1081-8.

Hoogstra, M.A. and Heiner, S. (2009), "Future orientation and planning in forestry: a comparison of forest managers' planning horizons in Germany and the Netherlands", *European Journal of Forest Research*, Vol. 128, pp. 1-11.

Hugosson, M. and Ingemarson, F. (2004), "Objectives and motivations of smallscale forest owners: theoretical modelling and qualitative assessment", *Silva Fennica*, Vol. 38, pp. 217-31.

Hulme, P.E. (2005), "Adapting to climate change: is there scope for ecological management in the face of a global threat?", *Journal of Applied Ecology*, Vol. 42, pp. 784-94.

Hysing, E. and Olsson, J. (2005), "Sustainability through good advice? Assessing the governance of Swedish forest biodiversity", *Environmental Politics*, Vol. 14, pp. 510-26.

Ingemarsson, F., Malmhäll, J., Merkell, B., Nasic, S. and Svensson, S.A. (2006), *Hur drabbades enskilda skogsägare av stormen Gudrun? – Rsultat av en enkätundersökning*, Swedish Forest Agency, Jönköping.

IPCC (2007), "Climate change 2007: impacts, adaptation, and vulnerability", Working Group II Contribution to the Intergovermental Panel on Climate Change Fourth Assessment Report, IPCC Secretariate, Geneva, pp. 1-22.

Jonsson, A.M., Harding, S., Barring, L. and Ravn, H.P. (2007), "Impact of climate change on the population dynamics of *Ips typographus* in southern Sweden", *Agricultural and Forest Meteorology*, Vol. 146, pp. 70-81.

Kerr, R.A. (2007), "Global warming: how urgent is climate change?", *Science*, Vol. 318, pp. 1230-1.

Kindstrand, C., Norman, J., Boman, M. and Mattsson, L. (2008), "Attitudes towards various forest functions: a comparison between private forest owners and forest officers", *Scandinavian Journal of Forest Research*, Vol. 23, pp. 133-6.

Koca, D., Smith, B. and Sykes, M.T. (2006), "Modelling regional climate change effects on potential natural ecosystems in Sweden", *Climatic Change*, Vol. 78, pp. 381-406.

Kurz, W.A., Dymond, C.C., Stinson, G., Rampley, G.J., Neilson, E.T., Carroll, A.L., Ebata, T. and Safranyik, L. (2008), "Mountain pine beetle and forest carbon feedback to climate change", *Nature*, Vol. 452, pp. 987-90.

Lindbladh, M., Bradshaw, R. and Holmqvist, B.H. (2000), "Pattern and process in south Swedish forests during the last 3000 years, sensed at stand and regional scales", *Journal of Ecology*, Vol. 88, pp. 113-28.

Mattsson, L., Boman, M. and Kindstrand, C. (2003), *Privatägd skog: Värden, visioner och forskningsbehov*, SUFOR, Alnarp.

NFI (2007), *The Swedish National Forest Inventory*, Department of Resource Management, Swedish University of Agricultural Sciences, Umeå.

Nilsson, C., Stjernquist, I., Barring, L., Schlyter, P., Jonsson, A.M. and Samuelsson, H. (2004), "Recorded storm damage in Swedish forests 1901-2000", *Forest Ecology and Management*, Vol. 199, pp. 165-73.

Pielke, R., Wigley, T. and Green, C. (2008), "Dangerous assumptions", *Nature*, Vol. 452, pp. 531-2.

Raupach, M.R., Marland, G., Ciais, P., Le Quere, C., Canadell, J.G., Klepper, G. and Field, C.B. (2007), "Global and regional drivers of accelerating CO_2 emissions", *Proceedings* *of the National Academy of Sciences of the United States of America*, Vol. 104, pp. 10288-93.

Reiner, D.M., Curry, T.E., de Figueiredo, M.A., Herzog, H.J., Ansolabehere, S.D., Itaoka, K., Johnsson, F. and Odenberger, M. (2006), "American exceptionalism? Similarities and differences in national attitudes toward energy policy and global warming", *Environmental Science & Technology*, Vol. 40, pp. 2093-8.

SCCV (2007), *Sweden Facing Climate Change – Threats and Opportunities*, Swedish Commission on Climate and Vulnerability, Stockholm.

SFA (2006), *Storme 2005 – en skoglig analys*, Swedish Forest Agency, Jönköping.

SFA (2008), in Loman, J.-O. (Ed.), *Statistical Yearbook of Forestry 2008, Official Statistics of Sweden*, Swedish Forest Agency, Jönköping, p. 337.

Skogskonferensen (2008), "Lövskogen i nytt ljus – Production, månfald och marknad", Skogskonferensen – Mötesplatesen för skog, industri och foreskning, SLU, Alnarp.

Stjernqvist, P. (2001), "Ordergivare eller rådgivare. Om skogsvårdsstyrrelsernas streategi fram till 1990", in Ekelund, H. and Hamilton, G. (Eds), *Skogspolitisk historia*, Report 8A, Swedish Forest Agency, Jönköping.

Sveaskog (2007), *Verksamheten 2007 med hållbarhetsredovisning*, Sveaskog, Stockholm, p. 94.

Sykes, M.T. and Prentice, I.C. (1996), "Climate change, tree species distributions and forest dynamics: a case study in the mixed conifer northern hardwoods zone of northern Europe", *Climatic Change*, Vol. 34, pp. 161-77.

Sykes, M.T., Prentice, I.C. and Cramer, W. (1996), "A bioclimatic model for the potential distributions of north European tree species under present and future climates", *Journal of Biogeography*, Vol. 23, pp. 203-33.

Törnqvist, T. (1995), *Skogsrikets arvingar. En sociologisk studie av skogsägarskapet inom privat, enskilt skogsbruk*, SAMU, Uppsala.

Vedung, E. (1998), "Policy instruments: typologies and theories", in Bemelmans-Videc, M.L., Rist, R. and Vedung, E. (Eds), *Carrots, Sticks, and Sermons: Policy Instruments and Their Evaluation*, Transaction Publishers, London, pp. 21-58.

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