Advanced Review

Adapting forest certification to climate change

Nicole L. Klenk,[1]* Brendon M. H. Larson[2] and Constance L. McDermott[3]

In the context of climate change, the forest sector must consider the extent to which sustainable forest management enables or constrains climate change adaptation and mitigation; it may be that existing values and principles, policies and decision-making processes, and institutions are no longer appropriate. Forest certification has emerged as an important arena for setting international and regional standards for forest management, but it is unclear to what extent it supports or helps develop adaptive capacity for climate change in the forest sector. This paper, therefore, combines a review of the literature on forests and climate adaptation with a systematic assessment of the Forest Stewardship Council Criteria and Indicators (in detail) and other forest and carbon certification schemes (in brief) to shed light on the role of certification standards in mediating forest and climate adaptation strategies. © 2014 John Wiley & Sons, Ltd.

How to cite this article:
WIREs Clim Change 2014. doi: 10.1002/wcc.329

INTRODUCTION

Forest certification has emerged as an important arena for setting international and regional standards for forest management, backed by multi-stakeholder decision-making processes. While to date certification has grown much more rapidly in temperate and boreal regions, than tropical ones,[1] researchers have noted its potential to influence forest policy worldwide.[2] Although certification standards aim to improve performance across a range of environmental and social issues, it is unclear to what extent they support or help develop 'adaptive capacity' for climate change.[3] For instance, the extent to which the globally recognized Forest Stewardship Council (FSC) Principles and Criteria[4] (P&C) address and/or reflect proposed climate change strategies in forestry is an open question.

*Correspondence to: nicole.klenk@utoronto.ca

[1]Physical and Environmental Sciences, University of Toronto Scarborough, Toronto, ON, Canada

[2]Department of Environment and Resource Studies, University of Waterloo, Waterloo, ON, Canada

[3]Environmental Change Institute, School of Geography and the Environment, University of Oxford, Oxford, UK

Conflict of interest: The authors have declared no conflicts of interest for this article.

It should be noted that the FSC was instituted in the early 1990s as a response to the failure of the Earth Summit in Rio to produce a legally binding commitment on forest management. Established to provide a worldwide forest certification system, the FSC was developed at a time when climate change awareness and knowledge was limited. Nevertheless, since the early 1990s knowledge on this topic has grown, as reflected in four Intergovernmental Panel on Climate Change Assessment Reports, and the topic of climate change has risen to the forefront of natural resource management and biodiversity conservation. Furthermore, a growing array of forest-related carbon standards have since emerged with climate as their primary focus. This paper, therefore, combines a review of the literature on forests and climate adaptation with a systematic assessment of the FSC (in detail) and other key forest and carbon certification schemes (in brief) to shed light on the role of certification standards in mediating forest and climate adaptation strategies. While these various schemes differ in their primary aims and degree of explicit focus on climate, all of the schemes hold in common a concern for long-term, responsible forest management. Thus adaptation to climate change is by definition relevant to all of the schemes under analysis.

CLIMATE CHANGE AND FOREST MANAGEMENT

Climate Change Strategies

Four broad climate change strategies have been repeatedly put forward in the forestry literature: resistance, resilience, response and, mitigation.[5–12] The first three strategies focus on adaptation to climate change. Resistance in forestry, for example, entails trying to maintain the compositional, functional, and structural identity of a forest despite pressures due to environmental change. A resilient response, in contrast, seeks spontaneous adaptation through natural succession and species migration but does not actively assist in forest adaptation to climate change. Resilience theory suggests that ecosystems persist within a range of critical controlling variables and climate change may cause ecosystems to shift into new states in which these variables have different values[13] (e.g., the transformation of a forest into a grassland due to persistent drought). Resilience thinkers stress the need to anticipate these thresholds when ecosystems are likely to undergo significant change of identity. A resilient approach involves assessing and managing the vulnerability of the forest and accepting inevitable surprises and uncertainties in managing it due to the complex and dynamic nature of social-ecological systems.[14] The third of the climate change adaptation strategies involves actively responding to and facilitating change in forest ecosystems. This strategy entails the use of silvicultural practices to change stand structures and composition to enable the forest to more quickly adapt to climatic change impacts than it otherwise would by natural processes.

The final category focuses on mitigating climate change by (1) enhancing carbon storage in forests; (2) reducing greenhouse gas emissions from operational activities in forest management (e.g., planning road development and decommissioning, long rotations, large tracks of mature forests); and (3) facilitating the development of new markets and technologies for the use of forest products made from lower quality wood or different forest species.

Recommendations for Climate Change Adaptation and Mitigation in Forestry

A literature review of academic journal articles and reports from government (Canadian and United States) and non-government organizations (e.g., CIFOR, IUFRO, and other environmental non-governmental organizations) resulted in a list of 92 recommendations for climate change adaptation and mitigation measures in forestry. We have organized these recommendations into 10 broad areas of concern, and within these areas we categorized the recommendations into the four climate change strategies (e.g., resistance, resilience, response, and mitigation). However, note that the categories may overlap and recommendations may fall within more than one category.

BOX 1

ASSISTED MIGRATION OF SPECIES AS A RESPONSE STRATEGY

The assisted migration of species was proposed several decades ago as a means of addressing the impacts of climate change on species populations within protected areas.[15] While its risks and benefits have been debated in the conservation biology and forestry research communities, and suggestions for planning and management provided, there is little consensus within the academic literature over whether to adopt it or not as a policy option.[16,17] The use of assisted migration in forestry, however, appears to be less contentious than in conservation biology, where it has been proposed as a species rescue strategy in response to climate change impacts and projections. In forestry, the potential use of assisted migration mainly targets widespread commercial tree species and seeks to change forest regeneration practices to protect the genetic diversity of these trees by moving populations of species within their historic range or slightly beyond this range.[18] The assisted migration of populations of commercial tree species and assisted range expansion are Response strategies that are consistent with the 'spirit' of the FSC International P&C. However, they may not be entirely consistent with the current FSC International P&C, depending on how 'natural' forests and 'endemic' species are defined. These adaptation options would also require reconsidering the role of plantation forestry in adapting forests to future climate as well as discussing the merits of current ideas about the 'natural' composition of forests and landscape scale planning objectives integrating new environmental values (e.g., carbon management).

For concision, the tables of results also indicate which, if any, of the FSC International P&C are related to each recommendation, though that does not mean they support the recommendation.

TABLE 1 | Recommended Climate Change Measures Broadly Related to Forest Values

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Diversify society's portfolio of forest assets	1, 2, 3	19—21	P5C5.1, P6C6.1, P7C7.1
2. Redesign and or implement institutions that facilitate cost effective and economically efficient adaptation	1, 2, 3	19,20	
3. Modify objectives for sustainable forest management and the means we use to achieve them	2, 3	19,22,23	P1C1.8, P5C5.3, P7C7.3
4. Engage the public in a dialog on forest values under a changing climate	2, 3	6,19—22,24	P3C3.5, P7C7.4, P9C9.1
5. Provide alternative coping mechanisms for vulnerable communities	1, 2, 3	21	P3C3.3, P4C4.1
6. Generate means to provide private owners with economic flexibility if they choose to use their land for forestry	1, 2, 3	21	P9C9.2
7. Enhance local welfare through the promotion of community-based forest management and restoration	1, 2, 3	21	P3C3.3, P4C4.4
8. Improve community wellbeing through partnerships	1, 2, 3	21	P3C3.3, P4C4.3, P5C5.4
9. Increase public participation in decision-making and planning	1, 2, 3	21	P4C4.1, P7C7.6, P9C9.1

Forest Values

The recommendations in the category of 'forest values' refer to strategic level, long-term planning, and policy directives, forest governance arrangements, and the social aspects of forestry (e.g., community wellbeing) (Table 1). Most of them can be assigned to one of the three climate change strategies, except for recommendations to engage in public dialog on forest values and changing forest values and to modify objectives for sustainable forest management, which might be considered either Resilient or Response strategies.

Preparing for Disturbance

The recommendations in this category mostly focus on climate change impacts on forest disturbances and their implications for forest management planning. Of the 10 recommendations in this category, all but 3 can be equally assigned to resistance, resilience, and response strategies (Table 2). Those recommendations that stress anticipating and preparing for change in ecosystem dynamics support letting change occur or facilitating change and thus fit within the resilience and response strategies.

Forest Composition

The recommendations in this category refer to questions about which forest species should be maintained, protected, or favored (Table 3). This category includes recommendations on species and genetic diversity (vis-à-vis adaptation potential) as well as ecological benchmarks and their associated values. Several recommendations fall within the strategy of resistance by aiming to maintain current forest composition despite successional pressures toward novel forest composition. It is in this category, however, that the largest number of pro-active response strategies occur.

Forest Regeneration

The recommendations in this category include revising site regeneration objectives and practices, modifying seed provenances, changing the objectives of breeding programs, using genetically modified species and establishing new mixes of native species ('neo-native forests') (Table 4). This category also includes a large number of recommendations that fit within a strategy of pro-active adaptation measures. Most of the recommendations for forest regeneration raise questions about ecological design of future forests and the silvicultural practices that may facilitate desirable species.

Harvesting

In this category, recommendations are focused on harvesting practices (Table 5). Most of the recommendations can be used across all three climate

TABLE 2 | Recommended Climate Change Measures Broadly Related to Preparing for Disturbance in Forest Management

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Monitor to determine when and what changes are occurring	1, 2, 3	[10,19]	P6C6.2, P8C8.1, P9C9.4
2. Adopt risk assessment and adaptive management principles	1, 2, 3	[19–21,23,25,26]	P8C8.3
3. Agree on standardized climate scenarios for analysis	1, 2, 3	[19]	
4. Include climate variables in growth and yield models, timber supply analysis, and forest management plans	1, 2, 3	[6,11,19–21,24]	P7C7.1
5. Anticipate surprises and threshold effects	2, 3	[7]	P8C8.2, P9C9.4
6. Anticipate variability and change and conduct vulnerability assessment	2, 3	[20,21]	P8C8.2, P9C9.4, P10C10.9
7. Foster learning and innovation	1, 2, 3	[20,21]	P8C8.3
8. Prepare for changes in disturbance regimes	2, 3	[6,12,19,21,27,28]	P10C10.9
9. Minimize or mitigate other threats or stresses	1, 2, 3	[6,10,19–23,26,27,29]	P6C6.3, P10C10.9
10. Actively manage forest disturbances	1, 2, 3	[20,21]	P10C10.7

TABLE 3 | Recommended Climate Change Measures Broadly Related to Forest Composition

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Adjust species composition	3	[6,9,11,19,21,24,25,30,31]	P6C6.6, P10C10.3
2. Rather than focusing only on historic distributions, spread species over a range of environments according to modeled future conditions	3	[22–24]	P6C6.6
3. Anticipate and respond to species decline	3	[27]	P9C9.1
4. Expand genetic diversity guidelines	3	[7,28]	P6C6.6, P10C10.2
5. Increase species and genetic diversity in plantations	3	[21,24]	P6C6.9
6. Maintain diverse gene pools	1, 2, 3	[5,20,21,24]	
7. Prioritize and protect existing populations on unique sites	1	[27]	
8. Continue managing invasive species	1, 2, 3	[11,12,20–22,24,26,27,30,31]	P10C10.3
9. Identify and protect functional groups and keystone species	1	[5,20,21]	P9C9.1
10. Consider loss of species' population on warm range margins and do not attempt restoration there	2, 3	[28]	
11. Translocate species	3	[22,25,27,29]	P10C10.3
12. Study response of species to climate change	1, 2, 3	[29]	

TABLE 4 | Recommended Climate Change Measures Broadly Related to Forest Regeneration

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Revise site regeneration objectives	3	7,11,20–28,30,32	P10C10.1
2. Practice high-intensity plantation forestry in selected areas to promote growth of commercial tree species	3	20,21,24	P6C6.9
3. Modify seed transfer zones/seed provenances	3	6,7,9,11,12,19–21,24–28	P10C10.2
4. Maintain seed or nursery stock of desired species for use following severe disturbance	2, 3	21,22,27	
5. Enrichment sowing and supplemental regeneration	1, 2, 3	12	P10C10.2, P10C10.5
6. Shift planting season	1, 2, 3	12	P10C10.2
7. Establish or encourage new mixes of native species ('neo-native forests')	3	7,12,20–23,27,28	P10C10.3
8. Use variable density thinning in dense young stands to provide more resources to surviving individuals and promote resilience and species and structural diversity	1, 2, 3	21,23,28	P10C10.5
9. Facilitate natural selection and evolution by managing the natural regeneration process to enhance disturbances that initiate increased seedling development and genetic mixing	2, 3	12,26,28	P10C10.5
10. Allow forests to regenerate naturally following disturbance	1, 2	20,21	P10C10.2
11. Plant genetically modified species and identify more suitable genotypes	3	20,21	P10C10.4
12. Breed for pest resistance and for a wider tolerance to a range of climate stresses and extremes in specific genotypes	1, 2, 3	12,20,21,24	

change strategies in forestry, but one recommendation is aimed at climate change mitigation: extended rotations.

Landscape Management

This category is a bit less coherent than the others because it includes a large number of disparate recommendations that to some extent relate to forest landscape planning (Table 6). The recommendations refer to reference conditions, landscape fragmentation, and connectivity, forest transitions to novel ecological systems, management for refugia, forest structure, and land use conversion, among other substantive issues. The recommendations span the full range of strategies.

Carbon Management

These recommendations focus on mitigation measures at the operational level of planning and decision-making (Table 7). The recommendations refer to increasing carbon storage, managing fire, and reducing greenhouse gas emissions.

Protected Areas

These recommendations refer to biodiversity conservation through managing habitats, corridors, and reserves (Table 8). These recommendations span the three climate change strategies, but some fit in a single strategy (e.g., increase reserves to protect ecosystem diversity). Most of the recommendations are at the strategic level of planning and decision-making.

Infrastructure

These recommendations refer to forest engineering concerns about issues such as the impacts of roads on forest hydrology and water quality, culvert sizing, and revising infrastructure guidelines to take into account climate change (Table 9). Most of the recommendations span the three climate change strategies.

Wood Processing

The last category only contains one recommendation, on wood processing technology (Table 10). This recommendation seeks to enable the forest sector to take advantage of changing wood quality and tree species composition under climate change.

TABLE 5 | Recommended Climate Change Measures Broadly Related to Forest Harvesting

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Be prepared to increase the amount of salvage logging	3	6,19,20	P5C5.2, P10C10.5
2. Prepare for variable timber supply	1, 2, 3	12,19	P5C5.2
3. Plan for seasonal operational limitations	1, 2, 3	7,11,12,19	
4. Develop alternative harvesting systems and implement alternative harvesting practices	3	5–7,11,12,19–21,24,26,30,31	P10C10.5
5. Shorten rotation length for increased flexibility	3	6,9,11,12,19–21,24,28,32	P10C10.5
6. Extended rotations for carbon storage and increased resilience	1, 2, 4	11,20,31	P10C10.5
7. Pre-commercial and sanitation thinning	1, 2, 3	6,12,20,21,24	P10C10.5
8. Adjust harvest schedules to harvest stands most vulnerable to natural disturbances	1, 2, 3	12,20,21	P5C5.2, P10C10.5
9. Limit harvesting operations to the winter in order to minimize road construction and soil disturbance	1, 2, 3	20	P10C10.5, P10C10.10

Summary

Out of the 92 climate change adaptation and mitigation recommendations extracted from the forestry literature and summarized above, approximately one third ($n = 32$) apply to all three climate change adaptation strategies. The other 60 recommendations adopt one or two of the strategies. To provide a more in-depth understanding of the extent to which the current FSC International Standard is consistent with climate change recommendations in forestry, in the next section we describe the extent to which FSC P&C reflect the four climate change strategies described above for each of the recommendations. We also summarize which recommendations were particularly problematic or inconsistent with the FSC International P&C.

CLIMATE CHANGE CONSIDERATIONS AND FSC CERTIFICATION

The FSC International P&C is currently composed of 10 Principles and 70 Criteria. The FSC P&C define the international norms for forestry performance, and they are updated periodically based on a process of expert review and stakeholder consultation. The application of FSC standards also incorporates regional or generic 'indicators' for measuring achievement of these norms and FSC International is currently developing a suite of generic international indicators. However, this article's analysis is restricted to the current FSC P&C (Version 5.0, 2012) as the primary normative text defining FSC goals. As reported in Tables 1–10, a little less than half of the FSC Criteria are related to more than one climate change strategy (33 out of 70 criteria), with one-third being related to all of them (25 out of 70 criteria). One in ten FSC Criteria are related solely to a Resistance strategy to climate change (7 out of 70 criteria), about 23% solely to the Response strategy (16 out of 70), and 9% of them to a Mitigation strategy (6 out of 70).

The majority of the FSC International Criteria are consistent with climate change recommendations in the literature that represent Resistance and Resilience strategies, especially regarding the objectives of protecting high conservation values (as articulated in Principle 9, on maintaining or enhancing High Conservation Values) and restoring forests to a historic benchmark. However, recommendations in the literature which refer to pro-actively assisting forest transition through species composition, structure, and function, but also ecosystem type and land-use conversion (e.g., forest to non-forest ecosystem), are problematic within the FSC framework because they depart from some of the guiding norms of the FSC P&C (e.g., restoration). For instance, some recommendations in the literature that depart from restoration principles refer to disregarding historic conditions and limiting restoration efforts that seek to recreate past ecosystem conditions. Among perhaps the most contentious

TABLE 6 | Recommended Climate Change Measures Broadly Related to Forest Landscape Management

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Maintain connectivity in a varied, dynamic landscape	2, 3	5,7,11,19–21,24–29,32	P6C6.4, P6C6.8
2. Realign management targets to recognize significantly disrupted conditions, rather than continuing to manage for restoration to a reference condition that is no longer realistic given climate change	3	20,22,28	P5C5.2, P6C6.5, P6C6.8, P9C9.1
3. Diversify risk by spreading habitats or plantations over a range of environments rather than strictly within the historic distribution	3	28	P6C6.4, P6C6.8
4. Use landscape-scale planning and partnerships to reduce fragmentation and enhance connectivity	2, 3	27	P6C6.1, P9C9.1
5. Manage for high value conservation areas	1	5,7,10–12,20–23,25–27,30,31	P6C6.5, P9C9.1, P10C10.11
6. Avoid planting new forests in area likely to be subject to natural disturbance	2, 3	21	
7. Minimize amount of edge created by human disturbances	2, 3	21	
8. Promote diverse age classes	2, 3	12,20–22,24,27,28	P6C6.8
9. Represent forest types	1	5,20,21	P6C6.5, P6C6.8
10. Increase redundancy and buffers	2, 3	5,7,20–22,28	P6C6.4, P6C6.8
11. Maintain large areas of old growth forests	1, 4	5,20,21,23	
12. Maintain forest health and diversity during transition	1, 2, 3	5–7,12,20–22,24–27,30,32	P6C6.7, P6C6.8, P10C10.10
13. Practice intensive management to secure populations of high value	1	21,29	P9C9.3, P10C10.5
14. Enhance forest growth through forest fertilization	3	20,21	P10C10.6
15. Employ vegetation control techniques to offset drought	3	12,20,21,24	P10C10.7, P10C10.8
16. Focus on high productivity sites rather than poor sites	1	24	
17. Assist transitions, population adjustments, range shifts, and other natural adaptations	3	7,10,20–24,28	P6C6.9, P9C9.3
18. Increase the colonization capacity in the areas between existing habitat and areas of potential new habitat	3	21	
19. Avoid land use conversion	1, 4	5,20,21,31	P6C6.9
20. Incorporate climate change into land use plans and consider the possibility of land use change at specific locales	3	5,6,23,24,29	P6C6.9

TABLE 7 | Recommended climate Change Measures Broadly Related to Carbon Management

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Deactivate and rehabilitate roads to maximize productive forest area and forest sinks	4	7,12,20,21	P10C10.10
2. Reduce emissions	4	7	
3. Decrease impact of natural disturbances on carbon stocks through fire management and pest management	4	20,21	P10C10.7
4. Increase the use of forests for biomass energy	4	20,21	P6C6.1, P7C7.1
5. Fire suppression to enhance carbon storage	4	20	
6. Assessment of GHG emissions from operations	4	20,21	P5C5.3
7. Fuels management and community protection	4	12,20	P10C10.11

recommendations in the literature, to the extent that they challenge customary thinking in the FSC P&C, are the use of genetically modified organisms, the use of intensive plantation forestry and the active translocation of species (i.e., assisted migration).

To grasp the significance of the level of engagement that the FSC has with climate change considerations, it is helpful to compare with forest carbon standards, which address both climate change adaptation and mitigation strategies.

FOREST CARBON STANDARDS

Recently, an array of international initiatives have emerged that focus on the role of forest carbon in climate change and mitigation. These include the intergovernmental mechanism, *Reducing Emissions from Deforestation and Degradation* (*REDD+*) under the UN Framework Convention on Climate Change (UNFCCC), and various bilateral and multi-lateral REDD+ financing mechanisms, as well as private certification schemes.[33] These initiatives in turn have generated a diversity of safeguards, operational policies, and certification standards of relevance to forest management, forest governance, and adaptation.[34]

Forest and land use carbon certification schemes that focus on climate 'co-benefits' are particularly germane to our analysis because they focus not only on carbon but on the wider array of social, economic,

TABLE 8 | Recommended Climate Change Measures Related to Protected Areas

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Adapt reserves to climate change	1, 2	31	P6C6.4
2. Increase reserves to protect ecosystem diversity	1, 2	21,27,28,31	P6C6.4
3. Protect the most acutely threatened species *ex situ*	1	5,20,21,24	
4. Increased regional cooperation in species management and protected areas management	1, 2, 3	21	P6C6.1, P9C9.2
5. Manage habitats over a range of sites and conditions, expand the boundaries of reserves to increase diversity	2, 3	27	P6C6.4
6. Maintain and create habitat corridors through reforestation or restoration	3	21,27,32	P6C6.5

TABLE 9 | Recommended Climate Change Measures Broadly Related to Forest Infrastructure

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Minimize road networks	1	[11,20,21]	
2. Adjust culvert size requirements and road design for changes in peak flow	1, 2, 3	[6,9,12,20,21]	P10C10.10
3. Develop guidelines under which restoration projects or rebuilding of human structures should occur after climate disturbances	1, 2, 3	[22]	P10C10.10
4. Avoid constructing roads in landslide-prone terrain where increased precipitation and melting of permafrost may increase the hazard of slope failure	1, 2, 3	[20,21]	P10C10.10
5. Maintain, decommission, and rehabilitate roads to minimize sediment runoff due to increased precipitation and melting of permafrost	1, 2, 3	[6,20,21]	P10C10.10
6. Ensure that infrastructure investments do not interrupt conservation or riparian corridors	1	21	P10C10.10

TABLE 10 | Recommended Climate Change Measure Related to Wood Processing

Recommendations	Strategy 1 = Resist 2 = Resilience 3 = Response 4 = Mitigation	Citing articles	Related FSC Principle (P) Criteria (C)
1. Develop technology to use altered wood quality and tree species composition, modify wood processing technology	3	[6,20,21,24,26]	

and environmental impacts of forest management. Comparing such schemes with forest certification standards can help to assess whether standards expressly focused on the forest-climate nexus may help to fill existing gaps. For this purpose the next section provides a case study of the Climate Community & Biodiversity Alliance (CCBA) Standard, currently the largest of the co-benefit standards in terms of certified area.[35,36]

The Climate, Community, and Biodiversity Alliance Standard

The social and environmental standards generated by the CCBA provide an interesting example of how to integrate climate change into the development of forest protection, restoration, and agroforestry initiatives.[37] The CCBA is a partnership of international non-governmental organizations created in 2003. It aims to leverage policies and markets to promote climate change adaptation and mitigation best practices in forestry through carbon-based projects. Planned projects represent over 9 million ha of conservation and over 450,000 ha of restoration of native forests, with total estimated annual emissions reductions of over 17 million tons annually.[37,38]

The CCBA Standards 'identify land-based projects that are designed to deliver robust and credible greenhouse gas reductions while also delivering net positive benefits to local communities and biodiversity' (Ref 37, p. 7). The 'climate section' of the requirements focuses on measuring and monitoring carbon stocks, GHG emissions, carbon 'leakages' (i.e., abnormalities in carbon accounting), carbon emissions impacts, and benefits of the project.

The 'community section' of the CCBA Standard refers to the use of appropriate methodologies for

BOX 2

OTHER FOREST CERTIFICATION STANDARDS

The most recent version of the Canadian Standards Association National Standards for Sustainable Forest Management[40] has to a certain extent integrated climate change adaptation and mitigation considerations.[3] This standard involves a combination of public participation, performance, and management system requirements and uses the Canadian Council of Forest Ministers Criteria and Indicators of Sustainable Forest Management as the basis of its sustainable forest management performance requirements (CCFM). Climate change considerations are found in the performance requirements, under the SFM criteria of 'Ecosystem condition and productivity' and 'Role in global ecological cycles'.[40] In the former criterion, the public participation process must include discussion of climate change impacts and adaptation to establish forest values and choose appropriate indicators. In the latter criterion, the public participation process must include discussion of carbon emissions from fossil fuels used in forest operations and the performance requirement must use net carbon uptake as a core indicator. Although climate change considerations have been integrated in the newest CSA Sustainable Forest Management Standard, the standard mostly supports a resistance strategy to climate change and to a lesser extent a resilience strategy.

In the United States, SFI certified area (56 million acres) is greater than FSC certified area[41] (34 million acres). In its most recent Standard (2010–2014), the SFI has begun to consider climate change adaptation and mitigation. Their climate change adaptation and mitigation objectives seem to represent a resilience strategy by focusing on best practices in sustainable forest management already present in the standard. Provisions related to climate change are tempered by the recognition that the science and regulatory framework for climate change mitigation and adaptation are still evolving. Climate change related provisions are found in:

'Performance Measure 15.3 *Program Participants* shall individually and/or through cooperative efforts involving *SFI Implementation Committees*, associations, or other partners broaden the awareness of climate change impacts on forests, *wildlife*, and *biological* diversity.

Indicators:

1. Where available, monitor information generated from regional climate models on long-term forest health, productivity and economic viability.
2. Program Participants are knowledgeable about climate change impacts on wildlife, wildlife habitats and conservation of biological diversity through international, national, regional or local programs.' (Ref 42, p. 15).

The focus of the SFI standards on climate impacts suggests a resilience focus, but in general defers to forest owners to establish their own priorities in regards to climate change.

estimating impacts on communities onsite and offsite, ways to mitigate these impacts and the selection of community-based values and variables to be monitored.

The 'biodiversity section' of the CCBA Standard involves creating a 'with project' scenario of impacts on biodiversity and comparing this to the baseline 'no project' biodiversity scenario. The indicators refer to native and non-native species, invasive species, and the prohibition against using genetically engineered species. Overall, these indicators support a strategy of resistance to climate change in protecting native species and aiming for a 'net biodiversity benefit' that uses current conditions as a benchmark.

The CCBA's Standard not only provides criteria and indicators for climate change mitigation projects in forestry, but also provides means of assessing meritorious climate change adaptation forestry projects. In particular, CCBA recognizes several levels of climate performance and the highest level, the 'Gold Level', reflects both the resistance and response strategies in forestry, seeking to protect the most vulnerable populations of species and people (note the 'pro-poor' orientation of 'exceptional community benefits'), while at the same time assisting their adaptation to climate change.

In sum, the emergence of specific forest carbon standards has helped to fill some of the gaps found in forest certification schemes, suggesting a possible role for dual certification. However the mitigation focus of CCBA and other forest carbon oriented efforts such as REDD+, risks obscuring adaptation concerns.[39] Furthermore, the proliferation of numerous forest and forest carbon standards and policies itself poses challenges for coordinated action and highlights the importance of seeking synergy among the many actors and institutions involved.

DISCUSSION AND CONCLUSION

An important challenge to customary thinking in sustainable forest management and embodied in the FSC P&C, which may need reconsideration because of climate change, is the belief (or hope) that it is possible to achieve the multiple benefits and values of forests using current best practices in sustainable forest management. However, the values of carbon management, ecological restoration, and maximizing forest products may require different and conflicting landscape management strategies. For example, should plantation forestry become a more prominent practice in forest management if it entails greater carbon sequestration, increased production of forest products and the ability to assist the migration of species? Short rotation lengths in the context of plantation forestry may provide foresters with the capacity to adapt to climate change impacts 'in real time' (e.g., a 15 year rotation length), as compared to planning for climate change adaptation in natural forest management where the rotation length can be very long (e.g., 80+ years). On the other hand, maintaining higher levels of species diversity may contribute to overall ecosystem health and resilience, and facilitate adaptation through natural selection. The current FSC International P&C offers little guidance for how to resolve conflicting values and goals in forest management with regards to climate change adaptation and mitigation.

The results of this literature review and analysis of the (in)consistencies of climate change recommendations for sustainable forest management in relation to the FSC International P&C suggests in many respects the current P&C endorse Resistance and Resilience climate change strategies. Underlying these strategies is the hope that current best practices in sustainable forest management that accord with the FSC P&C should allow forests to adapt to climate change naturally and without an overly pro-active Response strategy in forest management. This focus, while most fully elaborated by the FSC P&C, is also mirrored in other forest certification schemes. The growing array of forest carbon initiatives have contributed additional forest management standards and policies that are focused strongly on climate mitigation. These initiatives, from the inter-governmental REDD+ to private forest carbon certification schemes such as the CCBA, could contribute to filling some of the gaps found in forest certification standards. However, their focus on mitigation may also obscure concerns about adaptation. Our case study of the CCBA standard reveals the presence of some adaptation requirements, broadly defined. However, further study is needed to assess approaches to adaptation across the growing plethora of forest carbon standards. Furthermore, this multiplication of forestry standards itself poses a major challenge, and accents the importance of striving for greater synergy and coordination.

These findings also highlight key challenges for forest governance. The establishment of forestry norms, whether through state-based rule-making or multi-stakeholder standard-setting, is a socially negotiated process. As such, it does not guarantee a comprehensive or consistent coverage of key forest management issues, nor one fully informed by scientific debate. The findings of this study highlight the need for better dialog between climate and forest sciences and the multiple stakeholders engaged in setting forestry standards.

ACKNOWLEDGEMENTS

This research was funded in part by the University of New Brunswick Sustainable Forest Community-University Research Alliance grant to N. Klenk from the Social Science and Humanities Research Council of Canada (SSHRC). We appreciate research funding from a Standard Research Grant from the Social Science and Humanities Research Council of Canada (SSHRC) and an Early Researcher Award from the Ontario Ministry of Research and Innovation To Brendon Larson. We would also like to thank Dr. James MacLellan, Dr. Solange Nadeau, Roberta Clowater, Scott MacDougall, Margo Sheppard, and Greg Adams for their comments on an earlier version of the review.

REFERENCES

1. McDermott CL. Certification and equity: applying an "equity framework" to compare certification schemes across product sectors and scales. *Environ Sci Policy* 2013, 33:428–437.
2. Cashore B, Auld G, Bernstein S, McDermott C. Can non-state governance 'Ratchet Up' global environmental standards? lessons from the forest sector. *Rev Eur Commu Int Environ Law* 2007, 16: 158–172.
3. Johnston M, Hesseln H. Climate change adaptive capacity of the Canadian forest sector. *For Policy Econ* 2012, 24:29–34.

4. FSC. Principles and criteria for forest stewardship version 5, FSC-STD-01-001 (V5-0). Bonn, Germany; 2012. Available at: https://ca.fsc.org/principles-criteria.195.htm. (Accessed September 5, 2014).
5. Noss RF. Beyond Kyoto: forest management in a time of rapid climate change. *Conserv Biol* 2001, 15:578–590.
6. Spittlehouse DL, Stewart RB. Adaptation to climate change in forest management. *BC J Ecosyst Manag* 2003, 4:1–11.
7. Millar CI, Stephenson NL, Stephens SL. Climate change and forests of the future: managing in the face of uncertainty. *Ecol Appl* 2007, 17:2145–2151.
8. Millar CI, Stephenson NL, Stephens SL. *Reframing Forest and Resource Management Strategies for a Climate Change Context*. Pacific Southwest Research Station Sierra Nevada Research Center, Albany, CA: U.S. Department of Agriculture, Forest Service, Climate Change Resource Center; 2008, 8.
9. Bolte A, Ammer C, Lof M, Madsen P, Nabuurs G-J, Schall P, Spathelf P, Rock J. Adaptive forest management in central Europe: climate change impacts, strategies and integrative concept. *Scand J For Res* 2009, 24:473–482.
10. Galatowitsch S, Frelich L, Phillips-Mao L. Regional climate change adaptation strategies for biodiversity conservation in a midcontinental region of North America. *Biol Conserv* 2009, 142:2012–2022.
11. Gunn JS, Hagan JM, Whitman AA. Forestry adaptation and mitigation in a changing climate. A forest resource manager's guide for the Northeastern US. Manomet Center for Conservation Sciences Report NCI-2009-1, Brunswick, Maine, 2009, 16. Available at: https://www.manometmaine.org. (Accessed September 5, 2014).
12. Kolstrom M, Lindner M, Vilen T, Maroschek M, Seidl R, Lexer MJ, Netherer S, Kremer A, Delzon S, Barbati A, et al. Reviewing the science and implementation of climate change adaptation measures in European forestry. *Forests* 2011, 2:961–982.
13. Gunderson LH, Holling CS, eds. *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington DC: Island Press; 2002.
14. Holling CS, Meffe GK. Command and control and the pathology of natural resource management. *Conserv Biol* 1996, 10:328–337.
15. Peters RL, Darling JDS. The greenhouse-effect and nature reserves. *Bioscience* 1985, 35:707–717.
16. Hewitt N, Klenk NL, Smith AL, Bazely DR, Yan N, Wood S, MacLellan JI, Lipsig-Mumme C. Taking stock of the assisted migration debate. *Biol Conserv* 2011, 144:2560–2572.
17. Klenk NL, Larson BMH. A rhetorical analysis of the scientific debate over assisted colonization. *Environ Sci Policy* 2013, 33:9–18.
18. Pedlar JH, McKenney DW, Aubin I, Beardmore T, Beaulieu J, Iverson L, O'Neill GA, Winder RS, Ste-Marie C. Planning forestry in the assisted migration debate. *Bioscience* 2012, 62:835–842.
19. Williamson TB, Colombo SJ, Duinker PN, Gray PA, Hennessey RJ, Houle D, Johnston MH, Ogden AE, Spittlehouse DL. *Climate Change and Canada's Forests: From Impacts to Adaptation*. Edmonton, AB: Sustainable Forest Management Network and Natural Resource Canada, Canadian Forest Service, Northern Forestry Centre; 2009, 104.
20. Ogden AE, Innes JL. Application of structured decision making to an assessment of climate change vulnerabilities and adaptation options for sustainable forest management. *Ecol Soc* 2009, 14:11.
21. Innes J, Joyce LA, Kellomaki S, Louman B, Ogden A, Parrotta J, Thompson I, Ayres M, Ong C, Santoso H, et al. Management for adaptation. In: Seppala R, Buck A, Katila K, eds. *Adaptation of Forests and People to Climate Change. A Global Assessment Report*. IUFRO World Series, vol. 22. Helsinki: IUFRO; 2009, 135–185.
22. West JM, Julius SH, Kareiva P, Enquist C, Lawler JJ, Petersen B, Johnson AE, Shaw MR. U.S. Natural resources and climate change: concepts and approaches for management adaptation. *Environ Manag* 2009, 44:1001–1021.
23. Spies TA, Giesen TW, Swanson FJ, Franklin JF, Lach D, Johnson KN. Climate change adaptation strategies for federal forests of the Pacific Northwest, USA: ecological, policy, and socio-economic perspectives. *Landsc Ecol* 2010, 25:1185–1199.
24. Johnston MH, Campagna M, Gray PA, Kope HH, Loo JA, Ogden AE, O'Neill GA, Price DT, Williamson TB. *Vulnerability of Canada's Tree Species to Climate Change and Management Options for Adaptation: An Overview for Policy Makers and Practitioners*. Ottawa, Canada: Canadian Council of Forest Ministers; 2009, 44p.
25. Lawler JJ. Climate change adaptation strategies for resource management and conservation planning. *Year Ecol Conser Biol* 2009, 1162:79–98.
26. Lawrence A, Gillett S. Human dimensions of adaptive forest management and climate chance: a review of international experience. Forestry Commission Report. Forestry Commission, Edinburgh; 2011, 440p.
27. Swanson C, Janowiak M. Forest adaptation resources: climate change tools and approaches for land managers. US Forest Service technical report NRS-87. Newton Square, PA; 2012, 121p.
28. Joyce LA, Blate GM, McNulty SG, Millar CI, Moser S, Neilson RP, Peterson DL. Managing for multiple resources under climate change: National forests. *Environ Manag* 2009, 44:1022–1032.
29. Heller NE, Zavaleta ES. Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biol Conserv* 2009, 142:14–32.
30. Janowiak MK, Swanston CW, Nagel LM, Webster CR, Pali BJ, Twery MJ, Bradford JB, Parker LR, Hille

AT, Johnson SM. Silvicultural decision-making in an uncertain climate future: a workshop-based exploration of considerations, strategies, and approaches. USFS, Northern Research Station, General Technical Report NRS-81, 2010, 536p.

31. Evans AM, Perschel R. A review of forestry mitigation and adaptation strategies in the Northeast US. *Clim Change* 2009, 96:167–183.
32. Roberts G, Parrotta J, Wreford A. Current adaptation measures and policies. In: Seppala R, Buck A, Katila K, eds. *Adaptation of Forests and People to Climate Change. A Global Assessment Report*. IUFRO World Series, vol. 22. Helsinki: IUFRO; 2009, 123–133.
33. McDermott CL, Coad L, Helfgott A, Schroeder H. Operationalizing social safeguards in REDD+: actors, interests and ideas. *Environ Sci Policy* 2012, 21:63–72.
34. RECOFTC AND FAO. Forests and climate change after Doha: an Asia-Pacific perspective. Bangkok, Thailand; 2013.
35. Peters-Stanley M, Hamilton K, Yin D. *Leveraging the Landscape: State of the Forest Carbon Markets*. Washington DC: Forest Trends; 2012, 1–105.
36. Diaz D, Hamilton K, Johnson E. *State of the Forest Carbon Markets 2011: From Canopy to Currency*. Washington DC: Ecosystem Marketplace and Forest Trends, 2011, 1-93.
37. Climate, Community, Biodiversity Alliance (CCBA). *Climate, Community & Biodiversity Project Design Standards*. 2nd ed. Arlington, VA: CCBA; 2008.
38. Climate, Community, Biodiversity Alliance (CCBA). Fact Sheet. Arlington, VA: CCBA; 2011. Available at: https://s3.amazonaws.com/CCBA/Upload/CCBStandards_FactSheet.pdf. (Accessed September 5, 2014).
39. Long A. Taking adaptation value seriously: designing REDD to protect biodiversity. *Carbon Clim Law Rev* 2009, 3:314.
40. Canadian Standard Association. Sustainable forest management. A national standard for Canada. CAN/CSA-Z809-08; 2008.
41. Fernholz K, Bowyer J, Stai S, Bratkovitz S, Howe J. Difference between the FSC and the SFI certification standards for forest management. Dovetail Partners Inc. Minneapolis, MN, 2011. Available at: http://dovetailinc.org/files/DovetailFSCSFIComparison32811.pdf. (Accessed September 5, 2014).
42. Sustainable Forestry Initiative. Requirements for the SFI 2010–2014 Program. Standards, rules for label use, procedures and guidance. 2010, http://www.sfiprogram.org/files/pdf/sfi_requirements_2010-2014.pdf. (Accessed September 5, 2014).

FURTHER READING/RESOURCES

Klenk NL, Mabee W, Gong Y, Bull GQ. Forestry, governance and deforestation. In *Encyclopedia of Life Sciences*. Nature Publishing Group. London. UK. 2012. 16p. Available at: http://onlinelibrary.wiley.com/doi/10.1002/9780470015902.a0003293.pub2/abstract.

Long A. Taking adaptation value seriously: designing REDD to protect biodiversity. *Carbon Clim Law Rev* 2009, 3:314.

McDermott CL, Coad L, Helfgott A, Schroeder H. Operationalizing social safeguards in REDD+: actors, interests and ideas. *Environ Sci Policy* 2012, 21:63–72.

Merger E, Dutschke M, Verchot L. Options for REDD + voluntary certification to ensure net GHG benefits, poverty alleviation, sustainable management of forests and biodiversity conservation. *Forests* 2011, 2:550–577.