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Article

Preparing for and Responding to Disturbance: Examples from the Forest Sector in Sweden and Canada

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Abstract: Coping or adaptation following large-scale disturbance may depend on the political system and its preparedness and policy development in relation to risks. Adaptive or foresight planning is necessary in order to account and plan for potential risks that may increase or take place concurrently with climate change. Forests constitute relevant examples of large-scale renewable resource systems that have been directly affected by recent environmental and social changes, and where different levels of management may influence each other. This article views disturbances in the forest sectors of Sweden and Canada, two large forest nations with comparable forestry experiences, in order to elucidate the preparedness and existing responses to multiple potential stresses. The article concludes that the two countries are exposed to stresses that indicate the importance of the governing and institutional system particularly with regard to multi-level systems including federal and EU levels. While economic change largely results in privatization of risk onto individual companies and their economic resources (in Canada coupled with a contestation of institutional systems and equity in these), storm and pest outbreaks in particular challenge institutional capacities at administrative levels, within the context provided by governance and tenure systems.

Keywords: adaptation; adaptive capacity; Sweden; Canada; forestry; economic crisis; forest pests; storms

1. Introduction and Aim

Adaptation and adaptive capacity have become an increasing focus of the hazards and risk literature in recent years. This reflects the growth of the climate change issue in public awareness and media, but also growing awareness of how large events and changes influence increasingly complex societies and systems. For instance, extreme storms, floods and drought, such as the large drought in Europe in 2003, highlight the need for crisis response measures in society. In addition to raising awareness of climate change, such incidents have also been linked to potential increased risks due to climate change, for instance, for longer time droughts or more severe floods (for instance in low-lying areas in the UK [1]). The occurrence of large storms in areas where storms previously have been rather unusual is another example. The storms in southern Sweden in 2005 and 2007 that resulted in massive infrastructural consequences as well as storm-felling of wood are but one example [2]. The mountain pine beetle (*Dendroctonus ponderosae*) outbreak that caused large losses in the Canadian forest industry constitutes another example. Parallel risks can be seen both in the context of unseasonal temperatures and increased potential for movement of species through trade, whereby pest outbreaks may also occur in previously undamaged territories [3,4].

Such instances of large-scale disturbance emphasize societal requirements for dealing with long, as well as short-term, change (*i.e.*, outbreak or crisis situations). They also contribute to greater awareness of potential impacts on standing stock in forestry, a land use where some northern areas may have seen climate change largely as a positive contribution due to longer growing seasons and higher production [5]. However, as forestry is a large areal land use, it has been noted that “climate variability is particularly important… because extreme events such as extended droughts have much more drastic consequences on tree growth and survival than gradual changes in average climate conditions” [6]. Beyond environmental change, forestry has also seen large impacts from economic change, both gradual change in terms of changes in requirements for competitiveness over the long term, and short term impacts such as those linked to the recent economic crisis.

Concerns with these kinds of effects are echoed in the general literature on adaptation and adaptive capacity. While a focus on adaptation has developed in the climate change literature in particular, this literature exhibits awareness that climate change risks cannot be seen in isolation from globalizing features, such as large-scale economic and market change [7]. Adaptations to economic and environmental changes take place concurrently and these changes together constitute the structure within which actors in management and decision-making set priorities and determine responses [8]. As a result, it is important to discuss the ways different systems respond and whether common characteristics can be identified to support adaptation in forestry systems.

Following a comparative explorative approach, we highlight three stresses on forestry systems, namely economic change, abiotic (storms) and biotic (pest outbreaks) disturbances, and outline adaptations taken and limitations in adaptive capacity for dealing with these stresses. Two main questions guide our inquiry:

- What adaptations have been taken in response to the different stresses, and what sort of adaptive capacities have been drawn upon?
- Can similarities in limitation or development of adaptations or adaptive capacities drawn upon be identified?

Our paper draws from different cases in two large forest nations, Sweden and Canada, with an eye to different examples that, although context-dependent, may indicate needs for preparedness or adaptive foresight planning and potential measures to increase adaptive capacity at different management levels.

2. Theoretical Framework and Methodology

Vulnerability to change is defined as the sensitivity of a system to a particular type of exposure (so called exposure-sensitivity), mitigated by the adaptive capacity of the same system [9,10]. Exposure-sensitivity indicates the total impact on a geographical or organizational unit depending on its sensitivity to a stress, and the exposure to this stress (e.g., a storm) [11]. Adaptive capacity is defined as the ability of the unit in question—e.g., a community, region or larger system—to adjust to or otherwise handle (adapt or cope with) this stress. Adaptation involves the development of actions that go beyond earlier responses, while coping involves extending previous response patterns to cope with a new stress [8,12]. However, the boundary between coping and adaptation is fluid and coping patterns may develop into more innovative adaptations: "adaptations may be autonomous and manifest [themselves] through a modification of coping strategies" [8]. Adaptations may here be undertaken in an uncoordinated fashion by different actors (e.g., community, region, state, industry) and are often reactive in direct response to observed change. Planned or proactive adaptation or adaptation strategies, such as crisis response plans, would instead aim to limit vulnerability to further exposures [13,14].

Community vulnerability to an exposure such as an economic shock or drop in timber prices, for instance, thus depends on factors at several levels in multi-level governance systems—that is, not only how a particular community responds, but also on how the region or state responds, and what adaptive capacities are present at different levels [1]. Factors that impact community responsiveness to stresses may include the economic structure of forestry, regional economic structure, as well as the adaptive capacity of the local forestry communities, *i.e.*, drawing upon other sources of income or developing higher priced goods (refinement) that can mitigate price drops.

Adaptive capacity literature developed on social systems and hazard response holds that coping with and adjusting to change depends upon numerous features, including institutional, political, economic, social and individual/human resources [9]. For instance, the well-established framework in Smit and Pilifosova [15] grouped determinants of adaptive capacity under the headings of economic resources; technology; information and skills; infrastructure; institutions, and equity, which are treated in the following paragraphs. Other scholars offer similar categorizations as well as characterize the relationships among these features [16-18].

Economic resources include the economic assets and financial means that any actor can draw upon, for instance, access to loans, a mother company, or individual resources owned by a private entrepreneur. They may both include fixed assets such as infrastructure (e.g., roads, water and energy generation facilities, stores, factories, machinery) and liquid assets such as municipal budgets, individual and household savings, business cash flow and operating funds [19]. For the purpose of viewing adaptation within different territorial contexts in this paper, economic resources may also include regional, provincial, national, or federal aid programmes, company funds, or support for employment and innovation in a given region. Actors may also adapt by drawing upon *technological* resources, which may include technological upgrades to become more efficient and competitive in international markets, thereby raising the economic resources for adaptation.

Information and skills include knowledge about available adaptation options—for instance, knowledge about alternative buyers that might mitigate economic downturns or about plant material that may be better suited to climate change conditions in order to mitigate climate change risks. Such knowledge resources may include forest inventories, regional economic, labor force or other structural data. However, access to knowledge may be limited for instance by competition among companies, levels of government and communities in relation to market opportunities. *Infrastructure* encompasses both physical infrastructure such as access to roads or transport and, for example, access to decision-makers through which support (or physical infrastructure development to support businesses) may be gained.

Institutions include access to developed adaptation options and plans available to support adaptation, or those developed amidst change. The institutional dimension also refers to institutional and policy networks available to assist adaptation (see also Brown [20] for a discussion of institutional adaptive capacity). Finally, the *equity* dimension relates to the distribution of power, for instance whether small-scale and large-scale actors have the same chances of adapting or whether vulnerability is transferred to other actors and/or sectors by the adaptations undertaken. The equity dimension thus draws attention to interactions within the other dimensions (e.g., that knowledge may be stratified between different groups in society) [15]. It also recognizes the importance of where responsibility for adaptations rests, and whether this falls to state or individual actors, in order to highlight equity (allocation) dimensions and to make clear "adaptation by whom" [13]—in this case, whether the state, region, forest industry, individual forest managers, private forest owners or other actors.

Drawing upon previous research [19,21-25], Klenk [26] explicitly extended the framework of determinants of adaptive capacity to relate access of different groups to the determinant resources. Klenk [26] defines adaptive capacity as the potential of groups (e.g., communities, regions) to *access, mobilize and deploy* assets and endowments through *mobilizers* to plan and respond to change, without degrading those resources and mobilizers. The adaptation process or pathway is defined through the access to, mobilization and deployment of, capital assets. High adaptive capacity requires the presence of effective mobilizers, which include the role of cross-level institutional and governance arrangements and actors in facilitating or constraining adaptation actions taken by different stakeholders. Such a perspective [26] thus explicitly defines in particular the institutional parts of determinants of adaptive capacity as a linkage to the other capital resources [27]. Limitations to adaptive capacity are thus manifest when there is a lack of access to capital assets and ineffective mobilizers, for instance limited economic resources, knowledge or infrastructure, weak institutions, and poor governance and equity arrangements pertaining to the actors involved in adaptation processes or pathways [28]. If well-developed and case appropriate pathways are developed, this will support adaptation to the post-catalyst/opportunity environment resulting from a disturbance. On the other hand, if a process/pathway is resistant to change, adaptation mainly refers to the pre-catalyst or disturbance environment [21].

For the purposes of our analysis, we focus on key determinants of adaptive capacity in forest planning and policy. In order to understand crisis response, it is crucial to understand what adaptations are undertaken, as well as what adaptive capacities are relied upon, and whether these contribute to the development of planned adaptation strategies, rather than reactive management at the time of the crisis. Our analysis focuses on access to capital assets such as economic and technological resources, information and skills, and mobilizers such as effective institutions and governance arrangements, as well as equity in different spheres of social relations [15,19]. The institutional factor of determinants of adaptive capacity (*i.e.*, the ways in which plans and strategies to deal with disturbances are developed or drawn upon) will be given specific attention in this paper, given that planned adaptation or adaptation strategies (such as crisis response plans) are important to limit vulnerability to further exposures [14].

In this paper, we have chosen to focus on Sweden and Canada given that a large part of the GDP in both nations (4% and 3% respectively) derives from the forestry sector, which includes the wood industry, pulp and paper, and forestry [29]. Each country supports forestry on its state-owned lands (about 15% in Sweden and 90% in Canada), in Sweden managed by the state productive forest company Sveaskog among others, and in Canada managed by the provincial governments [30]. In Sweden, however, a large proportion of the land (about 50%) is also owned by small-scale forest owners, and a proportion is owned by private forest companies (some 25%) [31]. This is different from Canada where public timber is leased to the forest industry by way of licenses granted to individual forest companies by the province to undertake forest management and logging [20]. In both countries, the forest industry has focused on high-volume commodities such as pulp, paper and timber, which are today increasingly sold on a world market.

We have chosen to compare Sweden with Ontario, Canada given that these regions have a similar population size and density distribution along a latitudinal gradient, and they have similar geographical distribution of forest ownership (see further Table 1). In each region ownership by large companies is relatively more common in the north, while smaller private land-holdings are more common in the south. While much of the institutional capacity in Sweden may be developed on a national level and expressed in national law, ordinances or policy of the national Swedish Forest Agency (SFA) for instance, Canadian institutional capacity to respond to changes may be developed on a provincial level with regard to policy development. Thus it is reasonable to compare Swedish national responses with Canadian provincial responses in reviewing institutional determinants. In Sweden, responses may also depend on the actions of individual forest owners, forest owners' organizations and local businesses such as sawmills [12].

Table 1. General characteristics of territorial units (based on [32] unless stated otherwise).

Territorial unit / General characteristics	Sweden	Ontario	Canada
Area (km^2)	450,295	917,741	9,093,507
Population	9,316,256	13,210,667	34,299,000
Population density and distribution	20.6/km^2 Higher density in southern part of the country	13.8/km^2 Higher density in southern part of the province	3.41/km^2 Higher density in southern part of the country
Forest ownership	Private individuals (families) are the largest single category of forest owners. Approximately half of the country's forests are family owned, with the other half being divided by 6% other private owners, 3% state-owned, 14% state-owned companies, 1% other public ownership, and some 25% private-sector companies (Swedish Forest Agency 2009, [33]). The average size of a private forest is about 50 hectares. In the southern part of the country, they are the dominant category, accounting for 80% of forest land.	89% of forest lands are owned by the government; 11% is owned by private landowners; 1% of privately owned forests are used for production purposes. In Northern Ontario, 75% of commercial forest land belongs to the province [34]. In Southern Ontario, 87% of land belongs to private owners. About 8.5 million people (25% of Canadians) live in Southern Ontario.	80% provincial ownership, 11% federal ownership (mainly parks and military reserves), 9% private ownership (ranges from 3% in Saskatchewan to 92% in Prince Edward Island).

To review responses within these systems, we have selected recent disturbance events that refer to both changes that may become more common with climate change and changes that relate to a globalizing market environment, as neither would occur in isolation. Adaptation takes place in response to concurrent stresses that are likely to include both globalization or economic change and climate changes [7]. Storms (an abiotic change) and pests (a biotic change) are examples of disturbances that may become more common with climate change. Economic change is both identified by interviewees in the cases as well as by literature on globalization as change that needs to be considered as concurrent with environmental change, in order to understand adaptive options. To assess the extent to which policy developments are supporting or building the basis for adaptation to stresses in the future, we are thus reviewing not only explicit adaptation policy (which has so far been relatively limited in the areas, see [35]) but the general development of policy that supports responding to the selected stresses.

In general, the study data draw from literature reviews and semi-structured interviews, with a focus on regions where disturbances have occurred. Swedish data on responses to economic changes are drawn from semi-structured interviews with stakeholders in forestry in the county of Norrbotten (the Pite River Valley) in 2003–2004 (n = 12, described further in Keskitalo [12]) and with multi-use forest stakeholders in the municipality of Gällivare in 2008 for the case of economic restructuring (n = 27, [36]). These cases are from a low-populated county of Sweden which traditionally has been strongly forestry-dependent. Data may illustrate larger changes within Sweden but are specific to the region (e.g., in terms of the extent of impact on communities where forestry has played a large role and in relation to impact within a limited economic structure). Translations of quotes in the text are made by the lead author from the original Swedish.

Data on economic change in Canada are drawn from research on changes in Ontario's forest sector and forest communities during the 2000s [37,38]. The results presented herein reflect insights gleaned from 59 semi-structured interviews with stakeholders in a multi-level forest governance setting in the Northeast Superior Region of Northern Ontario, as well as a review of over 200 local newspaper articles, government, industry, civil society and labor reports, and regional public workshops covering the impacts of the regional forestry crisis.

In addition, Swedish data regarding storms derive from a survey of policy literature developed in response to storms and a pre-study undertaken during 2009 in Kronoberg county and Växjö municipality, which were among those strongly impacted by the 2005 Gudrun storm. Swedish data regarding pest outbreaks come from a literature survey of existing pest regulation and Swedish Forest Agency work. Likewise, the Canadian case studies on storms and pests draw on a literature survey and a knowledge synthesis of invasive alien species (IAS) and climate change in Canada [39], as well as a policy review of IAS legislation in Ontario [40].

3. Results

3.1. The Case of Economic Disturbance

Economic disturbances are defined here as changes that force adaptation within industry or a sector in general, such as restructuring or recession. Two different periods of forestry recession are discussed below, namely the 1990s in Sweden and the 2000s in Canada (the latter culminating with the recent global economic crisis).

Sweden: Economic restructuring has had a major impact on the Swedish forest industry especially in the 1990s and during the recent economic crisis. While gradual changes were identified over the time interviewees had been working in forestry, many saw changes as culminating in the 1990s (drawing upon 2003–2004 data). Stakeholders in the forestry sector thus described large-scale economic change not as an isolated event, but as an ongoing trend with large effects over time. The forestry industry was identified as increasingly internationalized, which has led to increased competition and to the bankruptcy of smaller local industries. Time periods with larger changes can be identified, such as the closure of small sawmills in the 1990s, although many small-scale operations have also continuously experienced higher competition. In general economic change in the last few decades has been characterized by decreased employment locally, increased technology and technology dependence, and increased size of operations, to the point that smaller sawmills have gone bankrupt. As one interviewee noted: "today you need large plants to make ends meet" (forestry industry). The structure for forest entrepreneurs has also regularly changed from smaller location-based, company-employed units, to larger mobile entrepreneur units. The forest industry is also largely technology-dependent, and many interviewees suggested that forestry has replaced "people with technology" during the last few decades. This means that technological resources and funding to invest in such have often been crucial for development of increased efficiency, at the cost of local employment.

Small-scale operations may adapt by finding customers who are able to pay more for a specialized product—for instance through the development of international sales networks—or, in one case, by gaining support from the mother company during times of crisis (thereby increasing availability of capital for investment). Some companies have grown within a specific niche in order to be able to better compete, for instance focusing on particular refinement (wood houses, doors, windows), whereas others have become part of larger operations such as the larger entrepreneur units that were formed from previous in-house or smaller units in order to increase competitiveness. Knowledge of foreign markets has thus become increasingly important, and the access to economic resources for restructuring has been crucial.

Limitations to adaptation include lack of available funding for reinvestment, limited international linkages to buyers (limited knowledge of foreign markets), and limited linkages between management and product development that become even more important with increasing competition. Given that Sweden does not have general subsidies for forestry, interviewees perceived institutional support to be limited in relation to economic change. Some interviewees also noted the problem with gaining state loans in the current economic climate (e.g., sawmill bankruptcy). With the large industry ownership of forest in Sweden, however, larger units, unlike small-scale operations, possessed capital for investing in technology and increased competitiveness. Larger-scale units have drawn upon structural changes at lower levels, such as promoting large separate entrepreneur units rather than employing entrepreneurs within the company. In responding to this process, interviewees also recognized that local entrepreneurship refinement or supportive sectoral cultures (e.g., nature tourism) had been limited and would need to develop to support local employment in the face of companies limiting their employment locally: "we need to get the persons who now inherit forests to start thinking along new lines" (forest owners interest organization).

Ontario, Canada: In Canada, forestry stakeholders well recognize the larger influence of economic restructuring and rural change on the domestic forest industry and communities. In view of the Swedish experience, similar changes have occurred over the long term in Canada with respect to efficiencies in commodity production gained through labor-replacing technologies, as well as the influence of multinational companies and export markets [41]. Yet the recent decade-long forestry crisis is commonly described as a 'perfect storm'—an unusual event that differs from bust periods observed in the past–attributable to the convergence of numerous challenges to the industry (e.g., rising energy costs, US housing market crash, weakening American dollar). Industry decline is illustrated by the drop-off in Crown timber harvesting (−45%) and related provincial revenues (−33%) between 2001 and 2008 [42].

In response, there has been consolidation in the industry where fewer, larger companies are increasingly controlling larger areas of forest land and provincial fiber allocations. This has been the case in Ontario for example, Canada's hardest hit forestry province, where over the past decade continuous corporate restructuring has produced a string of merger, takeover, and closure announcements and contentious rerouting of public wood fiber among regional mills.

To address the crisis, the provincial government responded by creating the Minister's Council on Forest Sector Competitiveness in 2005, which led to three major provincial aid programs [43]. In June 2005, the province unveiled a $350 million loan guarantee program to promote forestry investment and modernization. Perceived by some as a bailout, this support was intended to help the forest industry become competitive during a period of uncertainty and transition. In September 2005, another $330 million was provided through the Forest Sector Prosperity Fund, intended to encourage forest company expansion and modernization. In February 2006 the provincial Liberals revealed another $220 million in industry aid to assume costs for road construction and maintenance (previously paid for by companies) and reduced resource rents. Several months later an additional $140 million energy rebate was announced for northern pulp and paper producers. These provincial initiatives were meant to help companies adapt and be more innovative during crisis. For communities and workers affected by mill closures, the Ontario Ministry of Training, Colleges and Universities' Adjustment Advisory Program also created co-funded Community and Labor Adjustment Committees.

More fundamentally and forward-looking, in March 2009 the province set out to modernize the controversial Crown forest tenure and pricing system. The tenure system is commonly held to be problematic [44,45] and, as recognized by interviewees, it has constrained diversification and innovation by limiting access to fiber for new entrants such as local enterprise, First Nations and communities: "We've got a small log home producer... and we have a fella' out here on the hill making timbers. These guys have a hell of a time getting wood even though [the local] mill brings in wood that is too big for its own facility" (forestry industry). The present system has hampered development of non-conventional forest products and uses (e.g., bioenergy; medicinals; forest foods).

Ontario's current tenure policies are based on the century-old notion of sustained yield harvesting and were designed to provide a steady flow of fiber to designated processors through timber liquidation. Consequently, these policies emphasize timber harvesting rights (deemphasizing non-timber products) and long-term security for large investors through leases that are renewed every five years. About 80% of annual fiber allocations are associated with large-scale processing facilities that require high minimum fiber volumes to be economically viable, and 100% of the annual cut comes from designated forest areas [44].

This rigid institutional setting has made it difficult to change policies, reconfigure mill operations, and redirect fiber flows without impacting specific mills, towns, and forests. While reforms are ongoing as of February 2011, the provincial review is expected to separate management planning responsibilities from processors and there remains pressure from First Nations, municipalities, labor and civil society groups to create community-based tenures. Until recently in Ontario, there has been limited focus on and a lack of knowledge and institutions supporting forest product innovation and market development. As apparent from interviews, some forest companies and entrepreneurs are working to retrofit existing and idled mills for co-generation, wood pellet plants, and bioresource extraction and processing more broadly, though securing loans and fiber allocations remains challenging given the shifting institutional and economic climate. Non-timber forest products are also seen by major industry representatives as a niche market at best, and development of these products has been left to community-level research organizations and consultants (e.g., Food Security Research Network based in Thunder Bay; Northeast Superior forest Community Corporation based in Chapleau). The following statement by one major forestry company representative indicates the general attitude towards value-added among large-scale processors: "I don't think that the solutions are all these little value added... There's a place for that don't get me wrong... But what I'm saying is you absolutely need a strong primary forest products industry for any of these guys to exist" (forestry industry).

While provincial investments and tenure reforms are underway to improve the competitive environment for forest companies and entrepreneurs, a major limitation is that forest policy, management, planning, and enterprise remain dominated by conventional thinking. Centralized control of forest resources and a commodity export focus have lead to a culture of resource dependence. A focus on resource extraction is pervasive, shaping the way provincial officials, locals and business leaders think about and act on forestry problems and solutions, to illustrate: "For years we've relied upon mining and the forest sector and that's how we've seen it" (Provincial official).

3.2. Abiotic Disturbances: The Case of Storms

Abiotic disturbances such as storm events, fire or drought may increase due to climate change. This could in turn result in storm felling, especially under conditions such as wet ground, which may also become more usual during milder winters, and in specific forest structures. Storm felling could promote conditions beneficial to forest pests, thereby increasing risks of infestations [2,6,46].

Sweden: During recent years, Sweden has experienced two major storms, "Gudrun" in 2005 and "Per" in 2007, both of which impacted southernmost Sweden. Gudrun resulted in large-scale infrastructure disturbance including weeks-long power outages as well as large-scale storm felling amounting to the total annual felling in Sweden, damage to forest roads, increases in pests, and formal initiation of a discussion of adaptation to climate change in forest management. An example of immediate adaptation, the Swedish Road Administration undertook road improvements in Kronoberg County, with support from the European Union (EU). In addition, individual road owners could apply for state funding for road repair. The large impact of the storm caused major investigations and adaptive measures in forestry by the Swedish Forest Agency, the Swedish Road Administration, county administrative boards, and forest owners, which have supported the development of planned adaptations. The storm has also led to an increase in wood transport by rail rather than road among forest companies, improved clearing of forest surrounding railway lines in forest lands, and projects on limiting the spread of pests especially in national level forest management—a result of the large amounts of dead wood resulting from the storm.

Institutionally, forest companies have started to consider increasing the variation at the stand level from that of existing monocultures that are vulnerable to storms. The storm issue also informed the governmental Swedish Commission on Climate and Vulnerability finalized in 2007 [5] where Gudrun was mentioned as an example of consequences of storm occurrences. The Commission notes that both education and information efforts by the Swedish Forest Agency and individual actions on the part of forest owners are important to promote adaptation to future impacts of climate change. Given the large proportion of small-scale forest owners in southern Sweden, this group is in particular defined in the state investigation [5] as having significant responsibility for future adaptation. The need to review insurance protection for forest areas is also noted. General adaptations to make forests more storm-hardy would, among other things, include replacing economically valuable but storm (and drought) sensitive spruce with other species, especially in southern Sweden. However, it remains unclear whether many local forest owners or industry will take actions to modify forest structure, given that such changes may have economic impacts. For small-scale forest owners, possibilities of integrating adaptation measures in management may also be constrained by a lack of information and knowledge, as many small-scale forest owners live away from their holdings, limiting their engagement with management planning.

Adaptations can thus be seen both at the governmental level, including a focus on improved risk management in policy (the state and the state's response systems, infrastructure development and education efforts), and at the forest management level. On a forest management level, storm risk has been described as an issue for both forestry companies and private forest owners given that both groups are major property owners, but may be limited by economic, institutional and knowledge resources.

Ontario, Canada: In January 1998, a series of ice storms in Eastern Canada and some neighboring US states created a build-up of ice from freezing rain that caused extensive damage to forests and energy infrastructure. The storm left four million residents across eastern Ontario, and southern Québec and New Brunswick without power and some remained without power for three weeks. The emergency response planning and the emergent networks of actors including municipalities, police, fire, ambulance, public transit, health and social service personnel, Canadian army, as well as research organizations and thousands of volunteers, proved to be effective in mobilizing and deploying needed resources and skills to deal with the disaster on multiple fronts, including providing knowledge extension for maple sugar and woodlot owners among other impacted groups [47,48].

In Ontario, more than 604,000 hectares of forest were damaged in the ice storm. The economic impacts of the ice storm have been estimated to be $5.5 million in losses to the sugar maple industry, and depending on age and the amount of damage sustained, per hectare losses for red pine plantations ranged from $560 to $13,236 and those for white cedar ranged from $307 to $1,721 [49]. Within days of the storm, a joint federal/provincial program was established to assess damage and monitor the recovery of eastern Ontario forests [50]. This program addressed short-term needs including training technicians so that consistent damage assessments and recommendations suitable for urban, suburban, and rural landowners could be made, summarizing current literature and developing management guidelines. Longer-term needs focused on helping maple sugar producers and woodlot owners. The program was successful in implementing scientific experiments designed to document effects of damage on sugar maple stands, determining if one or more remedial treatments could reduce the required recovery time, and documenting responses of various species to damage and the biological/economic effects of damage and post-damage salvage for woodlot owners.

Apart from demonstrating the adaptive capacity of the Ontario Ministry of Natural Resources and the Canadian Forest Service to engage in timely and effective knowledge extension and production, training and monitoring, no forest policy-developments resulted from the ice storm. Research [51] showed that past forest management had no effect on the severity of the damage of the ice storm to forests; therefore there was little need to change forest regulations to prepare for future ice storms.

3.3. Biological Disturbances: the Case of Pests Outbreaks

Biological disturbances such as pest outbreaks and invasive species are an increasing risk both as a result of climate change, where wet and warm conditions with limited freezing periods, may be beneficial to these biological agents [52], and as a result of increased globalization, whereby pests and other species may be transported (e.g., in waste water or in wood packaging to locations where they have previously not existed) [3,4].

Sweden: In Sweden, the risk of pest outbreaks gained significance following storms Gudrun and Per, where large-scale government projects have targeted the spread of the spruce bark beetle (*Ips typographus*). An indigenous species, spruce bark beetle increased with impacts on storm-felled and standing forest following the Gudrun storm and may potentially cause large forest damage. With regard to this species, some post-storm funding has targeted information to individual forest owners and overviews of the state policy readiness. Consequently, the Swedish Forest Agency provided 34 million SEK (about 3.5 million Euro) for monitoring and analysis of insect populations and information on pests. The SFA also introduced a pest control project. Adaptations or adaptive capacity-building measures thus include awareness on the need for improved connections between forest interests conducting monitoring and coordination in the areas, as well as suggestions from the SFA to change regulations on when logged or fallen wood should be removed from grounds (a concern for fallen wood especially in nature reserves).

Concerns for invasive alien species such as the pine wood nematode (*Bursaphelenchus xylophilus*) have also increased given trade within the European Union (EU). Some countries, notably Portugal, have outbreaks of the pine wood nematode, with subsequent risks that it may spread to and become invasive in Sweden. The issue thereby becomes one for Swedish and European Community regulation, because Sweden, as an EU member, cannot unilaterally control issues that may conflict with the free movement of goods and services. At the EU level, there exists an early warning and information system, working groups on invasive species regulation options, and specific control measures for the pine wood nematode in particular in Portuguese source material; however, no harmonized EU level approach to control IAS has been developed.

On a Swedish national level, there exist a strategy including species monitoring and development of an early warning system as well as a multi-agency coordination group for invasive species. The pine wood nematode, regulated in Swedish law as a plant pest for which admission and spread is prevented, is currently the only species for which full consequence analysis and a plan for measures has been developed. The governmental strategy in 2008 observed that invasive species legislation is at present relatively undeveloped [53], thereby constituting a limitation to the possibilities for planned adaptation. This policy gap is partly a result of the fact that development of regulation on invasive alien species that are spread by waste water from ships or wood packaging for products in the EU may be considered a limitation of free trade within the EU and global context (under the World Trade Organization). It is also a result of the complexity of the issue including the large number of potentially invasive species and differential responses to pest outbreaks. While invasive alien species and trade are issues for individual forest owners, forest companies, and the Swedish state—and indeed institutional capacity overall—larger systems such as the EU and the global context thus also impact and currently limit the adaptations taken. As the pine wood nematode would benefit from warmer summers and drought stressed trees, risks are foreseen to increase over time as a result of climate change.

Ontario, Canada: In Ontario, the risk of pest outbreaks has come into focus in part due to the mountain pine beetle (*Dendroctonus ponderosae)* outbreak in British Columbia [52]. Columbo [52] notes that as the beetle benefits from higher summer temperatures and water stress, it may be a question of time until the mountain pine beetle migrates into Northern Ontario.

With regard to invasive alien species, many IAS have been reported in Ontario, and the province contains more IAS than any other province or territory in Canada [54]. Despite significant economic and ecological impacts of these non-native species (e.g., the annual cumulative cost of 16 IAS in Canada is estimated to be $13.3–34.5 billion) [55], IAS do not figure prominently in Ontario legislative policy. While recent strategic policy documents such as Ontario's Biodiversity Strategy and the Ontario Ministry of Natural Resources' (OMNR) 'Our Sustainable Future' mention the need to prevent, monitor and control IAS, there is no single coordinating agency in charge of planning for, implementing and enforcing IAS regulations in the province. Instead, policies have arisen somewhat haphazardly from a patchwork of government agencies at provincial and federal levels, as well as through networked environmental governance organizations.

The fragmented and uncoordinated development of IAS policy in Ontario reflects the multiple players involved in IAS issues in the province, as well as the complicated division of powers under the Canadian federalist system. The OMNR is the primary provincial agency responsible for IAS management and focuses mainly on monitoring, research, control, and public education. On the terrestrial front, the OMNR works in collaboration with several federal agencies, such as the Canadian Food Inspection Agency (CFIA), Canadian Forest Service, and Ministry of Agriculture and Food to monitor and control invasive insect, plant and plant diseases in Ontario Crown forests. In partnership with the Ontario Federation of Anglers and Hunters (a non-governmental, non-profit organization), the OMNR runs a public awareness program to prevent and monitor the spread of aquatic IAS, and to investigate their impacts and options for their control. The OMNR is also involved with the non-profit, multi-agency Ontario Invasive Plant Council, whose mandate is to coordinate Ontario's response to invasive plants. While a variety of players are thus involved, no single strategy exists to guide, prioritize and coordinate their efforts, and no single organization is responsible for overseeing and integrating provincial initiatives to prevent, control and eradicate IAS.

Lack of legislative policy on IAS issues in Ontario is an additional obstacle to effective management. Currently, only one piece of provincial legislation specifically deals prevention and control (and it is restricted to a single watershed), although several other acts and regulations deal incidentally with IAS issues. Overall, these legislative tools have limited taxonomic scope, and lack clear, consistent standards on what non-native species should be prohibited and accepted into Ontario. The legislation is further hindered by weak enforcement capabilities and a discretionary inspection system. In addition, because many IAS vectors and pathways are under federal jurisdiction (e.g., international trade, navigation and shipping, fisheries), but the sectors at risk from IAS in Ontario are under provincial jurisdiction (e.g., forestry, agriculture, health, *etc.*), IAS regulations require the concerted cooperation of federal and provincial agencies. To date there have been few examples of successful cross-jurisdictional implementation of regulations on IAS. For example, the CFIA regulates the importation of plants and plant products into Canada to prevent the introduction and spread of pests, including IAS. However, once in the country, there are no regulatory instruments in place to track or control the movement of IAS plants across provincial/territorial borders. In Ontario, a limited number of IAS plant species are regulated, and only if they occur on agricultural or horticultural lands.

Many opportunities for the mobilization of knowledge on IAS can be found in Canada and there is evidence that science uptake by policy-makers is occurring, at least to some degree. For example, the institutional capacity to disseminate IAS information to government exists in organizations such as the Canadian Aquatic Invasive Species Network, a national research consortium of IAS specialists focusing on improving prediction, prevention, early detection and rapid response strategies for aquatic invasions. Similarly, the Ontario and federal governments recently established an Invasive Species Centre in the province, with the aim of coordinating initiatives to control the spread of IAS provincially and nationally. What is missing, however, is the actual translation of scientific knowledge on IAS into concrete policy to address these threats in Ontario, limited among other things by the lack of federal leadership and coordination on the issue of IAS prevention and control.

4. Discussion and Conclusion

The case studies examined in this comparison highlight both similarities and differences between Sweden's and Ontario's preparedness for and response to disturbance in forestry systems. With regard to the economic disturbance case, similar larger trends and impacts can be identified, such as the consequences in terms of smaller unit (sawmill) closures and restructuring into larger units that may impact local communities and possibilities for localized responses to disturbances (see also [56]). A notable difference between the cases is the fact that Ontario introduced a provincial loan guarantee program, while Swedish forestry is largely operating without state grants (although exceptions exist, such as the possibilities to apply for state loans for smaller operations). In Sweden, the comparatively large industry ownership ("Europe's highest commercial forest ownership", [57]) may offer increased opportunities for forest industry to adapt to change, and also means that questions of tenure or ownership are not pronounced in a fashion similar to that in Ontario. Indeed the high level of provincial forest ownership in Ontario suggests a state responsibility and therefore strong opportunity for provincial leaders to initiate regional adaptation and preparedness strategies in the forest sector.

Although there have been large impacts on forestry structure (e.g., local sawmills and competitiveness) in both countries as a result of the globalization of the wood market and increased international competition, the pathways for coping with these stresses differ between the countries. In Canada, actions are largely situated at the provincial level, with locals, indigenous peoples, and some in industry lobbying the province for transfer of tenure to the local level. Capacities at higher levels (perceived as deficiencies in institutional systems and equity distribution) were thus highlighted in the Canadian case: forest product diversification and innovation are identified as limited by the tenure system, with provincial aid programs reinforcing the historical dominance of pulp and paper and lumber mills, while new entrants and alternative products and processes are underdeveloped (*i.e.*, a focus on institutional capacity)—illustrating a potential resistance to change rather than adaptation to a post-crisis environment [26]. In Sweden, then, adaptations to economic stresses are largely company-level and dependent on economic resources available in each individual case as well as technological developments to increase output from products: creating entrepreneurship, increased refinement and new competitive products (what may be seen as coping measures within the context of traditional forestry). Impacts of economic, technological and individual skills and knowledge capital [15] were thus highlighted in the economic change case study in Sweden, potentially a result of the structure of the forest industry in Sweden where the sector lacks general subsidies. In addition, in Sweden, a focus is placed on the need for developing entrepreneurship cultures (or adaptation pathways) that do not rely on forest production *per se* but may utilize other parts of the landscape, such as for instance tourism (adaptations that go beyond traditional forest industry practices).

For both Sweden and Ontario, the storms and pests cases highlight the impact of government institutional capacities (mobilizers) and infrastructure to respond to threats and develop policy (also highlighted in general for adaptive capacity in forestry in Canada by Brown [20] and Johnston *et al.* [56]). With regard to storms, an institutional linkage was made in Sweden both for the need for developing policy in general on risk events and also with regard to potential risks associated with climate change. This link to climate change may be related to the occurrence of the storms taking place during the development of an ongoing governmental investigation on climate and vulnerability that drew further attention to future risks. It was also perceived that storm impacts were related to forest structure. In Canada, on the other hand, linkages between storm risk and forest management were not developed, nor were storm risks framed within the context of climate change. This difference may be due to the different nature of the storms in Sweden and Canada. As a result, policy responses regarding short term (storm event) and long term (climate risk) concerns developed in Sweden but not in Canada. This highlights that the framing of risks are crucial, as the framing process may impact political preference setting and resources allocated to a problem [37]. Other climate change risks have, however, been related to forestry structure also in Canada. For instance, the mountain pine beetle infestation in British Columbia affects vast areas of pine forest (*Pinus* spp.) that dominate the province's landscape [14]. This makes it likely that adaptation to forest structure will need to be a part of the development of integrated climate change adaptation mechanisms.

With regard to pests, both Sweden and Ontario lack strong means to deal with IAS, largely defined as a result of limitations within the multi-level institutional structure and related institutional and political infrastructure capacities and mobilization. In Ontario, lack of coordination among multiple players, coupled with lack of leadership at the federal level, contribute to the problem. This lack of cohesion at the federal level is, for the Swedish case, mirrored by the lack of strong EU level regulation on IAS, as Sweden cannot unilaterally regulate risks related to movement of goods and services. Inherent features of IAS (being generally unpredictable, having impacts spread among many stakeholders, being persistent and extremely difficult to eliminate once established) [58], may also constitute some explanatory factors why IAS have so far not gained high attention despite the ecological and socio-economic threats they pose. However, on issues that Sweden and Ontario have been able to act on independently (such as domestic pests in Sweden, or the establishment of early warning systems), improved monitoring coordination has been developed.

With respect to IAS, there are significant adaptation constraints arising from the multi-level nature of requisite response systems With regard to adaptation to climate change in general in Canada, this institutional, multi-level and multi-actor focus is highlighted by Brown [20], who notes that government, industry, First Nation, community and civil society actors will need to act together in working or task groups. Some examples already exist in terms of interaction bodies such as the advisory Expert Panel on Climate Change Adaptation under the Ontario Ministry of the Environment, or the Eastern Ontario Model Forest, which has been active in stakeholder cooperation and research on climate change since the mid-1990s ice storm events [20]. Adaptation in forestry may thus also be dependent upon the development and mainstreaming of adaptation policy, the lack of which has been noted in Canada to constitute an institutional and policy barrier to adaptation [35].

In sum, the study illustrates that access to economic assets have been particularly important for adapting to economic disturbances [18]. Economic resources make it possible for businesses to develop and mobilize technological and knowledge assets. In general, economic resources can make it possible for smaller-scale actors to gain access to particular buyers that are able to pay well for very specific products. Such requirements may, however, place large demands on individual actors and result in large impacts on restructuring to improve economic viability, in particular for small-scale actors (thereby bearing on equity dimensions of adaptive capacity [15]). Economic resources are not the only important determinants of adaptive capacity, but are linked to institutional processes and governance arrangements, which is emphasized particularly in the Canadian case.

In contrast, effective institutional structures and processes and governance arrangements have played a larger role in adapting to natural disturbances (abiotic and biotic) in both of the case study areas, especially in relation to the mobilizing and deployment of information and skills necessary to cope with disturbances and opportunities. For example, the effective mobilization and deployment of assets through multi-level governance arrangements required for developing management and monitoring plans on an issue as complex as IAS is particularly challenging, both within the Canadian federal context and for Sweden within the EU context. For the issue of storms, framing (an institutional issue) as well as knowledge development within forest management is challenging. The results suggest that institutional development and foresight planning, as well as development of information and skills, on the part of the state (in Sweden) or province as well as at the federal level (in Canada), could potentially have a larger role than presently exists in developing responses to climate change risks [35]. In particular, there is a need to move beyond event-based, to some extent reactive policy development towards proactive integration of adaptation measures in forest management practice.

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