POLICY PERSPECTIVE

Eye on the taiga: removing global policy impediments to safeguard the boreal forest

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Abstract

The absence of boreal forests from global policy agendas on sustainable development and climate change mitigation represents a massive missed opportunity for environmental protection. The boreal zone contains some of the world's largest pools of terrestrial carbon that, if not safeguarded from a conversion to a net source of greenhouse gases, could seriously exacerbate global climate change. At the same time, boreal countries have a strong tradition of forest management—expertise that could be effectively leveraged toward global and national carbon mitigation targets and sustainable development. Current obstacles against such contributions include weak incentives for carbon sequestration and a reluctance to embrace change by forest managers and policy makers. We discuss possible solutions to overcome these obstacles, including the improvement of ineffective incentives, the development of alternative forest management strategies, and the need to maintain ecosystem resilience through the pursuit of policy and management options.

Introduction

The taiga (boreal forest) has been largely absent from global policy agendas on sustainable development and climate change mitigation. For instance, the United Nations Framework Convention on Climate Change and the Kyoto Protocol, while paying lip service to the role of forests, failed to provide a carbon accounting system that would adequately incentivize sustainable forest management practices (Ellison *et al*. 2011). Similarly, the European Union has firmly resisted the integration of forests into its climate policy framework (Ellison 2010), though there has been some progress on the adoption of a new European Forest Policy strategy. Although these concerns apply to all forests, the omission of boreal forests is of special concern given that they account for approximately 25% of the planet's forest area and contain more than 35% of all terrestrial carbon (Burton *et al*. 2010; Figure 1).

International attention paid to forests has been focused mainly on management actions that (1) reduce CO_2 emissions from deforestation and degradation (REDD), (2) maintain biodiversity in the tropics, and (3) alleviate poverty in the developing world. By contrast, boreal forests are viewed largely as carbon sinks (Pan

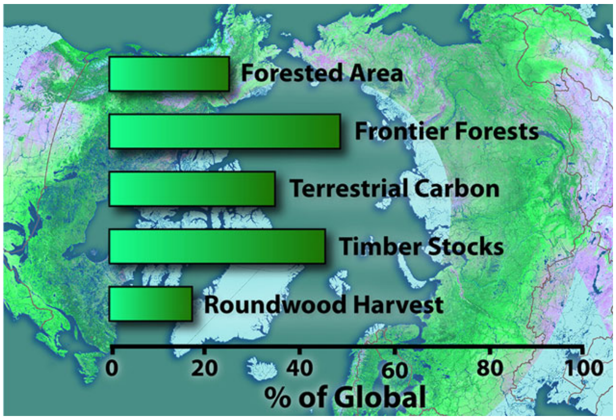

Figure 1 Global extent of the boreal region (background image is a colour composite of three spectral bands collected from the MODIS sensor, see Potapov *et al*. 2008bb for details). Overlaid are the global percentages of boreal forest areas, and some of the goods and services provided by them (Burton *et al*. 2010). Background image courtesy of Peter Potapov.

et al. 2011), with low species diversity relative to the tropics (Bradshaw *et al.* 2009), thus consigning them to low priority for global climate-change mitigation and mainstream conservation initiatives (Warkentin & Bradshaw 2012). Furthermore, increasing areas of the boreal region are considered "sustainably" managed, although principally utilized for intensive timber production (Kuuluvainen 2009), while remote, unmanaged regions are regarded as "frontier" forests' (Bryant *et al.* 1997) or "intact forest landscapes" (Potapov *et al.* 2008a). However, many of these frontier forests are currently being logged or transformed through forest management (e.g., Hansen *et al.* 2010; Potapov *et al.* 2011).

The omission of boreal forests from global agendas may represent both a dangerous oversight and a missed opportunity. The mind-set on boreal forests can perhaps be compared to the historical view on most marine fish stocks; just as they were once considered "limitless" (Sims & Southward 2006), but eventually became overexploited, the bounty of the boreal zone is likewise threatened. Certainly efforts to address forests in more regional and international frameworks are in their nascent stages. Forest biodiversity is increasingly being addressed in somewhat piecemeal and ad hoc fashion through projects like the European Natura 2000 Network or the international Convention on Biodiversity. Forest resilience, on the other hand, is even less consistently addressed, though the recent emergence of such fora as the European Forest Policy initiative may begin to point in the direction of increased attention to such matters. However the basic problem is the lack of more focused and internationalized efforts to address such issues. A broad inclusion of forests in the United Nations Framework Convention on Climate Change (the Kyoto Protocol) and climate policy framework could provide a trigger for enhancing national level action to build forest-based resources and protect them from the effects of climate change.

Boreal forests are already experiencing severe and escalating impacts from climate change (e.g., Burton *et al.* 2010; Park *et al.* 2014). These rapid changes in the boreal zone might represent the beginnings of a biome-level transformation resulting in the massive release of the carbon stored in soils and peatlands (Lenton *et al.* 2008; Chen *et al.* 2011). Recent evidence demonstrates a high susceptibility of boreal carbon stores to disturbances driven by both climate change and development (Bradshaw *et al.* 2009; Balshi *et al.* 2009; Seedre *et al.* 2011). In recent decades, large regions of the boreal zone have also become net carbon sources, challenging assumptions that the entire region will continue to store more carbon than it emits over the coming centuries (Metsaranta *et al.* 2010). Both the pace and nature of the trend, i.e., boreal forests converting from a carbon sink to a source, appear to be driven largely by the relatively greater rates of warming that have occurred and continue to occur across northerly latitudes. This warming has been particularly noticeable, when compared to other regions of the globe, during the 20th century and especially during the latter decades (IPCC 2013). The IPCC (2013) also reports that expected temperature increases toward the end of the century in the boreal zone will continue and may reach 8°C, depending on the emission scenario used.

The mechanisms driving the loss of the boreal ecosystem's function as a carbon sink include increases in the severity and frequency of fire over recent decades (Flannigan *et al.* 2009; Mann *et al.* 2012), and projections indicate ongoing increases in fire frequency over the coming century as warming continues across the boreal zone, leading to a doubling or more in carbon emissions (Balshi *et al.* 2009). Greater incidence and frequency of fire is also tied to increased melting of permafrost (Grosse *et al.* 2011) that, along with climate-mediated changes in vegetation, are projected to alter permafrost distribution (Schuur & Abbott 2011) with a substantial loss of deposits throughout much of the boreal forest (Hicks Pries *et al.* 2012). Most models also suggest more intense and frequent insect outbreaks (Kurz *et al.* 2008a, 2008b) that will extend north of areas where most defoliation has traditionally occurred (Candau & Fleming 2011; Régnière *et al.* 2012) along with a greater likelihood of drought (Peng *et al.* 2011; Figure 2). For example, 73% of Alaskan permafrost terrain is vulnerable to subsidence upon thawing because of its variable-to-high ice content (Schuur &

Figure 2 Top: Forest fire in Alaska (Photo: La'ona DeWilde, University of Alaska Fairbanks). Bottom: Spruce budworm (*Choristoneura fumiferana*) attack on white spruce forest (*Picea glauca*) of northern British Columbia (Photo: Troy Lockhart, British Columbia Ministry of Forests).

Abbott 2011), likely leading both to areas of increasing wetness that become methane sources (Zhuang *et al*. 2007) and to dry areas that are more prone to wildfire and insect outbreaks (Kasischke *et al*. 2010). There has also been an increased harvest of boreal forests to provide timber products (Potapov *et al*. 2011), as well as supporting an expanded use of forest biomass as a substitute to mitigate the impact of burning more energy-intensive fossils fuels (Poudel *et al*. 2012).

Given these trends and the increasing likelihood of the boreal forest having its key carbon-mitigating potential erode, we discuss the necessity of including policy options for sustainable development, conservation, and climate change mitigation specific to boreal forests in future climate negotiations. Our goal is thus to identify current policy obstacles and illuminate possible future solutions to increase policy alternatives open to decision makers (Pielke 2007).

Ecosystem services provided by the boreal zone

The boreal forest biome is a major global carbon storage pool (at least 600–1000 Pg C), comparable to tropical forests in both total amount of carbon stored and carbon density (Dixon *et al.* 1994; Tarnocai *et al.* 2009; Pan *et al.* 2011). However, these estimates are likely conservative, given the generally limited accounting of subsurface carbon in most carbon models. A substantial carbon storage role is played by boreal soils, particularly deposits in permafrost and peatlands (DeLuca & Boisvenue 2012), with soil organic matter accounting for as much as 84% of boreal carbon (Malhi *et al.* 1999). More recent estimates of peatland carbon accumulations (Yu *et al.* 2010) even compare with tropical soils (Pan *et al.* 2011).

Despite relatively sparse human populations compared to most other major biomes of the world, boreal biodiversity is increasingly threatened as a result of timber, oil, and mineral extraction, as well as hydroelectricity production (Bradshaw *et al.* 2009). Forest harvesting has resulted in decreased cover and greater fragmentation, especially of old-growth forests, and an alteration of the forest landscape, leading to loss of biodiversity and ecosystem services (Cyr *et al.* 2009; Kuuluvainen 2009). Today, roughly half of the boreal forest biome has been subjected to human industrial activity of some kind, including forest management (Potapov *et al.* 2008a, 2009).

The boreal region is also home to marginalized and/or indigenous cultures that depend on forest goods and services for their livelihoods and cultural integrity (Chapin *et al.* 2004). Members of these communities are proud of their capacity to adapt when given opportunities to engage in decisions about how boreal responses to climate change might be managed (Chapin *et al.* 2008). However, many of the communities are already feeling the impacts of climate change, for example, as erosion from permafrost thawing forces people to relocate at considerable economic and social costs (Huntington *et al.* 2012).

Boreal forests provide many ecosystem services, including provisional (e.g., timber, berries, mushrooms, fish, meat), regulating (climate, clean water), and cultural (recreation, aesthetics, spiritual) services, and are home to the organisms that support this biowealth (Burton *et al.* 2010). Similar to other forests in the world, the appreciation of multiple goals in boreal forest management has been hampered by a narrow policy focus on provisional services (timber) and the lack of a multidisciplinary framework that recognizes important social and cultural aspects of forest management (e.g., Bennett *et al.* 2009).

Obstacles

In contrast to many tropical nations, the relatively wealthy boreal countries are well positioned to implement innovative management approaches and to respond to changing environmental conditions and societal demands. Over 98% of the boreal forest lies within the borders of just six nations (Figure 1); all have functioning political systems, long-established forest inventories and management infrastructure, well-developed markets for wood-based products, and technical forestry expertise. Thus, we ask: what specific obstacles currently prevent boreal forests from taking a more prominent role in the global agenda on climate politics and sustainable development?

Weak incentives

The Kyoto Protocol framework is arguably the most important international agreement regulating country emissions of greenhouse gases. However, the framework fails to provide effective incentives for countries to maximize carbon sequestration (carbon stock changes) in standing forests and in harvested wood products. Effectively, only about 6–7% of the world's forests are under the jurisdiction of the framework (Ellison *et al.* 2013). To respond to the climate change mitigation challenge, this must change.

Although the framework does allow countries to collect carbon credits for forest-based carbon sequestration (in particular, through the net gains resulting from national afforestation, reforestation, and deforestation; Art. 3.3), it strictly limits the eligibility for credits under the forest management sector (Art. 3.4). The timber-rich boreal region is strongly disadvantaged by this accounting system (Ellison *et al.* 2013). In addition, both the restricted level of credits (the so called "cap"), and the recent introduction at the 2011 COP17 in Durban of "Forest Management Reference Levels," act as barriers. The cap sets the maximum allowable amount of carbon credits under the forest management sector, whereas the reference levels are the binding levels at which countries have voluntarily committed to achieve forest growth, but which remain ineligible for carbon credits. Both of these changes restrict eligibility for carbon credits irrespective of the carbon sequestration potential in each country. In comparison, the California Forest Protocol, the California Carbon Trading system and also New Zealand, impose no such limitations on the eligibility for forest-based carbon credits. Further, the exemption of important carbon pools from accounting (such as those contained in unmanaged forests, peatlands, and permafrost) fails to encourage preservation and conservation practices, potentially contributing to increased climate change-related emissions from these sources (Cowie *et al*. 2007; Anderson *et al*. 2009; Ellison *et al*. 2011, 2013).

The implications of the post-Durban carbon accounting rules, assuming all timber-rich boreal countries would sign up for the second Kyoto Commitment period 2013–2020, are such that up to 78% of forest carbon sequestration potential would remain nonincentivized (see Ellison *et al*. 2013 for details; Figure 3; all countries except Canada, Russia, Japan, and the United States has currently signed up). However, strong incentives remain in place to use biomass for energy purposes because emissions from bioenergy are considered carbon neutral by all potential developed countries (except in the United States). Countries with highly developed forestry sectors under intensive management, such as Finland and Sweden, are exceptionally disadvantaged by this incentive gap.

Knowledge lock-ins

Paradoxically, the apparent advantages to circumboreal countries in having established strong and effective governance systems and a long tradition of forestry have become obstacles to change. Because forests represent a key natural resource in many boreal countries, forestry research and education institutions have a long and revered history. For example, Sweden first regulated forest use in the 13th century, established a forest institute in Stockholm in 1828 to educate forestry professionals (including those sent overseas), and implemented the first forest conservation laws in 1886 (Puettmann *et al*. 2009). After World War II, rapidly expanding forest industries became the backbone of economies in many boreal countries, which further strengthened the societal and political position of forestry organizations. In many of these countries there has been a long-held emphasis on an even-aged timber management model of forestry (Puettmann *et al*. 2009). This management regime was justified with the misconception that frequent large stand-replacing fires dominate disturbance regimes all across the circumboreal forest (Cyr *et al*. 2009; Kneeshaw *et al*. 2011). Hence, management based on clear-cut harvesting and even-aged management was considered as ecologically sound and it became the management standard (Lundmark *et al*. 2013). Although the justifications for such a monolithic management regime have been seriously undermined by ecological research (McRae *et al*. 2001; Bergeron *et al*. 2002; Kneeshaw *et al*. 2011), and its ecological disadvantages have become more evident (Thorpe & Thomas 2007; Kuuluvainen 2009), it continues to be the most common management regime in the boreal region.

The success of this management regime in providing sustained and increasing yields for the timber industry in Scandinavia led to a widespread acceptance of this approach in other boreal countries (Burton *et al*. 2003). For example, foresters in Canada and the United States have viewed Scandinavian forest management as an example of successful forest management for a long time (Andrews 1872; Fernow 1911). This early success from efforts to increase timber production further affected forest policies such that much research and education focused on optimizing the efficiency of this regime, although little attention was paid to alternative viewpoints and management methods (Puettmann *et al*. 2009; Kuuluvainen *et al*. 2012; Kuuluvainen & Grenfell 2012), such as an emphasis on biodiversity (Spence 2001), alternative resource uses including recreation (Adamowicz *et al*. 2003), or the inclusion of carbon or habitat credits (Burton *et al*. 2010). Explicit methods to quantify tradeoffs among different management goals are also rare (Burton *et al*. 2013), as are the appropriate policies to accommodate them. This has resulted in a "lock-in" of experts to their traditional approaches and paradigms of thinking and working (Puettmann *et al*. 2009).

Worse still, self-confidence within boreal countries regarding their own capacities for sound and sustainable forest management (see e.g., the Canadian Boreal Forest Agreement and Canada's Forest Strategy for 2008 and beyond) has minimized the direct influence of international agreements. Instead, these treaties are regarded as unwarranted external interference, in comparison with indirect pathways of change (e.g., certification) whose impacts can be mediated by domestic politics (Bernstein & Cashore 2010). This overconfidence in the adequacy of domestic industry-oriented policies to meet the challenges now facing boreal forests has resulted in a mismatch of science, research and policy, and produced potentially premature decisions that "lock-in" to relatively inflexible, long-term management regimes (Collingridge & Reeve 1986; Thorpe & Thomas 2007). These are path-dependent (for instance, through investments in forest industries and infrastructure), and will be increasingly expensive or even impossible to reverse without substantial social and economic discomfort.

Solutions

Solutions to these obstacles must address policy change at all scales: from the management of forest stands through to engagement in international agreement processes. A necessary precursor, however, is that the importance of

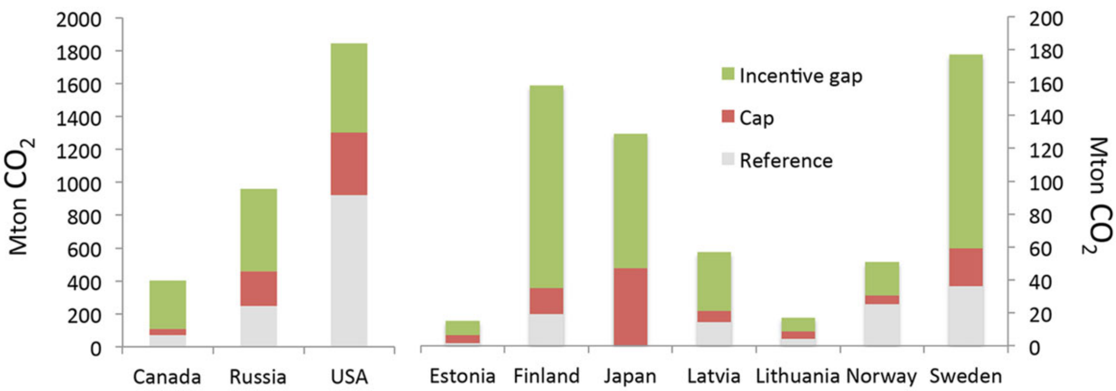

Figure 3 Three levels of estimated forest growth as incentivized under the Second Kyoto Commitment Period (2013–2020). The reference refers to the levels of forest growth countries have committed to achieving voluntarily (and for which they will not be eligible for credits; i.e., the so-called *Forest Management Reference Level*). The Forest Management cap is the maximum allowed amount of carbon credits for net removals in standing forests and the harvested wood products carbon pool. The nonincentivized segment (green bars) illustrates potential forest growth, i.e., that which could arise as a result of forest management, but is not currently incentivized in the Kyoto Framework. Note that the data refer to all forested area under Arts 3.3. and 3.4. The total forest area in individual countries is larger than the boreal area, and considerably so in the United States. However, current accounting procedures do not allow for separation of data. Data from Ellison *et al*. (2011, 2013, and unpublished).

boreal forests in climate change mitigation and biodiversity conservation be recognized at the global level. Recognition of the considerable potential that the boreal region offers for climate change mitigation, for instance through high rates of carbon sequestration in managed, young-stand landscapes (e.g., Hyvönen *et al*. 2007; Seedre *et al*. 2011), carbon substitution using harvested wood products (e.g., Sathre & O'Connor 2010; Poudel *et al*. 2012), or long-term increases of carbon storage in old-growth forests and their soil (at least in the absence of fire; Wardle *et al*. 2012), is essential to progress. Further, acknowledgment of the risks of large increases in climate- and development-driven carbon emissions from this region if current trends continue is also necessary. We propose three policy recommendations to minimize these risks.

Remove impediments and perverse incentives

It is necessary to extend national and United Nations income and product accounts to include environmental flows and natural assets (Kinzig *et al*. 2011), including all forest carbon pools as well as carbon stored in permafrost (Cowie *et al*. 2007). This will necessitate a much more extensive and rigorous assessment of belowground carbon than is available today (Chapin *et al*. 2006). By accounting for the full suite of expected impacts of climate disruption in forest management practices, it would be possible to develop more cost-effective and balanced uses of forest resources for climate change mitigation and adaptation. Adequately promoting carbon sinks in the Kyoto framework by eliminating the incentive gaps (in particular by removing caps on carbon credit eligibility) and the excessively complicated reporting and monitoring requirements (cf. van Oosterzee *et al*. 2012) could encourage better carbon sequestration in countries with considerable forest resource potential. Further, by firmly integrating forest-based resources into the climate policy framework, the European Union, Canada, the United States, and the post-Kyoto Protocol could improve the effectiveness of policy implementation. With these types of incentives, improved quantification of forestry impacts on climate, and reporting requirements in line with other sectors, the long-standing forest management traditions in the boreal region could be leveraged more efficiently and effectively, thus making a contribution toward achieving global climate targets. Admittedly, achieving such goals remains an uphill political battle, and "progress" in the Kyoto Protocol framework has been glacial at best. But the urgency brought about by the climate challenge continues to grow, ever increasing the potential attractiveness and thus political feasibility of such strategies.

Develop novel management policies and methods

New policies and management methods are needed that more fully support and integrate the socioeconomic needs of local communities, long-term carbon sequestration, biodiversity conservation, and the provisioning of a wide array of ecosystem services, including those of high economic importance. This will require the use of a wider variety of forest management and silvicultural options (Warkentin & Bradshaw 2012) and implies a shift away from the focus on stability and simplicity that is underlying the current management regime. A revised setting of priorities may necessitate the greater use of deliberative and collaborative management methods (e.g., Stacey *et al.* 2013). More holistic policies could, for instance, incorporate carbon credits or habitat payment schemes (e.g., biodiversity banking), thereby encouraging partial or small-scale harvest operations that emulate natural disturbance regimes in many boreal regions (Bergeron *et al.* 2002; Kneeshaw *et al.* 2011; Kuuluvainen & Grenfell 2012). This would compensate private landowners and local communities for possible reductions in harvest rates where carbon storage is prioritized.

Currently, payment for ecosystem services schemes are not mainstreamed within national forest policy frameworks in boreal settings, resulting in missed opportunities. Alternatively, land-sparing approaches where forest management is intensified in some areas, combined with the establishment of protected areas for biodiversity or for the delivery of cultural services (e.g., berry production or recreation) in others, could be implemented where ownership structures allow (Chapin *et al.* 2007; Messier *et al.* 2009). Further, marketing incentives that emphasize the sustainable use of a wide variety of forest products by local or indigenous communities, including developing markets such as bioenergy or nature tourism, could lead to a diversity of locally adapted management approaches (Chapin *et al.* 2008). Finally, the potential for substitution of fossil fuel-based materials and energy with forest products (e.g., cellulosic biofuels) needs to be better evaluated, including how markets can be developed, and how an increased demand for forest products might affect other ecosystem services. Diversity in management approaches and tools, together with supporting policies would also enhance adaptability, resilience, and thus long-term economic sustainability for private forest owners, local communities, indigenous cultures, and regional and national economies (Biggs *et al.* 2012).

Forest management has a key role to play in reducing the negative impacts of greenhouse gas emissions through targeted management. For instance, Terrier *et al.* (2013) suggested that approaches aiming to increase the proportion of deciduous tree species in the landscape can greatly reduce the risk of wildfires in boreal landscapes. In the tropics, successful control of the timing and intensity of wildfire can also generate substantial carbon benefits (Bradshaw *et al.* 2013), and there is no reason why similar approaches cannot be employed in the boreal zone. Management that focuses on mixed forests could also have additional advantages. Jactel & Brockerhoff (2007) demonstrated reduced herbivory in mixed stands compared to monocultures, and Gamfeldt *et al.* (2013) found positive relationships between tree species diversity and six other ecosystem services, including tree growth and carbon storage. A stronger focus on mixed forests will thus increase resilience by enhancing a response diversity toward disturbances in more diverse forest communities (see e.g., Thompson *et al.* 2009) .

On the other hand, management focused on a single ecosystem service may exacerbate negative climate change impacts. For instance, fire suppression strategies in British Columbia, Canada increased the proportion of mature lodgepole pine (*Pinus contorta*), which in combination with a changed climate (fewer extreme cold events), triggered the large-scale outbreaks of mountain pine beetle (Taylor *et al.* 2007), which in turn changed the forest from a net carbon sink to a source (Kurz *et al.* 2008a; Burton 2010).

Some of these efforts might thus have win-win outcomes, for instance by providing old-growth habitats that are indispensable for biodiversity preservation (Bradshaw *et al.* 2009), while at the same time maintaining a wide array of ecosystem services and encouraging optimal carbon storage (Stephenson *et al.* 2014). However, other combinations of strategies require decisions on trade-offs, making it important to develop more holistic management strategies where both synergies and trade-offs are considered (Puettmann 2014).

Maintain options for the future

Ongoing policy development and implementation should aim to sustain or enhance system resilience and the capacity to retain ecological and social functions in the face of shocks and surprises. New policies should aim to foster two specific characteristics: (1) the ability to respond quickly and effectively to change, including keeping policy and management options open, and (2) the maintenance of biodiversity, ecological processes and a sufficient amount of intact primary forest within reserves, thus increasing the safe space for operating (Bradshaw *et al.* 2009; Walker & Salt 2012; Biggs *et al.* 2012; Messier *et al.* 2013). The first of these maybe be achieved by, for example, fostering leadership, trust, and social networks within forest management institutions as well as more flexible decision making processes (Longstaff & Yang 2008). Key to securing both of these elements is diversity and redundancy at various scales and hierarchies: in institutions and governance (e.g., through legislation that will facilitate the adoption of different management regimes), in the actual management regime implemented (see e.g., the discussion on even- vs. uneven-aged management in the Nordic countries; Kuuluvainen *et al*. 2012), as well as in maintaining a high biological diversity to increase the capacity of the forest to respond to disturbances (e.g., Thompson *et al*. 2009). There is also a need to improve methods and models of decision-making and eliminate overconfidence in the current paradigm by developing more reflexive and adaptive methods which facilitate experimentation, learning and the maintenance of options, such as adaptive management (Rip 2006; Klenk *et al*. 2011; Rist *et al*. 2013). In particular, such methods will have to be made relevant to the industry that is expected to implement them (Paavola & Hubacek 2013).

These recommendations require that boreal forest policy and management are fully integrated into global climate policy processes. The three largest boreal countries, Canada, Russia, and the United States, must be encouraged to return to international climate negotiations as soon as possible, restoring the link between international efforts and domestic policy making that directly impacts such a large portion of the remaining global forests. Further, efforts must be undertaken to further align the currently skewed and diverse approach to forests in the international climate policy frameworks. Actions such as those we suggest could mitigate some of the effects of climate change and thus reduce the risk of large releases of carbon stored in soils, permafrost, and peatlands, and the resulting positive feedbacks. In the face of high uncertainty over climate change and its interactions with other human-driven sources of disturbances, one simple measure emerges as a candidate: as an initial approach, the protection of large, relatively undisturbed boreal ecosystems in Russia, Canada, and the United States, combined with thorough assessments of alternative mitigating strategies in the more intensively managed areas of Fennoscandia, could be implemented. This would provide the first step and would keep global climate change policy options open.

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