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The role forest plantations play in carbon cycle and climate change

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Abstract

Forests play major roles in a human being's daily life. For example, the trees in a forest can be made into raw materials for buildings, transportation, and communication, as well as food, cooking fuel and farmland (FAO 2012b). Over time, the connection between humans and forests has changed in social and economic aspects. As a result, many developing countries planted forests for those reasons. This paper is a review of the how forest plantations can help to mitigate climate change. First it will review the background of forest plantations, and then followed by a comparison of forest plantation versus natural forest stands. Based on this, the advantages and disadvantages of forest plantation will be discussed. Afterwards, a brief description of carbon cycle and climate change will follow, leading into a discussion of the two case studies of tropical (*Eucalyptus*) and temperate (*Pinus radiata*) forest plantations. Each case study will discuss the end-use product of wood for carbon storage, economy, climate change policy and sustainable management options. Finally, a recommendation will be suggested on sustainable forest plantation management to climate change or increase carbon sinks in plantations. Forest Plantations are neither good nor bad, it is based on what is used for and how is it managed. Carbon cycle can be used to mitigate climate change but is heavily based the life-cycle of wood products. For example, Brazil used timber as firewood which has a short life-cycle compare to countries like New Zealand used in constructions. Overall, ongoing sustainable management practices and consideration of carbon cycle will help combat climate change in forest plantation for the future.

Key words

Forest Plantations, Climate Change, Carbon Cycle, Temperate Forests, Tropical Forests, REDD, Kyoto Protocol,

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1 Introduction

1.1 Background

Forest plantations are established by human intervention through planting and seedling of trees (FAO 2012a). It contains semi-natural forests with native tree species and exotic species from planted forests (FAO 2012a). Forest plantations cover about 264 million hectares of land and are 7 percent of the forests globally (FAO 2012a). This amount has been estimated to be expanding at about 5 million hectares per year (FAO 2012a). The major expansion of planted forests is located in countries in Asia-Pacific region (Figure 1). Other plantations are in regions such as Europe, Latin America, Oceania and the United States. The growth of forest plantations has declined due to the increase of land price, lack of financial incentives, and strict environmental restrictions (FAO 2013a).

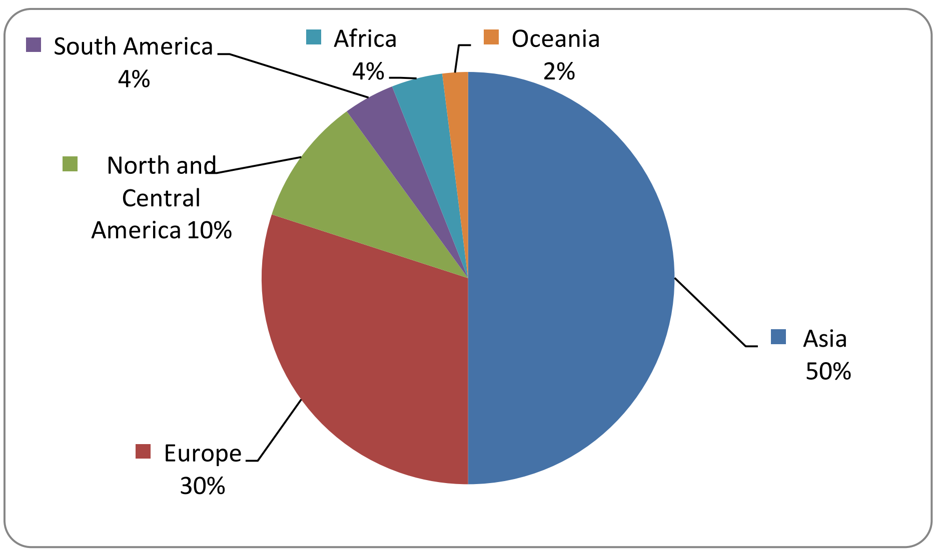

Figure 1: Distribution of planted forests by continent ***(Source: FAO 2012a)***

Forests today, have varied over millions of years and have been extremely affected by the swings of climate change, which had increased greenhouse emission on Earth. As a result, Carbon dioxide (CO_2) concentration in the atmosphere has increased from a pre-industrial value of 270 parts per million (ppm) to 390 ppm, and is expected to increase double in the next century as carbon emission rise from fossil-fuel burning and deforestation (Zeng 2013). Rising CO_2 concentrations will likely increase tree growth rates and carbon sequestration through carbon fertilization. This is a short term effect that is expected to diminish when other factors become limiting, e.g., soil nutrients (Millard et al. 2007).

Tropical forests are being extinct rapidly; however, over half of the biodiversity on Earth is in the Tropical region (Del Cid-Liccardi et al. 2012). Trees have long lives as they store carbon in wood and soil. For example, a pound of wood is estimated to have half a pound of carbon (CADPFFP 2010). Consequently small fluctuations in tree growth or in forest area can play an important role in the carbon cycle and act as a major driver of climate change (Hicke 2012).

1.2 Climate changes on natural forests

Forest tree plantations are in a dynamic environment. Climate-based species distribution models (SDMs) can create scenarios to forecast the redistributions of tree species over the next 100 years (Malcolm et al. 2002). The model does not require any biological capacity of populations, or recognition of local adaptation (Aitken et al. 2008). Common garden experiments are highly used to find traits from population of genetic variation to adapt to climate change (Savolainen et al. 2007). Research by Malcolm et al. (2002) generated 14 scenarios from global circulation models (GCMs) and global species distribution models (SDMs) which estimated a migration rate of 1000 meters per year.

SDMs are one of the best approaches available for forecasting the outcome of climate change, extinction rate and significant geographic locations for tree species management (Aitken et al. 2008). Global study done by Thomas et al. (2004) predicted a 3 percent to 38 percent extinction of plant species on a regional scale by 2050 under climate change scenarios. Climate change can affect interspecific competition dynamics between tree species and some may experience substantial adaptational lag (Aitken et al. 2008). If the growth rate slows down, interspecific competition for light will also be reduced (Aitken et al. 2008). Therefore, growth rates are reduced for all species due to maladaptation to climate and competition may be reduced (Aitken et al. 2008). Another assumption from the climate model is that extreme weather pattern happens more frequently and enhances variations in climate (IPCC 2007). Even if the climate remains steady, “increasing magnitude of variations is likely to decrease the main fitness of populations due an increase in the average deviation from the optimum” (Aitken et al. 2008).

2 Description

2.1 Forest plantations vs. Natural Stands

Natural forests are defined as forests “regenerated naturally without human intervention” (Carle and Holmgren 2003), whereas forest plantations are defined as forest stands established by planting and/ or seeding in the process of afforestation or reforestation (Carle et al. 2002). The difference between natural and planted forests can be difficult to identify. For example, in temperate and boreal forests, native species are grown on long rotations with mixed-species and mixed age stands which make them hard to distinguish planted forests from natural forests (FAO 2012a). The distinction is more obvious with plantations in other forest types that are monocultures with even age classes, short rotations and intensive management (FAO 2012a). Many planted forest can be found in tropical and subtropical regions. Intensively managed plantations will be significantly important for expansion of wood products and could possibly replace more natural forests as shown on Table 1 (Paquette and Messier 2010). Actions should be taken by industries, governments and other stakeholder groups to evade any adverse effect that may be related with the establishment of planted forests (FAO 2012a).

Table 1: Examples of forest and plantation timber yield *(Source: Paquette and Messier 2010)*

Type/species	*Average timber yield ($m^3 ha^{-1} yr^{-1}$)*	*Main countries or regions*
Intensive monoculture plantations *(mostly exotic to the country)*		
Eucalyptus	5–40	Brazil, South Africa, China, India, Chile, Spain
Tropical acacias	15–30	Indonesia, China, Malaysia, Vietnam, South Africa
Pines	8–35	Venezuela, Argentina, Chile, New Zealand, Swaziland, USA, Australia
Hybrid poplars	9–37	China, India, USA, Canada, Europe
Exotic larches	5–8	Canada, Europe
Extensive plantations *(mostly reforestation with native species)*		
Conventional conifer restocking following clearcut	2–6	Canada
Intensive forestry	2–7	Scandinavia
Natural forests		
Extensively managed	1–3	North America, Europe, China, Russia
Certified forests	< 1	Worldwide

The ecological effects of tree plantations differ between environments and forest types (Stickler et al. 2009). Planting single tree species generally sustain fewer native plant and animal species compared to the native ecosystems that they replace (Barlow et al. 2007). Forest plantations usually involve heavy machinery for site preparation and management, as well as the application of fertilizers and pesticides, which enhances the risk of soil degradation and chemical contamination (Schwarzenbach et al. 2006). Conversely, there are also some ecological of planted forests (Stickler et al. 2009). Landscapes that are degraded prior to tree plantations are dependent on seed dispersal agents, preparing the regeneration of plant and animal community (Parrotta et al. 1997). Planted trees on degraded lands can re-establish the high evapotranspiration rates, likely to decrease and regulate stream flows, and decrease the risk of flooding (Stickler et al. 2009). There are ecological risks for growth of forest plantations for the sake of carbon sequestrations, particularly when they remove long-lived native species that stores more carbon stores on short-lived species (Stickler et al. 2009). It is important to note the growth of planted forests are increasing in the future, thus plantations should not be used to replace native habitats or for water resources security but to balance assessments of forest plantations to make a distinction of both benefits and ecological costs (Stickler et al. 2009).

Any land use changes or cultivation will alter the soil organic matter (Schroth et al. 2002). In a review done by Davis and Condron (2002) on a series of paired sites in New Zealand, they found conversion of grasslands to forest plantations decreased organic carbon in the upper layers of the soil by 9.5 percent in the short term; however, organic carbon accumulated on the forest floor which exceed the loss of carbon in long term. Another study by Smith et al. (2002) found that conversion of native Amazonian forest to plantation forests has also change the amount of carbon in the soil. Trees can change the soil properties by interactions between plants and various microbes, root exudation, root turnover, and inputs of organic on forest floor (Chen et al. 2004). The conversion of Amazonian forest to planted forest in Brazil indicates that soil carbon content is dependent on tree species (Smith et al. 2002). Chen et al. (2004) concluded that soil carbon is significantly higher in natural forests than plantations; although the amount, chemical composition and transformation rate of organic material are different between the two forests. Soil pH is lower in natural forests than planted forests therefore a higher content of soil carbon can be observed under the natural forests   (Chen et al. 2004). Over all, changing the land use from natural forest to plantations will lead to a reduction in “soil total carbon, labile carbon pools and the bioavailability of soil carbon and to the change in chemical composition of soil carbon" (Chen et al. 2004).

2.1.1 Advantages of Forest Plantations

Forest plantations should not replace natural forests, but rather balance those of natural and semi-natural forests nor should they negatively impact the livelihood of forest dependent and First Nations (FAO 2013a). Planted forests can allow for the protection of be well conservation forests by producing timber on a short rotation (FAO 2013a). Planted trees are essential resources for roundwood, fibre, firewood and non-wood forest products which can be produced in a sustainable manner (FAO 2012a). Forest plantations can also maintain social and cultural values especially as natural forests have been reduced by deforestation in the tropics and subtropics or forest conservation purposes in the temperate forests (FAO 2012a). Tree plantings can assist sustainable forest management and are part of international processes with organizations like the United Nations Convention to Combat Desertification, the Convention on Biological Diversity, the United Nations Framework on Climate Change (including Kyoto Protocol) and the United Nations Forum on Forests (FAO 2012a).

2.1.2 Disadvantages of Forest Plantations

One of the disadvantages of some forest plantations is the use of exotic species for timber productivity, which can become invasive if it can out-compete native species for resources such as nutrients, light, space, water or food. Invasive species can also be introduced by machinery, road-building material, animals and birds, and wind dispersal (FAO 2013b). One of the efficient ways to reduce the spread of weeds is to monitor plantations regularly and respond rapidly when they do occur (FAO 2013b). Good management practices always provide prevention to reduce the risk first. Another drawback for planted forests is the possible spread of insects and pathogens. Many forest plantations are grown as monoculture, which may be susceptible to endemic attack (FAO 2013b). Planting mix-species forests will help reduce the risks while mix trees species will be more vulnerable to different pest and disease.

The use of nutrient and water is another issue for monoculture. Forest plantations can require lots of water, yet it depends on the species and on the environment; this can increase inter-specific competition in the ecosystem. Nutrient sustainability is also sites specific, and poor sites may require more fertilizers like nitrogen and phosphorus to enhance the site. Nonetheless, whole tree harvesting should be avoided on some sited especially sites with low phosphorus because it can degrade the soil reserves and that might threaten sustainability if the rate of weathering is low (FAO 2013b). Restriction on fertilizers may apply to forest plantations because of the declining supplies, increasing prices due to large energy consumption for production and generate a large environmental footprint (FAO 2013b).

2.2 Climate Change

2.2.1 Kyoto Protocol

Climate change first emerged as a major environmental issue in the mid-1980 (Bodansky 2010). The Kyoto Protocol was created by the United Nations Framework Convention on Climate Change (UNFCCC) to establish measurable emission reduction targets for developed countries and set up a market based mechanisms including carbon trading for accomplishing those targets (Bodansky 2010). The Kyoto Protocol includes forest carbon as sinks but not in deforestation because carbon stocks can decease during that period (Bodansky 2010). The Kyoto Protocol determines emission reduction targets for the principal developed nations. For the period 2008-2012, annual emissions should correspond to an average total reduction of 5.2 percent of 1990 emissions. There are individual reduction targets in each party (Karsently et al. 2003). To be consistent, an actual reduction necessity of 10 percent from current emissions are needed, while 30 percent from estimated emissions in 2010 (Karsently et al. 2003).

Carbon fluxes is a result from land-use, "land-use change and forestry (LUCF) are to be accounted for in the greenhouse gas emissions inventory of developed countries" (Karsently et al. 2003). Accumulated growing stock in plantations can improve the burden of commitments which are: CO_2 removals by forestry and other sinks in land use that can be deducted from emissions in other sectors (Karsently et al. 2003). The first commitment of the Kyoto Protocol had ended in 2012, many countries had withdrawn from the protocol, however; the European Union has again taken the initiative to achieve new binding targets for 2020 (Cirman et al. 2009). By 2020, the EU wants to reduce emissions by 20% compared to 1990 (Cirman et al. 2009).

The Kyoto Protocol offered three mechanisms to reduce the cost of emission targets through emission trading, the clean development mechanism (CDM) and joint implementation) (Karsently et al. 2003). Developing countries have rejected any obligation to take on quantified objectives for future emission levels and have claimed they are acting responsibly in the present situation. Equitable solutions need to be developed by taking into account population levels and development needs as future goals.

(Karsently et al. 2003).

2.2.2 REDD

REDD stands for 'Reduce Emissions from Deforestation and forest degradation in Developing countries'; it is a payment for sustainable forest management (Paquette and Messier 2010). Land-use change such as deforestation creates approximately 20% to 30% of global greenhouse gas (GHG) emissions (Kremen et al. 2000) approximately 17% of global GHG emissions are estimated yield from clear cutting and degradation of tropical forests (IPCC 2007). Carbon is released to the atmosphere through land use change as trees are harvested, thus the emerging REDD+ program has the possibility to increase the carbon density of the world's enduring tropical forest by reducing forest clearing and deforestation (Stickler et al. 2009).

Forest plantation should provide a positive feedback for every REED programs and it won't reduce the effect by activities that are being displaced (Paquette and Messier 2010). The problem here is that dead trees are worth more than live ones under current international and local market because economic values are worth more than ecological values (Paquette and Messier 2010). To solve these problems before REDD or other payments for the ecosystem services of forests to make a significant difference the international community need to design a market that address the following: "establishing a clear, stable policy environment; clarifying tenure for forest land and forest carbon; ensuing that payments are linked to the services provided; ensuing sustainable sources of funding; and addressing governance issues where institutions are weak" (FAO 2012b).

2.3 Carbon Cycle

Carbon dioxide (CO2) is the primary greenhouse gas in the atmosphere (Karsently et al. 2003). The cycle between different carbon pools is caused by its concentration in the atmosphere (Karsently et al. 2003). The forest carbon cycle is presented in the following diagram (Figure 2). In a given forest, the carbon cycle (photosynthesis, plant respiration and the degradation of organic matter) is influenced by climatic conditions and atmospheric concentrations of carbon dioxide (Karsently et al. 2003). The distinction between natural and human factors of plant growth is thus difficult to make (Karsently et al. 2003). The increase of CO2 in the atmosphere has a "fertilizing effect" on photosynthesis plant growth (Karsently et al. 2003). The explanation shows regional tendencies of enhanced forest growth and causes an increase in carbon absorption by plants and creates a significant increase in the potential size of the forests carbon pool assuming trees remain healthy in the face of other biotic and abiotic stresses (Karsently et al. 2003).

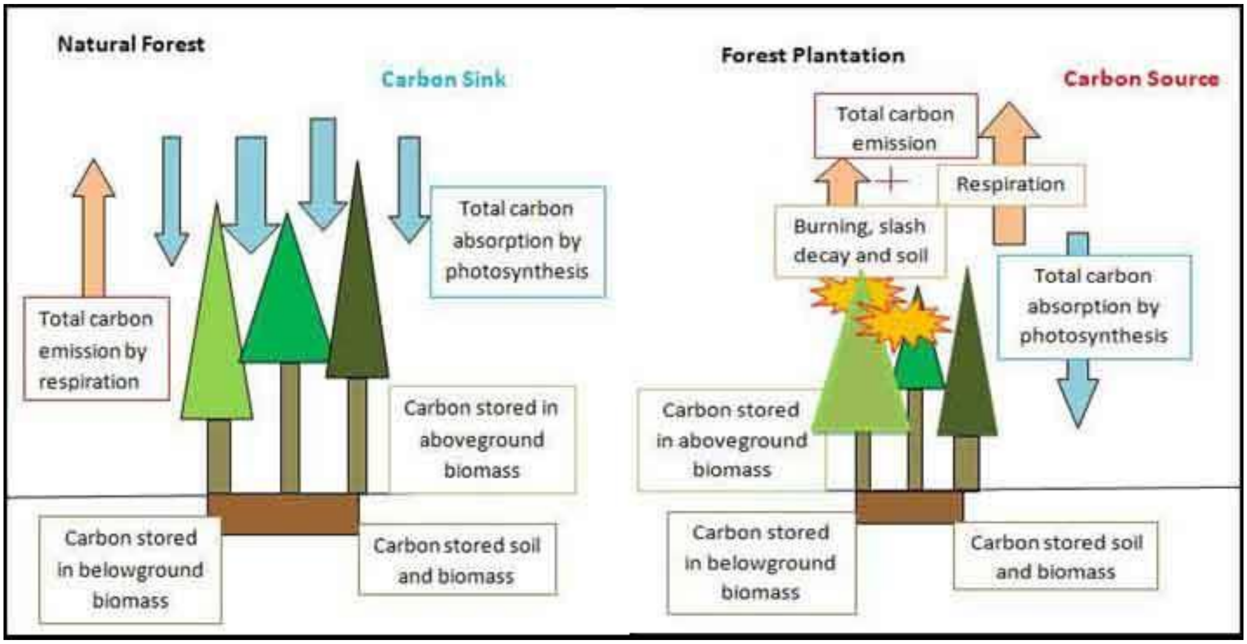

Figure 2: Carbon Flux on natural forests and forest plantations

People had a long history of documenting carbon cycle for mitigate climate change; it created a "positive feedback among carbon cycle and climate warming that increase the airborne fraction of anthropogenic CO_2 emission and amplified warming" (Bonan 2008). As atmospheric CO_2 increases, the reaction of plants will be photosynthetic enhancement if other resources are not limiting, and will create a negative feedback instead (Bonan 2008). Carbon storage of CO_2 fertilization can be limited by climate change (Bonan 2008). In boreal forests, climate change can increase NPP as a negative feedback when temperature rises whereas tropical forests will decrease NPP as positive feedback where moisture in soil decreases (Bonan 2008). Ecological feedbacks to climate change adjust the biogeophysical performance of forests and also provide climate response (Bonan 2008). Changes in stomatal conductance, leaf area index and species composition can be 'indirect' carbon cycle responses to accommodate changes in the ecosystem (Bonan 2008). Evapotranspiration can be reduced as a result of increased CO_2 concentration through decreasing the necessary stomatal conductance (Bonan 2008). Extensive vegetation covers with decline surface albedo can also decrease evpotranspiration (Bonan 2008).

Carbon sequestration in soil is also an important component of the carbon cycle. Goetz et al. (2010) emphasize the need for accurate assessment of the carbon in the biomass, soil and time horizon are measured critically for correct determination of the optimal forest and carbon management regime. In contrast, the durability time of the carbon sequestration in wood products does not impact the optimal management regime (Goetz et al. 2010). After disturbance or harvesting, a forest will become a net source of carbon over the first year, followed by a small peak of carbon sequestration as net ecosystem production (NEP) and gross primary production (GPP) increases in mature stands (Magnani et al. 2007). In older stands, NEP usually decreases as a result of the age-related reduction growth (Goetz et al. 2010) but old forests can store more carbon.

3 Case studies

3.1 Temperate Forest Plantations in New Zealand

Before 1800s, 85 percent of New Zealand was forested land (FAO 2004). As the European arrived in the mid-1800s, forested area decrease to 53 percent, and more than half of the land is used for cultivation (FAO 2004). As a result, forest plantations were established in the late nineteenth century during the Great Depression and were funded by the government as a sourced of employment (FAO 2013b). New Zealand's climate varies from subtropical in the north to the more temperate in the south (FAO 2013b). Precipitation is extremely variable and distributed evenly throughout the year; however summer drought is common and causes water stress and other abiotic factors including snow and wind damage (FAO 2013b). Many tree plantations were planted on lands degraded by grazing or other agricultural uses, or areas unsuitable for agriculture due to nutrient deficiencies (FAO 2013b).

New Zealand has a long history of planted forest management due to history of wood supply deficits and outstanding growing environments for fast growing non-native species, particularly *Eucalyptus* spp. and radiata pine (*Pinus radiata)* (FAO 2013b). Tree plantations are also used for soil erosion control. Approximately 90 percent of tree plantations are privately owned and on formerly degraded agricultural land; in contrast, almost all native forests are legally protected in New Zealand. Radiata pine harvesting has double from 25 million m^3 from 2011 since the last 20 years, with timber produced used for log export, saw logs, pulp logs, reconstituted, posts and poles, and energy. An estimated 48 percent of radiata pine is exported to Asia in log or chip or processed products and 45 percent used in New Zealand. Approximately half of the radiata pine plantations in New Zealand were certified by Forest Stewardship Council (FSC) (FAO 2013b).

New Zealand has two generalized management practices for radiata pine, with one requiring minimum tending schedules and the other following more intensive schedules (FAO 2013b). Managing on steep or low quality sites uses the lower-intensity management approaches without high pruning, while intensive schedules are used on more accessible and fertile sites (FAO 2013b). Radiata pine's rotation age is about 25-32 years old with a mean annual increment of 17-20 m3/ha/yr (FAO 2013b). Commercial plantations of radiata pine have also been heavily used to stabilize coastal sand dunes in New Zealand (FAO 2013b).

Over 60-70 years, New Zealand has lost about 0.12 percent of land to fire annually; this had fallen about 0.03 percent in the last two decades due improved management practices (Pearce et al. 2008).The fire protection cost is estimated NZ$12 ($8 US) per ha annually (FAO 2013b). Fire is not a huge threat compare to wind disturbance but is higher than pests and disease (McFarlane et al. 2002). As climate change occurs around the world, New Zealand is estimated to have temperature increase, less frost days, longer growing season, more hot days and changing precipitation patterns (Watt et al. 2008). Depending on how much atmospheric CO_2 concentration increase, the growth rate of radiata pine in New Zealand is expected to increase (Mason 2009). As precipitation decreases, red band needle blight (*Dothistroma septosporum)* infection will likely increase and will also increase the risk of wind damage in New Zealand; however, snow damage may decrease overall (FAO 2013b). The establishment of emission trading and carbon market in New Zealand may increase from planting radiata pines and lead to longer rotations with higher stocking (Manley and Maclaren 2012). Plantations of radiata pine can have a positive feedback on soil stability (O'Loughlin 2005) as the root gives mechanical reinforcement to the soil, and evapotranspiration dries the soil, allowing to absorb more rain before it becomes saturated (FAO 2013b). Fertilizer treatment does not have a huge impact on radiata pine plantations and could be eliminated to decrease the chance of stream contamination (May et al. 2009).

Forest plantations have been funded by the government since the mid-1980s through indirect and direct incentives. However, the government has little impact on the forestry sector now in New Zealand (FAO 2013b). Compared to agriculture, forest plantation profits are still lower than agriculture (FAO 2013b). A study done by Rivas Palma (2005) has found stakeholders view forest plantation as having high ecological value for water regulation and erosion control but as having fewer values for biodiversity, climate regulation and nutrient cycling. On the social services aspect, employment is essential to people, along with living standards and recreation (Rivas Palma 2005). New Zealand has approximately 3.5 people per 1000 ha of radiata pine plantation as direct employment and 9.6 people per 1000 ha for harvesting in 2009 (FAO 2011). The overall number has decreased one-third between 2002 and 2009 due to economic conditions, a downturn in plantation extent, and increased automation (FAO 2013b).

Natural forest and native ecosystem generally have richer biodiversity than planted forests (FAO 2013b). Planted forests also contribute to biodiversity on degraded lands or cultivated land but do not substitute for natural ecosystems. Plantation forests can also be beneficial for recreational activities like in New Zealand when they are near cities. One option to mitigate climate change is to afforestation for carbon storage (FAO 2013b). Captured carbon in planted tree are consider part of national carbon inventories; and forest plantations established after 1990 could counted for additional carbon storage under the Kyoto Protocol (FAO 2013b). Recently New Zealand has adapted to an emission trading system which could increase the number of trees planted; however, this has not increased the number of new tree planting due to ambiguity and the shifting of carbon credits (Adams and Turner 2012). Wood products that store carbon will have a positive feedback on climate change (Manley and Maclaren 2010); however, it depends on how the wood is used. Soil carbon also play a role in carbon storage and it can be either positive or negative (FAO 2013b).

The number of pest and diseases in radiata pine plantation has increased in the past decade due to introductions of exotic species from outside the country from human travel and trade (FAO 2013b). Some experts have argued that this is a hazard to native species, whereas others have suggested that there are advantages in using exotic species because they release from their natural enemies (Lombardero et al. 2008). There are three issues regards to this: first is the effects on species introduction on the forest plantations, second is if forest plantations grow faster than native species as a result from release of pests and lastly if pest population build up on forest plantations and negatively affect native forests (Lombardero et al. 2008). In addition, other advantage with forest plantations is they make them less risky to managed compare to natural stands (FAO 2013b). As a result, both natural and plantation forests ecosystem will change over time which makes it more difficult to forecast long-term outcomes.

The genotypes of radiata pine planted have also changed through tree breeding in ways that might reduce their resource allocation to defence mechanisms (Kay 2008). The life cycle and virulence of pathogens and pests might vary and add additional stresses to the ecosystem due to global climate change (Alfaro et al. 2010). Base on the climate models, Watt et al. (2011) suggested the possible impact of climate change on red band needle blight and pine pitch canker may decrease the fitness of radiata pine in some area of the world . Alfaro et al. (2010) recommended large-scale management efforts may be required to mitigate the impacts of climate change on pests and diseases in forests.

Plantations of radiata pine have higher growth rates than natural stands in part due to intensive silviculture practices that increase productivity (FAO 2013b). A previous study in New Zealand has shown with historical plot data that the mean annual increment (MAI) increased 25 percent in plot established in 1980s compared to the 1930s (Palmer et al. 2010). There are methods to avoid mortality such as using fertilizer and thinning to increase production of merchantable wood in a rotation (FAO 2013b). Many tree breeders and forest managers have altered the natural selection process in order to meet industrial needs; for example, selecting seed that increasing stand productivity and stem straightness of trees provided to growers (FAO 2013b). Good silviculture treatments can also improve growth of the stands and the magnitude of gain depending on limiting factors (FAO 2013b).

3.2 Tropical forest plantations in the Amazon

Tropical forests usually have higher rate of evapotranspiration, lower surface air temperature, and higher rainfall than lands used for grazing. (Bonan 2008). Many studies have been conducted on the Amazon, where lands were converted from forests to grazing areas, creating a warmer and drier climate (Bonan 2008). As vegetation is removed, surface temperatures increase from lower albedo and that offset strong evaporative cooling; many other countries like Africa and Asia has similar results (Bonan 2008). Tropical forests contain of 25 percent of the carbon in forested ecosystems, generate approximately 33 percent of terrestrial net primary production (NPP), and can sequester large amount of carbon annually (Bonan 2008). One study concluded that "tropical forests are carbon neutral or carbon sinks, which implies offsetting of carbon uptake by undisturbed tropical ecosystem" (Bonan 2008). Temperate forests hold about 20 percent of plant biomass globally and approximately 10 percent of carbon in the terrestrial ecosystem (Bonan 2008). One of the greatest challenges facing humans is to resolve social issues such as human need for food, fiber, and fuel with environmental protection (Stickler et al. 2009). The benefits of forest carbon are to reduce GHG emissions and to conserve the tropical forests (Bala et al. 2007). Carbon storage and sequestration in tropical plantation forests may be an important forest ecosystem services with the potential for a broad, global-scale market in carbon credits (Stickler et al. 2009).

Less than one percent of wood in tropical forests is certified (Siry et al. 2005). The operation of basic forest management methods for the tropical forests should be reducing carbon loss and increase carbon uptake and storage (Putz et al. 2008). The best management practices to reduce carbon loss and maximize carbon uptake and storage are dependent on species, site dynamics and silvicultural methods (De Cid-Liccardi et al. 2012). The rate of the carbon uptake will decrease with time after growing space is fully occupied, however, it takes a long period before net uptake reaches zero, and large wood debris can store carbon for a long period of time (De Cid-Liccardi et al. 2012).

Afforestation or reforestation will increase carbon sequestration as part of the nature and with many co-benefits (Zeng 2013). Unfortunately, the capacity of carbon is limited by land use and carbon sink slowly as forests matures (Zeng 2013). "The greatest potential for bio-sequestration may not come from one-time carbon storage in live biomass, but from using plants as a 'carbon scrubber' "(Zeng 2013). For instance, regardless of the aesthetic appeal of older forests, carbon sequestration will diminish as forests age (Zeng 2013). Another option to manage a forest is to separate 'carbon removal' using photosynthesis from the 'carbon storage' (Zeng 2013). If certain percentage of the large biospheric productivity decrease, then an endless stream of carbon sink can be produce (Zeng 2013). At present, wood produced for timber, paper and other wood products consumes 0.9 gigaton of carbon per year globally ($GtCy^{-1}$), containing both manufacturing roundwood and firewood (FAO 2005). Fuelwoods are widely used for cooking and heating in developing countries and most of the carbon is released back to the atmosphere as CO_2 (Zeng 2013). Some carbon will also be release through the processing and conversion of manufacturing roundwood (Ingerson 2009), and carbon fixed for paper and wood-based panel products have fairly short lives (Winjum et al. 1998). This type of carbon pool analysis is referred as 'life-cycle analysis. Approximately 20 to 30 percent wood harvesting is sequestered in long-lived products or landfills (Ingerson, 2009). Long-term storage pool of carbon varied in different forest ecosystem, it is likely to vary between deciduous and evergreen growth strategies, age, management regime, and climate (Luyssaert et al. 2007).

4 Recommendations

To enhance our understanding of how forests adapt to rapid climate change, and the role that forests play in carbon sequestration, additional research is needed. For instance, studies of genomics of local adaptation can identify better genotypes for new climates (Neale and Salvolainen 2004). Aitken et al. (2008) have suggested that doing short-term seedling common-garden experiments with genetic materials to clarify the physiological foundation of local adaptation, and understand species acceptance of severe climatic events, genetic responses to CO_2 and drought better.

Mature forests can play as positive a role in the carbon cycle as younger forest due to the emissions that occur after harvesting from decomposition of harvest residues and roots, and it will take up to decades for wood products or young plantations to balance the carbon being release (Bellassen and Luyssaert 2014). On the other hand, if mature forests become carbon sources due to declines in tree health, then harvesting and replanting might be the best option to combat climate change (Bellassen and Luyssaert 2014). There are three safe strategies or principles to reduce carbon emissions. First, scientists should be clearer on their assumptions because there are uncertainties (Bellassen and Luyssaert 2014). Second, encourage the carbon-efficient consumption of wood, for example in constructions, wood can replace steel or cement for walls where it can be stored for decades or even centuries, and then can be recovered and reused, recycled or burned (Bellassen and Luyssaert 2014). Third, prioritize the amount of wood produced and the carbon stocked stored in the forest in forest management objectives (Bellassen and Luyssaert 2014). Without conflict of forest uses such as replacing mortality or low-productivity stands, protecting young seedlings from harvesting, create more resilient stands by mixing tree species, and planting nitrogen-fixing species in afforestation to minimize fertilization, will all help mitigate climate change no matter how the global carbon sink evolves (Bellassen and Luyssaert 2014).

Conserving existing stands can reduce emission from deforestation; the forest biomass and soil in mature stands can store large amounts of carbon (Karsently et al. 2003). Enhanced forest harvesting techniques can also reduce emissions. Forest operation can damage the soil and stand if carried out inappropriately. (Karsently et al. 2003). Timber production also generates a large amount of waste wood, which can either be reduced through greater utilization, or used as a biofuel (Karsently et al. 2003). Wood can replace fossil fuels and energy-intensive materials such as concrete or steel for frames and beams which can cut down on emission because wood is renewable (Karsently et al. 2003). If 1m3of lumber is used in building as a substitute for other materials, it wills reduces net emission by 0.3 tons of CO2 compared to concrete and 1.2 tons of CO2 compared to steel (Karsently et al. 2003). Having good management practices may sequester more carbon both in above and below ground biomass, as well as enhancing forests productivity (Karsently et al. 2003).

5 Conclusions

Both tropical and temperate natural forests were used for grazing and farming or over harvesting of the land in the past which had negatively impact the ecosystem. Afforestation and reforestation projects were used to enhance the whole ecosystem and can also increase carbon sequestration in plantations to mitigate climate change. The role of plantation forests had met the demand for wood products and fibre materials. However, the future of forest plantation development is remaining unclear because of the swing of climate change. The main threats to managed forest plantations are climate change and outbreak of diseases or pests that limit species that grown for productivity (FAO 2013b). Climate change can possibly change some existing marginal forest plantations in the long term (FAO 2013b). On the other hand preserving a broad genetic base in breeding program will help to mitigate threats caused by climate change, and monitoring will possibly ensure the feasibility of forest plantations in most areas (FAO 2013). Many researchers have point to genetic diversity as a key buffer against non-indigenous species (FAO 2013b). As climate change policy like Kyoto Protocol had ended, many other countries had abandoned the Protocol and set their own targets to reduce emissions for the future. Economic, social and environmental values of forests can be conserved and enhance by sustainable forest management to benefit of present and future generations (FAO 2013b).

Planted forests are neither good nor bad; rather it's a choice that we make and how we used them. Forests generally involve many aspects of social and ecosystem services, such as biodiversity conservation, employment, water issues, and carbon sequestration but also include food security and cultural aspects from First Nations (FAO 2013b). Forest plantations can capture substantial amounts of carbon but management practices need to reduce the danger of nutrient depletion.). One of way to manage that is use photosynthesis to isolated 'carbon removal' from 'carbon storage' (Zeng 2013). Higher stocking levels and longer rotations in the future will enhance the wood quality and carbon sequestration in plantations (FAO 2013b). Overall forest plantations will likely improved environmental and economic performance for many countries.

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