Ref:APFNet /2010/PPF/001

Asia-Pacific Network for Sustainable Forest Management and Rehabilitation

PROJECT PROPOSAL

Title: Adaptation of Asia-Pacific Forests to Climate Change

SERIAL NUMBER: APFNet /2010/PPF/001

Dr. John Innes

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January 30, 2011

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SUBMITTED BY: Dr. John L Innes
ORIGINAL LANGUAGE: English

SUMMARY

Climate change is one of the most important threats to the capacity of forest landscapes to provide ecological, economic and social services in the Asia-Pacific region. However, the potential of forests to mitigate climate change also represents a major opportunity for the forest sector. Forest ecosystems can either serve as a carbon sink or carbon source depending on their level of health and their resilience to climate change.

There is remarkably little evidence that science-based decision-making processes are being incorporated into forest management practices in the region. As a result, considerable uncertainty exists over management policies aimed at enabling forests and forest-dependent communities to adapt to climate change. We propose applying state-of-the-art technologies and analytical approaches from climate modelling, geospatial analysis, and sustainable forest management to develop essential tools for climate change adaptation, including high-resolution climate models for the entire Asia-Pacific region, and ecological models for three major forest tree species in the region. We also propose to examine the current status of studies in climate change to identify knowledge gaps and develop initial hypotheses. A network will be built comprising scientists, stakeholders and policy makers from China, Canada, USA and Australia to strengthen the project team and to facilitate information sharing and knowledge transfer. Using tools developed in this project and pilot field studies carried out by the research network, we will develop adaptive strategies and recommendations for sustainable forest management practices in the Asia-Pacific region.

We anticipate that the project will increase the level of coordination in forest management responses to climate change, thereby increasing the resilience of natural forests, plantations, and forest-dependent communities, while facilitating forest rehabilitation in the Asia-Pacific region. The high-resolution climate models developed in this project will serve as important tools to generate historical and future climate data for any location in the region. Similarly, the ecological models we develop will predict the impacts of climate change on major forest tree species distributions, providing a scientific basis for impact assessments, identification of the most vulnerable species and populations, and developing adaptive strategies. Recommendations developed from the integration of climate and ecological model predictions with observed interactions between forest management practices and climate change at pilot sites will enable optimization of forest management practices for adaptation to climate change. The project will also improve understanding of the impacts of climate change on ecosystems and forests and enhance the awareness of the scientific community to potential changes in climate throughout the region. A network that connects scientists, forest managers and policy makers will facilitate information sharing and knowledge transfer through workshops, field visits and exchange of personnel (particularly from China to western North America). Web-based scientific tools, including interactive climate models and Google map based climate and bioclimate envelopes (suitable climate ranges) will allow stakeholders and policy makers to easily access up-to-date scientific information for decision-making processes.

EXECUTING AGENCY	Department of Forest Resources Management, Faculty of Forestry, University of British Columbia
DURATION	36 months
APPROXIMATE STARTING DATE	May 1st, 2011

BUDGET AND PROPOSED SOURCES OF FINANCE	**Source**	**Contribution in US$**
	APFNet: (among which, total costs for international consultants, monitoring and unforeseen expenses are at)	1,139,200
	Counterpart contribution in kind	1,072,500
	TOTAL	2,211,700

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PROJECT BRIEF

Climate change is widely recognized as one of the major threats limiting the capacity of forest landscapes to provide a range of services in the Asia-Pacific region, including ecological, economic and social functions. Meanwhile, the potential of forests to mitigate climate change represents a major opportunity for communities and governments. The health and resilience of forest ecosystems will determine whether they will serve as carbon sink or source in a changing global climate. However, science-based decision-making has not been sufficiently incorporated into forest management practices and, as a result, there is considerable uncertainty over the most appropriate policies to enable forests and forest-dependent communities to adapt to climate change. We propose applying state-of-the-art technologies and analytical approaches from climate modeling , geospatial analysis and sustainable forest management to develop adaptive strategies that will facilitate an increase in the resilience of forests and forest-dependent communities in the Asia-Pacific region to climate change. Our specific objectives include:

1) Analysis of the current status of climate change studies in forest ecosystems and forest dependent communities in the Asia-Pacific region to identify knowledge gaps and define working hypotheses;
2) Development of high-resolution climate models for western North America and the entire Asia-Pacific region;
3) Development of ecological models to predict impacts of climate change on distributions of three major forest trees (Chinese fir (*Cunninghamia lanceolata*); *Eucalyptus* (*E. urophylla* and *E.grandis*), in the Asia-Pacific region; and Douglas-fir (*Pseudotsuga menziesii*) in North America);
4) Development of science-based adaptation strategies in management practices that will increase the resilience of forests and forest-dependent communities in the Asia-Pacific region to climate change, including specific recommendations for the pilot study sites.
5) Establishment of a network of scientists, forest practitioners and policy makers in the Asia-Pacific region that will facilitate capacity building and knowledge transfer, and will support and strengthen decision-making over forest management responses to climate change;
6) Development of scientific tools to support scientific research and policy making for regional forest rehabilitation and afforestation in a changing climate.

It is anticipated that the project will increase the level of coordination in forest management responses to climate change, thereby increasing the resilience of natural forests, plantations and forest-dependent communities to climate change, while facilitating forest rehabilitation in the Asia-Pacific region. The following specific outcomes / project deliverable are anticipated:

1) A report analyzing the current knowledge on climate change studies on forest ecosystems or forest-dependent communities in this region. Knowledge gaps will be identified and working hypotheses will be established.

2) High-resolution climate models that generate climate data for any location in the western North America and the entire Asia-Pacific region for historical years (1901– 2010) and future periods (2020s, 2050s and 2080s).
3) High-resolution climate maps will be provided for some important climate variables for the entire region. These will serve as essential tools for climate change related studies and applications in the region. Such maps have already facilitated climate change studies in western Canada and are expected to benefit climate change research throughout the region.
4) Ecological models that predict the impacts of climate change on forest ecosystems and species distribution in Western North America, China and Australia. Maps of predicted shifts in suitable climatic conditions for the three major commercial tree species will be provided for various climate change scenarios. These models will be adaptable to other species and forest ecosystems in other countries through extension after this project is completed. Ecological models and their outputs will provide a fundamental framework for assessing climate change impacts and developing adaptation strategies in forest management practices and species selection. Predicted impacts on forest ecosystems will enhance the awareness within the scientific and forest practitioner communities about potential changes in climate throughout the region and will inform decision-making. Four pilot research sites will be chosen in the Asia-Pacific region to conduct pilot studies for the project. Interactions between forest management practices and climate change will be observed at these pilot sites. Sustainable forest management recommendations will be based on integration of predicted impacts of climate change on forest ecosystems and the observed interactions from the pilot sites under different environmental, cultural and political conditions. The recommendations will cover national, regional and local forest policies and plans. Specific recommendations will be provided from the pilot sites enabling resilience of forests and forest-dependent communities in the Asia-Pacific region to climate change.
5) A network that connects scientists, forest managers and policy makers in the region to share information, knowledge and new research products. Workshops, field visits and exchange of personnel (particularly from China to western North America) for training and knowledge transfer will be implemented through this network. This network will help decision-makers to be more familiar with decision-making processes under conditions of uncertainty.
6) Web-based scientific tools for regional forest rehabilitation and afforestation will be provided including interactive climate models and climate maps based on Google map for western North America and the entire Asia-Pacific region. Bioclimate envelope maps for major ecosystems (western North America, China and Australia) and important tree species will also be incorporated into Google maps. These tools will help scientists, stakeholders and policy makers gain easy access to up-to-date information and knowledge on climate change in this region.

The project team consists of twelve scientists from Canada, United States, Australia, China, and fifteen graduate students at the University of British Columbia (UBC), Chinese Academy of Forestry (CAF), Nanjing Forestry University (NFU), Jiangxi Agriculture University (JXAU) and the Research Institute of

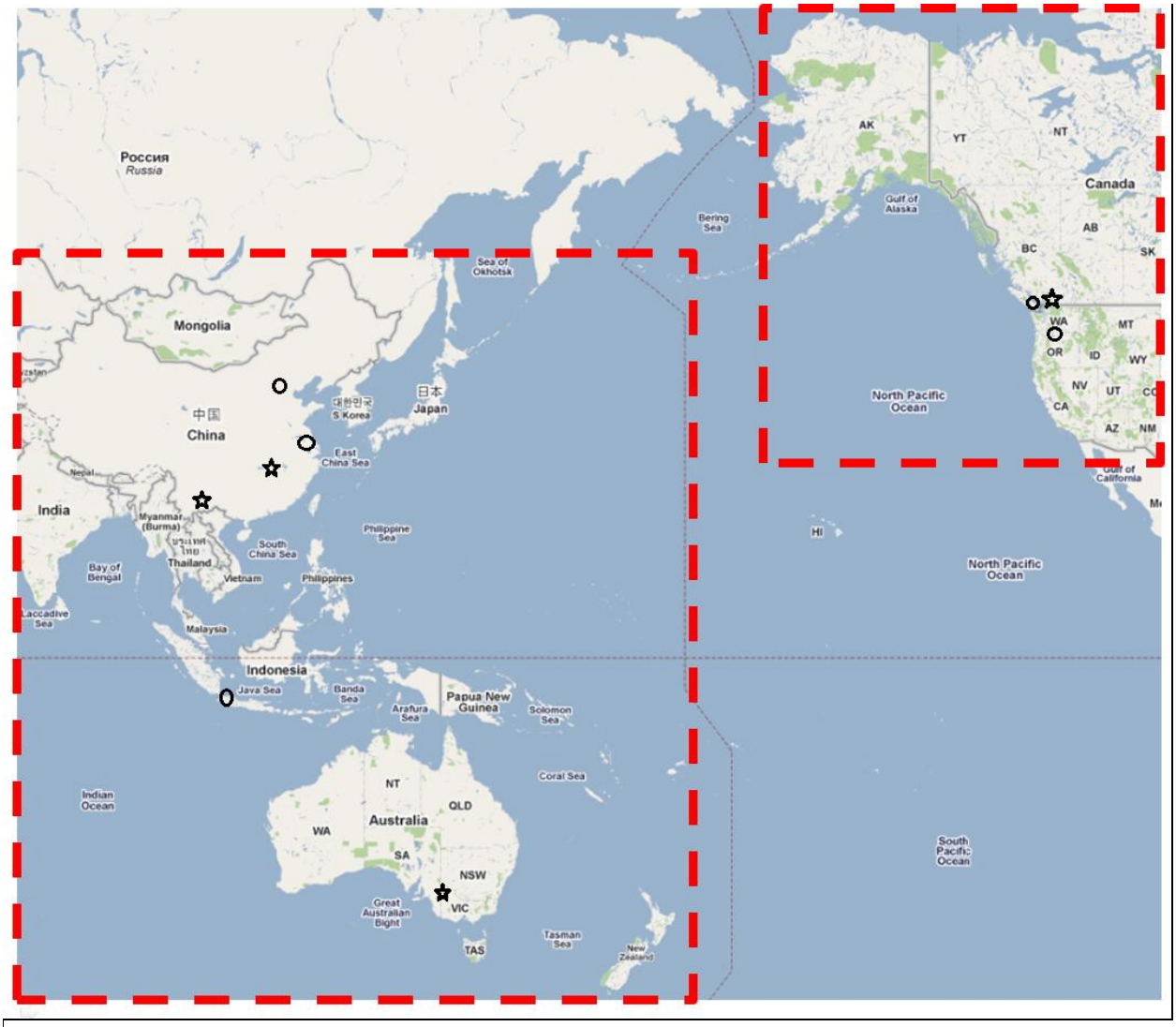
Resource Insects. The project management group includes Professor John Innes, the project leader, who will supervise the entire project. Dr. Guangyu Wang and Dr. Tongli Wang will be responsible for project management routines including coordination of the team members, progress monitoring and budget management. The project management team has extensive experience in managing budgets of large sizes (>$22 million/year) and international collaborating research projects (details in Annex E).

The project management group is supported by experienced researchers from Environment Canada (EC), the BC Ministry of Forests, Mines and Lands, and the USDA Forest Service. Dr. Craig Nitschke, Dr. Yongyuan Yin, and Dr. Shirong Liu are well-known in climate and adaptation research at the University of Melbourne (UM), Environment Canada (EC) and the Chinese Academy of Forestry (CAF), respectively. In addition, Peter Bradford (BC Ministry of Forestry) and David Peterson (US Forest Services, University of Washington) and Wenming Lu (CAF), Xiaoming Guo (JXAU) and Xiangqing Ma (FAFU) are experts in forest ecology, climate adaption and mitigation, and Dr. Judi Krzyzanowski is an expert in ecosystem-atmosphere interactions and forest resilience to environmental pressures. All project costs will be closely monitored by professional financial assistants within the Faculty of Forestry at UBC to ensure that they comply with the strict requirements laid down for the appropriate use of external funds.

LIST of ABBREVIATIONS and ACRONYMS

AMSD	Adaptation, Mitigation and Sustainable Development
AP	Asia-Pacific region
BC	British Columbia
C	Carbon
CAF	Chinese Academy of Forestry
CFERN	The Chinese Forest Ecosystem Research Network
ClimateBC	A climate model for British Columbia
ClimateWNA	A climate model for Western North America
ClimateAP	A climate model for Asia-Pacific
CAs	Collaborating Agencies
CO_2	Carbon Dioxide
EA	Executing Agency
EC	Environment Canada (Canadian Federal Agency)
FFEI	Future Forest Ecosystems Initiative
FFESC	Future Forest Ecosystems Scientific Council
GCM	General Circulation Model
GHG	Greenhouse Gas
IPCC	The Intergovernmental Panel on Climate Change
JXAU	Jiangxi Agricultural University
LANDIS	LANDscape Disturbance and Succession
NJFU	Nanjing Forestry University
PRISM	Parameter-Elevation Regressions on Independent Slopes Model (climatology)
SFM	Sustainable Forest Management
TACA	Tree and Climate Assessment Model
UBC	University of British Columbia
UK	United Kingdom
UM	University of Melbourne
UW	University of Washington

MAP of PROJECT AREAS



The study areas are highlighted by the red dashed-line rectangles, including western North America and the Asia-Pacific region. Climate models will cover the entire project areas, while the ecological models will be focused three major trees in North America (Douglas-fir or *Pseudotsuga menziesii*), China (Chinese fir or *Cunninghamia lanceolata*); and Australia (*Eucalyptus urophylla* and *E. grandis*). However, it will be possible to extend these models to other species in other countries in the region through extension of this project in the next phase. Pilot experiment sites (stars) and partners (circles) are also indicated on the map.

PART I. PROJECT CONTEXT

1.1. Relevance

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), temperatures are predicted to rise an average of 2 to 4°C globally by the end of the century. This magnitude of temperature rise and its associated climatic changes could overwhelm the resilience of even the most adaptable forest ecosystems and threaten their components, including plants and animals. Bioclimate envelopes (suitable climate niches) for the current forest ecosystems and their components, particularly forest trees, are predicted to shift much more rapidly than forest trees can migrate naturally. As a result, some local forest tree species currently occurring in these ecosystems will not be able to adapt to their local environments in the future. This will compromise the productivity and resilience of these ecosystems, and may change the forest landscapes from carbon sinks to carbon sources.

For instance, the >10 million hectares of forests destroyed in British Columbia by a mountain pine beetle outbreak induced partly by warmer temperature associated with climate change is a good example of what could happen elsewhere. According to the IPCC, ecosystems of the Asia-Pacific region are particularly vulnerable to climatic changes such as temperature and aridity that are expected to increase more rapidly in parts of this region than the global average. Climate change is therefore considered to be the most important threat to the capacity of forest landscapes to provide ecological, economic and social services. Mitigating and adapting to climate change are pressing challenges for the scientific community, stakeholders and policy makers.

The potential for forests to mitigate climate change through carbon sequestration represents a major opportunity for forestry. This is particularly important given the stated policy aim of planting 20 million hectares of forests in this region in the coming years. In establishing new plantations, there is an opportunity to select tree species that match current and future climate conditions in order to avoid maladaptation. Meanwhile, climate change will also bring new opportunities. Some planting sites may become suitable to grow species that grow faster and that are economically more valuable than the current local species.

The appropriate management of existing forests and the planning of the new plantations are critical to the adaptation of forest ecosystems to climate change and to determine the role of forests in mitigation of climate change. However, there is remarkably little evidence of sufficient quality to be incorporated into science-based decision-making and, as a result, there is considerable uncertainty over the most appropriate policies to enable forests and forest-dependent communities to adapt to climate change. There is a critical need to acquire relevant scientific knowledge and to develop fully functioning networks of scientists, stakeholders and policy makers. This will ensure the transfer of the scientific knowledge directly to decision-making processes.

In order to adjust forest management practices for existing forests and to take advantage of the opportunity for species selection in new plantations, we must understand the potential impact of climate change on forest ecosystems under different climate change scenarios. An effective approach is to first predict the shifts in bioclimate envelopes of forest ecosystems and forest species ranges under future climates. These predictions will provide the scientific basis for assessing the vulnerability of different

ecosystems and developing adaptive strategies. A representative example of research in this field is the niche-based modeling approach developed at UBC (Hamann and Wang 2006, Ecology) using multivariate statistics. Our team member, Dr. Tongli Wang, using a machine-learning approach “Random Forest”, has substantially improved the accuracy of the model and advanced this approach. However, in order to develop and apply this model, we need to have reliable high-resolution climate data for current and future periods. Tongli Wang, in collaboration with his colleagues, has developed a high-resolution climate model for Western Canada called "ClimateBC" and lately expanded this to cover western North America (ClimateWNA). The model downscales PRISM climate data (commercially available) developed by Oregon State University from a resolution of 4 x 4 km to point (scale-free) data through a combination of bilinear interpolation and a sophisticated elevation adjustment. The downscaled climate data reflect topography much better than the original PRISM data (Figure 1.1).

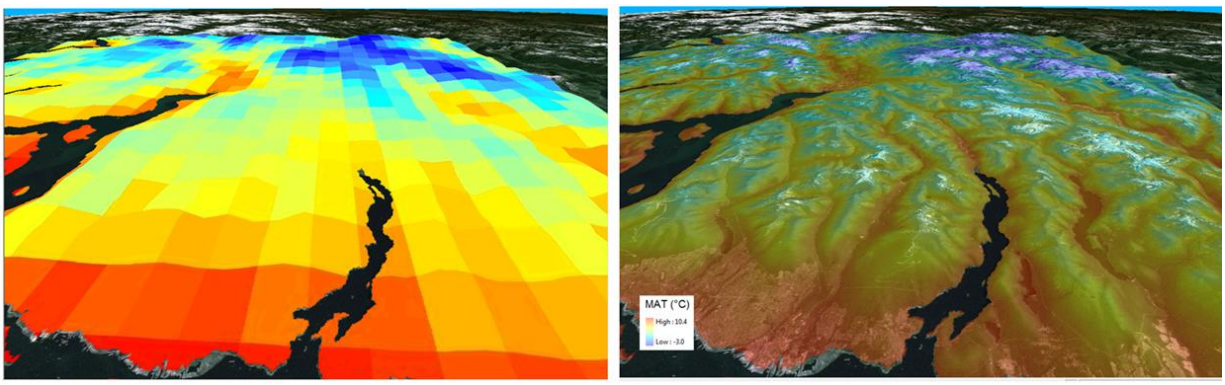


Figure 1.1 Maps of mean annual temperature (MAT) generated using PRISM data (left) and ClimateBC output (right) for an area near Vancouver, BC.

With such high quality climate data and using the Random Forest modeling approach, Wang was able to model the forest ecosystems of BC (Biogeoclimatic Ecosystem Classification (BEC)) with high accuracy (Figure 1.2) and was able to predict shifts in bioclimate envelopes for the ecosystems in future periods (Figure 1.3). As ecosystem classifications can serve as a fundamental basis for forest resource management activities, the predicted future forest ecosystems will provide the scientific basis for developing adaptation strategies for many forest management activities, including tree species selection, pest and disease control, fire control and silvicultural practices. Once a similar bioclimate model is developed for the Asia-Pacific region, these modelling methodologies can be used to model and predict forest ecosystems and species distributions for future climates in this region.

Similarly, predictions of shifts in tree species range are a critical component in a climate change adaptation framework. Using the same approach as described above, shifts in species range were predicted. Douglas-fir provides an example (Figure 1.4). Such examples provide the scientific information to match species to their favourable climate conditions in a changing climate.

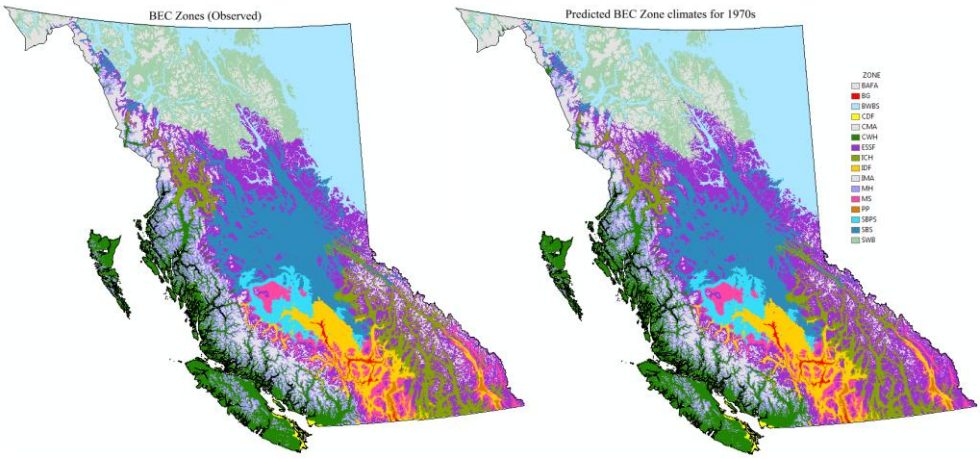


Figure 1.2 Maps of the current forest ecosystems of BC (left) and predicted bioclimate envelopes for the ecosystems (right).

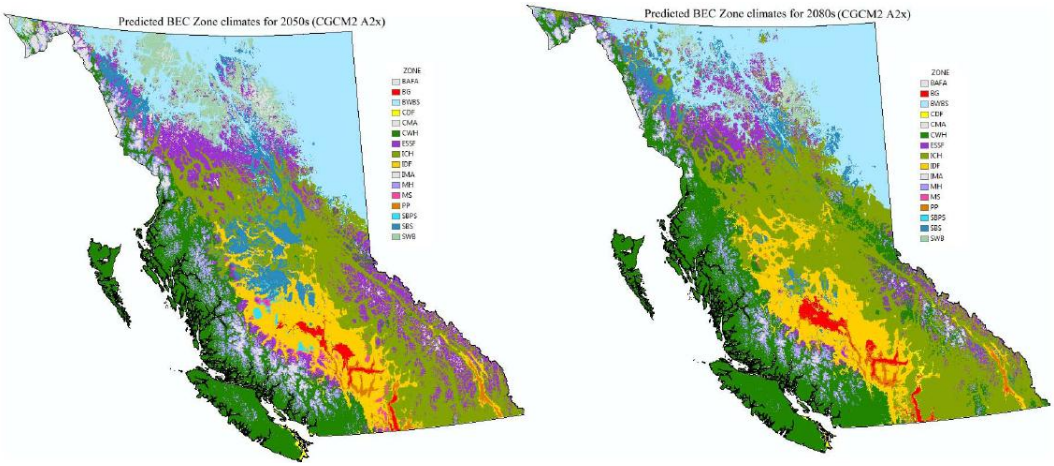


Figure 1.3 Maps of predicted bioclimate envelopes for the forest ecosystems of BC for 2050s (left) and 2080s (right) based on a mid-road climate change scenario (CGCM2 A2x).

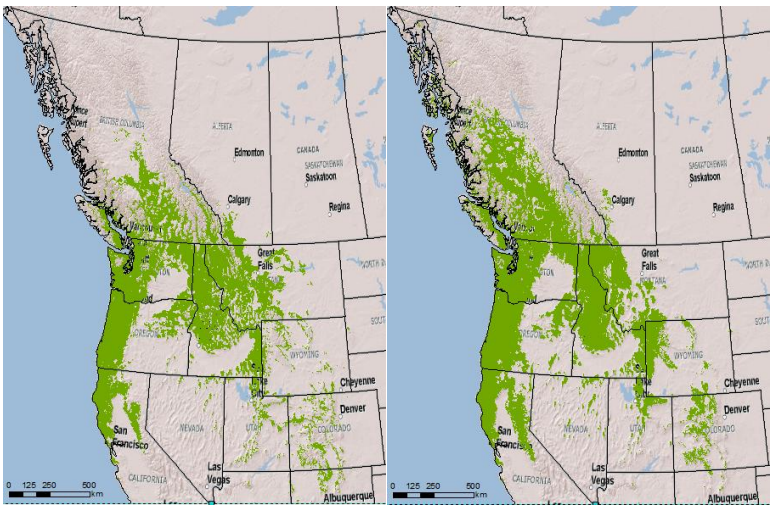


Figure 1.4 Predicted shift in bioclimate envelope for Douglas-fir in 2080s

This research is already playing an important role in climate change adaptation frameworks in Canada and has become highly influential in western North America's climate mitigation policy. Through

this project, we will extend and improve this work to the entire Asia-Pacific region. Through integration between model predictions and observations from pilot study sites and the involvement of stakeholders and policy makers, this project will provide recommendations that enable optimization of forest management practices for adaptation to climate change in the Asia Pacific region.

1.2. Relevance

The project will satisfy the objectives of APFNet by promoting forest rehabilitation, reforestation and afforestation in the region. The project will also strengthen sustainable forest management, improve forest quality in the region, and enhance the productive capacity and socio-economic benefits of forest ecosystems. Meanwhile, project outcomes will enhance biodiversity conservation and rehabilitation by developing science-based technologies to determine the impacts of climate change, and by providing strategies for integrating mitigation and adaptation as responses to climate change.

Canada is one of the largest counties in the Asia-Pacific region and its forests play an important role in climate change and forest mitigation or adaptation. The impacts of changing climate are already evident in every region of Canada, presenting new risks and opportunities, with significant implications for communities, infrastructure and ecosystems. The Government of Canada supports an aggressive approach to achieve real environmental and economic benefits for all Canadians. It also supports efforts to protect the environment by developing policies and programs, conducting scientific research, and working with other government departments, the provinces, territories and international partners in the fight against climate change.

Canada is committed to reduce its total greenhouse gas emissions by 17 per cent from 2005 levels by 2020. Forests will play a critical role for this commitment. Successful integration of forest resource management, ecosystem conservation and climate change adaptation policies will require new approaches built upon a foundation of better research into the links between the climate change and sustainable forest management (SFM). In this respect, the proposed project will tackle the issue of managing forest resource sustainability under climate change conditions by establishing a forest climate adaptation network that will develop effective climate change policies to reduce potential damage to forest ecosystems and ecological functions in the face of global climate change.

1.3. Target Area

The Asia-Pacific region is home to 20% of the world's forests, including some of the last remaining primary rain forests. Approximately 60% of the world's population live in the Asia-Pacific region. With forests in the Asia-Pacific region being among the world's most complex and threatened ecosystems; population, climate change and growing economies, coupled with extreme poverty, create many challenges and opportunities for the forests, which in themselves play an important climatic role. The degradation of Asian forests and forest ecosystems and it's the resultant consequences are profound. According to the *Future of Forests in Asia and the Pacific: Outlook for 2020*, complied by the Asia-Pacific Forestry Commission, the Asian region as a whole has experienced a net increase in forest area, yet many countries, especially in Southeast Asia, experienced a net loss. The quality and quantity of the reforestation and afforestation vary between countries. Due to the lack of scientific support in species selection, silviculture and forest

management, forestation objectives have often not been met. A reliable climate model and decision making tool will be essential for tackling these issues.

The project will cover the entire Asia-Pacific Region (Figure 1.1), the primary focus of APFNet. The pilot study sites will be located in western North America, Australia and China. The climate and ecological models will cover the majority of the region, including all of western North America, China and Australia. Through technical training and knowledge transfer, the ecological models may be extended to other parts of the region. As a result of the full coverage of the climate models, and the methodologies developed in this project, it will be relatively easy for other countries in this region to develop similar ecological models and to develop effective adaptive strategies.

1.4. Expected outcomes at project completion

The proposed research is expected to generate new knowledge and technology that will strengthen forest resource development, particularly in relation to tackling changing climate and deforestation and forest degradation. The outcomes of this proposed research will be:

1) Several scientific tools essential for climate change studies in this region will be developed; specifically climate models for the entire study area and ecological models for three major forest tree species in the region. Adaptive forest management will be developed and tested in selected pilot sites using these tools.
2) Increased knowledge and understanding of the impacts of climate change on ecosystems and forests in the Asia-Pacific region will be provided through an analysis of related studies, the use of climate and ecological models, pilot field studies, impact assessments and sensitivity analyses. The magnitude of climate change associated with various climate change scenarios and its impact on forest ecosystems, especially the shifts in bioclimate envelopes, will provide scientific information to identify the areas and ecosystems that are most vulnerable to climate change.
3) Recommendations for management practices that will increase the resilience of forests and forest-dependent communities in the Asia-Pacific region to climate change. These recommendations, generated from the integration of the results of impact assessments and information obtained from pilot field studies, will reflect local forest management practices and interactions between forest-dependent communities and forests.
4) A network connecting scientists, forest managers and policy makers in the region to facilitate capacity building, information sharing, and knowledge transfer through workshops, field visits and exchange of personnel (particularly from China to western North America). This network will help decision-makers become more familiar with decision-making processes under conditions of uncertainty.
5) Web-based scientific tools to support scientific research and decision-making for regional forest rehabilitation and afforestation in a changing climate. The web tools will include interactive climate models, and climate maps (based on Google maps) for the entire region. Bioclimate envelope maps for major ecosystems and some important tree species will be provided. We will develop interactive access to recommendations for SFM considering the effects of climate change under various climate change scenarios. The web-based climate models will allow users

to obtain climate data for historical and future periods. Maps predicting shifts in bioclimate envelopes will be viewable, together with physical maps and climate maps. These web tools will facilitate easy access for scientists, stakeholders and policy makers to up-to-date scientific information for scientific research or science-based decision-making.

Part 2. PROJECT RATIONALE AND OBJECTIVES

2.1. Rationale

It has been long recognized that the Earth is warming due to increasing atmospheric levels of carbon dioxide and other greenhouse gases. Significant changes in the Earth's climate have already impacted all forms of life, including humans, forests, fisheries, agriculture, and biodiversity. A series of international agreements have been reached, including the Framework Convention on Climate Change and its Kyoto Protocol, aimed at alleviating global warming /climate change, yet carbon dioxide emissions are continuing to increase at a rate consistent with the most pessimistic predictions of the IPCC. Developing countries, such those within the Asia Pacific region, continue to experience the consequences of climate change, including thousands of deaths and displacements caused by droughts, floods and disease. While there is increasing acceptance of the high probability of global climate change, and much discussion, few practical scientific tools have been developed that would enable policy and decision makers to identify adaptation and mitigation strategies to underpin climate change policy. In this project, we will bring scientists, government officials, forest managers, investors and local communities together to examine the implications of climate change, to develop and utilize essential tools such as high-resolution climate models and sophisticated ecological models for the Asia-Pacific region, and to facilitate information sharing and knowledge transfer.

Table1. Stakeholder analysis involvement in project

Stakeholder group	Characteristics	Problems, needs, interests	Potentials	Involvement in project
Primary stakeholders				
Policy and decision makers	Directly involved with planning, implementing, and managing forests	Uncertainty of forest dynamics under changing climate, failure of forest management, including regeneration and rehabilitation; interest in recommendations on mitigation and adaptation.	Improved management capability, adaptability to climate change.	Users of the results; The stakeholders are directly involved with the research, such as forest services, ministries of forestry, and forest managers from the pilot areas
Forest managers, timberland inventors and owners	Directly benefit from forest management and wood products	Issues of maintaining land productivity and revenue from wood products; need for guidelines on species selection, harvest rotation and management.	Ability to make better investment decisions; increased revenues from forest lands.	Users of the results; The stakeholders will be covered in the extension program of the projects and the project outcomes will be disseminated to a large range of the stakeholders in the region
Forest-dependent communities	Rely on the revenue generated from wood products and ecosystem services	The quality of life has been lowered due to the closure of wood mills, ecosystem degradation and deforestation. Interests in scientific outcomes and recommendations on the mitigation and adaptation.	Use the outcome of the research to educate locals and support mitigation effort.	Users of the results; The stakeholders will be covered in the extension program of the projects and the outcome will be disseminated to a large range of the stakeholders in the region
Secondary Stakeholders				
Wood manufacturers and the users of wood products	Indirectly affected by changes in forest practices and their outcomes	The supply and characteristics of the wood will change in the future (e.g. pulp quality); wood manufacturers will need to prepare for the changes.	Improved planning for changing supplies	The stakeholders will be consulted through questionnaire research and the outcomes and recommendations from the research will be available to them.
Academic and research organizations	Indirect and direct benefits from the research	Lack of scientific data on climate change at a fine scale has limited further research on forest adaption and mitigation; interest in better climate models	Improved modeling of changes, impacts and adaptation strategies	Researchers will have access to the results, enabling follow-on and complementary research projects.

2.2. Objectives

2.2.1. Development objective and impact indicators

A major problem for the forests of developing countries is that very few are managed sustainably. The International Tropical Timber Organization has estimated that only 5% of the forests in the developing countries of the Tropics are managed in a sustainable manner – i.e. such that they continue to supply benefits. As a result, they are failing to achieve their potential in reducing poverty development objectives. The problem extends beyond the developing countries of the tropics, and significant areas of the world's forests cannot be considered to be managed sustainably. Countries such as the Canada, Australia and the USA have the ability to provide the technological expertise that other countries need to manage their forests more sustainably. This project represents an important step in such a process of technology development and transfer.

Beyond the completion of this project, a greater proportion of the forests in the Asia-Pacific region will be managed sustainably, and forest managers will be better able to address climate change and related issues. Moreover, the ecological rewards that result from the implementation of sustainable forest management – such as enhanced biodiversity and reduced carbon emissions – Improve forest ecosystems, and their ability to provide a wide range of social-economic benefits for forest-dependent individuals, communities, and civil society. Such achievements are measurable using the following specific indicators:

1) The development of climate models and ecological/bioclimatic models will provide internet-based datasets to forest managers and practitioners, as well as guidelines for management plans, such as species selection, prevention of natural disasters, risk avoidance, and so on. This, in turn, will enhance their capability to maintain viable businesses. This use of this information (quantified via web hit counts etc,) will indicate the success of this extension activity.
2) The establishment of a knowledge pool (including the project website) related to climate change and sustainable forest management issues will communicate the information amongst stakeholders in the Asia-Pacific region. Again website usage will aid in evaluating knowledge use.
3) The establishment of pilot sites in selected countries (e.g., Canada, the U.S.A., China, and Australia) in the Asia-Pacific region will demonstrate and test "best management practices" associated with SFM and indicate some of the subtleties associated with ecosystem adaption to changing climatic variables.
4) An holistic and comprehensive Criteria and Indicators (C&Is) system has already been established in China, and will provide a frame of reference while taking into account the specific local context. These C&Is are also available for other areas in the region and are associated with certification and other management tools.

5) Acceptance and utilization of the established models in the Asia-Pacific region by researcher, policy makers and managers, will be a sign of success and extend the influence of this project and APFNet to the remaining parts of the world.
6) The creation of better formulated forest-related policies, laws, regulations, and initiatives under uncertain climate conditions, will verify use of the project's results by government officials to

2.2.2. Specific objective and outcome indicators

1) Analysis of the current status of climate change studies in forest ecosystems and forest-dependent communities in this region:
    - A report analyzing current knowledge from climate change studies in forest ecosystems and from forest-dependent communities in this region;
    - Knowledge gaps identified and working hypotheses defined.
2) Development of high-resolution climate models:
    - High-resolution climate models covering western North America and the entire Asia -Pacific region that can generate climate data for any location in the region for historical years (1901-2010) and future periods (2020s, 2050s and 2080s);
    - High-resolution climate maps will also be provided for some important climate variables for the entire region.
3) Development of ecological models:
    - Ecological models that define the bioclimate envelopes of three commercially important forest tree distributions and predict their shifts under future climates. These tree species will include Douglas-fir in western North America; Chinese fir in China and *Eucalyptus* species in Australia and will be used as economic indicators of climate change effects and successful mitigation/adaption policies;
    - Maps of predicted bioclimate envelopes for the tree species to be provided under various climate change scenarios to serve as a scientific basis for assessing climate change impacts and developing adaptation strategies in forest management practices and species selection;
    - Enhanced the awareness of the scientific community, stakeholders and policy makers as well forest dependent communities about the potential changes in climate throughout the region.
4) Development of adaptation strategies in management practices:
    - Establishment of 4 pilot sites for observation of local forest management practices and their interactions with climate change under various environmental, cultural and political conditions;

- Sustainable forest management recommendations developed through integration of ecological model predictions with observed interactions at pilot sites. Recommendations will be made at various levels to increase the resilience of forests and forest-dependent communities in the Asia-Pacific region to climate change. Specific recommendations will be provided based on results from pilot research areas;
- Changes to forest policies that avoid any unintended effects on forest resilience (e.g., restrictions on seed transfers and species selection for matching future climates).

5) Network building and technology transfer:
    - A network that comprises scientists, forest managers and policy makers;
    - Over 350 scientists, forest managers and policy makers will be trained;
    - Strengthened collaborative research and decision-making over forest management responses to climate change
    - Use of the network to seek the best-available solutions to complex problems related to climate change.
6) Development of web-based scientific tools:
    - Project website to highlight the project and to update the project progress. It will evolve to a website for extension after the completion of the project;
    - Interactive climate models including ClimateWNA (Western North America) and ClimateAP (Asia Pacific) that will allow users to easily access historical and future climate data for any location in the region;
    - Climate maps (for the entire region) and bioclimate envelope maps for some forest ecosystems and species ranges (for most of the region) to be overlaid onto Google maps for interactive visualization;
    - Recommendations based on local and regional climate change scenarios, and climate-smart indicators for sustainable forest management practices.

Part 3. DESCRIPTION OF PROJECT INTERVENTIONS

3.1. Outputs and activities

3.1.1. Outputs

Output 1: A report analyzing current knowledge on climate change studies in forest ecosystems and forest dependent communities in this region.

Output 2: High-resolution climate models that can generate climate data for any location in the region for historical years (1901– 2010) and future periods (2020s, 2050s and 2080s). High-resolution climate maps will also be provided for some important climate variables, such as mean annual temperature, mean annual precipitation, arid index and growing degree-days, for the entire region. These will serve as essential tools for climate change related studies and applications in this region, and will facilitate a wide range of climate change studies.

Output 3: Ecological models that predict impacts of climate change on major tree species distributions (Chinese fir; *Eucalyptus*; and Douglas-fir). Maps of predicted shifts in suitable climatic conditions for these major marketable tree species will be provided for various climate change scenarios. The models can be expanded to other species in other countries through extension in next phase after the completion of this project. Ecological models and their outputs will provide a fundamental framework for assessing climate change impacts and developing adaptation strategies in forest management practices and species selection. Predicted impacts on these tree species will enhance the awareness of the scientific and forest practitioner communities about the potential changes in climate throughout the region, and how appropriate management can mitigate these effects.

Output 4: SFM recommendations to increase the resilience of forests and forest-dependent communities in the Asia-Pacific region to climate change. These recommendations will be based on predicted impacts of climate change on major forest tree species and interactions between current forest management practices and climate change in different areas. The recommendations will be at different levels including national, regional and local forest policies and plans, and must be consistent with the principles of sustainable forest management while still allowing for changes to occur in many forest processes. Specific recommendations will be provided for the 4 pilot sites that are being used to demonstrate the implementation of the adaptive strategies.

Output 5: A network that connects scientists, forest managers and policy makers in the region to share information, knowledge and new research products. Workshops, field visits and exchange of personnel (particularly from China to western North America) for

training and knowledge transfer will be implemented through this network. This network will help decision-makers become more familiar with decision-making processes under conditions of uncertainty.

Output 6: Web-based scientific tools for regional forest rehabilitation and afforestation including interactive climate models, climate maps, bioclimate maps for major ecosystems and some important tree species. These tools will facilitate scientists, stakeholders and policy makers for easy access to up-to-date information and knowledge on climate change in this region.

3.1.2. Activities

For Output 1: Analysis of current knowledge on impacts of climate on forests in the Asia-Pacific Region

In this part, we will conduct a meta-analysis of climate change – forest studies in the region. The analysis will cover the existing literature, reports, proceedings and resource data to understand the status of current research on climate change and the responses of forests to these changes. The focus will be on forests in the Asia-Pacific region, since climate change influences on these forests are less documented than those of Europe, eastern North America, the Amazon, etc..

A key element in this early stage of the research is to define working hypotheses for the research. Gap analyses will be used to identify discrepancies between the expectations, implementation and achievements of climate change – forests analyses; the differences between current scientific outputs and the needs of managers and policy makers will also be examined. The analysis will provide a foundation for determining the scientific research, investment, and human resources needed for future research. This analysis will cover the following aspects:

1) Research on climate change and forest adaptation and mitigation
2) Climate issues in the Asia-Pacific region, and current strategies and actions
3) Accomplishment and effectiveness analysis, and opportunities for improvement

For Output 2: Development and application of high-resolution climate models ClimateWNA and ClimateAP

The development of high-resolution climate models is essential for the construction of ecological models to predict the impacts of climate change on forest ecosystems and species distributions. Historical climate data are critical for modelling plant-climate relationships, while future climate data are necessary for projections of future bioclimate envelopes for forest ecosystems and species distributions. ClimateBC is in the process being expanded to ClimateWNA to cover western North America. In this project, a new climate model "ClimateAP" will be developed to cover the entire Asia-Pacific region. However, as the coverage of

ClimateAP is much greater than that of ClimateWNA, we need to: 1) use different sources of climate data for the baseline dataset of the model; 2) develop a database for the recent period (2003-2010) of historical climate data; and 3) develop more sophisticated elevation adjustment functions to reflect the complex geographic variation in the lapse rates for climate variables across this region.

1) Data collection and processing

For baseline data, ClimateBC and ClimateWNA use the PRISM monthly climate data at a resolution of 2 arcminutes (approx. 4 x 4 km). However, the dataset is only available for China and Mongolia in the Asia-Pacific region. We will use the Annusplin interpolated monthly climate data at the same resolution provided by WorldClim (http://www.worldclim.org) for rest of the region. According to recent studies, the quality of PRISM data is better than that of the Annusplin interpolated data. We will therefore use PRISM data as much as possible. To integrate the ANUSPLIN data into the PRISM data, we will need to use ANUSPLIN to re-project the coordinates in order to match up the coordinates between the two datasets. The integrated dataset will then be formatted to serve as the baseline data for ClimateAP.

Historical monthly climate data for the years 1901– 2002 will come from Climate Research Unit (CRU) in the UK. The interpolated historical data are provided at 30 arcminute resolution with worldwide coverage (CRU TS 2.1). By subtracting the 1961– 1990 average from their gridded surfaces of individual years and months, we will recover their original anomaly surfaces (deviations from the 1961– 1990 normals). For the most recent period (2003–2010), we will need to generate the same monthly climate variables ourselves as CRU has stopped updating their data. We will use the same method as the one generating the CRU data to produce the historical climate data.

Global Circulation Model (GCM) projections for future periods (2020s, 2050s and 2080s) will be obtained from the Pacific Climate Impacts Consortium web site (http://www.pacificclimate.org). Predictions are from the IPCC Fourth Assessment for five emission scenarios (A1FI, A2, B1, B2 and A1B) commonly used in General Circulation Models (GCMs). Because different GCMs use different prediction locations and different spatial resolutions, we will interpolate these gridded data to a standardized to 1° latitude by 1° longitude grid using Annusplin. We will use anomaly data from the reference period 1961– 1990.

2) Model development

ClimateAP will use a combination of bilinear interpolation and elevation adjustments to downscale the baseline climate data (4 x4 km) in run-time to scale-free formats for locations of interest for the reference period (1961– 1990). The program first extracts

the monthly temperature, precipitation and elevation data for the four neighbouring tiles of the location based on its coordinates and then calculates their bilinear-interpolated values for the location. Partial derivative elevation adjustment functions will be developed for this region as we did for ClimateWNA, where the functions were developed for three geographic areas (subunits) separately within western North America. We will need to develop such functions for a larger number of subunits (around six) in the Asia Pacific region.

Using 36 climate variables in the input datasets, ClimateAP will produce the output for 85 climate variables. Most can be directly calculated from the monthly variables, while the rest will be derived based on the relationships between monthly variables and biologically important variables, such as growing degree-days, frost-free period, water deficit, etc. These climate variables are not provided by most of the climate models. Using various formulas and algorithms to model such relationships, ClimateAP will be able to output these climate variables. Historical climate data for modeling these relationships will be obtained from the Global Historical Climate Network.

Climate data for historical and future periods are at very coarse resolutions. Through downscaling the anomaly data for these periods and overlaying them onto the free-scale baseline data for the reference period (1961– 1990), ClimateAP will generate high-resolution climate data for historical and future periods. As the downscaling will be performed in run-time, no additional storage space will be required to store high-resolution data inside the model. It is anticipated that ClimateAP will substantially promote climate change related studies in this region.

A Microsoft Windows based software package will be developed to incorporate all the functions listed above with a user-friendly interface. This program will be able to run in other operating systems, such as Mac and Linux.

3) Model validation and the generation of climate maps for the reference and future periods

Climate model output will be validated using data obtained from weather stations in the region. The validation will be done both for basic variables and for the derived biologically-relevant variables. The model validations will be carried out for different countries including Canada, US for ClimateWNA, and China, Australia, Indonesia for ClimateAP.

On completion of the program, climate data will be generated for the reference period (1961– 1990) and three future periods (2020s, 2050s and 2080s) for the major climate variables and climate maps will be produced for visualization and downloading.

For Output 3: Development of ecological models

Modeling the plant-climate relationships and predicting suitable climate niches (bioclimate envelopes) for major forest trees in future periods are essential steps in developing effective approaches to assessing climate change impacts on forest ecosystems and developing adaptation strategies. Predictions of the impacts of climate change on BC ecosystems and species ranges using different modeling approaches have provided a tremendous amount of scientific information and have raised public awareness about the impacts of climate change in BC. Dr. Tongli Wang will lead this activity, and will apply the state-of-art modeling technique "Random Forest" and take advantage of ClimateWNA and ClimateAP. In this project, we will extend our modeling activities from BC to western North America and to the Asia-Pacific region, particularly China and Australia (where good calibration data exist).

Through the modeling of forest ecosystems and species distributions, we will be able to define the bioclimate envelopes for some major tree species, and project the shifts of these bioclimate envelopes in future periods under various climate change scenarios. Based on the impact of climate change on the bioclimate envelopes, we will also be able to identify the most vulnerable forest ecosystems and tree species in a changing climate.

1) Collection of vegetation data including the data for three major tree species distributions in western North America, China and Australia

   For modeling species ranges, ecological plot data will be obtained from Forest Inventory and Analysis (FIA) for the USA and the Long Term Ecological Plots data for BC. For China, the species distribution data for Chinese fir will be obtained from Chinese Academy of Forestry and Chinese State Bureau of Forestry. For Australia, we will use the national classification for forest type, cover, extent and tenure, and will obtain additional data from our collaborator in Australia. In addition, we will also model the relationships between insect epidemics or outbreaks and climate conditions in collaboration with the Research Institute of Insect Resources, Chinese Academy of Forestry.

2) Generation of high-resolution climate data for the locations where vegetation data are collected, and gridded climate data for projections of bioclimate envelope maps.

   In the modeling process, the digital maps of the three species will be rasterized at 1 km resolution. Climate variables for the reference period (1961– 1990) and three future periods (2020s, 2050s and 2080s) will be generated by ClimateWNA and ClimateAP and attached to the gridded ecosystem data points. Random Forest models will be developed with the climate data for the reference period. For predictions of bioclimate envelopes for future periods, the model runs will use future climate data to replace the climate data for the reference period. Three or more climate change scenarios will be used.

3) Development of models to capture the plant-climate relationships using the machine-learning approach Random Forest and process-based approach TACA and LANDIS models.

The machine-learning Random Forest modeling method was used to model the plant– climate relationships for the ecological models. Random Forests is an ensemble classifier which builds a large number of regression trees, collectively called a ‘forest’. Each decision tree in the forest is constructed using a bootstrap sample of the input data (i.e., a random sample with replacement) so that the resulting dataset (bagged sample) contains about 64% of the original observations and the remaining observations comprise the out-of-bag (OOB) sample. Each node of a decision tree is split using the best predictor (the one that minimizes classification error) among a randomly selected subset of predictor variables. After the Random Forest model is built, each observation in the OOB dataset is run down all trees to provide a "vote". The final result is based on the majority vote of the individual trees. The OOB dataset provides unbiased error estimates and independent predictions. This machine-learning approach is powerful; however, optimization of this approach is tricky. We are among the earliest users to apply this approach in modelling forest ecosystems and have accumulated extensive experience in optimization of the model.

The models for BC, western North America, China and Australia will need to be established and optimized individually. Due to the huge size of the datasets and the high demand in computing power, we will need to build up two work stations to conduct the modelling work.

Meanwhile, TACA, a process based modeling approach developed by Craig Nitschke (UM) and John Innes will also be applied. The TACA model is a process-based model that models the impacts of climate on the occurrence of specific vegetation species based on, for example, their dormancy requirements. LANDIS II is a spatially explicit model that can simulate forest succession, climate change and seed dispersion across large landscapes. These models will provide alternatives means of model validation. TACA and LANDIS II have been successfully applied by the UBC and UM team to model future distributions of forests in Yukon Territory, northern Canada, and have been adapted to model changes in forest distribution in southeastern Australia.

For Output 4: Pilot study and development of recommendations for SFM practices for adaptation

The development of best management practices and appropriate management plans for managing forests in terms of climate change adaption and mitigation have become an important element in forest policy. In this research, we will incorporate ongoing studies and analyses being conducted with the SFA on the development of sustainable forest management

criteria and indicators in China. This will be integrated with the climate and ecological models to assess current forest management practices, and to develop adaptation strategies and appropriate recommendations for best management practice under climate induced changes. Based on the results obtained from the assessments of potential impacts of climate change on forest ecosystems and species ranges, we will identify possible interactions between predicted impacts and management actions. This will require multi-scale analysis because although some policies are regional in nature, others are more local. This analysis will occur through a series of test sites located in China, Australia and western North America. A set of alternative forest adaptation practices will be selected, and environmental and economic impact analysis methods will be used to identify the social, economic, and environmental impacts of forest adaptation options. The results generated by this analysis will provide the basis for selecting effective forest adaptation options to reduce climate vulnerability and to enhance forest ecosystem resilience: Pilot study benefits and specifics include:

1) The studies will be undertaken in Western North America (Malcolm Knapp Research Forest), and China (Taihe Jiangxi and Research Institute of Insect Resources in Yunnan) and Australia (Victoria). We have discussed the research with an Australian plantation company (Elders Forestry), which is interested in hosting the pilot research. The pilot research work will identify data gaps especially for commercial forests, such as Chinese fir *(Cunninghamia lanceolata)*; *Eucalyptus* (*E. urophylla* and *E.grandis*), in the Asia Pacific region; and Douglas-fir *(Pseudotsuga menziesii)* in North America). .

    - Collection of long-term monitoring data from the four key areas (Taihe Jiangxi and Research Institute of Insect Resources in Yunnan) in China
    - Collection of long-term monitoring data from a research forest in North America (Malcolm Knapp Research Forest)
    - Identification of the impacts of climate change on forests – forest ecosystems and commercial forests
    - Observation of the interactions and relationships between forest health and climate changes
    - Definition of how management practices are likely to interact with climate change, extreme weather events, and land degradation

2) Integration between ecological model predictions and local forest management practices will be conducted to develop adaptation strategies and recommendations. In this stage, the TACA and LANDIS models will be integrated with the model predictions for forest ecosystems and major tree species predictions at the pilot study areas. The predictions will include three climate change scenarios for three future periods (e.g.

2020s, 2050s and 2080s). The integrated predictions together with the local forest landscapes will be used to:

- Analyze forest practices and management outcomes to examine the impacts of climate change,
- Determine the best management practices under different scenarios of climate change, and
- Develop recommendations for SFM to adapt to climate change for stakeholders and policy makers.

3) Application of best management practices to the pilot sites
   - Determine the best management practices at each of study sites, and
   - Create a long-term monitoring site in each study area based on best management practices. These will provide potential demonstration sites for APFNet in the future.

For Output 5: Communication, network building and technology transfer

Network building will be a key for stakeholder participation, communication and contribution to the research. The development of a scientific network that consists of a group of competent and high quality researchers dealing with climate change in the Asia-Pacific region will be imperative for APFNet to achieve its goals. We have already built up a substantial network based on past collaboration in this region, particularly between China, Australia and USA. This network will be intensified and expanded by this project through organizing workshops to train scientists, knowledge transfer, interviewing stakeholders and policy makers, and personnel exchange. This will facilitate capacity building and knowledge transfer, and will support and strengthen decision-making over forest management responses to climate change. Network activities are listed below.

1) Workshop to train scientists to use the climate models and climate envelope predictions of forest ecosystems in future climates;
2) Preparation of and delivery of workshops on decision-making under conditions of uncertainty;
3) Publication of results and recommendations in the form of policy briefs;
4) Preparation and distribution of extension notes aimed at decision-makers in forest-dependent communities;
5) Interviews with policy makers to supplement the information gained from the workshops;
6) Preparation of extension notes for the scientific community based on feedback obtained during the workshops with policy makers.

For Output 6: development of web-based climate tools for APFNet

The web-based tools will provide an easy access for users to the climate models, output of ecological models and other products achieved through this project. It will promote and facilitate a science-based decision-making processes in sustainable forest management practices to adapt to climate change. Some of these tools include those that follow.

1) Development of project website (in English, with parallel version in Chinese)

   The project website will launch immediately after the project is initiated. It will outline the project and provide updates on activities and progress. On completion of the project, the website will evolve to a project extension website that will promote information sharing and knowledge transfer.

2) Development of web-based climate models that will allow users to access high-resolution climate data for historical and future periods for the entire AP region.

   Web-based versions of the climate models will be developed, including ClimateWNA and ClimateAP. They will allow users to interactively access climate data for any location in western North America and the entire Asia-Pacific region.

3) Development of web-based climate maps for the entire Asia-Pacific region and bioclimate envelope maps for a large part of the region

   High-resolution climate maps will be generated based on the output of these climate models and will be overlaid onto Google maps. Some bioclimate envelope maps will also be posted in the same way for some major forest ecosystems and several major tree species in this region.

4) Expansion of the website to meet the needs of a range of different stakeholders, including regional and climate change scenario based recommendations and indicators for sustainable forest management practices

The activities are shown in the follow under each phase are listed in Annex A and Annex C3.

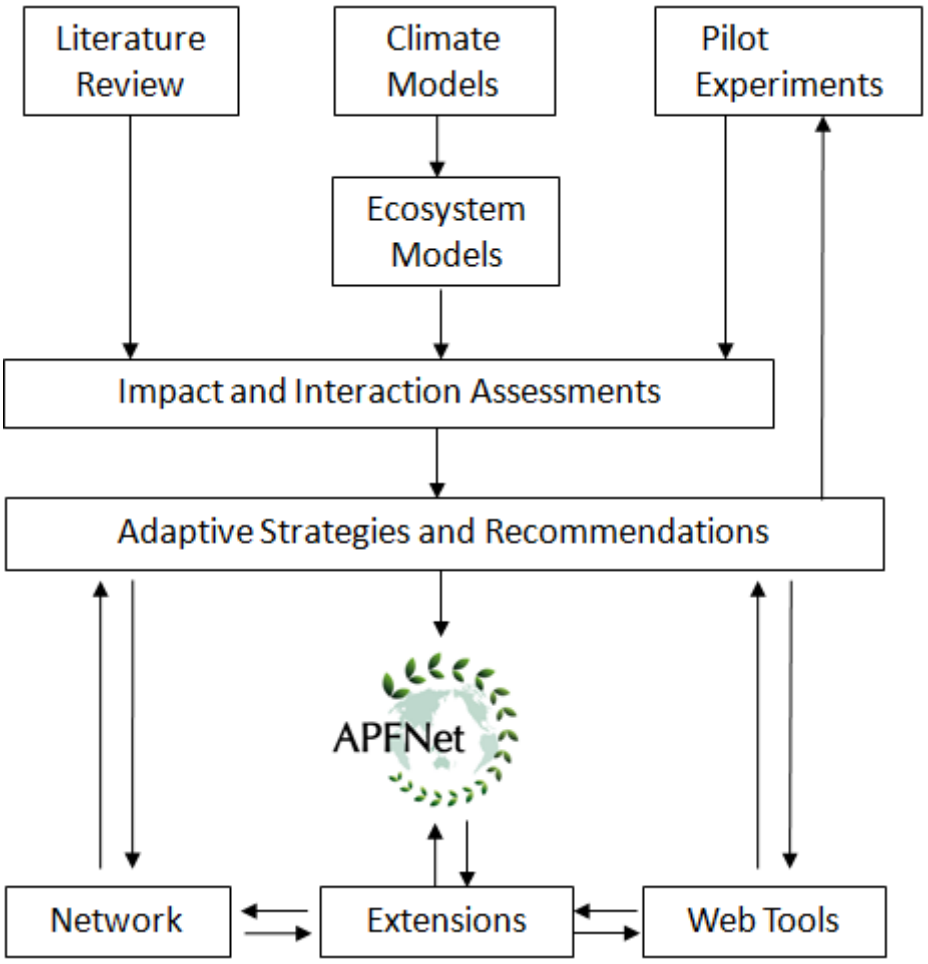


Figure 3.2.1. Schematic diagram of project activities and expected outputs.

3.2. Implementation approaches and methods

The project will work collaboratively and closely with all stakeholders directly or indirectly interested in adaptive forest management in response to climate change in the Asia-Pacific region. Using a participatory approach, it will engage interested groups to participate in the development of a common vision for best forest practices and sustainable forest management, while adapting to the changing climate in this region. Considering the significant geographical variation in the region, a phased approach will be implemented to ensure advancing one step at a time, helping to raise awareness, changing perceptions, analyzing problems, identifying the best adaptive forest management practices, testing at pilot research sites, and building networks connecting various stakeholders. The following steps will be taken to implement this collaborative development approach:

- Workshops to review the current situation: A workshop will be convened to examine the current status of climate change and its impacts on forest ecosystems and forest management practices in the Asia-Pacific region. We will invite scientists, forest managers and practitioners, policy-makers, and others to attend the workshop and contribute their expertise. Their

knowledge is particularly important in helping to understand and assess current strategies and actions adopted in different parts of the Asia-Pacific region to address climate change and related issues. Priority challenges and data gaps will be identified and tied into the formulation of the project hypotheses.

- Developing high-resolution climate models: Data from weather stations located across the entire Asia-Pacific region are required to complete the climate model. A new climate model "ClimateAP" will be developed intended to cover the region. A Microsoft Windows based software package with a user-friendly interface will be delivered; it is intended that this will be compatible with other operating systems, such as Mac and Linux.
- Developing ecological models: By extending the current modeling of forest ecosystems and species distributions from BC to western North America to the Asia-Pacific region, we will be able to define the bioclimate envelopes for some major species and to predict their potential shifts in their distributions.
- Building recommendations for SFM practices: Best management practices for adapting to climate change will be recommended, and will be tested at several sites selected from the Asia-Pacific region. Monitoring sites will be created to ensure implementation and to obtain field data to fill any identified data gaps.
- Capacity building and knowledge transfer: A network connecting scientists, forest managers and practitioners, policy makers, and other stakeholders, will be developed in the Asia-Pacific region, but will not be exclusive in this region. A project website, in both English and Chinese, will be constructed to ensure that all interested groups are able to access the project materials.
- Participatory monitoring and evaluation: A participatory monitoring and evaluation system will be established to monitor progress in the implementation of the project at different stages.

3.3 Assumptions, risks, sustainability

The verifiable indicators associated with this project are associated with sustainable forest management, as identified under the Montreal Process, and agreed by China, Canada, USA and Australia (as well as by Japan, the Republic of Korea, New Zealand, Mexico and Chile). It is assumed that countries will continue to report on these indicators. Experience has demonstrated that there is a significant risk that some will not issue reports, or that the reports will be incomplete. However, there is growing international pressure for the standardization of such reports. The assumptions, risks and sustainability associated with specific objectives are listed below.

- In developing high-resolution climate data, the reliability of source data might be low in some remote areas where weather station data are lacking. Although we will use the best interpolated climate data available, lack of weather station data from the remote areas will prevent us from effectively validate the reliability of our model output for these areas.

- In developing ecological models, it is essential to have vegetation data to model the relationships between climate variables and forest ecosystems or tree species ranges. However, it will be a challenge to obtain, screen and format the vegetation data required for impact assessment. We have several sources of data. However, screening the huge datasets to eliminate errors and format them to meet the modeling requirements will be challenging.
- Development of adaptation strategies will largely depend on the results of the impact assessments, and the data and knowledge obtained from field observations. Therefore, the assumptions and risks mentioned above also apply here. In addition, dealing with uncertainty in future climate will be another challenge. The magnitude and pattern of climate change will greatly affect the recommendations for sustainable forest management practices. Different climate change scenarios may lead to conflicting recommendations.
- For network building, we have built up a wide network through past and current collaboration. The available network will serve as a solid basis for developing a more comprehensive network associated with this project. There are no assumptions or risks involved.
- In developing the web based tools, the web-based climate models have high demand on computing resources. The web based ClimateBC and ClimateWNA hosted by UBC work well with the current volume of visitors. If ClimateAP has considerably more visitors, the responses of the server may be slower. We will work on alternative data access approaches to reduce the computing load, thereby enabling faster responses. The other web-based tools should not encounter this same problem.

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Part 4. Implementation Arrangements

4.1. Organization structure and stakeholder involvement mechanisms

4.1.1 Executing agency and partners

The executing agency will be the Faculty of Forestry, UBC and partners will be:

- Environmental Canada
- BC Ministry of Forests, Mines and Lands
- US Forest Services
- University of Melbourne
- Chinese Academy of Forestry
- Jiangxi Agricultural University
- Nanjing Forestry University
- Research Institute of Insect Resources, China

4.1.2 Project management team

- Dr. John Innes, Professor and Dean, Faculty of Forestry, University of British Columbia
- Dr. Guangyu Wang, PhD and Director, Faculty of Forestry, University of British Columbia
- Dr. Tongli Wang, PhD and Associate Director, Department of Forest Sciences, University of British Columbia

4.1.3 Project steering committee

The project steering committee will consist of number of key international recognized figures on climate change and forest adaptation and mitigation.

- Dr. Stewart Cohen, Senior Research Scientist, Adaptation & Impacts Research Division, Environment Canada
- Dr. Rod Keenan, Director Victorian Centre for Climate Change Adaptation Research Centre, Department of Forest and Ecosystem Science, University of Melbourne
- Dr. Hosny El-Lakany, Director of the CIFOR Board of Trustees, and member of the ICRAFT Board of Trustees, Former Assistant Director-General of FAO/Head of the Forestry Department
- Dr. Linda Joyce, Research Project Leader on Climate Change, US Forest Services,
- Dr. Ir. Hendrayanto, Dean of Forestry, Bogor Agricultural University, Indonesia
- Dr. Awang Noor Bin Abd. Ghani, Dean of Faculty of Forestry. University Putra, Malaysia
- Dr. John Innes, Professor and Dean, Faculty of Forestry, University of British Columbia
- one representative from APFNet, China

4.1.4 Stakeholder involvement mechanisms

The project naturally requires a large amount of stakeholder involvement, and will also be the key to the success of the project. Figure 3.2.1 shows the flowchart of the stakeholder participation. There are four mechanisms for the stakeholder involvement:

- Stakeholder participation: As indicated above, the project will bring together researchers from governments, academic and local forest managers in the Pacific region to tackle the issues of climate change and its impacts on forestry, and strategies on mitigation and adaptation. The researchers will not only bring their expertise to the research, but will also share their concerns and co-identify priorities for this and future research.
- Stakeholder contribution: The initial workshop will provide a platform for many of the stakeholders, and will enable them to influence the implementation of the research.
- Stakeholder support: The project has chosen one study area in North America, one in Australia and two in China, where forest managers, foresters, local governments and communities will be involved with the research project. This will enable different climate scenarios and vegetation types to be explored at a fine scale, and, importantly, it will enable the inclusion of local knowledge, expertise, experience and long term observation data in the research.
- Stakeholder training: one of the key objectives of the project is to publicize the research findings, recommendations, and encourage the use of the web-based climate model. The training component of the project will bring together a great number of trainees (stakeholders) from the Asia-Pacific region. The interaction and discussion with trainees will help the researchers understand their need and concerns, and improve the quality of the research and its extension.

4.2. Reporting, review, monitoring and evaluation

A systematic and comprehensive approach including reporting, review, monitoring, and evaluation, will be developed and adopted by the Executing Agency (EA) and Collaborating Agencies (CAs) to ensure the successful implementation of the project as soon as this project proposal is approved.

Once the project starts, appropriate monitoring will be adopted to identify for any gaps between the actual situation and the planned situation, depending on the indicators related to each activity listed in the Logical Framework Matrix (Annex A). Afterwards, corrective actions may be required to ensure the efficiency and effectiveness of project implementation and to achieve the ultimate objectives of the project. An early warning system will be set up to avoid encountering unexpected delays in such areas as output delivery, and to ensure the timing and actual availability of planned input items (e.g., personnel, equipment, funds).

A periodic progress review (after the completion of each output) will be conducted by the project steering committee to guarantee that the project implementation is on track to completing the anticipated objectives, using the associated Logical Framework Matrix and Workplan (Annex B) in the project documents as a reference. By actively interacting with the project staff involved in the project implementation, and by assessing the progress of the project according to the Workplan, recommendations and changes in actions will be suggested in order to better support the success of the project.

Throughout the project implementation, several reports will be prepared and submitted to APFNet. In the inception phase, an initial report will be composed containing information on the availability of personnel, equipment, and any changes since submission of the project document. During the

implementation phase, a Yearly Plan of Operation (YPO) and detailed Work plan will be developed to provide greater detail information about the project planning and other issues. Biannual Progress Reports will be prepared by the EA about the expenditures, progress, and achieved outputs according to the Work Plan during the last half year. Project Technical Reports presenting various outputs will be written up to ensure that the technical and scientific data and analysis are available and understandable to a wider range of audiences. A Financial Audit Report will be submitted by EA to APFNet to indicate the opening balance, expenditure incurred to date, and the closing balance for the project account. Upon completion of the project, EA will make a completion report to summarize the activities, inputs, expenditures, achieved outputs and objectives during the entire implementation phase and will identify any major differences between planned and realized budgets.

Given that the project monitoring and regular reviews will have examined progress of the project, a post-evaluation will be undertaken after the project completion to assess the validity, design, appropriateness, performance and the impact of the project. This will have the purpose of drawing conclusions, learning lessons, and providing recommendations for future projects.

4.3. Dissemination and mainstreaming of project learning

Various communication strategies and methods will be considered to disseminate the project results, including workshops, conferences, inclusion in teaching materials, newspaper and journal articles, guided visits of sample sites, and the internet.

- The primary means taken to communicate with and receive feedback from the relevant stakeholders is the construction of a comprehensive website. The website will be accessible to various audiences, including forest managers, scientists, and policy makers directly involved in the project, and those indirectly involved or unable to directly participate in the project. As a big proportion of this project is focused on China, the website will be provided in Chinese as well as in English. Documents pertaining to the project implementation and progress, technical reports and scientific publications will be posted on the website for free access.
- In terms of the advancement of relevant knowledge systems, the project outcomes will be compiled into a series of scientific manuscripts for publication in peer-reviewed journals and books.
- In addition to the scientific publications, various forms of reports will be prepared and submitted to the APFNet so that network participants can gain better insight into important outcomes and deliverables from the project.
- In order to engage a wider range of audiences, with or without specific knowledge or expertise, workshops will be held to inform the latest results and publications. This opens the opportunity to further communication far beyond the initial project scope.
- Training programs will be organized for forest professionals from the Asia-Pacific region, including China. By attending the training programs, forest professionals will be expected to increase their knowledge regarding to climate change and related issues. Potential recommendations and solutions will be discussed amongst various interest groups during the training programs.

- Exchange programs will be available for Chinese forest professionals to the collaborating agencies (preferably in Canada and the U.S.) to advance their knowledge and expertise in western countries. Upon the completion of the exchange programs, they are expected to identify any gaps between their own agencies and the visiting agencies and formulate potential adaptive solutions.

The collaboration between academia and government departments will increase dialogue and will lead to better formulation of scientific outcomes in policy making, which is often seen as inadequate. This, in turn, may result in changes to policy and legislation, may enhance the adoption of best practices, and may foster better forest law enforcement and governance. The results of this project could be extended to other countries in the Asia-Pacific regions to help them adapt their forests to climate change.

Annex A Logical framework

	Indicators	Means of verification	Assumptions
Development Objectives	Long-term maintenance of indicators of sustainable forest management, as identified under the Montreal Process, and agreed by China, Canada, USA and Australia (as well as by Japan, the Republic of Korea, New Zealand, Mexico and Chile)	Periodic reports that countries have agreed to provide under the Montreal Process.	The assumption is made that countries will report on the indicators that they have agreed. There is a significant risk that some will not issue reports, or that the reports will be incomplete. However, there is growing international pressure for the standardization of such reports.
Specific Objectives	• A report on the review of current knowledge on climate change studies in Asia Pacific region • Climate models as essential tools for climate change studies • Ecological models to provide scientific basis for impact assessments and for development of adaptive strategies • Management recommendations included in national, regional and local forest policies and plans to increase resilience of forest ecosystems • A functioning network of scientists and practitioners for collaboration and knowledge transfer • Web-based tools to support sustainable forest management and planning	• The project team has experience in climate change related studies including the development of climate models and assessment of impacts of climate change on forest ecosystems, as well as sustainable forest management. • The basis for developing adaptation strategies is from both the impact assessments and field studies • Policy information will be collated from existing policy documents and supplemented by interviews with key personnel in China and North America	
Output1 Literature review and gap analysis	• A report synthesizing the current knowledge on climate change studies in forest ecosystems and forest dependent communities in this region; • Knowledge gaps identified and hypotheses set up	• Comprehensive review of current knowledge and status on impacts of climate on forests in the Asia-Pacific Region	
Output2 Climate models	• High-resolution climate models covering the western North America and the entire Asia Pacific region that can generate climate data for any location in the region for historical years (1901-2010) and future periods (2020s, 2050s and 2080s) • High-resolution climate maps will also be provided for some important climate variables for the entire region • A manuscript for a SCI journal	• Quantify the historical and future climate conditions for each site • Developing high-resolution climate models as ClimateBC • Climate maps	• Reliability of the climate data might be low in some remote areas where weather station data are lacking.
Output3 Ecological models	• Ecological models that predict impacts of climate change on three major forest tree species distributions in western North America and China • Maps of predicted shifts in suitable climatic conditions for the major tree species will be provided for various climate change scenarios	• Assessing show the shifts of climatic niches for tree species ranges under future climates using Random Forest • Using models, such as Random Forest, TACA and LANDIS	• The observation for species ranges are consistent across countries

	• Two manuscripts for SCI journals		
Output4 Pilot studies and Recommendations	• Four pilot study sites to be establish • SFM recommendations based on integration between model predictions and observations from pilot studies • Specific recommendations for pilot study areas • A report and a manuscript for a SCI journal	• Testing Model framework by building on series of research sites in BC and an existing network in China (CFERN) • Developing adaptation recommendation to forest communities	• Climate data are reliable • The magnitude and the pattern of climate change will greatly affect the recommendations for sustainable forest management practices. • Different climate change scenarios may lead to conflicting recommendations
Output5 Communication, network building and technology transfer	• A network that comprises scientists, forest managers and policy makers • Over 350 scientists, forest managers and policy makers will be trained • Strengthened collaborative research and decision-making over forest management responses to climate change • Use of the network to seek the best-available solutions to complex problems related to climate change	• Organizing workshops • Training scientists • Interviewing stakeholders and policy maker • Personnel exchange	• No assumptions.
Output6 Development of web based tools	• Web based climate models allow users to obtain high-resolution climate data for historical and future periods • Web based climate and climate envelope maps for a large part of the region • Regional and climate change scenario based recommendations and indicators for sustainable forest management practices • A report	• Developing the free access website in English version and Chinese version • Outlining and updating the progress and outcomes from projects • Extending the website to meet needs of different stakeholders	• If ClimateAP has considerably more visitors, slow response from the server may occur.

Annex B Work plan

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Overall management/ M&E, etc.																																				
Output 1																																				
Activity 1																																				
Activity 2																																				
Activity 3																																				
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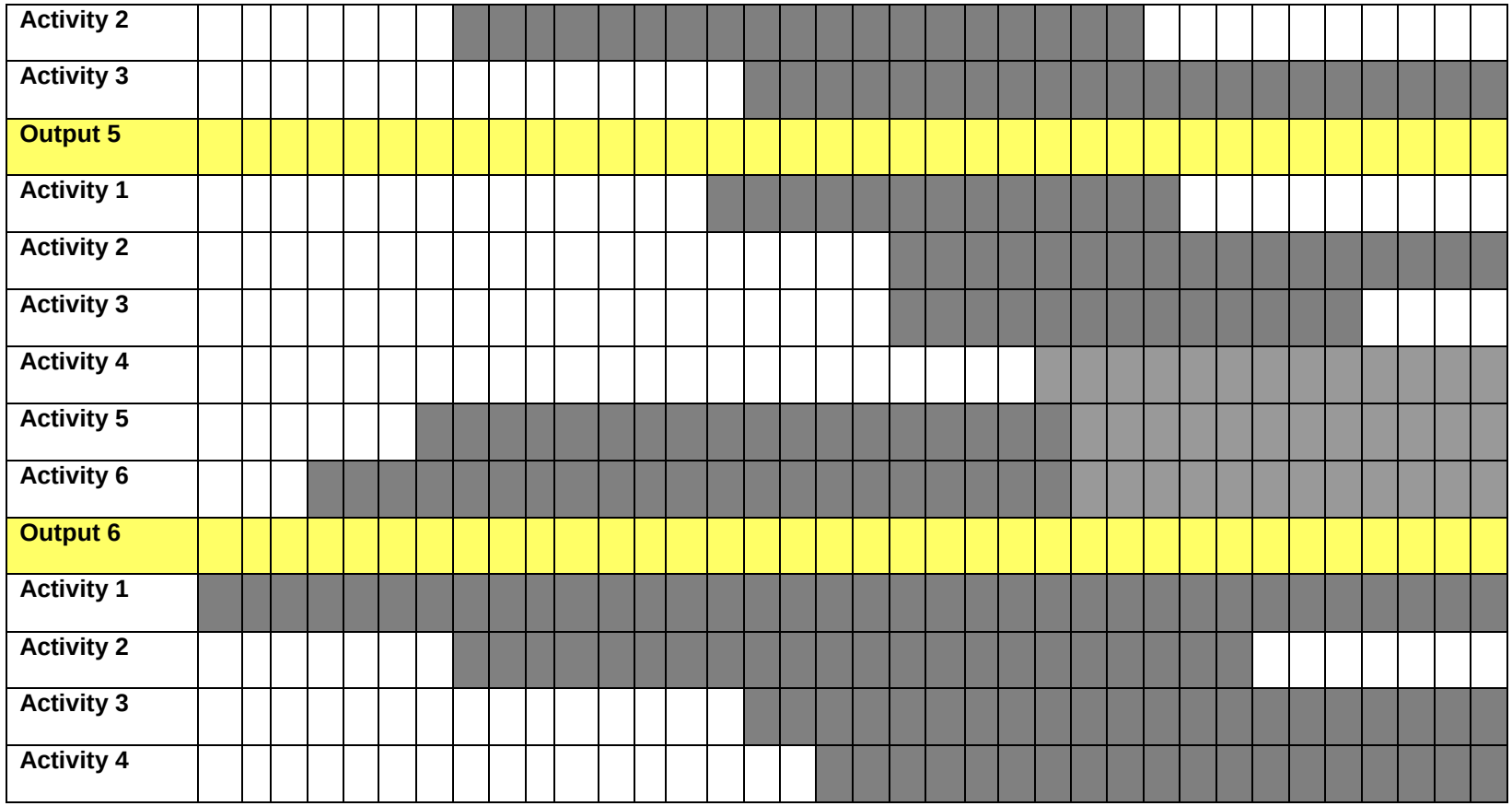
Activity 2
Activity 3
Output 5
Activity 1
Activity 2
Activity 3
Activity 4
Activity 5
Activity 6
Output 6
Activity 1
Activity 2
Activity 3
Activity 4

Annex C1 APFNet budget by component

Annual Disbursements / Budget components	TOTAL	Year 1	Year 2	Year3
1. Inception funds	0	0	0	0
2. International and national consultants	50000	50000		
3. Research and Modeling	264000	205000	59000	50000
4. Study tour & travel expenses	124000	62000	62000	
5. Survey/ case study	212500	62500	62500	85000
6. Sub-contracts	0	0	0	0
7. Training & workshops	229700	0	100000	129700
8. Website based tools development	100000	0	0	100000
9. Office expense	9000	3000	3000	3000
Subtotal 1	989200	382500	286500	367700
10. APFNet monitoring and review cost	55000			
11. APFNet evaluation cost	45000			
Subtotal 2	100000			
12. Unforeseen expenses	50000			
TOTAL	**1139200**			

Annex C2 Executing agency and partners budget by component

Annual Disbursements / Budget components	TOTAL	Year 1	Year 2	Year 3
1. Inception funds	45000	45000	0	0
2. International and national consultants	0	0	0	0
3. Research and Modeling	231500	113000	80075	38425
4. Study tour & travel expenses	0	0	0	0
5. Survey/ case study	120000	50000	30000	40000
6. Sub-contracts	0	0	0	0
7. Training & workshops	141000	11000	30000	100000
8. Web-based tools development	125000	16000	69500	39500
9. Office supply and expense	50000	20000	15000	15000
10. Office space and operation	255000	81000	82000	92000
Subtotal 1	967500	336000	306575	324925
10. Executing agency management cost	105000	35000	35000	35000
TOTAL	1072500	371000	341575	359925

Annex C3 Activity and Component

No.	Activities/item cost	Budget lines	Cost Budget	Detailed Expenses	Unit name	Total Input		Unit Cost	Total Budget	Year 1	Year 2	Year 3	Executing agency
						# of unit	unit						
A	Inception Workshop		Invited speakers and airfares	Consultant fee, hotel, and air ticket	person	2		2500	5000	5000			5000
			Rent car and local transportation	Car rental and pick up	person	60		100	6000	6000			6000
			Translators and equipment	Labors equipment rental	person sets	2 100	2 2	2000 10	10000	10000			10000
			Utilities and supplier	Rooms and					7000	7000			7000
			Food and visits	Food	person	100	2	60	12000	12000			12000
			Meting Package	Material, printing, bags	person	100		50	5000	5000			5000
SUB TOTAL Inception Workshop: $45000													
	Output 1: Impact assessments and modeling												
1.1	Literature review and assessment		Literature search, data collection and documentation	Data collection	person	2	30	300	18000	18000			18000
			Meta-analysis software building	software	set	1	1	1000	1000	1000			1000
			Data analysis	labor	person	2	40	300	24000	24000			24000
			Reporting	Labor	person	1	20	400	8000	8000			8000
	SUB TOTAL Activity 1: $ 51000												
1.2	Issues identification in Asia Pacific region		Data collection and documentation derive from global literature	Labor	person	1	45	200	9000	9000			9000
			Expert questionnaire survey	Material and communication		1500		30	45000	45000			45000
			Expert Questionnaire survey	Data collection and analysis	person	1	90	200	18000	18000			18000
			C&I Identification and analysis	Labor	person	3	30	200	18000	18000			18000
			Reporting	Labor	person	2	20	200	8000	8000			8000
	SUB TOTAL Activity 1.2: $98000												
1.3	Gap Analysis		Data standardization	Entry and	person	1	45	200	9000	9000			9000

				Standardization									
			Modeling and discourse	Software	set	1	1	1000	1000	1000			1000
			Gap analysis	Labor	person	3	40	200	24000	24000			24000
			Reporting	Labor	person	2	20	200	8000	8000			8000
	SUB TOTAL Activity 1.3: $ 42000												
	TOTAL BUDGET OUTPUT 1: $191000												
	Output 2: Climate Modeling- Climate WNA and Climate AP												
2.1	Modeling preparation		PRISM data	purchase	dataset	30		250	7500	7500			7500
			Data collection	Labor	person	1	50	300	15000	15000			15000
			Data process	Labor	person	2	80	300	48000	48000			48000
	SUB TOTAL Activity 2.1 : $70500												
2.2	Model development		Elevation adjusting functions	Labor	person	2	35	300	21000	21000			21000
			Derived variables	Labor	person	2	25	300	15000	10000	5000		15000
			Algorithms and Programming	Labor	person	2	65	350	45500	15500	30000		45500
	SUB TOTAL Activity 2.2: $81500												
2.3	Model validation		Baseline data validation	Labor	person	2	30	350	21000	10500	10500		21000
			Derived variables validation	Labor	person	2	30	350	21000	10500	10500		21000
			Historical and Future climate data	Labor	person	2	50	350	35000	15000	20000		35000
	SUB TOTAL Activity 2.3: $77000												
	TOTAL BUDGET OUTPUT 2: $229000												
	Output 3: Development of Ecosystem Models												
3.1	Collection of vegetation data		Ecosystem data	Labor and travel	person	2	50	200	20000	15000	5000		20000
			Tree species range data	Labor and travel	person	2	30	200	12000	6000	6000		12000
			data process	Labor	person	2	50	200	15000	5000	10000		15000
	SUB TOTAL Activity 3.1 :$47000												
3.2	Bioclimate Envelope development		The reference period	dataset	variables	85		30	2550		2550		2550
			Future periods for three climate change scenarios	dataset	variables	765		30	22950		11475	11475	22950
			Modeling		Person	2	90	500	90000		60000	30000	90000
	SUB TOTAL Activity 3.2: 115500												

3.3	Model development and predictions		Work stations	unit	2			5000	10000	10000			10000
			Model development	Labor		2	50	350	35000		17500	17500	35000
			Predictions for 3 climate change scenarios	Labor		2	25	350	17500		5250	12250	17500
			Web-based version	Labor		2	35	350	24500		7300	17200	24500
	SUB TOTAL Activity 3.3: $87000												
	TOTAL BUDGET OUTPUT 3: $ 249500												
	Output 4: Pilot researches and the development of SFM practice for climate mitigation and adaptation												
4.1	Pilot study		Pilot site visit and planning		person	3	30	250	22500	22500			22500
	Four research sites (Malcolm Knapp Research Forest, Canada, Taihe Jiangxi, Kunming Insect Resources Institute, China and Victoria, Australia)		Historical and long term monitory data documentation, standardization, and analysis	Data collection and category	person	8	20	300	48000	48000			48000
			Pilot researches and observation design and implementation	BMP and SFM	site	4	site	20000	80000	30000	25000	25000	80000
			Monitoring and Analysis		site	4	site	3000	12000	4000	4000	4000	12000
			Best management practices		site	4	site	5000	20000	8000	6000	6000	20000
	SUB TOTAL Activity 4.1: $182500												
4.2	Data integration and synthesis		Interaction between climate change and management practices		person	3	40	500	60000		30000	30000	60000
	SUB TOTAL Activity 4.4: $ 60000												
4.3	Recommendation and Application of the SFM and BMP		Develop a specific recommendations for the pilot sites, and stakeholders		Person	10	30	300	90000		30000	60000	90000
	SUB TOTAL Activity 4.5: $90000												
	TOTAL BUDGET OUTPUT 4: $332500												
	Output 5: Communication, network building and technology transfer												
5.1	Workshop to train scientist (hold in China)		Transportation	Car rental and pick up	person	60		30	1800			1800	1800
			Conference translation and Equipment	Labors Equipment rental	person sets	4 100	2 2	1000 20	6000 4000			10000	10000
			Conference Facility	Meeting Hall	Room	2	2	500	2000			2000	2000

			Food and site visit	food	person	100	2	40	8000			8000	8000
			Printing, materials and bags	Materials and bags	person	50		50	5000			5000	5000
			Travel cost	Travel cost	person	3	5	500	7500			7500	7500
	SUB TOTAL Activity 5.1 :$34300												
5.2	Workshops to policy makers		Transportation	Car rental and pick up	person	60		30	1800			6000	6000
			Conference translation and Equipment	Labors Equipment rental	person sets	4 100	2 2	1000 20	6000 4000			10000	10000
			Conference Facility	Meeting Hall	Hall	2	2	500	2000			2000	2000
			Food and site visit	food	person	100	2	40	8000			8000	8000
			Printing, materials and bags	Materials and bags	person	50		50	5000			5000	5000
			Travel cost	Travel cost	person	3	5	500	7500			7500	7500
	SUB TOTAL Activity 5.2: $42500												
5.3	Supplementation interview		Questionnaire design and interview		person	2	10	200	5900			5900	5900
			Data analysis and reporting		person	2	20	200	8000			8000	8000
	SUB TOTAL Activity 5.3: $13900												
5.4	Extension and technology transfer		Extension note for policy maker	Extension note development				5000	5000			5000	5000
			Extension note for forest community	Extension note development				5000	5000			5000	5000
			Extension note for scientific community	Extension note development				5000	5000			5000	5000
	SUB TOTAL Activity 5.4 : $15000												
5.5	Network building		Network study tours t UBC	travel cost	person	10		2300	23000		12000	11000	23000
			Pilot sites study	travel cost	person	11		3000	33000		22000	11000	33000
			Coordination visit	Travel cost	person	6		3000	18000	6000	6000	6000	18000
			Piolt site field survey	Field cost	person	30	10	300	90000		40000	50000	90000
			Capacity building	Meeting and presenting	person	20	10	400	80000		40000	40000	80000
	SUB TOTAL Activity 5.5: $244000												
5.6	Publications		Journal articles and Project reports						25000	5000	10000	10000	25000
	SUB TOTAL Activity 5.6: $25000												
	TOTAL BUDGET OUTPUT 5 : $370700												
	Output 6: Development of web-based scientific tools for APFNet												

6.1	Development of Project website		Initial launch	Labor	person	1	20	200	4000	4000			4000
			Updating	Labor	person	1	200	200	40000	10000	20000	10000	40000
	SUB TOTAL Activity 6.1 : $44000												
6.2	Web-based Climate Model		Software	software	package	3		2000	6000	2000	4000		6000
			Data process	Labor	person	2	35	300	21000		10000	11000	21000
			Programming	Labor and software	person	2	50	350	35000		15000	20000	35000
			Testing and reporting	Labor and server	person	2	20	300	12000			12000	12000
	SUB TOTAL Activity 6.2: $74000												
6.3	Google Map Based Climate and Bioclimate Maps		Server	year		1	2	1000	2000		1000	1000	2000
			Climate maps	Labor		2	35	350	24500		10000	14500	24500
			Bioclimate envelope maps	Labor		2	35	350	24500		4500	20000	24500
			Reporting	Labor		1	25	200	5000			5000	5000
	SUB TOTAL Activity 6.3: $56000												
6.4	Extension website for SFM and BMP management scenarios		Scenario based recommendations	Labor	Person	2	25	300	15000		5000	10000	15000
			Scenario based indicators	Labor	Person	2	30	300	18000			18000	18000
			Reporting	Labor	Person	2	30	300	18000			18000	18000
	SUB TOTAL Activity 6.4 :$51000												
	TOTAL BUDGET OUTPUT 6: $225000												

Noticed:

1) Annex C3 is only direct cost without including operation cost and management cost, as well as cost from APFNet.

2) The project will execute by EA with its partners. Therefore, the EA budget is the same as the total budget.

Annex D Profiles of the executing and collaborating agencies

University of British Columbia: As one of the world's leading universities, UBC's location in Vancouver, Canada's gateway to Asia, together with the large population of people of Chinese origin in Vancouver, makes Vancouver a strong location for collaborative ventures with China. UBC has developed long-term relationships with China's government, academic and business sectors. Several faculties, particularly the Faculty of Forestry, have strong links to China and have conducted many research projects including climate change, environmental protection, rural development and sustainable agricultural management. The results of these research projects will be of great help to the project.

UBC Faculty of Forestry is one of the most prestigious faculties of forestry in the world, and a key player in climate change research and related studies. The Faculty is a leading player in the development of high-resolution climate models, modeling and predicting potential impacts of climate change on forest ecosystems and species ranges and developing adaptation strategies for forests. It has a framework that supports a broad range of climate change related studies in western North America. There is a demand to expand this framework to the rest of North America. Through this project, a similar framework will be built up for the Asia Pacific region.

Environment Canada: The Adaptation and Impacts Research Section (AIRS) of Environment Canada is committed to helping Canadians become well-adapted to current and future changes in the atmosphere. As part of its national program, AIRS conduct collaborative scientific research projects to expand understanding of climate change impacts and adaptation, and linkages with sustainable development. The overarching goal of the Section is to provide integrated impacts and adaptation research that combines the new science of climate change and extremes, using the most up-to-date models, with the next generation of socio-economic modeling and risk management tools to protect Canadian society from climate change impacts and weather-related risk. AIRS also contributes internationally recognized expertise to study climate change impacts on ecosystems and economic sectors. For example, an AMSD (Adaptation, Mitigation and Sustainable Development) framework has been introduced by AIRS researchers to Chinese research institutes to study climate change impacts and adaptation on policy and outreach issues. The AMSD framework has been applied in a river basin in northwest China. The objective of this study is to mainstream adaptation and mitigation options into regional sustainable resource planning and regional SD strategies.

BC Ministry of Forests, Mines and Lands is mandated to protect the public's interest and provide leadership in the protection, management and use of the province's forests. The ministry is the main agency responsible for the stewardship of 47 million ha of provincial forest land and fire protection services for 84 million ha. The ministry's role also includes maintaining a policy and regulatory framework that creates a competitive forest industry. Adaptation to climate change has become a top priority in its agenda. British Columbia's Chief Forester established the Future Forest Ecosystems Initiative (FFEI) in 2006 to

adapt B.C.'s forest and range management framework to a changing climate, and established the Future Forest Ecosystems Scientific Council (FFESC) in 2008 to guide the allocation of a $5.5 million grant-in-aid to research that supports FFEI objectives. The Ministry has also recently launched a Zero Net Deforestation initiative to help reduce the atmospheric CO_2 associated with climate change.

US Forest Service established in 1905, the Forest Service is an agency of the U.S. Department of Agriculture. The Forest Service manages public lands in national forests and grasslands. The Forest Service has a workforce of approximately 30,000 employees that reflects the full range of diversity of the American people. This includes cultural and disciplinary diversity, as well as diversity in skills and abilities. The mission of the USDA Forest Service is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.

The research and development (R&D) arm of the U.S. Department of Agriculture (USDA) Forest Service works at the forefront of science to improve the health and use of our Nation's forests and grasslands. Research has been part of the Forest Service mission since the agency's inception in 1905. Today, some 500-plus Forest Service researchers work in a range of biological, physical, and social science fields to promote sustainable management of Nation's diverse forests and rangelands. Their research covers a lot of territory, with programs in all 50 states, U.S. territories, and commonwealths. The work has a focus on informing policy and land management decisions, whether it addresses invasive insects, degraded river ecosystems, or sustainable ways to harvest forest products. The researchers work independently and with a range of partners, including other agencies, academia, nonprofit groups, and industry. The information and technology produced through basic and applied science programs is available to the public for its benefit and use.

University of Melbourne is a public-spirited institution that makes distinctive contributions to society in research, teaching and knowledge transfer. The department of Forest and Ecosystem Science (DFES) was founded in July 2004 and is the culmination of a longstanding research partnership between the University of Melbourne and the Victorian Department of Sustainability and Environment (DSE). The new school comprises more than 50 scientists working in basic and applied fields that cover many aspects of forest and ecosystem science, from the molecular to the ecosystem level. The research in the Forest and Climate Change Research Group focuses on total greenhouse gas balance in ecosystem, carbon balance and carbon sequestration potential of native and planted forests and Impact of climate change on forest ecosystems.

Chinese Academy of Forestry is directly under the State Forestry Administration, comprehensive, multidisciplinary, national research institutions. The main focuses are forestry application of basic scientific research, strategic high-tech research, major social welfare research, soft science research and technology development with emphasis on China's forestry development and ecological construction in an overall, comprehensive, critical and major basic science and technology. The academy now has 4,476 staff workers, including 55 researchers, 230 associate researchers, 90 senior engineers, 654 research assistants and engineers, 730 primary technicians and 600 lab technicians. It has more than 150

disciplines, including 12 disciplines authorized to grant master's degree and 3 to grant doctor's degree. The academy is active in academic exchanges and has established cooperative relation with more than 20 national and international organizations. Since its establishment, the academy has accomplished 715 research achievements and won 245 various prizes, many of them related to climate change.

Jiangxi Agricultural University is a multidisciplinary institution of higher learning characterized by teaching and research in agriculture and bio-technology as well as sciences, arts, economics, management, arts and laws. Currently, over 1,440 faculty members are working in the university, Jiangxi Agricultural University has always attached great importance to teaching and research and has achieved great progress in talent training, scientific research and social service.

Fujian Agricultural and Forestry University is a key university in its province, with focus on production forestry. The university consists of 18 colleges with 63 specialties. Currently, there are 20,802 undergraduate and 2,267 students study for master’s and doctor’s degrees. More than one thousand professors and two thousand supporting staff, the university has become one of most productive university, with 100 national or provincial technological innovation platforms and research centers. It has a long history working on climate change and its impact on Chinese fir and Masson pine productivities and subtropical ecosystem stability(Not necessary, to be consistent with Page 1 Project brief.)
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Nanjing Forestry University is located in the east of Nanjing City, is a comprehensive university administered directly by Jiangsu Province. There are more than 60 departments in 20 colleges in the university, with total number 26,000 students, 500 professors and 600 supporting staff. There are 35 R&D research centers, national key open labs, engineering centers, institutes, and divisions approved by the State Forestry Administration and the provincial government, NFU pays a particular attention to climate change research programs and has attained great achievements.

Annex E Tasks and responsibilities of key experts provided by the executing agency

The project team from the executing agency consists of four professors from Canada:
Professor John Innes is Dean of the Faculty of Forestry at UBC and, as such, is responsible for an annual budget of approximately $22 million (ca. RMB 150 million). This involves the management of approximately 150 full-time staff and 900 students, as well as three research forests totaling more than 50,000 hectares. He has been responsible for the management and completion of more than 30 research projects, funded by a range of sources including the Government of Switzerland (>$16 million over 12 years), the Canadian Natural Sciences and Engineering Research Council (ca. $1 million), the Canadian Social Sciences and Humanities Research Council (ca. $1 million), the Sustainable Forest Management Network of Centres of Excellence (ca. $1.5 million), the British Columbia Government (ca. $2 million), the British Columbia Innovation Council (ca. $400,000) and a range of smaller grants. His research has been undertaken in Canada, China, South Africa, Namibia, Switzerland, the United Kingdom, Mexico, Brazil and Australia. He has previously worked on three projects based in China, including a project looking at the sustainability of the Min River Basin, a project looking at the introduction of certification and its association with forest tenure reform, and a project looking at the impacts of climate change on forests in Jiangxi Province. The proposed project lies well within the financial range of projects that Professor Innes has successfully managed in the past, and he has previous experience of work in China. Professor Innes has close links with forestry schools throughout the region, and will involve these in the extension of the results to a broader area within the region.

Dr. Tongli Wang is an expert in climate and ecosystem modeling. He is the designer and developer for the widely used climate models ClimateBC and ClimateWNA. His work on modeling forest ecosystems and forest tree species distributions for climate change is well known and influential in BC and in North America. Dr. Wang has recently published scientific papers in Ecology, Global Change biology, Ecological Applications, International Journal of Climatology, Journal of Applied Ecology and Journal of Vegetation Science. In this project, He will develop the climate model "ClimateAP" to generate high-resolution climate data for historical and future periods. He will also take lead on the development of the machine-learning Random Forest models that will define the bioclimate envelopes for forest ecosystems and species ranges in the study areas and predict their shifts under various climate change scenarios. Dr. Wang will take a leading role in the workshop to train participants to use the climate model and to demonstrate the impacts of climate change on forest ecosystems and species ranges. At a later stage in the project, he will develop some interactive web tools including the climate model ClimateAP, climate and bioclimate envelope maps. The output of climate and ecological models that he is taking the lead on will form a fundamental framework for this project. Therefore, Dr. Tongli Wang will coordinate and integrate scientific components of this project into this framework.

Dr. Guangyu Wang will be responsible for project management including coordination of the team members, progress monitoring and budget management. Dr. Wang is also responsible for impact assessment, best management practice and forest related policy development as well as the integration of

sustainable forest management under changing climate. Guangyu Wang is Director of Asia Strategies, Faculty of Forests at UBC. He has extensive experience in managing collaborative projects, particularly with partners in China. He has worked for Dr. Innes as a research associate on research projects in China for more than seven years. His research has been recognized by the international community. His background and experience also include managing a provincial government's forestry planning and budget management, and overseeing more than $500 million investment portfolio in the past ten years. His efficient coordination skills will ensure a smooth implementation of the project plan in a timely manner.

Annex F Terms of reference of personnel and consultants and subcontracts funded by APFNet

N/A

Annex G Recommendations of APFNet reviewer

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