Asia-Pacific Network for Sustainable Forest Management
and Rehabilitation

PROJECT DOCUMENT

Adaptation of Asia-Pacific Forestry to Climate Change Phase III

Synopsis, updating and extension of forest adaptation tools

University of British Columbia

12/2021 ~ 11/2023

Basic Information

Project title(ID)	Adaptation of Asia-Pacific Forestry to Climate Change Phase III – Synopsis, updating and extension of forest adaptation tools [2020P4-UBC]
Supervisory agency	NA
Executing agency	University of British Columbia
Implementation agency(ies)	Faculty of Forestry, University of British Columbia (UBC) (Local IAs are listed in the text)
Project Director: Tongli Wang, Associate Professor, Faculty of Forestry, UBC Tel: 1 604 822 1845 Email: tongli.wang@ubc,ca Fax: 1 604 822 9102	
Target area(s) China, Chinese Taipei, Malaysia and Myanmar	
Project implementation duration: [12/2021 to 11/2023, 24 months]	
Total budget(USD)	$164,100
APFNet grant(USD)	$135,000
Conouterpart contribution (USD) (list other funding souces and amounts, specify cash and in-kind constribution)	$29,100 in-kind

♦ Project description

Climate change brings the most important threats to existing forests and new plantations in terms of their productivity, resilience, and services. Development and applications of forest adaptation tools are critical for foresters and policymakers to promote sustainable forest management to enhance ecological functions and ecosystem security of forests under climate change.

Since 2011, APFNet has funded the project "Adaptation of Asia-Pacific Forests to Climate Change". The projects were executed by the University of British Columbia with 7 economies and regions targeted, including China, Chinese Taipei, Australia, Canada, Malaysia, and Myanmar. With 8-year endeavor, important forest adaptation tools have been developed, including: 1) the scale-free climate model ClimateAP; 2) climate niche models for 15 tree species and 4 forest ecosystems; and 3) and Forecast models, as well as 4) a web platform to facilitate easy access to climate data and spatial visualization of climate data and species distributions.

The overall goal of this project is to explore and realize the potential values of these tools developed in the previous projects, so that they can be better used in developing forest adaptive strategies in the Asia Pacific region to improve the health and productivity of forest ecosystems and their resilience to climate change. The main objectives of this project include: 1) to summarize climate niche models and their projections for 15 key species and 4 forest ecosystems; 2) to maintain a functional and updated ClimateAP to provide timely and superior climate data; and 3) to dissemination of project outputs. Expected outputs and outcomes include:

Output 1: a manuscript to summarize and synthesize climate niche models and their projections for 15 key species and 4 forest ecosystems.

Output 2: 1) a functional and annually updated ClimateAP; 2) updated climate projections to include the newly released climate change scenarios in IPCC Sixth Assessment Report (AR6); and 3) a manuscript to summarize and demonstrate the superiority of ClimateAP.

Output 3: 1) an ArcGIS-based web platform; 2) an updated policy extension note; and 3) presentations at two international conferences.

Potential beneficiaries and main stakeholders vary depending on the tools and the output of this project. 1) A summary of the climate niche models will benefit China, Chinese Taipei, Malaysia, and Myanmar. 2) All economies in the Asia Pacific will benefit from the freely accessible scale-free climate data; 3) The web platform will benefit the entire Asia Pacific for easy access to climate data and spatial visualization of climate variables and species and ecosystem projections, and 4) Policy briefs will summarize the major outputs of the project for policymakers and end users in the above-mentioned economies.

We initially developed these tools and have the full expertise and data to further explore and summarize the information that is important for foresters and policymakers' decision making. However, we will need consultation to partner economies to address their concerns and needs. For output 1, we will conduct additional analysis on the projections to include soil effects, to calculate more statistics and to integrate individual species into a framework showing species availability for any planting site for the current and future climates in connection with the forest ecosystem projections. For output 2, we will maintain and improve the functions of ClimateAP and incorporate the newly available monthly climate data each year to keep it updated. We will particularly incorporate recently released new climate projections included in IPCC AR6. ClimateAP will be compared with the commonly used WorldClim to demonstrate its superiority. For Output 3, we will disseminate model predictions and their applications in forest management for climate change adaptation. We will convert our Google-Map based to an ArcGIS-based web platform for better interaction and accessibility, which will be particularly beneficial to China to overcome the issues with Google. We will also prepare a manuscript policy brief and present our tools at international conferences.

Abbreviations and acronyms

AP	Asia-Pacific region
BEM	Bioclimatic envelope model
ClimateAP	A climate model for Asia-Pacific
CAs	Collaborating Agencies
CMIP5	Coupled Model Intercomparison Project 5
CMIP6	Coupled Model Intercomparison Project 6
CNM	Climate niche model
EA	Executing Agency
GCM	General Circulation Model
IPCC	The Intergovernmental Panel on Climate Change
IPCC AR6	IPCC Sixth Report
SDM	Species distribution model
SSP	The shared socio-economic pathway
UBC	University of British Columbia

Project details

1. Background and Rationale

Afforestation and forest management to maximize carbon sequestration are recognized as key strategies for climate mitigation by the Paris agreement of the United Nations Framework Convention on Climate Change. A major challenge of climate change to forestry is that climate change is causing a mismatch between the climate that trees are historically adapted to and the climate that trees will experience in the future. Such mismatches compromise the health, resilience, productivity and functions of forest ecosystems.

To address this challenge, APFNet supported a project on *Adaptation of Asia-Pacific Forests to Climate Change with Phase I and II* since 2011. The project was executed by the University of British Columbia. There were totally 7 economies and regions targeted, including China, Chinese Taipei, Australia, Canada, Malaysia, Myanmar and Laos. With 8-year endeavor, important forest adaptation tools have been developed, as follows.

1) ClimateAP – a software package to generate scale-free climate data for historical and future years and periods for Asia Pacific. It applies a dynamic local downscaling algorithm to generate climate data for specific locations, which has important advantages over the gridded climate data from other climate models. The superiority of the scale-free climate data has been well recognized in North America through its sister model ClimateNA, which has gained over 1920 users in a competitive environment. In contrast, the value of ClimateAP, with 255 users, remains largely undiscovered by users; most of them still use the WorldClim, which is considered inaccurate. ClimateAP approach has shown its value in Chinses Taipei, where it can reduce prediction errors of TCCIP data (government invested climate data) by 55-66% in temperatures. More studies and extension activities are needed to demonstrate the value of ClimateAP and to make it an essential tool in climate change related studies and applications in the Asia Pacific. In addition, ClimateAP also requires to be updated annually to incorporate the climate data from the recent years. It is particularly important to update the GCMs with the recently released GCMs by the IPCC Sixth Report (AR6). If not updated, this tool will lose its value very rapidly.

2) Climate niche models built for 15 major forest species and 4 forest ecosystems and their future projections. A climate niche model (CNM) is also called a species distribution model (SDM), or bioclimatic envelope model (BEM). It is widely used to predict the suitable climate habitat of a forest tree species for the current and future climates. These models and their future projections have a great potential to guide the development of adaptive forest strategies to climate change to overcome the climate mismatch problems. However, due to the limit of time and resources of the previous project, the information generated for the 15 species and the 4 forest ecosystems need to be further refined and summarized for a peer-review publication and an extension note for foresters and policymakers' decision-making. In addition, our projections for the 4 ecosystems have a great potential to be developed as a framework for managing multiple species collectively.

3) A web platform to facilitate data access and spatial visualization. The web platform allows users to obtain climate data for any locations just by clicking on the Google maps. It also enables users to visualize spatial patterns of climate variables, species and ecosystem distributions, and their future projections. It serves as an effective tool for transferring information from scientists to end-users. However, this tool has not been well known as it deserves. Its sister platform in North America has been intensively used in supporting regional policymakers to develop adaptive forest strategies, in university lab course training, and public educations about the impact of climate change. Its traffic can reach 2,000 visits/day. Apparently, more extension work is necessary to make the tool better know. Meanwhile, the inaccessibility of Google Maps in China also limits the use of this tool.

Climate change brings the most important threats to existing forests and new plantations in terms of their productivity, resilience, and services. Development and applications of forest adaptation tools are critical for foresters and policymakers to promote sustainable forest management to enhance ecological functions and ecosystem security of forests under climate change. Thus, the development and applications of these tools are of highly relevance to APFNet priorities, Priority #2 in particular, Promoting Sustainable Forest Management to Enhance Ecological Functions and Ecosystem Security of Forests.

2. Goal(s) and Objectives

The overall goal of this project is to explore and implement the potential values of these tools developed in the previous project, so that they can be better used in developing forest adaptive strategies in the Asia Pacific region to improve the health and productivity of forest ecosystems and their resilience to climate change. The main objectives of this project include:

1) To summarize and synthesize climate niche models and their projections for 15 key species and 4 forest ecosystems. We will conduct additional analysis on the projections to consider soil effects, to calculate more statistics and to integrate individual species into species availability framework for the current and future climates in connection with the forest ecosystem projections.

2) To maintain a functional and updated ClimateAP to provide superior climate data. We will maintain and improve the functions of ClimateAP and incorporate the newly available monthly climate data each year to keep it updated. We will particularly incorporate recently released new GCM projections included in IPCC AR6. ClimateAP will be compared with the commonly used WorldClim to demonstrate its superiority.

3) To disseminate project outputs. We will disseminate our tools and their applications in forest management for climate change adaptation. We will convert our Google-Map based to an ArcGIS-based web platform for better interaction and accessibility, which will be particularly beneficial to China to overcome the issues with Google. We will also prepare a manuscript policy brief and present our tools at international conferences.

3. Outputs and Activities

- **Output 1: A peer-reviewed publication to summarize and synthesize climate niche models and their projections for 15 key species and 4 forest ecosystems**

These tools have a great potential to guide the development of adaptive forest strategies to climate change. However, the species and the forest ecosystems were analyzed individually and additional metrics of climate change impacts can further explore the potential of these tools. Our objectives of this project are to further refine and synthesize these tools for developing a framework for managing multiple species collectively. We will consult the local users and visit a typical site to identify and understand the concerns and the need of local users, so that our summary report can address these issues and make it more useful for practical application. The users of this tool include all the four economies (China, Chinese Taipei, Malaysia, and Myanmar). All activities required for this output will be completed by Dr. Tongli Wang and his team of a postdoc and two PhD students.

Activity 1.1 Projection analysis

We will conduct additional analysis on the projections. The further analyses will include impacts of climate change on habitat distributions of the tree species and forest ecosystems in terms of the changes in area, geographic locations respective to latitude, longitude and elevation. We will also develop a niche model with soil variables to predict the suitable soil habitat for each tree species and forest ecosystem. We will then integrate predictions produced by from both the climate niche model and the soil niche model to make our predictions representing the combined habitat suitability in terms of both climate and soil conditions. We believe our integrated projections will be more realistic and applicable in forest resource management for climate change adaptation. In addition, we will update our projections using climate change scenarios from the CMIP5 with the ones from the CMIP6, which will be made available in this project. Furthermore, we will develop a framework to incorporate all the projections of the 10 tree species and the forest ecosystem in China to facilitate species selection for planting sites under the current and future climates for China. These analyses will be completed by the June 2023. The specific activities include:

1) Soil variable collections: Soil variables will be derived from the basic soil indicators of the Harmonized World Soil Database, containing a soil raster data layer with 30 arc seconds spatial resolution. The soil variables will be prepared for each of the four economies involved. This work will be completed by March 2022.

2) Soil niche model development: A soil niche model will be developed for each of the 15 forest tree species and the four forest ecosystems. Spatial distributions of the suitable soil habitat for each species and forest ecosystem will also be predicted. This work will be completed by August 2022.

3) Climate habitat projections for the future periods will be reproduced using the updated climate projections from the recently released CMIP6 project. This work will be completed by November 2022.

4) The predicted soil maps will be overlaid on the top of the previously predicted climate

suitability maps and serve as a filter to produce combined suitable habitat maps for each species and forest ecosystem for the current and future periods. This work will be completed by February 2023.

5) The impact of climate change on each species and forest ecosystem will be assessed in terms of the changes of the suitable habitat in terms of areas, latitude, longitude and elevation. This work will be completed by April 2023.

6) A framework will be developed to incorporate all the projections of the 10 tree species and the forest ecosystem in China to facilitate species selection for planting sites under the current and future climates for China. The usefulness will increase with more species added into this framework in the future when more projections become available. This work will be completed by June 2023.

Activity 1.2 Meetings with local stakeholders

First round of consultation meetings will be held soon after the project is launched. The consultation will focus on the current policy in China, Chinese Taipei, Myanmar and Malaysia, to identify the major issues, concerns, and possible applications of the ecological tools in developing their local forest adaptive strategies. Most of the consultations will be conducted online using Zoom, and we will visit one economy for 3-5 days in August 2022, which will be decided based on the results of the consultation. This work will be completed by September 2022. An online workshop will be conducted to communicate our summarized findings and updated tools at the end of the project.

1) For consultation meetings, we will have, at least, four zoom consultation meetings, one for each of the four economies. More consultation meetings will be conducted if there is a need based the outcome of the first meeting for each economy. The first round of consultation meetings will be arranged 1-3 months (January - February 2022) after the project is initiated. We aim to have 2-5 participants from each targeted economy and 2-3 participants from our end to participate the meetings. If needed, the second round meetings will be arranged between April – June in the first project year. Details of the meetings include:

    a. Issues: Online consultations to discuss and identify major issues, concerns, and possible applications of the climate change models in the four target economies/regions. The issues will be related to the model projections for individual tree species and forest ecosystems for China and Chinese Taipei. For Myanmar and Malaysia, the issues will be focused on projections for forest ecosystems. The issues about the applications of ClimateAP and the web tool will be relevant to all the four economies.

    b. Corresponding goals include: a) identifying issues and concerns in forest adaptation to climate change; b) understanding the interest and problems in applying the tools that we have developed; and c) discussing potential solutions to address the issues and concerns, particularly through the use of the tools.

    c. Participants will include project collaborators, policy makers, and local

stakeholders who are affected by climate change, and anyone who is interested with forest adaptation to climate change.

d. The collaborators for organizing the local participants include: Research Institute of Resources Insects of the Chinese Academy of Forestry, Kunming, China; National Ilan University, Chinese Taipei; Forest Research Institute, Myanmar; University Putra Malaysia, Malaysia.

2) For the field visit, we (Wang and a team member) will determine an economy to visit based on the local need (based on Zoom consultations) and the forest/ecosystem projections. We will choose an economy that has a strong desire and need to apply our tools. After the economy is chosen, we will identify a location where our model projections can be relatively easy to be validated on the ground. Either Yunnan Province in China or Chinese Taipei can be a good candidate.

Yunnan province has substantial changes in elevation, resulting in clear climatic gradients and sharp transitions from one ecosystem to another within a relatively small area. In addition, Yunnan pine (*Pinus yunnanensis*) shows a potential to expand its habitat distribution in China in the future climates. Our collaborator will be Research Institute of Resources Insects of the Chinese Academy of Forestry, Kunming, China. Similar objectives can also be achieved by visiting Chinese Taipei as the sharp elevational changes and the availability of our detailed model projections there. The collaborator will be School of Agriculture and Forestry, National Ilan University. The field trip will be arranged in August 2022. Our first objectives of our visit will include:

a. To discuss and identify major issues, concerns, and possible applications of the climate change models locally.

b. To ground-truth the currently mapped species/ecosystem distribution compared with our predicted distribution.

c. In addition, we will also attempt to observe the trend of changes in vegetation following the recent climate change.

An online workshop will be conducted to communicate our summarized findings and updated tools at the end of this project between October – December, 2023.

Activity 1.3 Preparing a peer-reviewed publication

A manuscript will be prepared to summarize and synthesize climate niche models and their projections for 15 key species and 4 forest ecosystems. The manuscript will also cover the results from our consultation meetings and field visit, and our recommendations. Our target peer review journal is Forest Ecosystem and Management. The first manuscript draft will be completed by April 2023.

♦ Output 2: A functional and Updated ClimateAP to provide superior climate data

ClimateAP can generate scale-free climate data for historical years (1901- present), future years

(2011-2100) and future periods (2011-2040, 2041-2070 and 2071-2100). ClimateAP provides scale-free climate data with much higher accuracy than gridded climate data from other currently available climate models. High-quality climate data is essential for developing credible ecological models including the ones developed in this project. The superiority of the scale-free climate data is gradually getting recognized in Asia Pacific with an increasing number of subscribers. However, ClimateAP requires to be updated annually to incorporate the climate data from the latest year for the historical climate data. Meanwhile, future climate projections are also need to be updated periodically, which is the case for this project period as a new version of GCMs was just released last month (October 2021). If not updated, this tool will lose its value very rapidly. In addition, we will add new features to the program to include more functions to improve its efficiency.

The activities required for this output will continue throughout the entire project period. Activities will be managed by Dr. Tongli Wang, with support from the rest of the research team. Activities will be completed at the Faculty of Forestry, UBC, using computer programs R, Python, ArcGIS, and Visual Studio.

Activity 2.1 Update of annual climate data for ClimateAP

Activity 2.1.1 data collection -- We will download the globally interpolated monthly climate data for the past year when they become available, which include 2020, 2021 and 2022. The climate variables will include monthly minimum temperature (Tmin), monthly maximum temperature (Tmax), and monthly precipitation (Pre). This activity will need to be conducted in both 2022 and 2023.

Activity 2.1.2 data processing -- A huge volume of the downloaded data will be extracted, converted and formatted for ClimateAP. The update of monthly data for the years 2020 and 2021 will be completed by June 2022, and for the year 2022 will be done by June 2023, respectively.

Activity 2.1.3 Data integration – Newly processed monthly climate data will be integrated into ClimateAP for desktop and web-based versions, and the updated versions will be released in July 2022 and July 2023, respectively.

Activity 2.2 Validation of the superiority of ClimateAP over the WorldClim

Activity 2.2.1 Site selection -- Consultation meetings will be held with the stakeholders and main participants of the previous project to discuss and identify typical forested areas in mountains where climate varies considerably. The selected areas should also have accessible observations from weather stations for validations. We will use a combination of ArcGIS, digital elevation model (DEM), and distribution of weather stations as well as the results of our consultations. Two test sites will be determined by the end of April 2022.

Activity 2.2.2 Data collection and processing

We will generate climate data from both ClimateAP and WorldClim, and compare them against observations from weather stations, which will be obtained from these regions. The data collections will be completed by June 30, 2022.

Activity 2.2.3 Prediction accuracy comparisons

Comparisons in the prediction accuracy will be conducted between the two data sources at

both monthly and annual scales. The model prediction accuracy will be evaluated in terms of the proportion variance explained (R square value), prediction error (RMSE), and the slope of the regression (*b* value). The data analysis will be completed by December 2022.

Activity 2.2.4 Preparing a manuscript to summarize the methods, major finding and to discuss the strength and weakness of the tool. A manuscript will be prepared and submitted in June 2023. The targeted peer review journal is Agricultural and Forest Meteorology.

Activity 2.3 GCMs Update to CMIP 6

The GCMs included in the current version of ClimateAP are from the Coupled Model Intercomparison Project v5 (CMIP5) included in the IPCC Fifth Assessment Report (AR5) (IPCC 2014). GCMs from CMIP6 have been available and reported in the IPCC Sixth Assessment Report (AR6) October 2021. A new version of ClimateAP will contain 13 CMIP6 climate models for the following emissions scenarios for each climate model: SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5, and normal periods will be provided for the following time periods: 2011-2040, 2041-2070 and 2071-2100. We will also generate ensemble for each GCM and period. In addition, we will generate a monthly time series for the ensembles for the years 2011-2100.

Activity 2.3.1 Data collection and processing

Monthly climate data will be downloaded from CMIP6 data portal for Tmin, Tmax and Pre for each the 7,250 combinations (i.e., 13 GCMs × 4 scenarios × 3 variables × 12 months × 120 years (30 historical and 90 future years) × 5 runs). In total, over 20,000 files will be download. The download files will be processed to have the spatial projection and units meeting the requirements of ClimateAP. We will also take the averages over the 5 runs. This work will be completed by March 2022.

Activity 2.3.2 Anomalies generating

To incorporate the future climate data into ClimateAP, the absolute values of the downloaded data need to be converted into anomalies relative to 1961-1990 normals. ClimateAP uses anomaly data to downscale future climate projections through a delta approach. All the climate variables for each month for the climate layers will be converted. We first need to calculate averages for the reference period 1961-1990 and the three future periods 2011-2040, 2041-2070, and 2071-2100 for each variable, GCM and scenario combinations. The anomaly data will then be downscaled from various spatial resolutions (1 – 3.5°, varying among the GCMs) to 1 x 1° and formatted to meet the requirements of ClimateAP. This work will be completed by June 2022.

Activity 2.3.3 Data integration and testing

The new GCM data for the three normal periods will be integrated into ClimateAP to make a new version ClimateAP v3.0. We will test the downscale GCMs against their original data spatially to make sure everything going correctly. We will also compare new GCMs with the previous version to check the corresponding scenarios are matching, for example, RCP 4.5 in the CMIP5 vs. SSP 2.45 in the CMIP6. This new version will be released by September

2022.

Activity 2.3.4 GCM time series

Monthly time series data for the years from 2011 to 2100 will be added to ClimateAP for the GCM ensembles and six individual GCMs for the four scenarios. To achieve this objective, we need to calculate anomalies for all GCMs, scenarios, months and years, as described in Activity 2.3.2. The time-series function for the future years will be enabled to allow users to generate time-series climate data for multiple locations for any period in the future. A new version (ClimateAP v3.10) will be released by June 2023.

♦ Output 3 Dissemination of model outputs

Results and tools obtained from scientific research often failed to reach the end users in order to generate benefit for the public. Tools developed in our previous projects have great potential to improve the health and productivity of our forests under a changing climate. Thus, a wide application of our tools can enhance the capacity of forest ecosystems to mitigate climate change. This requires collective effort. Our web platform allows users to obtain climate data for any locations just by clicking on the Google maps. It also enables users to visualize spatial patterns of climate variables, species and ecosystem distributions, and their future projections. It serves as an effective tool for transferring information from scientists to end-users. However, the inaccessibility of Google Maps in China limits the use of this tool. In this project, we will overcome this limitation by applying the online ArcGIS system (free for users as license is paid by UBC) to replace the Google Maps. In addition, we will also disseminate our tools through presentations at relevant international conferences and wor kshops to reach scientist communities, and preparing a policy note for local policymakers.

Activity 3.1 Conversion of the Google Maps based to an ArcGIS-based web platform

To use the ArcGIS-based mapping system to replace the currently Google Maps system is the objective of this output. The ArcGIS-based web platform will be more interactive and accessible in the region, particularly in China, where the majority users are located.

Activity 3.1.1 Methodologies

The methodologies will be explored through consultation with IT staff at the Faculty of Forestry and at the Computer Department, UBC. The methodologies will include the deployment of the ArcGIS system, dynamic accessibility of digital elevation model (DEM), and the overlay of climate and ecological maps. This part of the work will be done by June 2022.

Activity 3.1.2 Setting up an ArcGIS-based web platform

An ArcGIS-based web platform will be set up that will be able to be integrated with ClimateAP to display the current climate data by clicking on the map. The output will be validated and the debugging of the new mapping system will be completed by December 2022.

Activity 3.1.3 Data and maps uploading

We will transfer all the historical and future climate data into the new system and make sure that they are displayed correctly. Climate maps for some major climate variables (mean annual

temperature and precipitation) and ecological niche model projections for the individual forest tree species and the forest ecosystems will be uploaded to the new system by June 2023.

Activity 3.1.4 Web platform promotion

After the web platform is launched, we will promote the site through some major searching engines (Google and Baidu) and social media (Facebook and WeChat). The promotion will be achieved in two ways. First, we will connect with IT staff to create promotions that appear at the top of result pages when your users search for certain queries related to our climate and ecological models. Second, we will consider to pay Baidu and Google not exceeding $900 each. We will also promote our web platform through social media, including WeChat, Facebook and Twitter. For details, please refer to our Communication Plan (Annex F). This work will be completed by the end of the project (December 2023).

Activity 3.2 Presentations at international conferences to introduce our tools

To share the information about our tools and output of our new studies to a broader audience, results of Output 1 and 2 will be presented at 2 international conferences held in the region. The following two international conferences are targeted (but may be subject to change):

1) International Conference on Climate-Smart Agriculture, Forestry and Fisheries, May 03-04, 2023 in Singapore, Singapore. We will present and discuss our main findings about the innovation and unique features of our ecological models in forest resource management on this conference.

2) International Conference on Agriculture, Forestry and Food Science, August 16-17, 2023 in Tokyo, Japan. We will present and discuss our share experiences and scale-free climate model and its application in forest adaptation to climate change.

Activity 3.3 Prepare a manuscript policy brief

A policy brief will be prepared for each economy to describe the methodologies, major results and our conclusions of the ecological models and their projections. For China, the policy brief will cover all individual species, forest ecosystems and the integrated framework for planting-site based species selection. For Chinese Taipei, the policy brief will cover both individual tree species and forest ecosystems. Only forest ecosystems will be covered for Malaysia and Myanmar. Possible solutions will be discussed with our recommendations. We will upload it to the web platform and send to the collaboration network that we have built previous in this project. It will be completed by October 2023.

4. Risks and Assumptions

This project is at a low risk in general. This is because we have developed the major tools and technologies in the previous project. We have the full expertise and experience to refine, extend, summarize and update these tools and technologies to facilitate broad applications. However, due to COVID-19 pandemic, travelling for field visit and attending conferences may pose some uncertainty. This uncertainty includes the timing and the cost. Most of the

travel costs have considerably increased. To address this concern, we may need to make our field visit flexible in time. To deal with the increasing travel cost, we may need to reduce the number of people to attend the conference.

5. Institutional Management and Communication

Project Team:

Dr. Tongli Wang is an expert in climate and ecosystem modeling. He is the designer and developer for the widely used climate models ClimateNA and ClimateAP. His work on modeling forest ecosystems and forest tree species distributions for climate change has been well known and influential in North America, Europe and Asia Pacific. Dr. Wang has developed most of the tools in the previous projects, including ClimateAP, climate niche models for the 15 forest tree species and 4 forest ecosystems, as well the web platform. He will also be supervise and participate in all the output activities included in this project.

Dr. Guangyu Wang is Associate Dean in the Faculty of Forestry at UBC. Dr. Wang has extensive experience in managing collaborative projects, particularly with partners in China. Dr. Wang will be responsible for assistance on project management including coordination of collaborators and outputs dissemination. His efficient coordination skills will ensure a smooth implementation of the project plan in a timely manner.

Dr. Dawei Luo is a postdoc research scientist in Dr. Tongli Wang's lab. He is experienced in developing forest ecological models and growth and yield models to represent the response of forest populations to climate change. He will be involved in the further analysis and synthesizing the ecological models for the 15 forest tree species to develop the species selection framework for future climate conditions for any give planting site.

Jing Jiang is a PhD student with Dr. Tongli Wang working on forest ecosystem classification and climate change adaptation. She is experienced in AI computing and modeling. She will be focus on the further analysis of the four forest ecosystems. She will explore an effective way to integrate the forest ecosystem projections into the species selection framework.

Wenhuan Xu is a PhD student with Dr. Tongli Wang working on forest species projections and assisted migration. He has a strong modeling and computational skills. He will also be involved in the further analysis and synthesizing the ecological models for the 15 forest tree species to develop the species selection framework for future climate conditions for any give planting site.

Project management

As the nature of project phase III, almost all the activities will be conducted by the Executive Agency, UBC, the project management will be relatively simple and straightforward. We will have the first project meeting (project team only) in January 2022 right after the launch of the project. We will have regular project meeting monthly. The progress, technical challenges, the need of collaboration will be discussed and addressed at the project meetings.

Consultation meetings will be conducted with each collaborator starting in January, 2022, right after the project launched. Through the consultations, we will identify the major issues, concerns, and possible applications of the ecological tools in developing their local forest

adaptive strategies. Most of the consultations will be conducted online using Zoom, and will visit one economy, which will be decided based on the results of the consultation. This work will be completed by September 2022.

- The project management structure and communication mechanism should be illustrated by chart(s) as Annex;

As the nature of project phase III, almost all the activities will be conducted by the Executive Agency, UBC, the project management will be relatively simple and straightforward. Dr. Tongli Wang will be the Project Director response for planning, participating and supervising all the project activities. Dr. Guangyu Wang will help on coordinating collaborators. Rosemarie Cheng will be the financial officer. Jing Jiang will be the communications officer.

6. Project resources and financial management

For a detailed budget, please refer to Annexes D "Overall Project Work Plan and Budget" and G "Project Budget by Category".

In addition to APFNet contribution of $135,000, UBC and the Faculty of Forestry would like to contribute $29,100 in kind to the research. UBC has a rigorous financial management system controlled centrally by professional accountancy staff, and an effective financial and research management control framework for monitoring the use of funding. Funding will be managed by the UBC Central Office and reimbursements will occur through the department's financial reporting systems.

Consistent monitoring of project resources and budget will be completed throughout the project and reported in various reports submitted to APFNet. Annual work plans will provide detailed information about project planning and yearly budgets. Annual progress reports will cover the expenditures, progress, and achieved outputs according to the annual plan in the middle and at the end of each project year. Independent internal audits and financial statements will also be submitted by the EA to APFNet to indicate the opening balance, expenditure incurred to date, and the closing balance for the project account.

7. Monitoring and evaluation

- Describe the indicators and plans for monitoring and evaluation to keep project implementation on track and measure the success and lessons learned.
- The project will follow systematic approaches to project management, including reporting, review, monitoring, and evaluation, and UBC and the Faculty of Forestry will ensure that these approaches are adopted. The project team will follow the established procedures of providing annual plans, annual progress reports, and regular project meetings to identify any gaps between the actual and planned situations. Timely corrective actions will follow to ensure the efficiency and effectiveness of project implementation and to achieve the ultimate objectives of the project.

  Internal monitoring and evaluation will be conducted regularly in order to ensure the

efficiency and effectiveness of project implementation, to achieve the ultimate project objectives, to avoid encountering unexpected delays in such areas as output delivery, and to ensure the timing and actual availability of planned input items.

Upon completion of the project, the EA will produce 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. All reports will be completed according to the timeline given in Annex F "Project management activities timeline" and will follow the document templates and requirements provided by APFNet. All reports to be completed throughout this phase of the project include:

1. Project Document
2. 1st Annual Work Plan
3. 1st Project Progress Report (1PPR) (Financial Statement) (12^{th} month)
4. 2nd Annual Work Plan
5. Technical Report
6. Project Completion Report
7. Overall financial statement
8. Terminal Audit Report

8. Dissemination, duplicability and sustainability

- Describe the plan to disseminate results and outputs of the project, including form and contents, and the target audience, and how to extend project's impacts.
- Describe expectations for the project beyond the funding period, factors that ensure the achievement and efforts to be sustained over time.

The key to the third phase of this project is to disseminate the major outcomes achieved during the first two phases. The dissemination will be achieved through the following approaches: 1) summarizing and synthesizing the results that have been achieved in the previous two phases of the project; 2) updating and improving the tools to retain and enhance the values of the tools so that the tools remain attractive to the users; and 3) disseminating the tools and their applications through peer-reviewed publications, presentations at international conferences and social media.

The tools developed in this project reflect state-of-art and cutting-edge technologies in the field of climate and ecological modeling for forest adaptation to climate change. There is currently no comparable tools for the Asia Pacific region. An R-based scale-free climate model, which adopts the algorism of ClimateAP to generate scale-free climate and runs in R programming environment, is in development in Europe funded by EU using the same downscaling techniques that we have developed. However, the R-based tool is slow and with an upper limit in processing the number of locations.

All the tools and their applications (projections) are sustainable for at least 5-10 years as the

new version of GCMs (CMIP7) are not likely to be available in the next 5 years. After they are deployed, they can be accessed through a web browser. The maintenance of the web host is at low cost, which can be covered by us with no problem. However, ClimateAP should be updated annually to incorporate the climate data from the latest year and the new GCMs periodically (5-year or longer). Otherwise, its usefulness can be compromised with time.

Annex A: Project sites map and relevant information

This part presents the map and the current status of the project sites, including its size, forest type, natural, socio-economic conditions as well as the land use status, potential demonstrative effect to other regions or economies.

The areas involved in this project include the following economies:

China: China is a large and diverse economy with a wide range of forest resources ranging from boreal mixed woods in the northeast to temperate coniferous forests in the east and on the Tibetan plateau to subtropical mixed and tropical forests in the south. As of the 2019 national forest inventory, about 220 million ha (i.e., 22.96% of the total land area) were identified as forested. Plantation forests represent a large percentage of the total forest area and reforestation has been a priority in recent years. Forest degradation represents a problem in many parts of China, largely due to over harvesting of fuel wood and conversion to agriculture. Large-scale afforestation is a significant feature, which offers an opportunity to select forest species for future climates.

Chinese Taipei: Located off the southeast coast of mainland China, Chinese Taipei has a large forest area relative to its size (~36,000 km^2). It contains more than 2 million ha of forestland including several forest types, ranging from tropical hardwoods in the lowland areas to cold temperate conifer forests along a gradient of increasing elevation. Chinese Taipei has a well-developed industrial economy and an established plantation forestland base designed to support a variety of ecosystem services including wood production, carbon storage, watersheds, and conservation of biodiversity.

Myanmar: The Republic of the Union of Myanmar (Myanmar) is situated at the western end of Southeast Asia. Myanmar is the largest economy in Southeast Asia, covering approximately 676,578 km^2 and extending 800 km east to west and 1,300 km north to south. Forests in Myanmar play a vital role in stabilizing environmentally critical areas such as coastal areas, dry zones, and hilly regions by providing protection against natural disasters. Myanmar forests have extremely high floral and faunal diversity. They harbour about 7,000 species of vascular plants including 1,696 species of climbers, 65 species of rattans, and 841 species of orchids. 85 species of trees have been identified as being premium sources of timber.

Malaysia: With more than 18 million ha of its total land area (32.6 million ha) covered with natural forest, Malaysia enjoys one of the highest percentages of forested land among tropical economies. Consequently, the timber and timber products industry are very important and play a significant role in Malaysia's economy. At the same time, there is increasing recognition of the protective roles that forests play, such as the conservation of biodiversity, protection of soil and water resources and stabilization of the climate. Forestlands in Malaysia are dominated by dry inland Dipterocarp forests but also include mangroves and peat swamp areas. More than 75% of forestland in Malaysia has been designated as permanent forest reserve and is managed for conservation, timber production, and protection of ecosystem services. However, deforestation and degradation remain a problem for forest managers.

Annex B: Project logical framework

Items	Intervention logic	Objectively verifiable indicators of achievement[5]	Sources of information and means of verification[6]	Assumptions[7]
Goal(s)[1]	To explore and implement the potential values of these tools developed in the previous project, so that they can be better used in developing forest adaptive strategies in the Asia Pacific region to improve the health and productivity of forest ecosystems and their resilience to climate change	1) Summarized and synthesized ecological model projections for a broader use 2) A updated and improved ClimateAP can provide scale-free climate data superior to the climate data from other sources 3) Our tools will be disseminated to reach a broader audience	1) A report will be published and a new tool for species selection will be delivered 2) Two new versions of ClimateAP will be released 3) A more effective web platform will be launched and Presentations will be given at the targeted conferences	No assumption applicable.
Objectives[2]	1) To summarize and synthesize climate niche models and their projections for 15 key species and 4 forest ecosystems 2) To maintain a functional and updated ClimateAP to provide superior climate data 3) To disseminate our tools and their applications in forest management for climate change adaptation	1) A peer-reviewed publication to summarize and synthesize ecological niche model projections 2) A planting site based species selection framework for future climates 3) A functional, updated and improved ClimateAP and a peer-reviewed publication to demonstrate the superiority of ClimateAP over other climate models 4) An more interactive and accessible web platform for data access and spatial visualization 5) 2-4 conference presentations to present our tools. 6) An updated policy notes	1) A manuscript to be submitted on time 2) To be delivered on time for testing 3) Two new versions of ClimateAP will be released and A manuscript to be submitted on time 4) The web platform will be launched after the completion 5) Presentations will be given at the targeted conferences 6) An updated policy notes will be submitted to APFNet.	Due to COVID-19 pandemic, travelling for field visit and attending conferences may pose some uncertainty. We have options to deal with it.

Annex B: Project logical framework

Expected outputs[3] **Output 1**	A peer-reviewed publication to summarize and synthesize climate niche models and their projections for 15 key species and 4 forest ecosystems	1) Further refine and synthesize these tools for developing a framework for managing multiple species collectively 2) A peer-reviewed publication	We have collected all the data except the soil variables, which will be collected in this project period	We have the full control of the data, methodology and human resources for this work
Activities[4] Activity 1.1 Activity 1.2 Activity 1.3	**Activity 1.1 Projection analysis:** 1) Soil variable collections 2) Soil niche model development 3) Climate habitat projections for the future periods with CMIP6 GCMs and scenarios 4) Overlaying the soil maps on the previously predicted climate suitability maps 5) The impact assessment of climate change on each species and forest ecosystem 6) A framework to incorporate all the projections of the 10 tree species and the forest ecosystem in China **Activity 1.2 Meetings with local stakeholders** 1) Consultation meetings with the targeted economies to identify the major issues, concerns, and possible applications of our tools 2) A field visit to further look into the issues, concerns and new potentials	**Activity 1.1 Projection analysis** 1) 14 soil variables will be collected for entire targeted areas. 2) A soil niche model will be developed for each tree species and forest ecosystem 3) New projections with the updated GCMs in ClimateAP 4) Projections reflecting both climate and soil effect to be generated 5) Statistics of the climate change impact to obtained 6) The new tool to facilitate selection of species for each planting site for future climate **Activity 1.2 Meetings with local stakeholders** 1) Major issues, concerns, and possible applications of our tools to be summarized 2) Some ground-truthing information to be obtained in addition to identifying issues **Activity 1.3 Preparing a**	**Activity 1.1 Projection analysis** 1) World Soil Database 2) Random Forest model to be applied 3) Using the established models and the climate data from the updated ClimateAP 4) To be analyzed in ArcGIS and in R 5) The same as 4)	The same as the above

Annex B: Project logical framework

	Activity 1.3 Preparing a peer-reviewed publication A manuscript to summarize and synthesize climate niche models and their projections for 15 key species and 4 forest ecosystems	**peer-reviewed publication** A manuscript to be submitted on time.	**Activity 1.3 Preparing a peer-reviewed publication** Manuscript writing	
Output 2	A functional and Updated ClimateAP to provide superior climate data	1) Annually updated historical climate data 2) Validated superiority of ClimateAP over the WorldClim 3) GCMs Update to CMIP 6	1) CRU global time-series to be the source data 2) Comparisons between ClimateAP and WorldClim in mountainous regions against observations 3) IPCC AR6 GCMs from CMIP6 to be the source data	NA
Activity 2.1 Activity 2.2 Activity 2.3 Activity 2.4	**Activity 2.1 Update of annual climate data for ClimateAP** 1) Monthly climate data collection for the latest year 2) Data processing to meet ClimateAP requirements 3) Data integration to update ClimateAP **Activity 2.2 Validation of the superiority of ClimateAP** 1) Site selection 2) Data collection and processing 3) Prediction accuracy comparisons 4) Manuscript preparation	**Activity 2.1 Update of annual climate data for ClimateAP** 1) Monthly climate data to be downloaded for the last year 2) The downloaded data will be extracted, converted and formatted 3) Newly processed climate data will be integrated into ClimateAP **Activity 2.2 Validation of the superiority of ClimateAP** 1) Two sites to be selected in mountainous regions with observations available 2) To generate climate data from both ClimateAP and WorldClim, and from weather station observations 3) To make comparisons against observations 4) To summarize the methods, major finding and to discuss the strength and weakness of the tool	**Activity 2.1 Update of annual climate data for ClimateAP** 1) CRU global time-series to be the source data 2) Using the R environment to process the data 3) Using R, Visual studio **Activity 2.2 Validation of the superiority of ClimateAP** 1) Based on consultations and spatial analysis 2) Using R and ArcGIS 3) Using R and ArcGIS	

Annex B: Project logical framework

	Activity 2.3 GCMs Update to CMIP 6 1) Data collection and processing 2) Anomalies generating 3) Data integration and testing 4) GCM time series	**Activity 2.3 GCMs Update to CMIP 6** 1) Monthly climate data will be downloaded from CMIP6 data portal 2) The downloaded data need to be converted into anomalies relative to 1961-1990 normals 3) The new GCM data for the three normal periods will be integrated into ClimateAP 4) Monthly time series data for the years from 2011 to 2100 will be added to ClimateAP	**Activity 2.3 GCMs Update to CMIP 6** 1) CMIP6 data portal to be the data source. Over 20,000 files will be download 2) Using R and Python 3) Using R and Visual Studio 4) Using R, Python and Visual Studio	
Output 3	Dissemination of model outputs	1) To make the current web platform more accessible and interactive 2) To transfer the scientific knowledge to a broader scientific community and end users 3) To summarize the tools and results into a policy note for stakeholders and policymakers	1) To ArcGIS system to replace the Google Maps 2) To present our tools and findings at international conferences 3) To update the policy notes with update tools to address the local specific issues	
Activity 3.1 Activity 3.2 Activity 3.3	**Activity 3.1 Applying ArcGIS system to the web platform** 1) Methodology exploration 2) Set up an ArcGIS-based web platform 3) Data and maps uploading 4) Web platform promotion	**Activity 3.1 Applying ArcGIS system to the web platform** 1) Methodology exploration through consultation with IT staff at the Computer Department, UBC 2) To set up the ArcGIS-based web platform integrated with ClimateAP 3) To upload climate data, climate and ecological projection maps into the new system 4) To promote the web platform	**Activity 3.1 Applying ArcGIS system to the web platform** 1) Consultation, training and exploring 2) Using the online ArcGIS system 3) Using the online ArcGIS system 4) Using our own website, searching engines (Google and Baidu), social media (Facebook, Wechat and Twitter)	

	Activity 3.2 Presentations at international conferences 1) To present and discuss our main findings about the innovation and unique features of our ecological models 2) To present and discuss our scale-free climate model and its application in forest adaptation to climate change **Activity 3.3 prepare 4 manuscript policy briefs** 1) A policy note will be prepared for each economy to describe the tools, major results and our recommendations	through web site and social media **Activity 3.2 Presentations at international conferences** 1) International Conference on Climate-Smart Agriculture, Forestry and Fisheries 2) International Conference on Agriculture, Forestry and Food Science **Activity 3.3 prepare a manuscript policy brief** 1) A policy note will be prepared for each economy based on the last policy brief with substantially enriched content and economy specific. China: individual species, forest ecosystems and the integrated framework for planting-site based species selection Chinese Taipei: individual species + forest ecosystems Myanmar: ecosystems Malaysia: ecosystems	**Activity 3.2 Presentations at international conferences** 1) May 03-04, 2023 in Singapore, Singapore 2) August 16-17, 2023 in Tokyo, Japan **Activity 3.3 Prepare 4 manuscript policy briefs** 1) The 4 policy briefs will be published on our web tool and the APFNet websites	

This part mainly illustrates the project management structure and communication mechanism.

Dr. Tongli Wang will be the Project Director response for planning, participating and supervising all the project activities.

Dr. Guangyu Wang will help on coordinating collaborators.

Rosemarie Cheng will be the financial officer.

Jing Jiang will be the communications officer.

Attachments to the PD

Annex D: Project budget table (by activity)

Annex E: Project budget table (by category)

Annex F: Communication Plan

Annex G: Project timeline