International Union of Forest Research Organizations

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FOREST AGENCIES' EARLY ADAPTATIONS TO CLIMATE CHANGE

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EXECUTIVE SUMMARY

Forest agencies around the world are expected to manage their forests not only under today's climatic conditions, but also tomorrow's. The expected impacts of climate change on particular forests are often highly uncertain, which hampers effective planning. Nevertheless, many agencies are introducing new policies and management measures to respond to the effects or the threats of climate change. This review studies the responses in fourteen countries and classifies adaptation measures under twelve headings, each with a unique set of characteristics. Although forests' adaptations are clearly still in early stages, the variety of responses discovered gives confidence that solutions are available.

Forests around the world are both vulnerable to climate change and a substantial part of a portofolio of mitigation strategies. Forest agencies are expected to deal with these uncertainties through the development of a wide range of adaptation strategies. This report seeks to determine to what extent forest agencies are changing their policies and management operations in response to current and anticipated future climate change. In order to achieve this goal, we summarize the state of the art of forest policy responses regarding adaptation to climate change in Australia, Austria, Brazil, Canada, Chile, China, Costa Rica, Finland, France, Germany, Russia, Spain, Sweden, and the United States.

The diversity of adaptation measures encountered during the expert survey and content analysis of major agency documents is clustered according to timing, temporal and spatial scope, function, and form (Table 1). The main findings resulting from the analysis are:

- Most countries are in the early stages of adaptation, mainly developing enabling programs and stimulating research.

- The prevailing functions of forests and the expected impacts shape the strategy chosen by forest agencies.

- Anticipatory measures are more frequently adopted than reactive ones, probably due to the expected long term effect of climate change in forests and the difficulty of finding evidences of actual impacts.

- In contrast with mitigation mechanisms, economic instruments are rarely developed for adaptation.

- It is difficult to disentangle adaptation to climate change from general sustainable forest management practices.

Forest agencies in the countries analyzed present different patterns and strategies regarding adaptation to climate change. The diversity of measures found is a positive aspect that suggests the availability of possible solutions. The promotion of regional collaboration in this field at an agency level might help to spread successful practices that are adapted to local conditions and encourage managers to select the most suitable options.

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Table1: Analysis matrix

Measure	Timing		Temporal scope			Spatial scope			Funtion/Effects			Form				Number of countries with example (from 14)
	reactive	anticipatory	short term	medium term	long term	policy level	forest management	stand level	resistance	resilience	preemption	informational policy	economic policy	regulatory policy	management measures	
Targetted monitoring	X			X			X				X	X				7
Enabling programmes		X	X			X				X		X				13
Altered silvicultural regimes, mid rotation	X			X				X		X					X	7
Altered silvicultural regimes, cross-rotation		X			X			X			X				X	5
Increased threat suppression capability	X			X			X		X						X	7
Increased threat protection		X		X			X			X					X	6
Increased threat prevention		X	X			X			X					X		3
Tree breeding/genetics		X			X	X					X			X		5
Altered spatial arrangenment of conservation reserves		X			X		X		X					X		1
Increased management intensity	X			X				X	X						X	2
Infrastructure development		X		X		X			X						X	2
Forest converion incentives		X			X	X					X		X			2
TOTAL	4	8	2	6	4	5	4	3	5	3	4	2	1	3	6	

CONTENTS

INTRODUCTION

Forest agencies in all parts of the world are facing challenges from expected climate change and the need for pro-active policy is clear (MacIver and Wheaton 2005). Although the particular impacts vary from region to region, there is commonality in the sense that agencies can no longer be guided simply by past and present growing conditions, but must factor in a highly uncertain climatic future (Millar et al. 2007). These decisions involve a significant level of cost and risk, and it is not surprising that agencies everywhere are moving cautiously. Nevertheless, there is progress being made in many jurisdictions, and a solid groundwork being laid in many others. This review examines policy responses from Australia, Austria, Brazil, Canada, Chile, China, Costa Rica, Finland, France, Germany, Russia, Spain, Sweden, and the United States. The countries and jurisdictions examined in this review were chosen on the basis of their importance in global forestry (forest cover, forest industry or forest science), the likelihood of their advancement in climate change adaptation (due to having high national adaptive capacity) and the availability of verifiable data. Although direct comparisons are impossible, the review will be of use to forest policy practitioners and scientists in showing the general direction of adaptation policy development in other jurisdictions. The rationale behind this selection method is to gain a maximum of information on a poorly developed and documented phenomenon, that of forest management agencies' policy adaptations to climate change. The study does not address adaptation in any African or southeast Asian countries. This is due in part to our limited access to data and networks there, and the low adaptive capacity of most forested tropical countries (see e.g. LACFC 2008; Jumbe et al. 2008).

We seek to determine to what extent forest agencies can be seen to be changing their policies and management operations in response to the need to adapt to current and anticipated future climate change. Many organizations have conducted comprehensive vulnerability assessments (i.e. Lemmen and Warren 2004; ECCP 2007; CCSP 2008) often including recommendations for policy and management responses. Similarly, there is a wealth of academic literature relating to forest's vulnerabilities (i.e. Joyce and Birdsey 2000; Hulme 2005; Kellomäki and Leinonen 2005; Lindner et al. 2008), with suggestions for remedies. These documents however rarely cite examples of adaptation methods having already been implemented.

Our focus is on policy responses and management adaptations at an agency level, those agencies being the bodies directly responsible for forest policy, management or research in each jurisdiction. National policy statements were previously reviewed by Roberts (2008); covering National Communications and National Adaptation Plans of Action supplied to the United Nations Framework Convention on Climate Change rather than forest agency, public company or Ministerial-level policy documents.

The role of forests as carbon sinks has placed forest agencies in the front line for many nations seeking to meet their Kyoto commitments and there is no doubt that successful mitigation actions will require consideration of climate adaptation (Reyer et al.

2009). The examination of agencies' greenhouse gas mitigation policies is for the most part however beyond the scope of this review. The few instances where mitigation is discussed here serve to contrast relatively well developed mitigation policies with an apparent lack of corresponding consideration for adaptation in those jurisdictions.

Other recent reviews pertinent to the general topic of forests' adaptations to climate change include a review of forest-relevant sections of the IPCC's Fourth Assessment Report (Klein and Roberts 2007), a multidisciplinary review of forests' adaptations to climate change (Eastaugh 2008), an analysis of forest policies in parts of Africa (Kelame et al. 2008) and a review of biodiversity-related issues (Mohr 2008). At the time of writing, ongoing projects relevant to this field include the European Forest Institute's literature and questionnaire-based survey (Lindner et al 2008) and the international Collaborative Partnership on Forest's Expert Panel on the Adaptations of Forests to Climate Change (Seppälä et al. 2009). The European Union's Commission of the European Communities is currently examining public submissions to their 'Adapting to climate change in Europe – options for EU action' Green Paper (CEC 2007).

In some respects a review of this nature may be premature, as the demands of the adaptation paradigm are still filtering through agencies and often have not yet reached the stage of informing forest policy. There are however some concrete examples of policy change, and there is benefit in these being communicated to others grappling with similar challenges. This review may also serve as a baseline to subsequent work, to help determine the advancement of adaptation policy over the next few years.

METHODS

To assess the degree of policy concentration on the adaptation of forests to climate change in different countries a parallel, descriptive case study design was implemented. The phenomenon for each case is the adaptation of forest management by forest agencies, and the case the respective country. In this qualitative research approach the focus is on learning from the insider's point of view, i.e. the forest agencies and forest authorities. We aim to provide a comprehensive, idiographic explanation of the adaptation of forest management to climate change in each country (de Vaus 2001). This approach does not aim for statistical generation but allows theoretical generalization, i.e. a partial generalization from the case to a broader reality. Hence, no statistical variation between adaptation strategies from different countries is assessed but the diversity of adaptation measures is studied (Kumar 2005).

Sampling within each case/ country

Within each country, the institutions responsible for forest policy, management or research were selected according to the principles of purposive and snowball sampling. Purposive sampling involves the selection of important actors or experts in the field of research by the researcher himself (Kumar 2005). In many cases the actors selected were also asked to identify and forward our request to other experts in the field. This approach is called snowball-sampling (Kumar 2005). Both sampling strategies were pursued until a saturation point in receiving information for each respective case/country was reached. The different models of forest administration make direct comparisons difficult, but the approach used here extracts a firm sense of the directions and emphases of adaptations policy in each jurisdiction. For each country, an introductory paragraph justifies its inclusion in this report and briefly explains national forest governance to indicate at what level adaptations policy could be expected.

Data generation

Where possible, this review relies on formal forest agency documentation to determine how far the agency has progressed towards making adaptation-specific policy changes. If official documentation is not available, we rely on personal communications from senior agency officials, policy practitioners and academic experts in the field. Where no real evidence is found, we present references to the jurisdiction's most recent major forest management report, and note that little or no mention of climate change adaptation is made in that document. Documentation is then subjected to a thorough qualitative content analysis, extracting and condensing adaptations-relevant material. We also conducted small expert surveys with unstructured, open-ended, non-standardized interviews via email, telephone and face-to-face with the selected persons from the different organizations. Hence, different methods (content analysis, expert survey via email, telephone and interviews) and sources (different organizations within each country) lead to a triangulation of methods and sources (see e.g. Yin 2003). The experts were then asked to verify the accuracy and comprehensiveness of our data. All

respondents to our initial information request were asked to comment on a first draft of the report, and the report revised in light of their contributions. That draft was then again being distributed to the respondents for comments before publication. In this way, we hope to provide a balanced and verifiable summation of adaptation policies in each jurisdiction studied. This approach serves to increase the internal validity of the findings and gives confidence that the review is a comprehensive and representative summary of the positions in each jurisdiction. Most respondents to our original survey are listed in Appendix 1, along with those who provided us with comments not available in published documentation.

COUNTRY REPORTS

AUSTRALIA

Australia is a federation of six self-governing states and two territories. Native forests are concentrated in the eastern states and in the southwest of Western Australia, with significant plantation developments in the state of South Australia. Total area of open and closed forest in Australia is in excess of 50 million ha (ABARE 2007). State governments are responsible for forest policy and management, except where this is limited by international agreements. The national government has nominal control of National Parks, but management of these is given over to the state environmental organizations. Policies regarding international agreements and broad industry and environmental policy are made in the national parliament, but practical forest management policies, regulation and extension services are exclusively a state issue. Australia also has a significant corporate plantation estate. Australia's current National Forest Policy Statement is a 1992 document prepared by the Department of Agriculture, Fisheries and Forestry (DAFF). The Statement does not mention climate change per se, but stresses that forest policy must be formulated in a manner that is adaptable to change in general (DAFF 1992).

Tasmania

Tasmania's state forest agency Forestry Tasmania (FT) is investigating planting new forests on degraded agricultural land, for the purpose of carbon sequestration (MBAC 2008), and establishing a bioenergy market to utilize harvest waste and minimize contentious regeneration burning. A new ten year plan is under development, which will include climate change, carbon storage, bioenergy and monitoring trends against the possibility of needed adaptation approaches.

Forestry Tasmania's published carbon policy is to: reforest after harvest, maintain forest age/growth stages, maximize wood recovery from harvest areas, promote the use of bioenergy from wood waste, protect forests against wildfires pests and diseases, encourage long-life wood products and recycling, promote research into forest carbon issues (accounting and life cycle assessment) and regularly report on forest carbon stocks (FT 2008). Forestry Tasmania recognizes that fire management procedures may need to be changed to meet a growing climate-change driven threat (Bob Gordon, Managing Director FT, media report FT 5 December 2007)

New South Wales

Early attention has focused on research into the likely impacts of climate change (supported by the Department of Primary Industries (DPI) and Forests NSW). Most research is focused on mitigation, but Forests NSW is supporting adaptation research

through their project, 'Developing Elite Trees for Economically Viable Plantations in Low Rainfall Environments of Australia' (e.g. Henson et al. 2007) and the DPI is working on the development of more resilient agricultural and forestry production systems (Fairweather and Cowie 2007).

Victoria

The Department of Sustainability and Environment (DSE) released a Green Paper on 'Land and biodiversity at a time of climate change' for public discussion and input in April 2008 (DSE 2008a). The focus of the Green Paper is firmly on preservation of existing biotypes rather than adaptation. A White Paper (statement of government policy and program directions) is expected in April 2009. The outcomes from this policy formulation process are expected to include commitments to ensure that Victoria's natural reserve system is relevant to a changing climate and that the nature and impacts of climate change are understood by planners, decision makers and the community.

Forest management practices do not appear to have been adapted specifically in response to climate change (MBAC 2008), but DSE has increased its focus on prescribed burning for fire fuel reduction and is establishing a network of strategic fuelbreaks around Melbourne's water catchments (DSE 2008b).

Corporate plantation growers

Sixty percent of Australia's plantations are privately owned, generally by large financial management corporations. Some examples of adaptation already practiced by these organizations include: thinning plantations in response to drought conditions, diversification into new growing areas in the north of the country, and trials into reducing fire risk through using harvest residues for biofuels (MBAC 2008).

AUSTRIA

Austria is a federation of nine provinces and, with a forest area of about 47 % and an annual increase in forest covered land area of about 7 500 ha, one of the most forested countries in Europe. The authority over forest legislation is held by the federal state but the execution of forest regulations is the responsibility of the regional administration at both provincial and district level. Other legal sectors regarding forests such as hunting and nature protection are exclusively within the authority of the individual province and hence competency conflicts over the forest area may arise between national and state forest legislation (Czamutzian 2000). It must also be considered that about 80% of Austrian forest is in private hands and voluntary and compulsory private forest owners' associations – the former grouped under the 'Austrian Federation of Forest Owners' Associations' – are important actors and stakeholders in forest policy making (BMLFUW 2008).

The Austrian forestry code is designed in order to 'guarantee the sustainable (economic, ecological and societal) management of the forest' but does not mention climate change (Forstgesetz Österreich 2007). The impacts of climate change on the Austrian forest and forest biodiversity as well as possible silvicultural adaptation strategies have been discussed by several authors (Lexer and Seidl 2007; Niedermair et al. 2007) and are also mainstreamed into more practice-oriented literature (BFW 2006). In 2007, 31% of all funding for research projects from the Austrian Forest Agency (ÖBf) was provided for climate change projects (ÖBf 2008). In the preparation process of the national adaptation strategy, a vulnerability assessment places the forest sector as one of the priorities that require adaptation measures (Kromp-Kolb 2008; Hojesky 2008). Similarly to other European countries, intensive traditional land use and associated degradation effects have increased the vulnerability to climate change (H. Hasenauer, University of Natural Resources and Applied Life Sciences, pers. comm. 28 November 2008).

Research focuses on the conversion of forests towards mixed, site-adapted and structurally diverse stands, changing forest management and the genetic diversity of forest stands. Some practical measures are already carried out, particularly reforestation with mixed-species stands and changed pest and wildlife management regimes (Haberl and Balas 2008; Drack 2008; Gingrich et al. 2008). Specialized adaptation strategies are not yet integrated into the forest law but the forest act enables a wide range of measures to implement adaptation strategies. As science advances and best practices evolve they become part of discussions and forest consultants integrate adaptation strategies (such as shortening rotation cycles of spruce in lower altitudes, increasing mix of tree species, focus on forest health, considerations of alternative tree species etc.) in their advices to forest owners (M. Höbarth, Austrian Chamber of Agriculture, pers. comm. 21 August 2008). The scientific community has started to develop 'down-to-the-ground' adaptation strategies in close cooperation with the state forest agency (e.g. Seidl et al. 2008). Regional subsidy schemes exist that support forest owners after catastrophic events such as storms (Landesregierung Oberösterreich 2007) or acute risks of insect mass

reproduction. Similar indirect adaptation measures are part of the Austrian forestry code. It regulates the suppression of forest pests by obliging forest owners to combat emerging mass reproductions and may enforce further measures such as felling and debarking of infected trees by decree (Forstgesetz Österreich 2007).

BRAZIL

Brazil is a federation of 26 states and one federal district. It has an area of 851 million ha (IBGE 2000) of which natural forests cover 478 million ha and planted forests 5.7 million ha. Over 210 million ha are public forests of which 185 million ha are protected areas divided into Federal and State Conservation Units and Indigenous Reserves (SFB 2008). Environmental protection, improvement and policies are managed as shared responsibilities between Union, State, Federal District and Municipalities which compose the National Environment System (SISNAMA). At the national level SISNAMA has the Ministry of Environment (MMA) as the central agency, the National Environment Council (CONAMA) as a consultative and deliberative agency and the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) as the executive agency. States and Municipalities can have complementary laws that must be in agreement with the national policy. Environmental agencies at these levels are also responsible for the implementation and monitoring of Federal, State and Municipal laws.

Forests are managed under the Brazilian Forestry Code (Law 4.771/1965), the National Environmental Policy (Law 6.938/1981) and the National System of Nature Conservation Units (Law 9.985/2000) among other State and Municipality laws. Sustainable Forest Management has been constantly emphasized in policies, as have protection, conservation and afforestation. The Brazilian Forest Service (SFB) is responsible to the MMA, and, along with the National Forest Development Fund (FNDF), was created in 2006 (Law 11.284/2006). The SFB is responsible for ensuring sustainable production from public forests through concessions.

Regarding climate change the Brazilian Climate Change Forum was created in 2000 (Decree 3.515/2000). The Interministerial Committee on Climate Change (Decree 6.263/2007) elaborates the National Plan on Climate Change (PNMC), although this is not yet formally approved. The PNMC is divided into sections (I) mitigation; (II) vulnerability, impact and adaptation; (III) research and development; (IV) capability and divulgation. Identifying environmental impacts caused by climate changes and the support of scientific research to define adaptation strategies with reduced socio-economic costs are part of the specific aims of the PNMC. The vulnerabilities, impact analyses and adaptation measures will be soon reported in the 'Second National Communication to the UNFCCC'.

For section (II) the Center for Weather Forecast and Climate Studies (CPTEC/INPE) under the Ministry of Science and Technology (MCT) is already developing the regional climate change model 'Eta/CPTEC' for South America (PNMC 2008). It is an important project because: (i) temperature and especially precipitation values estimated by Global Circulation Models have been highly uncertain and diverse under different scenarios, (ii) precipitation has been the most influencing factor on tropical region ecosystems, and (iii) the spatial and temporal scale of Global Circulation Models is limited. The development of more reliable long term climate change models with adequate regional spatial resolution and more detailed temporal resolution are

considered necessary for Brazil. The results of the 'Eta/CPTEC' model will be used to define the new adaptation measures (PNMC 2008) – respecting the country's dimension and ecosystem diversity and other differences.

The PNMC states as ongoing adaptation measures related to forests and/or relationships between communities and forests: the National Action Program to Combat Desertification and Mitigate the Effects of Drought (PAN-Brasil) (which is also developing the Early Warning System for Drought and Desertification); the Sustainable Management Program of the Plate Basin Water Resources – Considering Variability and Climate Changes Effects; the Workgroup 'Impacts of Climate Changes in Brazil' and the CONAMA role in Adoption of Adaptation Measures. Adaptations policy in Brazil is constrained by the need for socio-economic development. Understanding the connectivity between the environment, society and the economy increases overall resilience (Adger et al. 2003), and the National Plan on Climate Change includes both capacity building and direct adaptation measures (PNMC 2008).

In future adaptation measures Brazil will also be using the existing infrastructure and programs such as:

1) National Institute of Amazon Research (INPA) – develops several projects in the Amazon region such as the effects of different fire intensity on the forest;
2) Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) – international research initiative led by Brazil (INPA) which has been developing several projects in the Amazon such as the 'Dry-Forest' that simulates a 50% precipitation reduction;
3) Brazilian Research Network for Global Climate Change (REDE-CLIMA) – study alternatives to adaptation of natural systems is one of the aims;
4) State Center for Climatic Change (CECLIMA) and Nucleus for Adaptation to Climate Change and Management of Environmental Risks in the Amazonas State (State Law 3.135/2007);
5) Global Climate Changes and Biodiversity Effects – study conduced by CPTEC/INPE (PNMC 2008);
6) Climate Changes and Possible Alterations on Atlantic Forest Biome study;
7) Research Center in Degraded Soils Restoration and Desertification Combat (NUPERADE).

The environmental effects on the high flora and fauna biodiversity in the Brazilian biomes and the relationships between species are still challenges to science. Even without available modeling results from Eta/CPTEC public and private entities have been doing vulnerability studies for sectors related to biomes changes, biodiversity, costal zones and desertification among others (PNMC 2008). The National Institute for Space Research (INPE) has been doing studies on the larger Brazilian biomes' redistribution under climate change impacts (PNMC 2008).

Climate changes and deforestation could reduce Amazon forests between 30% and 60% by 2050 and increase levels of GHG in the atmosphere substantially, while

fragmentation changes the species composition and increases fire risks (Laurance et al. 1997; Nascimento and Laurance 2006). Most parts of the planned strategies for the Amazon region are classified as mitigation to climate changes through avoiding deforestation and sustainable forest management. Management alternatives using reduced impact logging have been suggested however adaptation to climate change have not been mentioned as part of the aims (Boltz et al. 2003; D'Oliveira 2000; Huth and Tietjen 2007).

The PNMC also promotes as mitigation measures: National Forest Inventory (IFN) – starting in 2009 and supervised by the SFB, sustainable forest management, agro-forestry systems, non-wood products production, National, State and Municipal deforestation control plans, afforestation on degraded protected areas and climate change information dissemination to all community levels.

CANADA

The Canadian Forest Service is part of the national Ministry 'Natural Resources Canada', but the ten provinces and three territories have constitutional control of the management of natural resources. This is a hefty responsibility, as Canada is the world's largest timber exporter, with a 2005 value of forest industry exports almost $41.9 billion. The most important Province in this respect is British Columbia in the west, although significant hardwood areas may be found in Quebec, and the Yukon and Northwest Territories have vast boreal forest areas.

National

At a national level, the primary focus of the Canadian government is on adaptation-enabling activities, specifically to raise awareness of adaptation issues, to support coordinated action, to incorporate adaptation into operational and policy decisions, to support research and communication networks and to provide adaptation planning tools (Roberts 2008). The federal ministry Environment Canada is contributing to an investment of $85.9 million aimed at supporting improved adaptation strategies (pers. comm. Jim Farrell, asst. dep. Minister, Canadian Forest Service 29 October 2008). Natural Resources Canada supports climate impacts and adaptation research through their establishment of the Canadian Climate Impacts and Adaptation Research Network (www.c-cairn.ca).

The Canadian Model Forests Network (CMFN) was established in the early 1990s to support sustainable forest management, and is active in facilitating research and information exchange regarding adaptation to climate change. Pertinent conference reports include 'Climate Change and Forests: making adaptation a reality (McKinnon and Kaczanowski 2003) and 'Communities and Climate Change Workshop: planning for impacts and adaptations' (Wainwright and Zimmerman 2006).

British Columbia

One of the most apparent symptoms of climate change in Canada is in increased incidence of serious insect infestations such as the Mountain Pine Beetle (MPB) (Carroll et al 2004). British Columbia is one of the North American regions most heavily affected by MPB and has developed a reactive action plan in response (BC Government 2006). This plan focuses on increasing timber harvest in infested areas, removing small isolated outbreaks before they can spread, developing new markets for salvaged timber and promoting diversification in affected forest communities. Timber harvest will be concentrated on stands with greater than 70% pine component, and a bioenergy market will be developed for infested timber (MFR 2007).

Improved fire management plans were put into place following the 2003 fire season, including prescribed burns, tree removal and other fuel reduction measures (BC Ministry of Environment 2004). Forests funded under the Forests For Tomorrow program

(aimed at ensuring timber supply following fires and beetle infestations) are required, where possible, to consist of a mixture of species, and use natural regeneration (MFR 2006).

The British Columbian government has established the Future Forests Ecosystems Initiative (FFEI) to develop appropriate adaptation strategies (MFR 2008). The stated objectives of the FFEI are to understand the functional constraints of key species and processes, to forecast how these may be affected by a range of climate change scenarios, to monitor those species and processes over time, to evaluate new and exiting management practices for their value in increasing forest resilience, to disseminate the results and adapt management frameworks. It is expected that it will be a few years yet before operational adaptation plans are implemented. Nevertheless, the 'capacity building' focus of the FFEI is considered to be a necessary first step in adaptation planning (Walker and Sydneysmith 2008). Spittlehouse (2008) has noted that at present there are no requirements for adaptation strategies in forest management plans, there are few guidelines or experienced personnel available and that there is a lack of funding for long-term planning. The Chief Forester has however requested interim guidelines relating to, among other aspects, the suitability of new tree species and provenances to changed climates (Dave Spittlehouse, BC Ministry of Forests and Range, pers. comm. 23 July 2008). Following a technical report by O'Neill et al. (2008), the Chief Forester's Standards for Seed Use (Snetsinger 2008) have been amended to increase the upper planting limit of several provenances by 100 to 200 meters. The use of seed from some provenances at altitudes significantly lower than their source is discouraged. The new standards are to take effect in April 2009.

Quebec

Quebec has a stated objective to "Ensure that forest management reflects the realities of climate change" (MRNF 2008). This is to be reflected in three broad areas: the consideration of forests as carbon sinks, flexible management to rapidly cope with climatic change and the promotion of the use of wood products (Michel Campagna, Direction de l'environnement forestier, Ministère des Ressources naturelles et de la Faune, pers. comm. 23 October 2008). Few specifics are available in this Ministry of Natural Resources and Wildlife report, but there are comments that mill supplies may be affected through an increase in salvage logging.

Approx. 70% of Quebec's productive forest is presently managed as an 'ecosystems protective zone', where all activities are integrated under an ecosystem management scheme. The MRNF is proposing to lease sites severely damaged by past natural disturbances with poor regeneration to private companies for the establishment of carbon sink plantations (MRNF 2008). The Ministry of Development, Environment and Parks (MDDEP) expects that by 2013 forest management planning will include consideration of likely future climate scenarios (MDDEP 2008).

Yukon

At a province level, a recent climate change action plan draft report (Yukon Government 2008) mentions only that forest health will be monitored, and adaptation methods determined. Sub-provincially, Ogden and Innes (2008) studied the Strategic Forest Management Plans for the Champagne and Aishihik Traditional Territory (ARRC 2004) and the Teslin Tlingit Traditional Territory (TRRC 2007), and found that while many of the management prescriptions were consistent with best practice adaptations strategies, climate change was not specifically addressed as the driver of these changes.

CHILE

The Republic of Chile is organized as a centralized state. Forest policy is defined by the Ministry of Agriculture (MINAGRI) and implemented by two organizations attached to the same Ministry; the Forestry Institute (INFOR) and the National Forestry Corporation (CONAF) (MINAGRI 2000). The Office for Agriculture Policy and Studies (ODEPA) and the Foundation for Agricultural Innovation (FIA) are also attached to this Ministry and contribute to the development of forestry policy. Environmental policy related to the protection of natural resources is developed by the National Commission of Environment (CONAMA). This institution is in the process of changing into a new Ministry of Environment. This Ministry will be in charge, among other competences, of climate change and natural resources protection policy, planning and action. The most important forest areas in Chile are in the temperate area. Plantation industries make up 90% of forests' contributions to the economy, which is in total 3.44% of the GDP of 2005 (INFOR 2005).

Chile is in a preliminary phase of adaptation to climate change, focusing on efforts to analyze the vulnerability of the forest sector and to identify possible adaptation measures. A project prepared by the University of Chile for the First National Climate Change Communication to UNFCCC – 'Analysis of vulnerability and adaptation in agriculture, forest resources and groundwater' – was its first attempt (Claro 2007). The actual policy framework regarding climate change is the National Action Plan for Climate Change 2008-2012 (CONAMA 2008a). The document proposes the further evaluation of climate change impacts on different sectors including biodiversity and forestry and the release of a National Adaptation Plan for the period 2010-2030. Regarding adaptation measures it encourages the execution of the Program of Genetic Improvement for agriculture and forestry species in the context of new climate change scenarios, the creation of a National Found for research on biodiversity and climate change and the implementation of an integrated project that aims the development of adaptation tools for agriculture and forestry (CONAMA 2008a).

The Ministry of Agriculture is working on the development of a coherent forestry adaptation policy for 2009 (A. Laroze, ODEPA, pers. comm. 24 July 2008). A workgroup for adaptation to climate change was established between ODEPA, FIA, INFOR and the Agricultural Research Institute (INIA) in order to analyze the vulnerability of the forestry and agricultural sectors and to design adaptation policies (FIA 2007). The first projects that will help in the accomplishment of these objectives are the result of an agreement between ODEPA, FIA and CONAMA in 2007 (Claro 2007). These organizations are working together to improve knowledge on impacts, vulnerability and adaptation to climate change in the forestry and agricultural sectors (IVACC) (A. Neuenschwander, FIA, pers. comm. 11 September 2008). Examples of these projects are the 'Analysis of the vulnerability and adaptation of the forestry and agricultural sector, water and soil resources of Chile' (CONAMA 2008b), 'International and national policies and strategies of climate change adaptation of the forestry and agricultural sector' (FIA 2008) and 'Socioeconomic study of adaptation to climate change in Chile' (ODEPA 2008). An

interesting project planned by FIA is 'Impact, vulnerability and adaptation to climate change in the forestry and agricultural sector in Chile' which aims at the analysis and development of adaptation practices for small farmers, including both agriculture and forest plantations (A. Neuenschwander, FIA, pers. comm. 11 September 2008). INFOR is also working on vulnerability analysis to climate change focusing on the impact on forest ecosystems from a socioeconomic and ecophysiological point of view (C. Bahamondez, INFOR, pers. comm. 30 July 2008).

Documented examples of the implementation of adaptation measures are still scarce. CONAF is working on tools to facilitate plant establishment in arid conditions through rain and fog harvesting and management (W. Alfaro, CONAF, pers. comm. 4 August 2008). The current phase of research is in the analysis of the ecophysiological responses of plants to these systems. In the short term they aim to apply these techniques to the relict oak forests of *Nothofagus macrocarpa* (A.DC.) Vásquez & Rodr. which are clearly threatened by climate change (W. Alfaro, CONAF, pers. comm. 4 August 2008). The private sector is also carrying out or funding initiatives that might be seen as adaptation measurements. One example is the project of the Austral University of Chile, financed by forest companies with the aim of evaluating the influence of large monoculture plantations on runoff reduction in high precipitation areas (Huber et al. 2008). The projected reduction of precipitation plus the hypothesized reduction of runoff may threaten the socioeconomic sustainability of these plantations (J. Gayoso, UACH, pers. comm. 31 August 2008).

CHINA

Forests in China cover an area of 175 million hectares and 42% are owned and managed by the state forest companies at different levels, all of which are administered by the State Forestry Administration (SFA) (SFA 2008). The remaining 58% are managed by regional collectives under the jurisdiction of the Forest Law of the People's Republic of China (People's Congress 1998) and monitored by the SFA. The SFA and local governments are responsible for all the protected areas located in forested land. Forest management in China can be classified into five levels, ranging from the SFA at the central government level, through forest departments in provinces, forest bureaus at city level, sub bureaus at country level and forest stations in individual towns.

Adaptation to climate change is an important part of China's National Climate Change Program (CNCCP) (NDRC 2007). Forestry is one of the six key areas regarding adaptation to climate change, within which three policy principles are addressed. These aim to:

1) Amend the Forest Law of the People's Republic of China (1998) and the Law of the People's Republic of China on the Protection of Wildlife (People's Congress 2004) and draft new laws such as a Law of Nature Reserve and Regulations on Wetland Protection in order to provide legal background to improve the capacity of the forests to adapt to climate change (NDRC 2007). The Amendment of the Forest Law of the People's Republic of China is already listed as the first priority in the schedule of the People's Congress of China, which states that it will be accomplished before 2011.

2) Strengthen the protection of existing forests and other natural ecosystems through reducing human disturbance, controlling forest fires with better forecasting, monitoring and suppression systems and establishing a national forest ecosystem monitoring system.

3) Apply technical innovation to improve the control of insects and disease and select and breed trees with high resistance to climate change. Develop technology for biodiversity conservation and restoration, etc.

Despite the importance attached to forest adaptation in the CNCCP the practical implementation of forest adaptation policy is only recently underway. On 3rd June 2007, the CNCCP was distributed by the central government of China for nationwide implementation. The principles of the CNCCP are to be implemented according to specific regions and departments; in case of forestry the SFA is responsible for forestry-related CO_2 mitigation and adaptation to climate change. An office dealing with climate change issues was established within the SFA in July 2007. In December 2007, five working groups were established focusing respectively on bioenergy, carbon sinks, forest restoration and sustainable management, energy use reduction and economical use of wood resources (SFA 2007). However, forest adaptation is not specifically mentioned in the working groups.

It is likely that the practical implementation of formal forest adaptation policy in China will take some years to develop. Currently, discussions and negotiations about possible forest adaptation policy in China concentrate on broad strategies and generic goals, with the evaluation of specific adaptation measures still at qualitative levels. The government may not able to actually implement these policies because cost efficiency analyses cannot yet be applied (Zhu et al. 2007).

Climate change impacts research is already being undertaken in China. A substantial research project studying the impact of climate change upon forest ecosystems was initialized by the Chinese academy of forestry (Wu Shuirong, pers. comm. 13 November 2008).

Some scientists and officers at the climate change office of the SFA suggest that the general principles of forest adaptation are already well considered and implemented in many forest management plans, although without specifically highlighting the term 'forest adaptation' (He Chao, pers. comm. 15 November 2008). Stand diversity measures in accordance with adaptation strategies are adopted in six key national forestry projects in China (Prof. Zheng Xiaoxian, Beijing Forestry University, pers. comm. 16 November 2008). Also, the national afforestation technical regulation GB/T15776-2006 (GAQSIQPRC 2006) was modified in 2006, shifting from a wood-centered focus to a sustainable forest management approach. In this regulation, measures such as the promotion of indigenous tree species, the encouragement of mixed-species forests and the control of pests and forest fires are clearly indicated, but without a stated emphasis on adaptation to climate change.

COSTA RICA

Costa Rica is a unique state with respect to biodiversity and nature conservation. Forests cover 46.8% of the total area, providing a large range of services not apparent in the sector's small official contribution to the GDP of 0.75% in 1999 (MINAE 2001). Forest administration in Costa Rica is the responsibility of the Ministry of Environment and Energy (Forestry Law 7575 /1996). This department carries out its functions through the National System of Conservation Areas (SINAC) (Regulation of the Forestry Law 1997). The Ministry establishes policies and priorities and SINAC implement them. The forestry law of 1996 also created the National Forest Office (ONF) which is charged with proposing forest strategies and policies to the Ministry and promoting prevention programs against pests, fire and other threats. Other institutional actors related to climate change are the National Meteorological Institute (IMN) with an important role in providing policy advice on all aspects of climate change including adaptation and the Joint Implementation Office of Costa Rica (OCIC) dealing with mitigation actions in the context of carbon markets.

Environmental policy is innovative and advanced, apparent in the implementation of a successful financing system based on payment for environmental services provided by forests (Chomitz et al. 1999). The Environmental Services Payment Program (ESPP) is the innovative financial system developed to compensate forest owners for actions to mitigate climate change and for the protection and conservation of biodiversity (Forestry Law 7575 of 1996). Forest owners may get benefits from the ESPP to carry out projects of afforestation, reforestation, forest protection and increasing tree cover in agro-forestry systems (FONAFIFO 2007). The program is financed from the 3.5% fuel tax, donations from national and international institutions and recently from private investors and loans. The program could be a useful tool to promote forest adaptation practices, but this issue is still not yet considered in the payment process (R. Viggnola, CATIE, pers. comm. 20 August 2008).

Climate change policy with respect to forests in Costa Rica addresses mainly the mitigation effect of forests, through the forestry financing system (MINAE 2001). In fact, Costa Rica is one of the few countries aiming to be carbon-neutral for 2021 (Ministry of the Presidency 2008) Nevertheless adaptation measures are still scarce. Efforts in adaptation are partly focused on the monitoring of the ecological situation of protected areas and biological corridors (SINAC 2007b). This constant evaluation will facilitate the adaptive management of the natural resources pointing out relevant changes (SINAC 2007b). Biodiversity conservation programs in Costa Rica are also seen in some cases as adaptation strategies (SINAC 2007a), for example the National Program of Biological Corridors. This program specifically aims for the strengthening of protected areas and their connectivity (Decree 33106/ 2006).

Several international projects are trying to addresses this general lack of policy implementation on adaptation to climate change. The Tropical Forests and Climate Change Adaptation research project (TroFCCA) is based in three regions of the tropics;

Southeast Asia, West Africa and in Central America Costa Rica, Nicaragua and Honduras. Its objective is the analysis of vulnerability of goods and services provided by tropical forests and the development of adaptation policy strategies (TroFCCA 2006).

FINLAND

Finland is the most important forest industry nation in Europe, with 86% (26 million ha) of its area considered forest land (MAF 2005). 60% of forest land is privately owned, and forestry industry exports contribute roughly one third of Finland's export income. The country has a centralized forest administration, run under the auspices of the Ministry of Agriculture and Forestry (MAF). Forest policy is set under the National Forestry Program, the current issue of which covers the period to 2015 (MAF 2008). Thirteen regional forest centers administer compliance with the national policy and promote sustainable forest use and other environmental goals. Metsähallitus manages state-owned forests, while forest extension work for private owners is carried out by the Forestry Development Center Tapio.

The previous National Forest Program (NFP) 2010 (MAF 1999) contained no reference to adaptation and just one brief mention of climate change. In contrast, Finland's National Forest Program 2015 (MAF 2008) discusses emerging impacts of climate change such as an increased demand for wood-sourced energy production and the need for sustainable management to maximize carbon sequestration. The program expressly calls for increased wood production, climate change mitigation, fossil fuel replacement and increased carbon storage in wood products.

To increase the sustainability of roundwood production, MAF aims to increase the management intensity through support for measures such as increased use of artificial regeneration, fertilization, upgrading of forest roads and drainage ditches, improved forest genetics, prevention of root-rot fungus, improved wood-product hygiene measures and the development of new mechanized forest management methods (MAF 2008). MAF aims to increase the use of wood chips for energy production from 3.4 million m^3 in 2006 to 8-12 million m^3 in 2015. Finland guarantees State subsidies for private forest owners to conduct management operations in support of sustainability that would otherwise not be profitable (UNECE 2001).

Adaptation is briefly covered in MAF (2008), in the sense of preparing for anticipated risks associated with climate change. The document recognizes that abundant and genetically diverse tree populations are more adaptable to changing climates, and that both biotic and abiotic risks are likely to increase. MAF plans to prepare forecasts for likely adverse effects, improve forest damage monitoring and develop emergency plans for instances of severe forest damage. Changes to forest management recommendations arising from continuing research will be focused on forest vitality, the importance of forests as carbon sinks and on improved harvesting conditions.

Finland's National Strategy for Adaptation to Climate Change (MAF 2005) includes a component for forestry, which points out that 'not much' adaptation research had been conducted to date. The strategy is optimistic about the adaptive capacity of Finnish forestry, but highlights the need for adaptation measures to be initiated soon. The document describes Finland's network of gene reserve forests, and some issues regarding

growing species outside their current breeding range. The Strategy cites advantages for both natural and artificial regeneration, and advocates shorter rotation times to increase the rate of adaptation. Road networks will require improvement to cope with earlier thaws.

The FINADAPT program was established in 2003 as a research consortium to examine the adaptive capacity of Finland's environment and society (Carter 2007). In the section relating to forestry, Kellomäki et al. (2005) highlight tree species selection, modification to thinning intensities and rotation lengths and infrastructure improvements as the most pressing needs.

A stakeholder portal developed through the European Union-funded BALANCE program (www.northportal.info) provides an interactive forum on climate change in the arctic and disseminates some basic knowledge on adaptation in forests. At the time of writing information for Finnish forests only was available, although the intent seems to be to include Sweden, Norway and northwest Russia.

FRANCE

Public and community forests in France are organized into 11 European and four postcolonial regions by the National Forest Office (ONF), a subsidiary body of the Ministry of Agriculture and Fishery (MAP) where forest law and policy are decided and also of the Ministry of Ecology, Energy and Sustainable Development (MEDD). However, these forests represent only about one fourth of all French forests, with the remainder being in private hands. Any private forest larger than 25ha requires a management plan approved by the Regional Center of Forestry Properties (CRPF, currently merging into the National Professional Center of Forestry Properties (CNPPF) – national public institutions supporting private forestry and guaranteeing the application of national directives on private land). More than 40% of French forests therefore have management plans following the same legal structure and for certain of the remaining forests there are obligatory or voluntary planning documents, e.g. for nature conservation or hunting (Piel et al. 2000).

Possible impacts of climate change on forests and forestry in France have been described and studied for several years (Loustau 2004; Riou-Nivert 2005). The network GIP ECOFOR (Forest Ecosystems) is in charge of the coordination of research in the field of adaptation of forests to climate change. The challenges of adaptation may require fundamental changes in forest governance with the central government taking a more important role and increased focus given to sustainable forest management in response to climate change-induced constriction of multifunctional forestry (Roman-Amat 2007a). Adaptation to climate change is part of the national strategy for sustainable development (MEDD 2006) and the first report on impacts and adaptation by the national observatory of global warming impacts (ONERC) was produced in 2005 (ONERC 2005a). ONERC, the state institution dealing with climate change, also published the National strategy of climate change adaptation (ONERC 2007). This document however is of a general nature (covering all sectors that may be affected by climate change) and provides recommendations rather than normative measures. No definitive prescriptions are given for how forest management should adapt, but enhancing the resilience of forests by using site adapted and mixed species and decreasing water stress through early and strong thinnings is recommended (ONERC 2007). ONERC also gives special attention to forest fires under a changing climate and the adaptation of forest fire fighting methods, particularly the change in vulnerable regions (ONERC 2005b). There is a task force, constituted by the three ministries in charge of agriculture, ecology and interior, recommending how to take into account an increased and extended risk of forest fires, not only in the Mediterranean region, but elsewhere in France too. This is a good example of forest adaptation for the short and medium term (JL Peyron, GIP ECOFOR, pers. comm. 18 February 2009). Similarly, the French NFP does not mention any specific normative adaptation measures but promotes the anticipation of climate change under the framework of sustainable forest management and points out the necessity of adaptation of silvicultural methods and species selection (MAP 2006).

Forest management institutions have been active in research and information dissemination and in recent years some publications specific to forests' adaptations have appeared (Legay and Mortier 2006; Piermont 2007). For state and community forests that are managed by the ONF there is a comprehensive report on impacts and adaptation by Legay and Mortier (2006) which collates research knowledge on the issue and gives clear adaptation indications. This has also been specified in 2008 for Mediterranean forests (Legay and Ladier 2008). The national commission on genetic forest resources (CRGF 2008; Lefevre and Collin 2008) provides guidelines for forest managers aiming at a silviculture that maintains genetic diversity over the long-term (natural regeneration, planting species with a broad range of genetic material and provenances from drier regions, increase plantation density in order to have higher adaptation potential). Gaudin (2008) points out that climate change risks require integration into site catalogues to assist with species selection and other management decisions. The importance of species mixture is stressed to forest managers adapting stand compositions (Legay et al. 2008).

The regional centers of forest owners (CRPF) now have a climate change correspondent which is coordinated by the Institute of Forest Development (IDF, part of the CNPPF) to advise private forest owners. Using an intensive stakeholder dialogue process CNPPF has also developed five factsheets ('management of forest stands', 'genetic material', 'the forest site', 'risk management' and 'production and harvest'). These factsheets address the main questions and needs of private forest owners concerning adaptation to climate change and possible current and future responses. (Riou-Nivert 2008a,b,c,d,e; Gauberville and Riou-Nivert 2008).

Roman-Amat (2007b) provided a report to the MAP and the MEDD that gives a comprehensive strategy on how to adapt French forests to climate change. Action plans and clear propositions are stated for research and development, risk management, public policy, biodiversity, public governance and the creation of a network of forest organizations on forests and climate change (RMT) that has been implemented in 2008 (P. Riou-Nivert, IDF, pers. comm. 1 December 2008). The coordination of research studies on adaptation has also been allotted to GIP ECOFOR. However, the Ministries are still deciding on these issues during 2008. The earliest decisions are expected to be on research and development (B. Roman-Amat, Director ENGREF, pers. comm. 25 August 2008).

The new contract of the ONF that is the legal document for their work for the period 2007-2011 stresses the importance of sustainable forest management (ONF 2006a). The multifunctionality of forests should be guaranteed under a changing climate and the inclusion of a provision to handle climate change risks is proposed. The creation of a joint research venture between the national agriculture research institute INRA and the ONF is proposed, and the integration of adaptation issues into the guidelines for regional land use planning directives (DRA) and schemes (SRA) is recommended (ONF 2006a). An example of integrated climate change adaptation in such a land use plan may be found in the DRA of the Lorraine region (ONF 2006b). In this document, the anticipation of change via diverse stands with adapted species and provenances and the management of crises resulting from climatic changes are the two main elements.

GERMANY

The federal republic of Germany consists of 16 federal states and, though densely populated all over its territory, contains 11 million ha of forest which is about one third of the total area (BMELV 2004). Legislative power over forestry is shared by the federation and the individual federal states with the federation providing broad guidelines that are to be followed and filled with concrete strategies by the federal states (Roering 2004). Thus, federal and national forest policy may be influenced by both the federation and each federal state. Only a very small part of the German forest (3.5%) is owned by the federation, the more influential actors in forestry are the federal states (with almost 30% of forest ownership), the communities (around 20%) and private owners (almost 48%, but often in very small holdings and including holdings from trusts) (BMELV 2004).

The German literature on the impacts of climate change on forest ecosystems has been abundant since the early 1990s (e.g. Thomasius 1991; Spiecker et al. 2000; Zebisch et al. 2005). Thomasius (1991) developed broad ideas on the adaptation of forests that face climatic change at a rate that exceeds their natural adaptive capacity. The future of Norway spruce (*Picea abies* L. Karst) and Common Beech (*Fagus sylvatica* L.), the most important coniferous and broadleaved species throughout Germany, are often subject to debate (Bolte 2005). Secondary Norway spruce forests that are out of the natural distribution range of this species are already being converted into more structurally diverse stands with mixed species composition (Spiecker et al. 2004). This concept of 'forest conversion' is also being applied to other plantation forests e.g. Scots pine (*Pinus sylvestris* L.) (Zerbe 2002).

Federal

The Expertise Centre for Climate Change Effects and Adaptation in the Federal Environmental Agency (KomPass) was set up in 2006 by the Federal Environment Minister Sigmar Gabriel (c.f. media release BMUNR 2006). KomPass conducts regular cross-sectoral workshops on adaptation to climate change and stresses the equal importance of adaptation and mitigation (Schuchard et al. 2008). The 'German adaptation strategy to climate change' has recently been approved by the government and stresses the importance of adaptation. This includes increasing forest conversion towards (current and future) site adapted forests with a diversification of risks and adjusted game densities. Information dissemination about adaptation measures and their necessity to forest owners is also covered (German Government 2008). Stable, mixed, resistant stands with a high adaptive capacity towards a changing climate shall be the focus of forest managers. Non-native species may be considered if nature conservation objectives are not threatened. The federal states are responsible for providing scientific decision support tools and the knowledge exchange between science and praxis has to be intensified, as does environmental monitoring.

The German Forestry and Wood Council recently identified the adaptation of German forests to climate change as one of the four main challenges of their work (DFWR and DHWR 2008). In April 2008, 80 representatives of scientific organizations,

public administration, non-governmental organizations, industry associations and forest owners approved the 'Eberswalder Declaration' that recognizes the importance of climate change to the whole forest sector and especially stresses the need for adaptation in forest management (MLUV 2009). A clear statement on the need for adaptation of forests and forest management against climate change has been made in the 'National Biological Diversity Strategy' (BMU 2007). Less concretely, the German NFP identifies the risk of climate change to forests, acknowledges the mitigation potential of forests and stresses the importance of further research into mitigation and adaptation (BMELV 2000). Despite knowledge gaps, the NFP emphasizes the conservation of the vitality and adaptation potential of forests by fostering mixed and diverse stands managed according to nature-based forestry (see Diaci 2006). Maintaining diverse tree and shrub species as well as in-species genetic diversity is held to be a precondition for successful adaptation to changing environmental conditions (BMELV 2000). The conservation and development of structured forest stands with a high resistance against climate extremes and pest outbreaks and a high adaptive capacity to future environmental change is part of the concept of nature-based forestry (BMELV 2003). The importance of 'climate-tolerant' forests, forest conversion towards mixed species and structurally diverse stands and new forest management strategies in response to a changing climate were acknowledged at a recent Ministerial conference (SMUL 2008a; BMELV 2008). However, during the roundtable discussion of the third phase of the NFP the issue of adaptation to climate change has not yet been discussed and throughout the whole NFP process no concrete adaptation measures are proposed, although some strategies that are part of sustainable forest management practices may also be considered being adaptive practices.

Following the severe drought of 2003 the discussion of adaptation intensified (Borchert and Kölling 2004, Bolte and Ibisch 2007). Forests' adaptation was raised in a Federal Parliamentary discussion and the government stressed the importance of site-adapted, structurally diverse and healthy forests, (managed entirely under a nature-based forestry system) and an adaptation of the whole forestry sector to occurring climate change (BMU 2008). The most comprehensive official report on adaptation (Zebisch et al. 2005) provides recommended adaptation measures (forest conversion, increasing genetic diversity, plantation of non-native tree species, rejuvenation of ageing stands, prevention of forest fires, changing water management plans, reducing additional threats, and improved risk management) and ranks the vulnerability of the German forest sector – assuming adaptation measures are applied – as 'low'. Conversely, other authors have identified the forest sector being one of the most threatened sectors if it fails to implement adaptation measures (Schulz and Kölling 2007). A recent survey found that forest experts expect critical climate change impacts on the whole forestry sector and fear adaptation failure as the rate of change exceeds adaptation measures and the adaptive capacities of forests (Mickler et al. 2008).

The concept of climate envelopes has been presented as a decision support tool for forest managers, whereby the current and possible future distributions of 27 tree species are displayed in order to support species selection for site adapted forest stands (Kölling 2007). This approach provides applicable knowledge, although the only site

determining factors addressed so far are mean annual temperature and mean annual precipitation, and a reliance on these simple climate parameters may not be sufficient (Bolte et al. 2008). Similarly, forest conversion is being seen as a tool for regional adaptation, although it may be to slow if not finished until 2100 (Erdmann et al. 2008).

Bavaria

Bavaria is by far the most forested region of Germany and comprehensive studies have been made on the impact of climate change, with suggestions for possible adaptation measures (Beierkuhnlein and Foken 2007). A governmental program for the Bavarian agriculture and forestry sector announces support for the adaptation of the forest sector to climate change as a focus of regional governmental policy (StMLF 2008). The Bavarian government and 20 forest organizations and associations recently signed the 'Weihenstephaner Declaration', stressing the importance of adaptation and mitigation measures in the forest (BFV 2008).

The main focus of adaptation measures to date is on the conversion of 260 000 ha of the most vulnerable spruce stands (Bernhart 2007) to a more mixed-species makeup, with an increasing focus on forest health and sanitation. Most of these forests are in private ownership (Kölling and Ammer 2006). The regeneration and conversion of vulnerable stands may start a lot earlier (at the age of 50) and is normative (BaySF 2007). Forest site mapping including new species compositions and the identification of adaptation hotspots (most vulnerable regions) is underway. Bavarian authorities initiated the 'forest conversion program for climate change in state forests' and since 2006 this has begun to be implemented in medium and long-term forest management planning (Möges 2007). This program aims for a conversion of 5 000 ha of coniferous plantations forests, additional to 50 000 ha of 'regular' conversion (Möges 2007). A program entitled 'Action plan Forest conversion' aims for the conversion of 100 000 ha out of 260 000 ha of highly unstable spruce forests by 2020 in private forests (StMUGV 2007). An additional €15 million funding (plus €7.5 million for protection measures in mountain forests) for forest conversion has been announced for the period 2008-2011 (StMUGV 2007). However Bernhart (2007) points out that the forest conversion process of the total 260 000 ha should not exceed a timeframe of 30 years (to 2036) and hence this effort needs to target 9 000 ha per year. Climate envelopes developed by Kölling (2007), downscaled for Bavaria, have been made publicly available for forest managers by the Bavarian forest administration (LWF 2008).

Brandenburg

Being located in an already dry environment, Brandenburg in the north-east of Germany may be one of the most impacted regions (Gerstengarbe et al. 2003). The forestry section of the 'catalogue of countermeasures for climate change mitigation and adaptation of the federal state government' (Landesregierung Brandenburg 2007) focuses on forest conversion towards diverse forests, with small-scale species mixes adapted to micro-site conditions and greater importance given to secondary species. Additionally, the conversion of forests stands poorly suited to present site conditions to more site-

adapted arrangements is prescribed for all state forest of Brandenburg by a renewed regulation (MLUV 2006), where for example pure coniferous plantations are no longer permitted. The greater internal stability of site-adapted, diverse, species rich and multi-structured forests is likely to increase their adaptive capacity, and the forest conversion process should incorporate the latest scientific findings (MLUV 2007). The need for small-scale potential vegetation mapping and site specific management practices has been stressed in order to generate 'climate-plastic' forests (Jenssen et al. 2007).

Saxony

Similarly to Brandenburg, there are serious concerns about increased drought and associated tree mortality in Saxony, and the ongoing forest conversion process requires continual optimization and revision in order to respond to new climatic challenges (Irrgang 2002; Küchler and Sommer 2005; Eisenhauer 2008). For the period 2007-2013 there has also been an additional €10.5 million of funding made available for the conversion of private and community forests (Wöller 2008). The current state of adaptation policy and research is summarized in the progress report of the agency working group 'climate consequences' (SMUL 2008b). The main issues for adaptation planning are identified as forest structure, species composition, biotic forest damages and the adaptation of forest planning in circumstances of increased risk. The guidelines for forest planning in state forests in Saxony acknowledge the importance of regionally differing climatic changes and demand their integration into long-term silvicultural planning (Eisenhauer et al. 2005). Häntzschel et al. (2006) point out that the then-current climate classification scheme for the forests of Saxony was unable to provide silvicultural decision-support under a changing climate. This led to an updated climate classification being developed for the forests of Saxony that considers changing climatic conditions and regional model predictions (Gemballa and Schlutow 2007). According to these updated maps, new climate change adapted forest types have been defined, including both different forest structures and new species compositions (Schlutow and Gemballa 2008).

RUSSIA

The Russian Federation comprises 83 federal subjects: 46 provinces, 21 autonomous republics, 9 territories, 4 autonomous districts, 1 autonomous province and 2 federal cities. Federal subjects are grouped into seven federal districts, each administered by an envoy appointed by the President of Russia. Federal districts' envoys serve as liaisons between the federal subjects and the federal government and are primarily responsible for overseeing compliance with federal laws.

Forests are completely in state ownership. At the top of the forest sector is the Ministry of Agriculture. The Ministry has legislative functions and defines the functions and aims of management of all forests in the country, taking into account the geographical aspects and the resource ability of the regions. The Federal Forestry Agency (FFA) is administered by the Ministry of Agriculture of the Russian Federation (RF Government 16.06.2004 N283 amended from 11.06.2008 N445).

The FFA is a federal executive body which carries out the implementation of government policies, the provision of public services and the management of state property in the area of forestry relations (RF Government 16.06.2004 N283, amended from 22.12.2005 N801, 24.05.2007 N314, 20.12.2007 N900). The FFA operates directly through its territorial bodies and subordinate organizations in coordination with other federal executive bodies, executive bodies of subjects of the Russian Federation, local authorities, associations and other organizations (RF Government 16.06.2004 N283, amended from 07.11.2008 N814).

It is important to note that the forest sector in Russian is currently undergoing a process of deep reform and that the changes in forestry related legislation that have occurred in recent years have changed the whole structure and functions of the sector (Shvarz 2006; Girjaev 2008). The recently accepted Forest Code of the Russian Federation (since first of January, 2007) brings the decentralization of many administrative functions in the forest sector. The Forest Code legislatively established the power of state authorities of the Russian Federation (article 81) and the subjects of the Russian Federation (article 82) in the area of forestry relations (article 83). The power in the field of forest administration was redistributed between the federal center and the subjects (Article 83) (Komarova and Roschupkin 2007). All managerial functions are being handed down to the federal subjects. State authorities and authorities of federal subjects are responsible for forest management, however the FFA still controls and supervises the enforcement of the powers of state authorities of the Russian Federation (RF Government 24.05.2007 N314).

In spite of the continuous changes and reform in the forestry sector Russia has signed the Kyoto protocol and is actively endeavoring to implement it at the local level. The legislative base relating to the joint implementation of the Kyoto protocol includes the Resolution of the Government of the Russian Federation N332 of 28th of May 2007 ‘Regulation about ratification and control of the implementation process of projects

which are carried out according to chapter 6 of the Kyoto protocol'. Federal authorities are considering the documentation on the project and control the implementation of projects. The Ministry of Economic Development and Trade of the Russian Federation is the coordination and approval center for the preparation of projects. Afterwards the Ministry provides a list of projects for approval to the Government of the Russian Federation (RF Government 28.05.2007 N332). There are lists of the projects in the Ministry of Economic Development and Trade regarding the reduction and limitation of CO_2 emissions to the atmosphere. There are some projects in the forestry sector for the mitigation of climate change through establishing carbon sequestration forest plantations (Girjaev 2008). Since 2007 such plantations have been created in two regions of Russia and the FFA is preparing plans to create similar plantations in 8 regions of the Russian Federation by 2012 (FFA 2008b). However, most of the activities and discussions related to the adaptation to climate change are carried out at the scientific level, not at the legislative level (Krankina et al. 1997; V.V. Dmitriev, Federal Agency of Forestry, pers. comm. 26 December 2008). At the same time, the government realizes the importance of the climate change problem. The role of the forest sector under national and international climate change mitigation and adaptation programs through innovative financial mechanisms and investment partnerships was discussed at the International conference on the 'Role of Forests in Climate Management: Research – Innovations – Investments – Capacity Building' that took place on October 4-7, 2008 in St-Petersburg (FFA 2008a). One outcome of this conference was a 'Declaration on the Enhancement of The Role of Forests in Climate Management by Promoting Innovative Approaches, Technologies, Investments, and Human Capacity Building' (FFA 2008c). This conference was organized and fully supported by the Federal Forestry Agency, and is an indication that Russia is ready to make a first step in adaptation to climate change (A.V. Zigynov, St.-Petersburg Forestry Institute, pers. comm. 24 December 2008).

In spite of the activities in the scientific level and at the international policy level the Ministry of Agriculture of the Russian Federation does not have current policies relating to the adaptation of forest management to climate change (V.V. Dmitriev, Federal Agency of Forestry, pers. comm. 26 December 2008). In spite of constant development and improvement of management and exploitation of forests (Girjaev 2008) there is no documentation in the legislation related to adaptation to climate change (V.V. Dmitriev, Federal Agency of Forestry, pers. comm. 26 December 2008). The uncertainties of future global climate change impacts at local or regional scales may limit development and timely deployment of specific adaptive measures in Russia (Krankina et al. 1997).

SPAIN

Spain is a decentralized country with 17 Autonomous Regions 'Comunidades Autónomas' (CC.AA.) and two city states 'Ciudades Autónomas'. The political devolution process since 1978 has led to the transfer of responsibility for forestry from the Central Administration (AGE) to the CC.AA. The State has responsibility for basic forest legislation (art. 149.1.23 of the Spanish Constitution), national forest policy, international forest affairs (Forest Law 43/2003) and coordination and complementation of the forest policy of the CC.AA. (MIMAM 1999). The regional bodies have the remaining legislative and executive functions. Policy and management development differ among the CC.AA and they may adopt different political and administrative strategies (MIMAM 1999). The administrative structure is also very diverse: Forestry competencies can be shared between different bodies such as Agriculture or Environment or merged in a unique Forestry body. Among the forest policy instruments available the main options adopted by the CC.AA. are Regional Forestry Programs or Forestry Strategies.

Local governments have also some competencies on forestry when they are forest land owners and therefore may establish their own forest management agencies. There are two State advisory bodies related to forestry, the Sectoral Conference of Environment with its Forest Committee and the State Council for Nature Heritage and Biodiversity. Both institutions only have an advisory role but facilitate the coordination between regional and central administrations and the participation of other bodies in forest planning and management.

Climate change and specifically the adaptation of forests to its impacts are clearly taken into account in the national forest policy and regulations. The fundamental forest law in Spain is the Forest Law 43/2003, modified by Law 28/2006. This Law demands a management system that considers the resilience and resistance of forests to climate change as a principle. Regarding policy documents, the Spanish Forestry Strategy (SFS) focuses on the need for research to anticipate the impacts of climate change (MIMAM 1999), while the Spanish Forestry Program (SFP) also encourages the management of forests to improve their capacity for climatic adaptation (MIMAM 2002). The SFP addresses the multifunctional management approach aiming to increase the biodiversity and functionality of those forests with excessive density, low complexity or lack of tree cover. It plans for preventive management to fight against possible forest pathology afflictions. The prevention scheme is based on those integral practices that can enhance the vitality of plants, such as the use of species genetically suitable or the promotion of structural diversity. It also includes other lines of action that are not linked expressly with climate change, but could be considered to be general adaptation measures. These include the promotion of sustainable forest management, support of preventive management against wildfires and protection and enhancement of biodiversity in forest areas and forest genetic resources.

The conservation of diversity is considered as an objective and principle in forestry and nature conservation policy in Spain (MIMAM 1998, 2002). This aim is

partly developed by the Spanish Strategy for the conservation and sustainable use of forest genetic resources, which points out the importance of genetic diversity to assure the adaptability of forest species to climate change (MIMAM 2006). The Strategy plans the release of different general programs, and specific ones for a single or a group of tree species at a supra-regional level. The programs will develop methodologies to monitor the genetic status of the species, to conserve the genetic diversity of tree species through in-situ and ex-situ measurement and promote their adaptability through tree breeding (MIMAM 2006). The Spanish Biodiversity Strategy (SBS) mentions global warming as a possible threat to biodiversity and proposes general measures to avoid fragmentation and facilitate genetic exchange, such as the establishment of an ecological corridor network using fluvial ecosystems and cattle ways (a traditional network of public land strips connecting much of rural Spain) (MIMAM 1998).

Global warming may increase the problem of desertification in Spain (Vallejo et al. 2005). This is recognized by the National Action Program to Combat Desertification which proposes several actions in the fields of forest and soil management, wildfires and desertification monitoring (MARM 2008). Among the measures adopted, several are related to the adaptation of forest ecosystems to extreme conditions, such as genetic selection, enhancing quality and biodiversity of protective forests or preventive management against wildfires.

Following the UNFCCC recommendations, the Spanish Climate Change Office (OECC) developed the National Adaptation Program to climate change (MIMAM 2006b). This document was based on the Preliminary Assessment of the Impacts of Climate Change in Spain (ECCE), where a panel of more than 400 experts identified the impacts of climate change and possible adaptive options (Moreno 2005). It has as lines of action in the forest sector, among others, the development of guidelines to promote an adaptive management to climate change, the development and application of forest growth models under different climate change scenarios, the evaluation of carbon balances in forest ecosystems and the development of a system of forest indicators for climate change. Under the first work program, started in 2006, efforts are being directed towards the development of regional climate scenarios and impact assessments on coastal areas, water resources and biodiversity. Later work programs will apply these results to further refine forests' adaptation actions.

Spain has established a specific action within the National Research and Development Program on Energy and Climate Change (CICT 2007). Among other things it aims to develop methods, tools and information on impacts, vulnerability and adaptation to climate change. This program targets several priority sectors for Spain. In the first phase (2008-2011), the program tackles four sectors: health, tourism, agriculture and forests, with the aim to generate an enhanced knowledge-base to allow for the first likely integration of adaptation to climate change in sectoral policies, at all administrative levels.

In a broader context, the Ibero-American Network of Climate Change Offices (RIOCC) including among 21 other countries Spain, Brazil, Chile and Costa Rica, is

currently developing the Ibero-American program of Assessment of Impacts, Vulnerability and Adaptation to Climate Change (PIACC). The main objective of the program is to strengthen and implement adaptation strategies in the region and to assist in the assessment of vulnerabilities, impacts and adaptation options in the member countries (RIOCC 2006). Regarding forest adaptation, the program is supporting the Cooperative Project on Mitigation and Adaptation to Climate Change in Sustainable Forest Management in Ibero-America (MIA). The MIA project aims to bring more knowledge about adaptation to SFM and at the same time to strengthen capability for adaptive management. Currently, the project is surveying activities related to sustainable forest management in adaptation and mitigation to climate change (RIOCC 2008) and a call for financing projects has been launched (J.R. Picatoste, OECC, pers. comm. 5 December 2008).

SWEDEN

Sweden is one of the most densely forested countries in Europe and 57% of its land area is covered with productive forest. Only 10% of the forest area is state forest; forest companies own 39% and individual private owners 51% (Lundkvist et al. 2000). Hence, the Swedish Forest Industry Association for the forest companies and the National Federation of Swedish Forest Owners' Association (Skogsägarnas Riksförbund) for the different individual private forest owner associations are important stakeholders in forest policy and decision-making. However, forest policy is decided by the Ministry of Agriculture and the implementation of forest policy and overall authority remains with the Swedish Forest Agency (a department of the Ministry of Agriculture).

The final report from the Swedish Commission on Climate and Vulnerability from 2007 gives a full overview of the impacts of climate change on forestry and forest industries as well as nature conservation (SOU 2007). As in some other European countries, Norway spruce is identified as being the most vulnerable tree species but adaptation through changing species compositions is restricted by high game densities (SOU 2007). The same document also identifies numerous possible adaptation measures in the domains of forest management, forest harvesting, forest planning, forest education and research and development. The document proposes adaptation measures but clearly states that forest governance and rules and regulations concerning these issues require changes in order to prepare for implementation. So far, the Swedish Forestry Act (1994) only regulates the treatment of insect damages and calamities and requires forest owners to implement measures defined by the Swedish Forest Agency. This may be seen as a concrete adaptation measure as insect damages are likely to increase with changing climate.

A case study on vulnerability and adaptive capacity in forestry was carried out in the Pite River Basin in the north of Sweden. This study summarized ideas on climate change adaptation and related (mostly economic) impacts for regional forest actors (Keskitalo 2008). Forest actors in this research seemed to be quite clear about what local adaptation measures they need (road construction and maintenance, market oriented production, planting of *Pinus contorta* in anticipation of wood shortages in the future) but also report conflicts of possible adaptation measures with environmental policy and traditional land rights by indigenous (Saami) people (Keskitalo 2008).

There are several ongoing research projects. The Mistra SWECIA-Program (Swedish Research Program on Climate, Impacts and Adaptation) plans a 'Forestry Case Study' from 2009-2010 (Mistra 2007). Additionally the 'Future Forests — Sustainable Strategies under Uncertainty and Risk' with a budget of about €14 million is being carried out by the Swedish University of Agricultural Sciences (SLU), Umeå University and Skogforsk (the Swedish Forest Research Institute) which deals with developing "sustainable strategies for forest management in an uncertain future" (Mistra 2008). A third program with the working title 'Climate and Forestry' is being run by the Royal Swedish Academy for Forestry and Agriculture (Sonesson 2006).

UNITED STATES OF AMERICA

The United States Forest Service (an agency of the Department of Agriculture) controls almost 79 million ha of national forest and rangeland, with the 50 state governments responsible for the remainder of the nation's forests. The most important forest areas are in the northwest of the nation (the states of Alaska, Washington, Oregon and California), with large conifer plantation developments in the southeast (particularly Georgia and Alabama). Forest may fall under either state or federal jurisdiction, depending on the nature of their ownership. State laws are subject to federal oversight. Legal challenges to federal forest regulations or management prescriptions are not uncommon, but state forests are somewhat protected through their founding charters, requiring them to produce an income for local county governments.

Federal

The Forest Service is required under the 1990 Food Protection Act to 'assess the impact of climate change on renewable resources in forests and rangelands, and identify opportunities for mitigation' (Joyce et al. 2008) and several comprehensive research reports have been produced both by the USDA Forest Service itself and in collaboration with other agencies in the US Climate Change Science Program (in particular, see CCSP (2008)). Forest adaptation is considered necessary to maintain essential ecosystem services, and current research aims at maintaining ecosystem health (Solomon et al. 2008). The Forest Service recognizes the need for adaptation policies and practices to be localized depending on specific needs and aims, and hence the USDAFS Global Research Strategy 2009-2019 (Solomon et al. 2008) has a focus on developing decision support tools for land managers and policymakers.

The Forest Service has analyzed range-shifts for 80 tree species and made the results publicly available (Scott et al. 2008). Nevertheless, instances of policy change in response to anticipated climate change are at present difficult to find. As of December 2006, only 15 out of 121 individual forest plans identified 'climate change' as a risk to management or performance goals (Joyce et al. 2008). The US National Fire Plan does not include consideration of climate change (Joyce et al. 2008), which has been mentioned as an 'issue of concern' by the National Association of State Foresters (NASF 2007). Few National Parks address climate change in their Strategic Plans (Baron et al. 2008), and then only superficially. National Wildlife Refuges are not yet implementing adaptation strategies to explicitly address climate change (Scott et al. 2008).

Climate change adaptation in general has until recently been largely ignored in the United States (Luers and Moser 2006). In the absence of federal action, some states (i.e. Alaska, California, Florida, Maryland, Oregon, and Washington) took an early lead in climate change adaptation statements (Rabe 2002; PCGCC 2008). Some states have commissioned climate change action plans, which commonly refer to initiatives for forest thinning, afforestation/reforestation, increased attention to wildfire issues and investigation of forest biofuel possibilities (for examples, see CCAG 2006; Ritter 2007). More recently however, there are indications that Federal departments are taking a

stronger guiding role through monitoring environmental change and disseminating information (Powledge 2008). The USFS is particularly active in research/management partnerships for future policy development, and in web-based extension work (Abigail Kimbell, USFS Chief, pers. comm. 22 September 2008). The USFS considers successful forest adaptation (particularly of vulnerable ecosystems) to be a necessary prerequisite for climate change mitigation, and current work in USFS regions involves customizing the recommendations contained in CCSP (2008) to suit local challenges (David Cleaves, Chairman, USFS Climate Change Council, pers. comm. 27 October 2008). No broad-scale policy changes have yet been proposed specifically to address adaptation, but the need for proactive adaptation within a wide range of USFS responsibilities is recognized.

Alaska

Proposed adaptation responses in Alaska have a strong focus on the needs of communities, although the only firm policy statements of relevance to forestry pertain to wildfire issues. Hartig (2008) notes that the state has increased fire support personnel, carries out routine air pollution (smoke) monitoring in the fire season (using portable equipment) and issues smoke pollution forecasting warnings for public health reasons. Alaska is one of only three states to have thoroughly assessed climate change risks to wildlife and to have provided recommendations in their federally mandated State Wildlife Action Plan (Koopman et al. n.d.). The state aims to monitor species for early warning of climate change impacts, with a specific goal of maintaining Kittzlitz's Murrulet (*Brachyramphus brevirostris*) within its historic range and natural population density.

Washington

In an internal staff communication in February 2008, the Washington State Commissioner for Public Lands announced a number of measures aimed at adaptation to climate change (Sutherland 2008). These include:

- Thinning and controlled burning to reduce fire spread,
- Establishment of a pilot program to demonstrate forest health practices to private forest owners to increase forest resilience,
- Support for urban forestry,
- Resisting of urbanization (buy-outs of private forest land),
- Work to include in-forest carbon storage in cap-and-trade measures.
- Forest health legislation (and information distribution), to reduce beetle spread,
- Possible expansion of nursery capacity for post-disturbance recovery,
- Possible establishing of seed banks of more suitable genetics for commercial species and for rare and at-risk species,
- Increasing road system environmental flexibility through fish-passage culverts,
- Possible development of monitoring plans for conservation areas, and
- Exploring bioenergy possibilities (as a market for forest-health thinnings).

To reduce the risk from Mountain Pine Beetle, heavy forest thinning is sometimes recommended, and harvesting when insects are present (Oneil et al. 2007). The removal of at-risk stands or species may sometimes be warranted. Washington State is developing forest health legislation to reduce beetle spread. Franklin et al. (2008) provide detailed management guidelines for dry forests in the east of Washington State, highlighting the need for climate change considerations to be incorporated.

The Washington Department of Natural Resources (DNR) Policy for Sustainable Forests 2006 (DNR 2006) and the Strategic Plan for 2009-2011 (DNR 2008) each contain a single reference to climate change, with no specific adaptation responses. DNR's Forest Health Highlights 2007 (Nelson et al. 2007) notes the effects of abnormally hot and dry weather on insect and fire damage occurrences, but does not mention climate change.

Oregon

Comprehensive advisory reports pertinent to the adaptations of forests to climate change have been produced (OFRI 2006; CCIG 2008) but there is little evidence of this having yet resulted in policy change. Oregon's Statewide Planning Goals and Guidelines were amended in 2006, but contain no reference to climate change (DLCD 2006). Neither the Department of Forestry's Forest Practices Act (ODF 2007) nor the Forest Health Highlights of 2007 (ODF 2008) mention climate change.

The Oregon State legislature recently passed House Bill 3543 (2007), which establishes an Oregon Global Warming Commission. Among other goals, the Commission is to evaluate forest adaptation methods, insofar as they pertain to increasing carbon sequestration. The Oregon Department of Forestry considers its well-developed policies on native forest regeneration and forest-land retention to be foundational to climate change adaptation (David Morman, Director Forestry Resources Planning Program, Oregon Department of Forestry, pers. comm. 29 July 2008).

California

California's 'Scenarios Project' (Cayan et al. 2008) included forestry as one of the six sectors of the states economy studies for the projected impacts of climate change. Although California is well developed in climate change policy formulation in many areas (Franco et al. 2008), this does not yet appear to be reflected in forest policy or management specifically aimed at adaptation.

California has established a state-based voluntary emissions accounting scheme (www.climateregistry.org), with forests being eligible for credit as carbon sinks. Senate Bill 812 (2002) requires that forests managed for carbon sequestration must be mixed age and mixed species to qualify for inclusion on the carbon sink registry (CCAR n.d.).

Most state agency work plans reported by the California Climate Action Team relate to greenhouse gas emission reductions. The California Department of Forestry and

Fire Protection does however state an aim to increase fuel reduction burning threefold and double forest thinning by 2020 (CCAT 2005).

ANALYSIS

Analysis Classification Schemes

Various methods of classifying adaptation actions exist, depending on what differentiating attribute is of interest. Smit et al. (1999) suggested that adaptation responses may be classified according to purposefulness, timing, temporal scope, spatial scope, function/effects, form or performance. There is a degree of subjectivity in most of these parameters, as the range of policies or management actions often form a continuum rather than falling into neat categories. Our classification scheme is based on the relevant classes from Smit et al. (1999), and each adaptation measure is then assessed either according to previously published criteria or in a way defined in this paper. Five of Smit et al. (1999)'s classes are used:

A) Timing:	i) reactive, ii) anticipatory
B) Temporal Scope:	i) short term, ii) medium term, iii) long term
C) Spatial Scope:	i) policy level, ii) forest management, iii) stand level
D) Function/Effects	i) resistance, ii) resilience, iii) preemption
E) Form:	i) informational policy instruments, ii) economic policy instruments, iii) regulatory policy instruments, iv) management measures

Smit et al. (1999)'s included a class of 'purposefulness', within which Carter et al. (1994) distinguish between planned and autonomous adaptation. Autonomous adaptation may then be divided into inbuilt (physiological), routine (conscious adjustments to changed circumstances) or tactical (implies behavioral change, but still internal to the system). The UNFCCC (2006) define 'autonomous' as "not requiring external intervention" and Rozenzweig and Tubiello (2006) add that 'autonomous' is "independent of policy". This class is therefore not relevant within our classification scheme, as all the adaptations measures we examined are planned.

Timing is covered by Klein and Tol (1997), who separate adaptation into 'reactive' and 'anticipatory'; an approach since followed by the IPCC (Burton et al 2001). Burton et al. (2001) also divide responses into 'human' and 'natural', and human responses into 'public' and 'private'. Klein and Tol (1997) note that natural responses are always reactive and autonomous. Planned adaptation (human by definition), may be either reactive or anticipatory. By Klein and Tol (1997)'s definitions, human actions that enable natural systems to adapt autonomously may be classed as planned anticipatory adaptation (describing both purposefulness and timing). We will follow this approach. Burton et al. (2006) use different terminology, but separate reactive and anticipatory

according to the nature of the action. Actions or policies that aim to reduce impacts of events after they have occurred (such as debarking and removing of insect infested trees) are reactive, while measures to reduce the risk of unwanted situations (such as tree species change) are anticipatory.

Temporal scope may be somewhat arbitrarily defined by 'short, medium or long term'. Long term implies that the action will be continued or will continue to have a substantial effect for a full forest rotation (roughly 50-250 years). Short term actions may be in response to an immediate threat, with little long-term effect beyond a few years.

Spatial scope with reference to forestry may be covered by the EFI (2008)'s use of 'stand level, forest management or policy level'. Following EFI (2008)'s definitions, 'stand level' includes forest regeneration, tending and thinning and harvesting, 'forest management' is management planning and forest protection, while 'policy level' includes infrastructure and transport, nurseries and forest tree breeding and adaptation risk management in risk management and policy.

Function/effects appear to be poorly covered in the literature to date. Smit et al. (1999) offer the possibilities: 'retreat, accommodate, protect, prevent, tolerate, spread, change or restore'. We define function/effects in terms of 'resistance, resilience or preemption'. Resistance oriented policies and actions aim to maintain current forest communities in the form in which they now exist. Resilience implies that polices and actions will assist the forest to autonomously adapt to climate change, while preemption suggests that policies and actions will substantially change forest structures or species to a form better suited to anticipated future climate.

Form is discussed somewhat confusingly by Burton et al. (2006) as also being either proactive or reactive, depending on whether the aim is to reduce exposure to future risks, or to alleviate impacts once they have occurred. This appears to have little connection with Smit et al (1999)'s discussion of form, which suggested 'structural, legal, institutional, regulatory, financial or technological' as appropriate descriptors. We comply with Smit et al. (1999)'s usage of 'form', and follow Roberts (2008) in classifying form as either 'management measures or policy instruments, and further dividing policy into 'regulatory, economic or informational'. We consider that Burton et al. (2006)'s concept of form has more to do with the temporal scope of planned anticipatory actions than with Smit et al. (1999)'s methodological concepts, and thus may be adequately covered under previously defined categories. Ogden and Innes (2007) classed adaptations actions as either 'operational' or 'strategic', but this also appear to us to be adequately covered under other form, spatial or temporal classifications.

Smit et al. (1999) also include a class of 'performance', which relates to the practicality, fairness, cost and efficacy of adaptations actions. Heller and Zavaleta (2009) allude to performance issues when they discuss whether a proposed action is a 'general principle' or 'actionable', but this is not appropriate to a discussion of already actioned policy or management responses. Performance issues in the sense of Smit et al. (1999) are difficult to judge without hindsight and so are not possible in this review.

Analysis Matrix

With the attributes and descriptors defined in the previous section it is possible to break down the results of our review and group adaptation measures according to their attributes (table 1). Brief descriptions of each measure follow the table.

Table 1: Analysis Matrix.

Measure	Timing		Temporal scope			Spatial scope			Funtion/Effects			Form				Number of countries with example (from 14)
	reactive	anticipatory	short term	medium term	long term	policy level	forest management	stand level	resistance	resilience	preemption	informational policy	economic policy	regulatory policy	management measures	
Targetted monitoring	X			X			X				X	X				7
Enabling programmes		X	X			X				X		X				13
Altered silvicultural regimes, mid rotation	X			X				X		X					X	7
Altered silvicultural regimes, cross-rotation		X			X			X			X				X	5
Increased threat suppression capability	X			X			X		X						X	7
Increased threat protection		X		X			X			X					X	6
Increased threat prevention		X	X			X			X					X		3
Tree breeding/genetics		X			X	X					X			X		5
Altered spatial arrangenment of conservation reserves		X			X		X		X					X		1
Increased management intensity	X			X				X	X						X	2
Infrastructure development		X		X		X			X						X	2
Forest converion incentives		X			X	X					X		X			2
TOTAL	4	8	2	6	4	5	4	3	5	3	4	2	1	3	6	

Targeted monitoring: Long-term, successive measurement of forest or forest species for change in response to climate change. Most jurisdictions have some form of general purpose forest inventory program, but these pre-date the realization of climate change and so should not be considered as adaptation actions.

Enabling programs: Policies established to assist other organizations to adapt to climate change. This may include establishing advisory bodies, sponsoring research, organizing major conferences etc.

Altered silvicultural regimes, mid rotation: Thinning and tending operations (intensity, frequency), in response to altered climatic conditions (i.e. drought).

Altered silvicultural regimes, cross-rotation: Changes in planting densities, adjustments of revegetation species mix, etc.

Increased threat suppression capability: Increase in resource availability for fire suppression or pathogen control. Measures to suppress threats when they occur.

Increased threat protection: Actions such as fuel-reduction burning or forest thinning aimed at reducing the flammability of the forest or reducing the likelihood of damage from pests or diseases. Measures to reduce the harm from future threats without increasing suppression capabilities.

Increased threat prevention: Enhanced quarantine measures, stricter regulatory control on fires, forest health legislation etc. Measures to prevent threats from occurring.

Tree breeding/genetics: Programs to develop and distribute new cultivars of species, or to establish provenances outside their traditional climate range in the expectation of climate change.

Altered spatial arrangements of conservation reserves: Includes reserve expansion, moveable boundary reserves and connectivity corridors, where these changes are targeted at assisting the conservation of species threatened by climate change.

Increased management intensity: Includes actions such as more intensive thinning regimes, shorter harvest rotations etc. Differs from the mid-rotation silviculture class in that the aim is to resist the impacts of climate change on stands rather than to assist the development of resilience.

Infrastructure development: Forest road system development in the expectation of shorter harvest periods in a warmer climate.

Forest conversion incentives: Policies to encourage private landholders in the insertion of different, mostly broadleaved species into former coniferous plantations by either natural regeneration or underplanting in order to increase the structural diversity and the

stability of the stand in the face of climate change associated risks such as insect outbreaks.

Method discussion

According to Yin (2003) and Silverman (2006) the findings of case studies have an increased validity if based on several sources and if applying different methods to collect data. Hence a triangulation of sources and methods is a logical approach under consideration of the natural variability of the perception of the phenomenon (adaptation of forest management) amongst the actors of each case. However it is important to note that the main documents analyzed in a content analysis represent an organizations' viewpoint and may differ from individuals' opinion within that organization. This may lead to two different data sets and to different levels of answers and thus need to be analyzed with care (Mason 2002). In this study, the main importance however is on the different angles the phenomenon can be viewed from and thus triangulation remains an appropriate qualitative research design for valid case studies. Having experts commenting on our findings we check the validity of our interpretations with those that have the most knowledge in this weakly explored field. In general, the case study design as implemented in this study is a strong tool to gain insight into this poorly developed and documented area and enables the integration of actors that are at the forefront of the emerging science of adaptation.

Analysis discussion

Adaptation science

Although arguments about the difference between forest adaptation measures or the precise classification of those measures may be somewhat academic from a forest manager's perspective, the formal examination of these issues can provide insights useful for policy formulation. These in turn can be of great relevance to managers. The development of the classification scheme in this document has allowed more precise definitions to be made of both adaptation methods and their characteristics, and may assist policy makers to more accurately target their responses to particular challenges.

In some cases, forest managers may be moving ahead with adaptation mechanisms in advance of formal agency policy change (John Innes, UBC, pers. comm. 20 July 2008). These actions are generally unverifiable in formal documentation, although some circumstantial examples are collated in MBAC (2008). Other authors have noted that agency staff and other forest stakeholders often have a higher level of concern about climate change than formal policy would suggest (Keskitalo 2008; Powledge 2008). We have avoided these examples due to the difficulty in providing evidence, but future research in this area would most likely provide interesting insights not only into adaptation issues but also into forest management philosophy, psychology and general governance issues.

Sustainable forest management

Often, clear adaptation strategies are not distinguished from general 'sustainable forest management practices' and hence it is difficult to define specific adaptation measures. Similar conclusions were drawn from a recent survey in Europe (Lindner et al. 2008). Undoubtedly, successful adaptation depends on sustainable forest management, and sustainable forest management equally depends on successful adaptation. Nevertheless, most of the countries reviewed in this report are signatories to either the Montreal Process or the Ministerial Council for the Protection of Forests in Europe (MCPFE 1993), which obliges them to follow sustainable forest management practices whether confronted by climate change or not. General announcements of adherence to sustainability principles should not then be considered as specific adaptation policies. A future challenge for research on climate change impacts and adaptation is to disentangle climate change-driven changes from management-driven changes at the stand level, although certainly the two are closely linked:

> *"Fortunately, logical management responses to climate change – such as reducing stand densities and fuels, treating landscapes, and shifting to more drought-tolerant species – are consistent with management responses to other important issues, including forest health, wildfire control, older forest attributes, and protection of habitat…".*
>
> (Franklin et al 2008).

Adaptations policy documents often refer to basic activities that would have been carried out anyway, or ongoing processes that may only slightly be adapted to reach a climate change goal. While completely separating politics from policy is most likely impossible, it is instructive to examine whether extras funding is allocated for the adaptations aspect of an otherwise unremarkable SFM policy, and whether new programs and processes with their own funding scheme are developed especially for adaptation.

Research

Most jurisdictions have some form of research program of direct relevance to forests' adaptations to climate change. There is of course a role for research in informing policy, but we hesitate to class research as an adaptation measure per se. Similarly to climate impact studies or vulnerability assessments, research is a vital part of the adaptation *process*, but does not, by itself, result in altered management practices.

The adaptation classification scheme that we have developed here is not well-suited to compartmentalizing different classes of research, although some concepts may be relevant. It may be possible to classify research programs according to spatial scope (policy, forest management or stand level), but the other descriptors used here are not readily applicable.

CONCLUSIONS

Most jurisdictions appear to be in the early stages of adaptation, with a strong concentration on research activities and other enabling programs to aid in coordination of agency responses. Rather than taking an ad-hoc, piecemeal approach, forest agencies are concentrating on developing information and putting appropriate structures in place.

Some activities (such as forest conversion or infrastructure development) are only relevant in countries with a highly industrialized forest estate. The focus of forestry and the expected impacts (or the vulnerability of different forest functions and their respective importance) shape the adaptation foci of the different countries. In Finland for example wood production is very important hence forest road quality is a main adaptation focus.

More policies and adaptations reported on in this paper are anticipatory, rather than reactive. It may be that reactive actions are just done, because they have to be (in response to a clear immediate threat), without the support of a policy that specifically discusses climate change. Medium and long-term measures are prevalent, in the recognition that the greatest impacts of climate change are yet to come. Political uncertainties regarding the post-Kyoto regime may also impede short-term responses, as the place of forestry in upcoming carbon regulations is not yet clear. The longevity of forests and the high proportion of young forests in central Europe tend to encourage a focus on mid-term silvicultural alterations as a preferred adaptation response.

Economic instruments are not commonly used, which is surprising given the focus on these instruments in carbon mitigation discussions. There is scope perhaps for economic instruments to play a greater role in encouraging adaptation measures, particularly in private forestry.

Threat suppression measures are more common than threat prevention, although this may be a result of political rather than management imperatives. In developed nations funding is generally made readily available for threat suppression activities, while longer-term preventative measures are sometimes less well supported.

Apart from research activities, all of the adaptation measures found in this review may be classed under one of only twelve specific headings. Although at first glance this seems to imply that adaptations responses are quite limited, the spread of new adaptations measures appears to be well-distributed across the various categories of table 1. This suggests that forest agencies have available a diverse suite of possible measures, depending on their particular local challenges.

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APPENDIX 1: EXPERT SOURCES

Wilfredo Alfaro	CONAF, Ministry of Agriculture of Chile
Alexander Buck	IUFRO, Vienna
Michael Campagna	MRNF, Quebec
Magda Campos	IMN, National Meteorological Institute
Chao He	Bejing Forestry Univeristy, College of Economics and Management
David Cleaves	USDAFS Climate Change Council

Vladimir Viktorovich Dmitriev	Federal Forestry Agency of Russian Federation
Jim Farrell	Canadian Forest Service
Jorge Gayoso	Universidad Austral de Chile
Peter Glück	University of Natural Resources and Applied Life Sciences
Hubert Hasenauer	University of Natural Resources and Applied Life Sciences
Martin Höbarth	Austrian Chamber of Agriculture
John Innes	University of British Columbia
Abigail Kimbell	USDA Forest Service
Marja Kolström	European Forestry Institute
André Laroze	ODEPA, Ministry of Agriculture of Chile
Sonia Lobo	SINAC, National System of Conservation Areas of Costa Rica
Candace Montoya	DNR, Washington State
David Morman	Oregon Dept. of Forestry
Margret Möges	Bavarian State Forest Agency
Aquiles Neuenschwander	FIA, Ministry of Agriculture of Chile
José Ramón Picatoste	OECC, Spanish Climate Change Office
Nikolai Evgenievich Prokazin	All-Russian Research Institute for Silviculture and Forestry Mechanization (VNIILM)
Geoff Roberts	GCR Forestry, Australia
Carmen Roldán	ENCC, Ministry of Environment and Energy
Bernard Roman-Amat	Paris Institute of Technology for Life, Food and Environmental Sciences (Nancy)
Philippe Riou-Nivert	National Professional Centre for Forest Owners
Gerardo Sánchez	Spanish Ministry of the Environment, Rural and Marine affairs
Friedrich Schmitz	Federal Ministry for Food, Agriculture and Consumer Protection
Rupert Seidl	University of Natural Resources and Applied Life Sciences
Shuirong Wu	Institute of forest policy and information, Chinese Academy of Forestry
Dave Spittlehouse	MFR, British Columbia
Igor Vladimorovich Unov	Russian Federal State Unitary Enterprise Roslesinforg
Rafaelle Vignola	CATIE, Tropical Agricultural Research and Higher Education Center
Alexandra Wieshaider	Austrian Federal Forest Company
Xiaoxian Zheng	Beijing Forestry University, College of Forestry
Yali Wen	Beijing Forestry University, College of economics and Management
Yuanzhao Hou	Institute of forest policy and information, Chinese Academy of Forestry
Anatolyi Vasilievich Zigynov	St.Petersburg Forestry Institute (PETRONIILH), Russia

APPENDIX 2: ORGANISATIONAL SOURCES

(Note that not all of the organizations listed in this table had something pertinent to add to our review).

Country	Organizations	Methods			
		Content Analysis	*Email*	*Phone*	*Interview*
Australia	Department of Sustainability and Environment (Victoria)	x			
	Forestry Tasmania	x			
	Department of Primary Industries (New South Wales)	x			
	Forests New South Wales	x			
	MBAC Consulting		x		
	Department of Climate Change	x			
	Department of Agriculture, Forests and Fisheries Parks Victoria		x		
Austria	University of Natural Resources and Applied Life Sciences		x		
	Austrian Federal Forest Company (Österreichische Bundesforste AG)	x	x		
	Austrian Chamber of Agriculture		x		
	Federal Ministry for Agriculture, Forestry, Environment and Water	x			
Brazil	Ministry of Environment (MMA)	x			
	Secretary of Climate Change and Environmental Quality	x			
	Climate Change Department	x			
	Secretary of Biodiversity and Forest	x			
	Forest National Commission (CONAFLOR)	x			
	Biodiversity National Commission (CONABIO)	x			
	Genetic Heritage Management Council (CGEN)	x			
	Environment National Council (CONAMA)	x			
	Brazilian Biodiversity Portal (PORTALBio)	x			
	Forest National Program (PNF)	x			
	Protected Areas Department	x			

	Genetic Heritage Department	x	
	Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) - Vinculado	x	
	Chico Mendes Institute for Biodiversity Conservation (ICMBio) - Vinculado	x	
	Brazilian Forest Service (SFB)	x	
	Ministry of Science and Technology (MCT)	x	
	Secretary of Policies and Programs in Research and Development (SEPED)	x	
	Brazilian Climate Change Forum (FBMC)	x	
	National Institute of Space Research (INPE)	x	
	Weather Forecast and Climate Studies (CPTEC/INPE)	x	
	National Institute of Amazon Research (INPA)	x	
	Large Scale Biosphere-Atmosphere Experiment in Amazonia	x	
	National Institute for Semi-Arid (INSA)	x	
	Interministerial Committee on Climate Change	x	
	State Center for Climatic Change (CECLIMA)	x	
	National Forest Inventory (IFN)	x	
	Research Center in Degraded Soils Restoration and Desertification Combat (NUPERADE)	x	
	National Action Program to Combat Desertification and Mitigate the Effects of Drought (PAN-Brasil)	x	
	Brazilian Agricultural Research Corporation - Forest (EMBRAPA FLORESTA)	x	
	Amazon Institute for Environmental Research (IPAM)	x	
	Federal University of Parana (UFPR)	x	
Canada	Natural Resources Canada	x	
	Ministry of Forests	x	x
	Environment Canada	x	
	Canadian Climate Impacts and Adaptation Research Network	x	
	Canadian Model Forests Network	x	
	Ministry of Forests and Range (BC)	x	x
	Ministère des Ressources naturelles et de la Faune (Quebec)	x	x

	Ministry of Development, Environment and Parks (Quebec)		x			
	Environment Yukon		x			
Chile	Resources and Research for Sustainable Development (RIDES)		x		x	
	University Austral of Chile (Bosques proCarbono)		x		x	
	Forestry Institute (INFOR)		x		x	
	Foundation for Agrarian Innovation (FIA)		x		x	
	Office for Agriculture Policy and Studies (ODEPA) Ministry of Agriculture		x		x	
	National Forestry Corporation (CONAF)		x		x	
	National Commission of Environment (CONAMA)		x		x	
	Centre for Environmental Studies				x	
China	Institute of forest policy and information, Chinese Academy of Forestry	x				
	Chinese Academy of Forestry		x	x	x	x
	Beijing Forestry University, Faculty of Forestry		x	x	x	x
	State Forestry Administration of China		x	x	x	x
Costa Rica	National System of Conservation Areas (SINAC)		x	x	x	
	National Climate Change Strategy (ENCC)		x		x	
	National Meteorological Institute (IMN)				x	
	Tropical Agricultural Research and Higher Education Center (CATIE)		x		x	
	National Forestry Office (ONF)			x	x	
	National Forestry Financing Fund (FONAFIFO)				x	
	Tropical Scientific Center (CCT)				x	
	Ministry of Environment and Energy (MINAE)		x		x	
Finland	Ministry of Agriculture and Forestry		x			
	Joensuu University			x		
France	National Forest Agency (ONF)		x	x		

	French National Institute for Agricultural Research (INRA)	x			
	National Professional Centre for Forest Owners (CNPPF)		x		
	Paris Institute of Technology for Life, Food and Environmental Sciences (AgroParisTech /ENGREF)		x		
	National Forest Agency, Regional office 'Lorraine' (ONF, section Lorraine)		x		
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	x			
	Federal Ministry of Food, Agriculture and Consumer Protection	x	x		
	Bavarian State Forest Agency (Bayerische Staatsforsten)	x	x		
	Bavarian State Institute of Forestry (Bayerische Landesanstalt für Wald und Forstwirtschaft)	x	x		
	State Forest Agency Saxony (Staatsbetrieb Sachsenforst)	x	x		
	Brandenburg Ministry for Rural Development, Environment and Consumer Protection	x			
	Brandenburg State Institute of Forestry (Landesforstanstalt Eberswalde)	x			
International	International Union of Forest Research Organisations (IUFRO)		x		
	European Forestry Institute (EFI)		x		
Russia	Federal Forestry Agency (ROSLESKHOS)	x	x	x	x
	All-Russian Research Institute for Silviculture and Forestry Mechanization	x		x	
	IUCN Programme Office for Russia	x			
	Russian Forest Protection Center (Roslesozashita)	x			
	Federal State Unitary Enterprise Roslesinforg	x		x	
	ST. Petersburg Forestry Institute	x		x	x
	Far East Forestry Research Institute	x			
	Al-Russian Research Institute of Forest fire Protection and Forestry Mechanization	x			

	Information on Forest Resources Fund	x		
	Federal State Institution (Centrles)	x		
	Centre for Problems of Ecology and Productivity of Forest, Russian Academy of Science	x		
	Institute of Forestry, Russian Academy of Science	x		
	Forest Research Institute (Karelian Research Center of the Russian Academy of Science)	x		
	Moscow State Forest University	x		
	St. Petersburg State Forest Technical Academy	x		
Spain	Spanish Climate Change Office (OECC)	x	x	x
	Spanish public environmental company (TRAGSATEC)		x	x
	Forum of Forests and Climate Change		x	x
	Ministry of the Environment, Rural and Marine affairs	x	x	
	IUCN Centre for Mediterranean Cooperation		x	
Sweden	Joensuu University		x	
	Foundation for Strategic Environmental Research (Mistra)	x		
	Swedish Forest Agency	x		
	Ministry of Agriculture	x		
USA	United States Forest Service	x	x	
	US Climate Change Science Program	x		
	National Association of State Foresters	x		
	California Climate Action Group	x		
	USFA Climate Change Council		x	
	Public Lands Commissioner (Alaska)		x	
	Department of Natural Resources (Washington State)	x		
	Oregon Forest Resources Institute	x		
	Oregon Department of Forestry	x	x	
	California Climate Action Team	x		
	California Department of Forestry and Fire Protection	x		

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