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Climate Change and Forests in the Asia-Pacific Region: Impacts, Policies and Strategies

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Abstract

This essay explores the issue of climate change in the Asia-Pacific region, particularly focusing on the forestry sector. Following an overview of forest resources in the region, it describes current and projected trends in climate. Potential impacts of climate change on forests are then discussed. A few scientific models that have been utilized to predict climate change patterns are also introduced. The essay then reviews few suggested improvements on adaptation strategies. It concludes with some national policies aimed at combating climate changes, and typical challenges that are faced by many tropical countries in the region.

Keywords:

climate change, Asia-Pacific, forest

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Acronyms

AIM	Asia-Pacific Integrated Model
FAO	Food and Agriculture Organization
GAR	Global assessment report
IPCC	Intergovernmental Panel on Climate Change
IUFRO	International Union of Forest Research Organizations
NAPA	national adaptation programmes of action
NC	national communications
NTFP	Non Timber Forest Product
SFM	sustainable forest management
SRES	Special Report on Emissions scenarios
TFRK	traditional forest-related knowledge
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Global climate change in recent years has become and will continue to be one of the most heated issues around the world considering its significant impacts on human society and the nature. Forests resources, including trees, wildlife, streams and carbon, are directly affected by rising temperature and extreme weather events which are becoming more frequent. Abnormal climate has also resulted in a significant loss of forest lands and posed adverse impacts on economy and social sectors. Therefore, there is an urgent need for projecting trends of climate change and for learning more about the potential impacts. Effective adaptation strategies and policies are also important in the face of climate change.

More attention has been placed specifically on the Asia-Pacific region, which has the highest population, a large amount of forest dependent communities and a rapidly growing demand for forest products. Furthermore, the region is home to a great variety of forest types and rich biodiversity, which has a great potential for successful adaptation and mitigation. However, recent studies show there is an emerging trend of increasing deforestation in the region due to city expansion and economy development.

Observed evidences have indicated that climate has evolved differently during the last decade in the region. Air temperature increase, sea level rise and the emergence of extreme events have been noticed in various places in the region. Modeling results demonstrate that such trend will continue or even deteriorate in future. These changes in climate will pose negative impacts on forests, including causing extinction of many flora and fauna species, increasing abiotic and biotic disturbances, increasing the vulnerability of existing forests, and even changing tree species.

Currently there are many models that are utilized to provide estimations of climate change trends and impacts. The Asia-Pacific Integrated Model (AIM) is one particular model focusing on the Asia-Pacific region. It is equipped with three main models

projecting greenhouse gas emissions, global climate change and climate impacts respectively. Its products have been widely used by many institutions and organizations for scientific reports and assessments.

In the light of climate change, adaptation strategies need to be robust, active and responsive. This requires improvements to current institutional structures and forest management. Community-based management has been highly valued recently as it helps to enhance the effectiveness of management plans from a number of ways. Adaptive forest management should also be promoted to enhance the resilience of ecosystems to increasing disturbances.

Many countries in the region have addressed the issue of climate change in their existing forest policies with regulations aimed at improving forests' adaptive capacity. However, there are still many institutional obstacles and financial difficulties that limit countries' ability to improve.

This essay examines some current issues of climate change related to forests in the Asia-Pacific region. However, it provides only a brief description of the issue rather than a deep insight. Some other important topics that are not discussed in this paper include mitigation strategies and adaptation and mitigation synergies. International collaboration is also a critical strategy in terms of adapting to climate changes successfully.

1. Introduction

1.1 An Overview of the Region

The Asia-Pacific region geographically extends from the mountainous nation of Pakistan in the west to small island developing states in the Pacific in the east, and stretches from the north of Mongolia to the southern borders of Australia and New Zealand (Waggener & Lane, 1997) (Figure 1). The land area is roughly 2.8 billion hectares, which represents approximately 22 percent of the world's land area (Waggener & Lane, 1997). About 60 percent of the global population resides in the region, including 70 percent of the world's poor (UNEP, 2011). The Asia and the Pacific region can be divided into four sub-regions with the following 49 countries (FAO, 2011):

- East Asia: China, Democratic People's Republic of Korea, Japan, Mongolia, Republic of Korea;
- South Asia: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka;
- Southeast Asia: Brunei, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Viet Nam;
- Oceania: American Samoa, Australia, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, New Zealand, Niue, Norfolk Island, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna Islands.

Figure 1. Map of Asia-Pacific (Source: Government of Canada, 2012)

1.2 Forest Resources

1.2.1 Area

The forested area in the Asia and the Pacific region was 740 million hectares in 2010, making up about 18 percent of the global forest area (FAO, 2010b) and accounting for slightly less than one-third of the regional land area (FAO, 2011). In 2010, East Asia had the largest forest area of 255 million hectares, with the rest located in Southeast Asia (214 million hectares), Oceania (191 million hectares) and South Asia (80 million hectares) (FAO, 2011).

The five most forest-rich countries in the Asia-Pacific region are China, Australia, Indonesia, India and Myanmar. They account for 74 percent of the forest in the region, while China and Australia alone contain half of the forest area of the region. However, six countries in the region reported a forest cover of less than 10 percent of their total land area and among these, two countries (Nauru and Tokelau) reported no forest at all (FAO, 2011).

FAO's report of the States of the World's Forest Resources (2011) summarized the changes of forest areas from 1990 to 2010 in the Asia-Pacific region. Forests in the region lost 0.7 million hectares per year in the 1990s, but gained 1.4 million hectares per year from 2000 to 2010. However, Southeast Asia and Oceania both experienced a large decline in forests in the last ten years with an annual net loss of 0.9 million hectares and 0.7 million hectares respectively (Figure 2). Countries including Cambodia, Indonesia, Myanmar and Papua New Guinea reported large forest loss in the last decade. The main contributor for a growth in forests in the whole region was China, where a large scale afforestation programme increased the forest area by 3 million hectares per year since 2000.

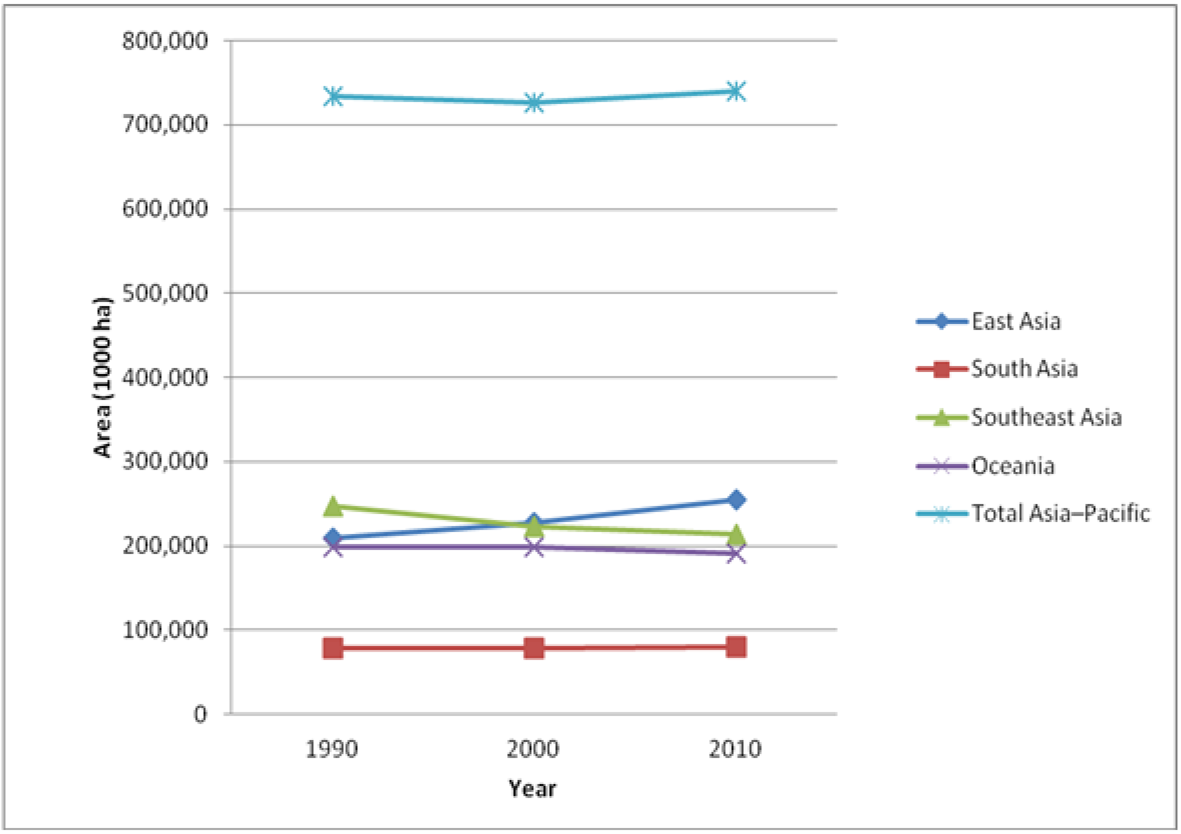

Figure 2. Comparison of forest areas in sub regions of Asia-Pacific, 1990-2010 (Source: FAO, 2011)

1.2.2 Forest Type

With such a wide geographical range, the Asia-Pacific region spreads over four climatic zones — boreal, arid and semi-arid, tropical and temperate (UNFCCC, 2007) — and has a variety of forest types, including temperate, boreal, subtropical and tropical forests. The forest area in the Asia-Pacific region can be divided into primary and planted forests (FAO, 2011). Primary forests show no visible evidence of historic or present human activities, and made up 19 percent of the total forest area in 2010. This percentage decreased for all sub regions over the period 1990-2010. Planted forests (i.e., those established through planting) accounted for 16 percent of the forest area in the region, and the percentage increased dramatically during the last decade (2000-2010) at a rate of 2.9 million hectares per year.

The area of forests designated for biodiversity conservation represented 14 percent of the total forested area, increasing from 13 percent in 2005 (FAO, 2010a) and representing a growth of almost 14 million hectares over the whole region since 2000 (FAO, 2011). Another 19 percent of the forest area in the region was designated for soil and water protection and this number rose from 17 percent in 2005. The total forest area designated primarily for production of wood, fibre, bioenergy and/or Non Timber Forest Products (NTFP) decreased from 37 percent in 2005 to 32 percent in 2010. The area designated for production has fallen since 2000 as forests were designated for other management purposes such as conservation of biodiversity and protection of soil and water (Figure 3). However, South Asia and Oceania showed an increasing trend for production (FAO, 2011).

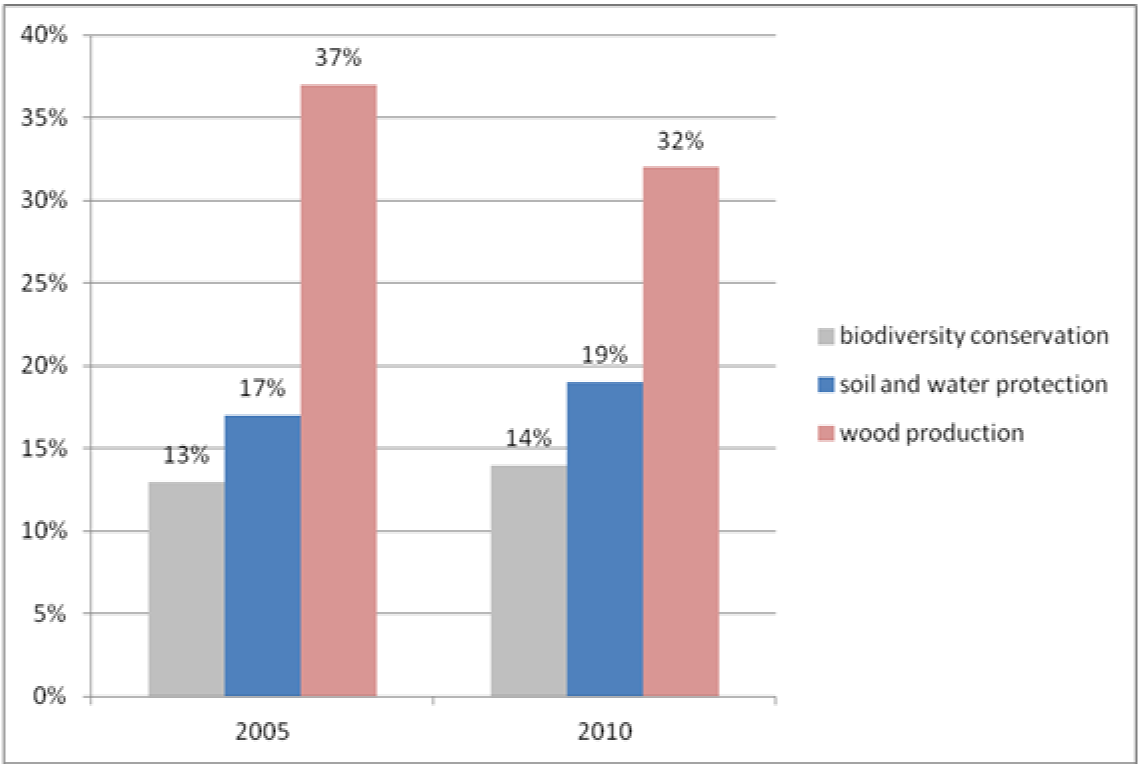

Figure 3. Forest functions in Asia and the Pacific (Source: FAO, 2010a & FAO, 2011)

1.3 Deforestation

The tropical domain within the Asia-Pacific region is characterized by aggressive deforestation for agricultural purpose, timber harvesting, NTFP collection and fuel wood. Deforestation increases the vulnerability of forests to climate change by increasing CO_2 emissions and causing loss of forests area and forest fragmentation, which reduces the adaptive capacity of forests and communities (Roberts, 2008).

Countries in the region can be divided into three development patterns, with different predicted impacts over time (FAO, 2010a). In developing nations such as Malaysia and Republic of Korea, where industrialization is considered the priority, causes of deforestation include mining, urbanization and infrastructure construction. Countries that are highly dependent on agriculture will experience an increasing pressure from forest conversion, while in developed countries like Japan and New Zealand, major interests are placed on ecosystem services from forests and hence forest resources and productivity are highly valued, which provides a strong policy incentive for forest conservation (FAO, 2009).

It is anticipated that Asia will experience an increasing demand for wood products because of rapid urban expansion and the need for construction materials (Fischlin et al., 2007). The large-scale growing of commercial crops including oil palm is also a driver of deforestation in the region (FAO, 2010a). This pressure could further accelerate deforestation in the region. On the other hand, some Asian countries such as China are growing towards becoming large exporters of wood products like furniture (FAO, 2010a). This trend provides an incentive for establishing forest plantations in the region. Asia is expected to have the highest increase of plantation forest until 2030 (Carle & Holmgren, 2008).

2. Climate Change Impacts

Climate change can cause many negative impacts including more droughts and wind throw events, ice storms, increased fire hazards, increased pest infestation and weed invasion, finally leading to reduced forest outputs (Williams & Liebhold, 2002; Irland, 2000). There is already a large body of evidence presented in published reports that climate change has negatively affected forest ecosystems, causing decline in tree growth and dieback, invasive species problems, species distributions and migrations, seasonal patterns in ecosystem processes, demographics and even extinctions (IPCC, 2007). In this section, evidence of recent climate change and projections of future climate change and its impacts on forest resources in the Asia-Pacific region are reviewed.

2.1 Evidence of Recent Climate Change

Climate change in Asia is characterized by a large increase in surface temperature, changes in precipitation patterns and sea-level rise. The surface temperature in Asia showed an increase of 1-3 °C over the last century (IPCC, 2007). In addition, many Asian countries began to experience much longer heat waves than before (Cruz et al., 2007; Tran et al., 2005). Precipitation patterns in the region are developing towards an increasing frequency of intense rainfall events in many parts of Asia, with a decrease in the number of rainy days and the total annual rainfall (FAO, 2010a). These trends in precipitation have negative consequences in rural areas, with increasing floods and drought events caused by a lower proportion of retainable precipitation (FAO, 2011). The frequency and/or intensity of many extreme weather events, including tropical cyclones, droughts, intense rainfall, tornadoes, snow avalanches, thunderstorms, and severe dust storms, has increased significantly in the Asia region (Cruz et al., 2007). In coastal areas of Asia, sea-level raised 1-3 mm/year, which was slightly higher than the global average (Woodworth et al., 2004). The rate of sea-level rise has accelerated to

3.1 mm/year during the last ten years, compared to an overall rate of 1.7 to 2.4 mm/year over the twentieth century as a whole (Rignot et al. 2003).

The temperature has risen about 0.4 – 0.7 °C since 1950 in northwest Australia and southwest New Zealand, along with more frequent heat waves and more rainfall, while in southern and eastern Australia and north eastern New Zealand there has been a decrease in rainfall amount (FAO, 2010a). Drought events in Australia have become hotter since 1973 (Nicholls, 2004). Data from 1950 – 2005 show an increase in extreme precipitation events in north western and central Australia and over the western tablelands of New South Wales, while a decrease in the southeast, southwest and central east coast (Gallant et al., 2007).

In the Pacific, air temperature has increased more than the global average of 0.6 °C during the twentieth century (FAO, 2010a). The rate of mean sea-level rise is about 2 mm/year (FAO, 2010a). An increase in the annual number of hot days and warm nights has been observed in the South Pacific from 1961 to 2003, while the annual number of cool days and cold nights decreased, particularly after the beginning of El Niño (Manton et al., 2001; Griffiths et al., 2003). The frequency and intensity of tropical cyclones that originate in the Pacific have shown an increasing trend over the last few decades (Fan & Li, 2005).

2.2 Future Scenarios

It is projected that extreme weather events, including heat waves and intense rainfall, will continue to increase in South Asia, East Asia and Southeast Asia (Walsh, 2004; Kurihara et al., 2005). Sea surface temperature is predicted to have an increase of 2 – 4 °C and will result in a 10 – 20 percent increase in the intensity of tropical cyclones (Knutson & Tuleya, 2004).

Predictions show that within 800 km of the Australian coast, the temperature is expected to rise (relative to 1990) about 0.1 – 1.3 °C by 2020, 0.3 – 3.4 °C by 2050 and 0.4 – 6.7°C by 2080, while New Zealand will experience a smaller warming of 0.1 – 1.4 °C by 2030s and 0.2 – 4.0°C by 2080s (FAO, 2010a). There will also be an increase in the frequency of heavy rainfall events particularly in western areas (MfE, 2004). The global projection of mean sea-level rise of 0.18 – 0.59 m by 2100 (Meehl et al., 2007) would apply to Australia and New Zealand with a ±25 percent modification due to regional divergence (Gregory et al., 2001). Sub-tropical countries are also expected to experience more extreme weather events and a decrease in precipitation over the region. The surface temperature in South Pacific is projected to have an increase of no less than 2.5 °C compared to the 1990 level (Lal, 2004).

IUFRO (2009) classified current global emission scenarios into the following four categories, each with different future projections:

Unavoidable: The atmospheric CO_2 concentration was artificially set at year 2000 levels. Although unrealistic, this scenario intends to provide an estimate of minimal impacts and the least adaptation required.

Stable: With technological developments CO_2 emissions are expected to decline near the end of this century (IPCC SRES reference scenarios A1T, B2 and B1). A new equilibrium will be built up; however, the influence of this new carbon concentration on climate systems is uncertain.

Growth: Under same technological changes but without powerful policy tools, CO_2 emissions will keep growing even after this century, ending up with an unbalanced climate for centuries.

Fast growth: Under this scenario, global emissions are expected to exceed any projections of the Special Report on Emissions scenarios (SRES).

According to the global assessment report (GAR) (IUFRO, 2009), forest will be most likely to adapt to climate change under the stable cluster, although the forest productivity in semi-arid to arid climates is expected to decline. The growth and fast growth clusters are the most dangerous for forest ecosystems. It is projected that forests in semi-arid to arid climates will experience a decrease in productivity to a point where forests are no longer viable.

Projections show that when temperature increases by $3^{o}C$ relative to pre-industrial conditions, there will be a more than 40 percent risk that terrestrial ecosystems will turn into net sources of carbon, further accelerating carbon emissions to the atmosphere (IUFRO, 2009).

2.3 Potential Impacts

The spatial distribution of forest types and tree species are primarily impacted by climate change (Woodward, 1987). The growing environment of a particular tree species is restricted by climate. Populations of forest trees are generally adapted to local climate (Aitken et al., 2008). Changes in local climate will result in an increase of the vulnerability of existing forests to abiotic and biotic stress.

In tropical domains, increasing surface temperatures, along with other anthropogenic stresses, will threaten the survival of many existing flora and fauna species (FAO, 2010a). Sea-level rise is likely to increase coastal erosion and flooding events to coastal cities (FAO, 2010a). Forests that are already under high human-caused pressure will experience more stresses caused by climate change induced events such as flood, drought, fire, diseases and insects (Roberts, 2008). For developing countries within tropical Asia, vulnerabilities of forests to climate change will be more significant due to lack of financial and human resources to combat climate change (Roberts, 2008).

Sub-tropical countries, including Australia, Japan, China and New Zealand, have vulnerable forest ecosystems that are sensitive to climate change because the forests are often in poor growing conditions. Sub-tropical forests are predicted to migrate poleward over the next 100 years under the effects of climate changes. It is expected that sub-tropical forests will expand into the temperate domain. Changing climate will result in an extension in growing period leading to faster growing forests, which are unstable and thus more vulnerable to climate change (Roberts, 2008).

Temperate countries in the region, which includes Australia, Japan, New Zealand and China, have shown a decline in forest health and changes in species distribution and composition from conifers to deciduous trees. The temperate domain is vulnerable to water shortages caused by decreasing precipitation or increasing evaporation. Due to changing growing conditions, it is expected that temperate forests will expand poleward into the boreal domain with the magnitude of 50-500 km over the next century, which is faster than many forests. Climate change will also increase the growth rate of temperate forests because of a longer growing season, higher CO_2 concentration and increased efficiency in photosynthesis. However, this benefit may be offset by increasing disturbances caused by climate change, including fire, droughts, diseases and insects. Trees growing on mountains will migrate from lower elevation to higher elevation, where growing conditions are more suitable (Roberts, 2008).

Because of increasing drought and fire, the productivity of the forestry sector is predicted to decline in most of southern and eastern Australia, and in parts of eastern New Zealand (FAO, 2010a). Communities in Pacific islands are expected to experience more frequent and intense flooding events, storm surges, coastal erosion and other natural disturbances caused by rising sea-level (FAO, 2010a). Climate change facilitates the spread of invasive species that can adapt to a wide range of climatic zones (Dukes, 2003), such as *Leucaena* spp. and *Eupatorium* spp., which have negative effects on forest health (FAO, 2010a).

In the Asia-Pacific region, mangrove ecosystems are particularly valuable because of their uniqueness and abundant biodiversity. Because of climate change, mangroves are expected to experience more temperature stresses leading to reduced photosynthetic and growth rates (McLeod & Salm, 2006). Increased extreme events will add more stresses; however, the greatest threat to this distinct ecosystem comes from the rising sea level. As a result, mangroves may shift inland responding to sea-level rise, and will expand into some areas like Australia's Northern Territory (FAO, 2010a).

Table 1. Summary of climate change impacts in the region

	Asia	Australia and New Zealand	Pacific
Recent Changes	**Surface temperature:** rose 1-3 °C over a century; Longer heat waves; **Precipitation:** increased intense rainfall events; decreased total rainfall amount. **Extreme events**: increased frequency and intensity (tropical cyclones, droughts, etc.). **Sea-level:** rose 1-3 millimetres/year.	**Surface temperature:** rose 0.4 – 0.7 °C since 1950; more heat waves (northwest Australia and southwest New Zealand); hotter droughts. **Precipitation:** more rainfall in northwest Australia and southwest New Zealand; less rainfall in southern and eastern Australia and north eastern New Zealand. **Extreme events:** increased extreme rainfall events in north western and central Australia; decreased in the southeast, southwest and central east coast.	**Surface temperature:** increased faster than 0.6 °C in twentieth century; Increased number of hot days and warm night in the South Pacific. **Sea-level:** rose about 2 millimetres/year. **Extreme events:** increased frequency and intensity of tropical cyclones originated in the Pacific.
Future Scenarios	Increasing extreme events (heat waves and intense rainfall) in South Asia, East Asia and Southeast Asia;	Increasing frequency of heavy rainfall events; temperature will rise about 0.1 – 1.3 °C by 2020 within 800 kilometres of Australian coast; 0.1 – 1.4 °C by 2030s	Surface temperature will rise greater than 2.5 °C in South Pacific.

	Asia	Australia and New Zealand	Pacific
	sea surface temperature will rise 2 – 4 °C; increasing intensity of tropical cyclones.	in New Zealand; Sea-level will rise 0.18 – 0.59 meters by 2100 (±25 percent modification).	
Potential Impacts	Rising risk of species extinction; increasing coastal erosion and floods.	Declining productivity of forests.	More frequent and intense floods, storm surge and coastal erosion.

3. Modelling

Modelling helps to quantify the impacts of climate change and predict future scenarios which facilitate policy makers to establish strategies against climate change. There are numerous computer models that can provide scientific analysis of current status and projected future conditions of the Asia-Pacific region under changing climate.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) conducted 23 different climate model simulations, which were from Climate Model Diagnosis and Intercomparison, to project climate change impacts on the Asia-Pacific region (White et al., 2010).

3.1 The Asia-Pacific Integrated Model (AIM)

The Asia-Pacific Integrated Model (AIM) is a large scale computer simulation model that helps to conduct an integrated assessment over the Asia-Pacific region (Matsuoka et al., 2001). This model aims to assist the development of policies for combating climate change in the Asia-Pacific region by lowering the level of greenhouse gas emissions and preparing for the impacts of climate change (Matsuoka et al., 2001).

The AIM contains three main models: the greenhouse gas (GHG) emission model (AIM/emission), the global climate change model (AIM/climate) and the climate change impact model (AIM/impact). The AIM/emission model incorporates various assumptions such as global population and economic trends to generate estimates of energy consumption, land use types and, more importantly, projections of GHG emissions (Matsuoka et al., 2001). The AIM/climate model predicts concentrations of GHG in the atmosphere (AIM Project Team, 2012) and calculates global average temperature change while the AIM/impact model focuses on environmental and socio-economic impacts of climate change in both regional and global level (Matsuoka et al., 2001).

Products generated by the AIM have been frequently used in research on climate change. Its outputs, including global and regional emission scenarios and regional impact assessments, have been utilized by IPCC (Matsuoka et al., 2001). Stanford Energy Modelling Forum has applied this model for a global comparison of different emission scenarios and impact assessment. The AIM has also made contributions to Eco Asia (the Congress of Asian Ministers for the Environment), the Global Environmental Outlook Program of UNEP, the UN Global Modelling Forum, and the Asia-Pacific Network Program (AIM Project Team, 2012).

4. Adaptation

In order for forests to develop under changing climate, there are several adaptation strategies that are recommended in the IUFRO's (2009) global assessment report titled *Adaptation of forests and people to climate change*, including indigenous people involvement, adaptive forest management and changes needed to be done to forest policies. The following discussions on adaptation are largely based on this report.

4.1 Indigenous peoples' involvement

Local communities and indigenous peoples are the direct stakeholders that benefit from forests; however, forest management strategies are often made without their participation (FAO, 2010a). To improve the effectiveness of forest adaptation, firstly, the role of indigenous people should be recognized, including their traditional forest-related knowledge (TFRK) and their participation in local forestry policy making. Local forest-related knowledge has accumulated ever since humans first resided on the land, long before the establishment of forest science. Traditional knowledge that has survived under the changing climate for centuries is a valuable asset for forest management. It can help cultivated tree species to adapt to local environmental changes. It can also assist modern science in monitoring the effect of climate change on forests (Vlassova, 2002).

Although traditional knowledge has demonstrated its benefits in enhancing the adaptation capacity of forests to climate change, there are still limitations that need to be addressed (FAO, 2009). Traditional knowledge is often not codified and is usually restricted geographically, which makes the knowledge vulnerable to loss over time. In many places, local knowledge is disappearing (IUFRO, 2009). Also, the ability of such knowledge to adapt quickly to the dynamic climate is uncertain. Therefore, modern scientific knowledge needs to be combined with traditional knowledge in order to provide more strong and robust solutions to manage forest in future. It is important to recognize the role of TFRK and utilize it in the management practices.

Development of effective synergies between modern science and traditional knowledge requires the effort to embrace indigenous and local communities into the decision making process of forest management strategies. In Yunnan, Southeast China, a pilot project about participatory technology development (PTD) for conservation of sloping land demonstrates how indigenous people's involvement can have mutual benefits to both governments and local communities (FAO, 2010a). PTD promotes farmers' participation in scientific research by combining indigenous knowledge of farmers with scientific knowledge of professional researchers (He et al., 2009). It is a useful framework that can help forest managers establish powerful management strategies in the face of climate change.

There is a need for adaptation strategies to develop towards adaptive co-management (ACM) of forests. ACM emphasizes the need for active stakeholders to participate in the decision making process and to adjust management practices by monitoring and learning from the past (Nabuurs et al., 2007). There are several countries in the region that have adopted ACM in practice and generated positive results, including Indonesia, Nepal and Philippines (FAO, 2010a). For example in Indonesia, the adaptation of ACM in Sumatra's Bary Pelepat and Kalimantan's Pasir facilitates the cooperation of researchers and local communities in preparing forest management practices, and contributes to shared learning (Kusumanto et al., 2005).

Effective efforts have been done to restore and strengthen the incorporation of TFRK into sustainable forest management. In 2007, during the IUFRO conference in Yunnan China, the potential contribution of TFRK to fighting against poverty and the role of traditional knowledge in sustainable forest management were explored and discussed (Parrotta et al., 2009). Traditional forest-related knowledge should be recorded for future generations (FAO, 2010a), as Malaysia did when its young population demonstrated a loss of interest in TFRK (SGPPTF, 2007).

4.2 Adaptive Forest Management

Adaptive forest management for climate change is consistent with SFM (IUFRO, 2009). Adaptive management involves design, management and monitoring processes and requires constant learning from the past to plan for the future (FAO, 2010a).

The major goal of adaptive management is to enhance ecosystem resiliency to disturbances by releasing stresses so that forests can survive under changing climate (Salafsky et al., 2001). Biodiversity conservation is an important measure to achieve this goal because more diverse ecosystem tends to be more resilient to disturbance events such as insect outbreak. Tree species should be conserved with dispersed and viable populations in order to reduce the risk of extinction (Fischlin et al., 2007). Planting forests with mixed species rather than single species can also leads to higher biodiversity in the ecosystem (Spittlehouse & Stewart, 2003).

Lindenmayer *et al.* (2006) described various strategies to maintain and improve ecosystem biodiversity, including the following: establishing large reservation areas, setting up buffers for watersheds, arranging harvest units appropriately, retaining large fallen logs on site, increasing rotation years for tree harvesting, utilizing high retention silvicultural systems instead of clearcutting, and designing effective fire management practices as well as strategies for preventing other disturbances.

From the administrative point of view, forest managers should be allowed “freedom to fail” within an allowable extent when implementing their forest practices, because considering variable environmental factors it is difficult to achieve goals in a first trial (Locatelli et al., 2008). Although there are models that can be used to predict the impacts of climate change, results are often limited to a general trend rather than detailed impacts (FAO, 2010a). Therefore, forest management strategies need to be robust and diverse considering such uncertainty and the increasing disturbances under climate change. Community-based management can help to ensure the responsiveness of management plans, while monitoring can help to secure the activeness (FAO, 2010a).

For example in Nepal and many Indian states, local communities have sole control over forest management and the power in policy-making process. Community-based management has resulted in more efficient feedback from the direct stakeholders in the community and has also led to improved policies benefited from field experience (Poffenberger, 2000).

5. Policies

The International Union of Forest Research Organizations (IUFRO) along with Geoff Roberts from GC Roberts Forestry Consultancy produced the report: *Policies and instruments for the adaptation of forests and the forest sector to impacts of climate change as indicated in United Nations Framework Convention on Climate Change National Reports* (2008). It provides a deep insight into global forest policies through the analysis of 95 national communications (NCs) and national adaptation programmes of action (NAPAs) provided for United Nations Framework Convention on Climate Change. The following content will be based upon this report with a major focus on the tropical domain of the region, as more than half of the countries in the region fall into this domain and they are faced with the most difficult challenges.

The tropical domain includes the following countries: Australia, Fiji, Cambodia, India, Nepal, Solomon Islands, Tonga, Bangladesh, Bhutan, Samoa, Tuvalu, Vanuatu, Maldives, Pakistan, Sri Lanka, Brunei, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Viet Nam, American Samoa, Cook Islands, Federated States of Micronesia, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Northern Mariana Is-lands, Palau, Papua New Guinea. Forests located in developing countries in the tropical domain are especially vulnerable due to existing deforestation and anthropogenic degradation, which seems to be accelerated by climate changes. Throughout the domain, national programmes focusing on afforestation and community based forest management are widely promoted. However, a common obstacle to implement many of the projects is a lack of financial support.

Countries in the tropical domain are highly dependent on forests and thus have greater difficulty adapting to climate change. Normally, the adaptation options for the tropical domain emphasize the releasing of human caused stresses on forests by utilizing regulatory, economic and informational instruments.

5.1 Forestry Policies Related to Climate Change

Community based forest management to promote afforestation and forest resources conservation is utilized by many countries in the domain, including Bhutan, Cambodia, Sa-moa, Tuvalu, Vanuatu, Fiji and Nepal. In an attempt to adapt to increasing fire events caused by warming climate, Bhutan and Samoa have developed community based fire prevention projects, which include education and equipping villages. Bhutan and Cambodia have also developed community based afforestation programmes that help to increase the resilience of ecosystems to flood events caused by heavy rainfall and glacial melt (Roberts, 2008).

The restoration and preservation of mangroves are included in the community based programmes of many nations including Bangladesh, Cambodia, Samoa, Tuvalu and Vanuatu. In Tuvalu's national adaptation programmes of action (NAPA), the Tuvalu government prioritized the establishment of a forest belt along coastal areas to defend against storm surges and cyclones in its community based project. India and Vanuatu have also reported mangrove afforestation plans along the coastal areas to prevent against storms and cyclones.

The tropical domain is frequently disturbed by severe weather events including floods, droughts, cyclones and storms. As a result, many programmes and initiatives aimed at alleviating the influence of these disturbances. For example, Bangladesh has constructed cyclone and flood shelters, coastal embankments against ocean surges and has improved drainage systems. Bhutan and Samoa also adopted the introduction of fast growing tree species which will be more resistant to natural disturbances, such as insect, disease and fire. Tree species with short rotations are able to improve the resilience of forests to climate change (NC, India).

The promotion of SFM, afforestation and reforestation was reported in National Forest Programmes, Forest Law or equivalents of Bangladesh, Vanuatu, India, Fiji and

Nepal. In Fiji, they use National legislation (National Code of Logging Practice) coupled with a Forest Stewardship Council (FSC) certification as a way to promote SFM. Samoa, India and Nepal have reported the use of formal protection areas and SFM for forest conservation as an option to adapt to climate change.

Establishing reservation areas is also applied in policies of some countries as an adaptation strategy. Forests are used for the preservation of communities and ecosystem benefits such as watersheds. Countries that reported doing so include Bangladesh, Bhutan, Cambodia, Samoa and Fiji. India reported that connecting reserves, including protected areas, wildlife reserves and forest reserves, is a way to eliminate fragmentation and hence to reduce the vulnerability of forests to climate change. Additionally, Nepal and Solomon Islands are promoting different ways of utilizing forest resources, such as the use of non-timber resources and non-wood fuels.

There has been an increasing recognition of the importance of information exchange and capacity building among the countries in the domain. Bangladesh and Vanuatu have reported the use of capacity development by information disseminating, such as training and research. In Bangladesh, Tonga and India, there are numerous projects aimed at providing communities with climate change information, including the predicted impacts and possible adaptation options. Samoa also values the importance of monitoring current vulnerabilities and predicting future impacts.

FAO's report *Forest and climate change in the Asia-Pacific region* (2010a) has produced a comprehensive list of national adaptation programmes and forest policies for most countries in the region. There are detailed descriptions of the policies as well as national institutions that deal with the climate change issue. Table 4 (see below) is a summary of the number of policies and institutions that are related to forests and climate change for some countries in the region. This can indicate, to some degree, the importance of climate change issue that each country attaches to. The table ranks the country according to the amount of policies. As the table indicates, China, India and Nepal are the three countries with the maximum number of forest policies in the region, which is 12, while Afghanistan and Papua New Guinea have the least amount which is 2.

China also has the most institutions while 10 countries have no institutions deal with the issue.

Table 2. Number of relevant policies and institutions in the Asian-Pacific region (Source: FAO, 2010a)

Country	Key policies relevant to climate change and forests	Institutions
China	12	8
India	12	0
Nepal	12	0
Indonesia	10	6
Philippines	10	0
Cambodia	8	5
Myanmar	8	1
Sri Lanka	8	0
Japan	7	3
Lao PDR	7	7
Malaysia	7	0
New Zealand	7	0
Pakistan	7	4
Bangladesh	6	0
Bhutan	6	2
Mongolia	6	0
Singapore	6	1
Australia	5	2
Maldives	5	0
Republic of Korea	5	13
Thailand	5	2
Timor-Leste	5	4

Country	Key policies relevant to climate change and forests	Institutions
Brunei	4	1
Taiwan	4	0
Democratic People's Republic of Korea	3	0
Viet Nam	3	4
Afghanistan	2	4
Papua New Guinea	2	1

5.2 Challenges and Strategies

Financial instruments for climate change adaptation have very limited use within the tropical domain (Roberts, 2008). Lack of financial and human resources have significantly inhibited the creation and implementation of policies, projects and programmes on adaptation to climate change in the tropical domain. Countries that have reported this problem include Bangladesh, Bhutan, Cambodia, Samoa, Tuvalu, India and Nepal (Roberts, 2008). Many countries (Bangladesh, Bhutan, Cambodia, Samoa and Tuvalu) have identified the costs for projects in their NAPAs; however, the source of the funding remains unclear.

There is a need for improvement of existing projection models to reduce uncertainty and increase the success of adaptation (NC, Nepal). Such improvement is of great significance particularly to tropical developing countries where limited financial resources only allow effective adaptation.

One other necessary strategy to decrease the vulnerability of forests to climate change, which was reported by India, is institutional strengthening of departments and bodies related with forest management, research and protection, including the strengthening of legislation enforcement . This will be achieved by increasing human and technological resources in the field. Similarly, Cambodia and Fiji also suggested the strengthening of community based and participatory forest management.

Reforestation is required throughout the region. Nepal reported that the afforestation efforts were insufficient to compensate the level of deforestation. It is therefore suggested that forest harvesting level should be set according to the regeneration capacity of the forest and should also have the flexibility to cope with possible changes in forest condition and health.

It is necessary to have knowledge about the current condition of forests in order to determine appropriate adaptation strategies (NC, Solomon Islands). Monitoring programmes and further researches into climate change predictions are an important action for adaptation. India suggested incorporating climate change into short to long-term planning in forest management plans and forest policies. The NAPA projects of Bangladesh and Vanuatu also mentioned capacity building and information disseminating in order to increase the public awareness of climate change issues and solutions.

Bangladesh recommended introducing experts and professionals for community based training on afforestation and tree growing, although funding is an issue for such projects in developing nations. This kind of method is also expected to create employment opportunities for communities and hence enhance the socio-economic stability (NAPA, Bangladesh).

Some countries are seeking a way to balance forestry sector with the need of agriculture and society. Cambodia, Samoa, Vanuatu, Nepal and Tonga have promoted agroforestry as a way to mitigate climate change impacts on the environmental and social sector by increasing fuel wood supply and improving agriculture.

6. Conclusions

The Asia-Pacific region is the most populous in the world and is also rich in biodiversity, spreading over boreal, arid and semi-arid, tropical and temperate climatic zones. Its forest resources are considered of great importance in the light of climate change. Forests in the region account for 18 percent of the total forest area on earth, and are regarded as having a great potential to adapt to climate change considering its species' richness and abundance.

Climate change has shown many obvious signs in the region, including rising sea-level, increasing temperature, more frequent extreme events and changing precipitation patterns. These changes could pose significant impacts on forest resources. In tropical area, forests that are already under anthropogenic stresses will become more vulnerable and many flora and fauna species will face higher risk of extinction. Sub-tropical forests are expected to migrate into the temperate domain, while temperate forests will expand poleward into the boreal domain with the magnitude of 50-500 km over the next century. The productivity of forest sector will decline due to more frequent disturbance events. The spread of invasive species is predicted to become more common.

If managed properly, forests in this region have a great potential for successful adaptation. This requires improvements to existing forest regulations and policies, as well as enhanced management strategies. Indigenous people involvement is strongly encouraged as the benefits are already demonstrated in many case studies. Adaptive forest management need to be robust, flexible and diverse in order to cope with the changing climate. Many countries in the region are confronted with a lack of financial supports and human resources. These constraints significantly limit countries' ability for further improvement and policy changes. Also many developing countries in the region are mainly focusing on economic development and urban expansion, and hence have little incentive for enhanced forest management.

This essay provides only a brief introduction to the climate change issue in the Asia-Pacific region, rather than a deep insight. Some important topics like mitigation strategies, adaptation and mitigation synergies and information instruments to help adaptation are not covered in this essay. International collaboration is also a critical strategy in terms of successful adaptation strategies.

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