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Climate Change Mitigation Options in the Forestry Sector of Malaysia

(Pilihan Mitigasi Perubahan Iklim di Sektor Perhutanan Malaysia)

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ABSTRACT

The Intergovernmental Panel on Climate Change (2013) reported that more than half of the observed increase in global average surface temperature was caused by the anthropogenic increase in Greenhouse gas (GHG) concentrations and other anthropogenic forcings together. Continued emissions of GHGs will cause further warming and changes in all components of the climate system. Thus, limiting climate change will require substantial and sustained reductions of GHG emissions. Deforestation and burning of fossil fuels are the major anthropogenic source of carbon emission in the developing countries including Malaysia. Climate change mitigation options in the forestry sector could play an important role in reducing emissions and improving carbon sequestration. Therefore, this article attempts to identify the potential climate change mitigation options and their characteristics in the forestry sector of Malaysia. The major mitigation options include forest protection and conservation, afforestation, reforestation, sustainable forest management, enhanced natural regeneration, urban forestry, agroforestry, short rotation tropical tree plantations, and use of wood based bio-energy. This article suggests for a comprehensive research on the economic analysis of mitigation options which would be useful to address Malaysia's emission reduction target in a cost-effective way.

Keywords: Climate change; mitigation options; carbon sequestration; forest sector; Malaysia

ABSTRAK

Panel Antara Kerajaan Mengenai Perubahan Iklim (2013) melaporkan bahawa lebih daripada separuh daripada kenaikan suhu permukaan purata global yang disebabkan oleh kenaikan antropogenik dalam konsentrasi gas Rumah Kaca (GHG) dan juga antropogenik yang lain bersama-sama. Pelepasan gas GHG yang berterusan akan menyebabkan pemanasan dan perubahan selanjutnya dalam semua komponen sistem iklim. Oleh itu, menghadkan perubahan iklim memerlukan pengurangan GHG yang besar dan berkekalan. Penebangan hutan dan pembakaran bahan api fosil adalah sumber antropogenik utama pelepasan karbon di negara-negara membangun termasuk Malaysia. Opsyen mitigasi perubahan iklim dalam sektor perhutanan boleh memainkan peranan penting dalam mengurangkan pelepasan dan meningkatkan penambakan karbon. Oleh itu, artikel ini cuba mengenal pasti kemungkinan pengurangan perubahan iklim yang berpotensi dan ciri-cirinya dalam sektor perhutanan Malaysia. Pilihan mitigasi utama termasuk perlindungan hutan dan pemuliharaan, penanaman semula hutan, penanaman semula hutan, pengurusan hutan lestari, peningkatan semula semula jadi, perhutanan bandar, agroforestri, ladang pokok tropika berputar pendek, dan penggunaan bio-tenaga berasaskan kayu. Artikel ini mencadangkan untuk penyelidikan yang komprehensif tentang analisis ekonomi pilihan mitigasi yang berguna untuk menangani sasaran pengurangan pelepasan Malaysia dengan cara yang kos efektif.

Kata kunci: Perubahan iklim; pilihan pengurangan; penyerapan karbon; sektor hutan; Malaysia

INTRODUCTION

Global warming and climate change have become a critical issue due to the increasing accumulation of greenhouse gases (GHG) dominated by carbon dioxide (CO_2) (Tangang et al. 2012). Forest ecosystems can play a significant role to reduce CO_2 from the atmosphere via photosynthesis and store carbon in tree biomass and in the soil. Tropical forests cover 80% of the earth's total forests. These forests have a huge potential to sequester atmospheric carbon dioxide along with protecting forested lands, reducing deforestation, and balancing climatic condition with different mitigation options (Brown et al. 1996). The world's forests are estimated to be a net source of 1.8 Gt C (carbon) per year due to deforestation and forest degradation, of which 20% can be recognized to tropical deforestation (IPCC 2000).

According to the FAO (2010), around 20,456,000 ha of Malaysia is forested which is 62.3% of the total land area. Among them, 18.7% (3,820,000 ha) is classified as primary forest, which is rich in biodiversity and carbon-dense form of forest. Malaysia lost an average of 96,000 ha or 0.43% per year of forest cover in between 1990 and 2010. Overall, Malaysia lost 8.6% of its forest cover which is almost 1,920,000 ha (Table 1). Forests in Malaysia stored around 3,212 million metric tons of carbon in tree biomass.

TABLE 1. Trends of forest cover in Malaysia (FRA 2015)

Year	1990	2000	2005	2010
Natural forest cover (1000 ha)	20,420	19,932	19,317	18,649
Planted forest cover (1000 ha)	1,956	1,659	1,573	1,807
Total forest cover (1000 ha)	22,376	21,591	20,890	20,456

Forests in Malaysia are playing various beneficial roles such as the protection from natural calamities like tsunami (Rashid 2016), protection of watershed and soil, biodiversity conservation, wildlife habitat protection, satisfying aesthetic and recreational needs, controlling the climatic condition, and reducing emission through atmospheric carbon sequestration, which keep a significant role in reducing the negative impacts of climate change (BUR 2015). According to the Malaysia's Second National Communication (NC2), GHG emission in Malaysia was 290,230 Gg CO_2eq in 2011 and removal (Sink) was 262,946 Gg CO_2eq (Table 2). The net total emission after subtracting the sink was 27,284 Gg CO_2eq. It has shown by the some of the studies in Malaysia that a significant amount of carbon is sequestered by existing forested areas. In addition, huge amounts of carbon are also sequestered through plantation and reforestation programs including the managed land used programs in the suburban, urban and city areas.

TABLE 2. GHG inventory in Malaysia for 2011 (BUR 2015)

Sector	Emissions (Mt CO_2eq)	Sink (Mt CO_2eq)
Energy	218.914	
Industrial processes	18.166	
Agriculture	15.775	
LULUCF	2.490	262.946
Waste	34.885	
Total	290.230	262.946
Net total (after subtracting sink)	27.284	

Concern about climate change due to the increasing atmospheric accumulation of GHGs have urged the search for methods of carbon sequestration in plant biomass. In recent years, much more attention has focused to encourage tropical forestry for sequestering carbon because of its cost effectiveness, high potential rates of carbon uptake, and associated environmental and social benefits. Sohngen (2009) considered forestry as the most cost-effective measures to reduce international climate problems. He added that there is a huge scope to increase this carbon potency to mitigate the damages in future due to climate change. Sohngen (2009) reported that approximately 1 trillion tons of CO_2 has stored by the terrestrial ecosystem alone in the biomass of living trees and plants. He added that global forestry sector could store almost 6.7 billion tons CO_2 of annual net emission reductions at a carbon price of $30 per ton by 2030.

Both aboveground and belowground carbon density in the forests of Malaysia was decreased from the year 2000 to 2010 (Table 3) while a little bit of carbon biomass has recovered in 2015. It seems that climate change mitigation potential in Malaysia is reducing due to deforestation and forest degradation. Hence, it is urgent need to increase the rate of forest carbon sequestration for climate change mitigation in Malaysia.

TABLE 3. Trend of forest carbon sequestration in Malaysia (FRA 2015)

	Carbon (Million metric tons)				
Year	1990	2000	2005	2010	2015
Above-ground biomass	4,842	6,105	5,767	4,355	4,782
Carbon in aboveground biomass	2,276	2,869	2,711	2,047	2,248
Below-ground biomass	1,162	1,465	1,384	1,045	1,148
Carbon in belowground biomass	546	689	651	491	539
Carbon in litter	47	45	44	46	47

In Malaysia, deforestation is prevailing. Malaysia had a severe rate of deforestation between 1990 and 2010. Deforestation rate in Malaysia is accelerating faster than any other tropical country. Reducing forest cover in Malaysia occurs due to urbanization, agricultural and forest fires, forest conversion for oil-palm plantations and other forms of agriculture. Jomo et al. (2004) reported that Sarawak lost almost 50% of its forest cover in between the year 1971 and 1989. In 2012, Sarawak has lost 90% of its primary forest. Jomo et al. (2004) added that forest cover in Peninsular Malaysia disappeared to near half of its original amount in between 1971 and 1989. Osman et al. (2012) reported that because of the expansion of oil palm plantations, more than 1.85 million ha of forests were lost in Sabah state (approximately 50% of Sabah's total forest cover) in between 1990 and 2008. FRA (2015) reported that Malaysia's annual deforestation rate increased almost 86 percent between the 1990-2000 period and 2000-2005 (Table 4). In total, Malaysia lost an average of 140,200 hectares (0.65 percent) of its forest cover per year since 2000.

Tropical deforestation is considered as the second largest source of anthropogenic GHGs emissions (IPCC 2007; Norhayati et al. 2014). Tropical deforestation occurs biodiversity loss, flooding, soil degradation and threats to the livelihoods and cultural reliability of forest dependent communities. Hence, deforestation is one of the major reasons for global climate change. Appropriate forestry activities contribute to reduce GHG emissions by avoiding deforestation, conserving more

TABLE 4. Deforestation rate in Malaysia (FRA 2015)

Time duration	Trends in total (net) forest cover Negative number represents deforestation		Trends in natural forest cover Negative number represents deforestation	
	Annual change rate (1000 ha)	Annual change rate (percent)	Annual change rate (1000 ha)	Annual change rate (percent)
1990-2000	-79	-0.36	-49	-0.2
2000-2005	-140	-0.66	-49	-0.24
2005-2010	-87	-0.42	-128	-0.64

forest land and improving forest management. With a huge amount of natural and plantation forests in Malaysia, it can play a great role in mitigating climate change impacts. In addition, Malaysia has extensive degraded forest lands and other waste lands to be reforested. Climate change mitigation is not possible unless the forests are protected from deforestation to reduce carbon dioxide from the atmosphere. This can only be done cost-effectively through forest carbon sequestration by various mitigation options. Understanding the mitigation potential of different forestry options is important for contributing to reduce the negative impacts of climate change. Thus, this article attempts to conduct a review of literature of the potential mitigation options toward achieving national emission reduction targets through the forestry sector of Malaysia.

MITIGATION OPTIONS IN THE FORESTRY SECTOR

The mitigation options in forestry could be classified into three broad categories (Sathaye & Ravindranath 1997). First is conservation of forest carbon by controlling deforestation, protecting forests, changing harvesting regimes, and controlling other anthropogenic disturbances, such as fires and pest outbreaks. Second is enhancing and expanding carbon sink by increasing forest area, soil carbon density and storage of carbon in durable wood products. Third is by substituting the use of fossil fuel-based energy generation with biomass-based energy or the use of biomass products in place of energy-intensive ones.

Forest resources are being degraded and depleted worldwide as a consequence of increasing demand for forest products, agricultural expansion, and environmental mismanagement. If appropriate plans are formulated, and adequate investments are made, the forestry sector of Malaysia is expected to offset GHG as part of its carbon efficiency measures. Different forestry options are targeted for sequestering carbon to mitigate climate change. The following sections discuss the potential mitigation options to increase the carbon pool in the forestry sector of Malaysia.

FOREST PROTECTION AND CONSERVATION

Forest protection and conservation increase the climate change mitigation potential by sequestering carbon and conserving forest ecosystems as well. Natural, old forests typically store more carbon than managed forests because they have a greater proportion of older trees with high carbon density (Kurz et al. 1998). Protecting forests from exploitation avoid emissions and conserve carbon stock in the form of biomass. This option protects the carbon and other GHG in both the vegetation and soil. Since protected areas cover nearly 20% of tropical forests, appropriate treatment of protected areas is a critical element to mitigate climate change (Scharlemann et al. 2010). The number of protected areas in Malaysia includes Forest reserve, Virgin Jungle reserve, Protection forest reserve, Wildlife reserve, national and state parks, Communal and Protected forest, wildlife sanctuaries etc. has shown below (Table 5).

TABLE 5. Categories of protected areas and their number in Malaysia (UNEP-WCMC 2017)

Categories of protected areas	Forest reserve	Virgin jungle reserve	Protection forest reserve	Wildlife reserve	National park	Communal forest	Protected forest	Mangrove forest	Wildlife sanctuary	State park	Commercial forest reserve
Number of areas	345	123	42	33	29	28	23	17	12	3	2

There is a huge scope in Malaysia to establish more protected areas and the improvement of existing ones for the conservation and protection of forest and biodiversity that will help ultimately to mitigate climate change. According to FRA (2015), total land area of protected forests in Malaysia is only 1.45 million ha (Table 6) where a huge amount of forest land can be transformed into protected areas. So, there is a wide scope to mitigate climate change by declaring more forest lands as protected areas in Malaysia.

TABLE 6. Protected land area in Malaysia (FRA 2015)

National 2010 Categories	Area (1000 hectares)							
	1990	2000	2005	2006	2007	2010	2011	2012
(a) Permanent reserved forest (PRF)								
- Peninsular Malaysia	4,750	4,800	4,800	4,726	4,696	4,920	4,912	4,894
- Sabah	3,350	3,600	3,600	3,600	3,605	3,607	3,607	3,609
- Sarawak	4,500	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Total PRF	12,600	14,400	14,400	14,326	14,301	14,526	14,519	14,503
(b) State land forest	6,820	4,640	4,141	3,529	3,416	4,718	4,630	4,656
(c) National parks, wildlife & bird sanctuary	1,120	1,120	1,120	1,946	1,946	1,859	1,859	1,859
Total forested area (a+b+c)	20,540	20,160	19,661	19,801	19,663	21,104	21,009	21,019

AFFORESTATION

Afforestation refers to convert non-forest land to forest. Afforestation may play a significant role in solving some ecological and environmental problems in the world. In addition to timber production, afforestation provide many other forest ecosystem functions such as carbon sequestration, soil protection, clean water production and biodiversity conservation (Keles 2017). According to FAO (1997), afforestation is the establishment of a tree crop on an area from which it has always or very long been absent". Afforestation was proposed as an effective method of carbon sequestration in the Kyoto Protocol due to the carbon stored in forest biomass. It results in carbon sequestration in tree biomass, dead wood, litter and soil. The carbon benefits slowly accumulate over time as trees grow. In fact, one of the main strategies to mitigate climate change is based on this carbon sink (Lal et al. 2015).

In general, the conversion of non-forested land to forest land is usually associated with benefits in carbon sequestration as forests accumulate carbon in the biomass. Furthermore, afforestation aiming at the production of renewable energy derived from woody biomass will contribute to the reduction of GHG emissions through substituting fossil fuels. Nevertheless, the carbon balance of afforestation may vary considerably according to a wide range of factors, which have to be considered. Research activities focusing on afforestation in Malaysia were carried out since the 1960's (Mitchell 1957). Total area of afforested land is increasing every year in Malaysia (Table 7) even in all of the major states (Table 8). Increasing carbon sink by plantation program on the non-forested lands in the rural, urban and sub-urban areas in Malaysia can be a potential mitigation option for climate change.

TABLE 7. Trend of forest plantation in Malaysia (FRA 2015)

	Forest area (1000 ha)							
	1990	2000	2005	2006	2007	2010	2011	2012
Area of Forest plantation	120	228	258	399	468	603	701	743

TABLE 8. Area of forest plantation in Malaysia (FRA 2015)

	Forest plantation area (1000 ha)				
	2006	2007	2010	2011	2012
Peninsular Malaysia	83	105	109	186	198
Sabah	133	181	217	226	239
Sarawak	182	182	277	290	306

REFORESTATION

Massive reforestation programs have been implemented around the world to restore deforested and degraded forest land for mitigating climate change. Reforestation is the process of restoring forest areas and woodlands which once existed but were deforested, degraded or destroyed in the past. Reforested forest can provide both ecosystem services and resource benefits as well as recreate the potential to become a major carbon sink. Enhancing carbon sink by reforestation could be a tool to mitigate global climate change. Reforestation can be implemented in different types of forests including monoculture forest plantations to highly diverse forests.

Reforestation is a priority issue in the climate change policy agenda in both developed and developing countries. This issue is particular relevant to developing countries, due to their faster rates of deforestation (Allan & Lanly 1991). It is therefore seen as an interesting option for countries seeking ways of fulfilling their obligations to the Kyoto protocol of the Climate Convention (UNFCCC). Reforestation in developing tropical countries is particularly attractive, due to high tree growth rates and low costs compared to similar measures at higher latitudes (Brown et al. 1996). Reforestation has also been proposed as a means of offsetting high rates of deforestation in tropical countries like Malaysia.

The deforestation rate in Malaysia has slowed down because Malaysia is actively involved in reforestation projects. FRA (2015) indicates that reforestation in Malaysia increased from an average of 989 ha per year in 1988-1992 to 6,839 ha per year in 1998-2002. In 2003-2007, Malaysia's reforestation rate increased to an average of 33,009 ha per year, an increase of nearly five times of that in 1998-2002. Within 2005-2010, it becomes 1,34,242 ha per year (Table 9). So, there is a huge scope to increase carbon sink by increasing

TABLE 9. Reforestation rate in Malaysia (FRA 2015)

	Annual forest establishment (hectares/year)				...of which of introduced species (hectares/year)			
Year	1990	2000	2005	2010	1990	2000	2005	2010
Reforestation rate	989	6,839	33,009	1,34,242	940	6,482	31,154	1,28,487

reforestation program in the deforested and degraded land which could be a potential mitigation option for climate change in Malaysia.

SUSTAINABLE FOREST MANAGEMENT

Sustainable Forest Management is the way of management in which growth exceeds timber harvest, now also encompasses economics, environmental and social qualities that contribute to the sustainability of forest dependent communities and ecosystems as well as the forest itself. Sustainable forest management criteria and indicators have become an important tool used for measuring the sustainability of forests (Tolunay & Akyol 2015). Forest management in Malaysia is based on the Selective Management System which involves the selection of a management regime to optimize not only the objectives of efficient and economic harvesting and sustained yield but, more importantly, to ensure that forest development is ecologically and environmentally sustainable. Malaysia practices sustainable forest management on both production and protection of forests to ensure sustainability. To achieve Sustainable Forest Management, Malaysia has committed to maintain at least 50% of the land area under forest cover (Woon & Norini 2002).

Though about 1.8 million ha of forest land added under sustainable forest management in Malaysia from 1990 to 2000 (Table 10), there is no increment of the total forest land under the consideration of sustainable forest management within the period 2000 to 2010. Sustainable Forest Management is impossible to achieve if a country does not have a management system. In this regard, the use of more systematic approach in managing the forests in Peninsular Malaysia began in 1901 when the first forest officer was appointed (Ismail 1996). Since then, forest management practices in Peninsular Malaysia had been subjected to constant review and refinement so as to ensure their suitability in achieving forest renewal and sustained yield. Malaysia is fully aware of the need to manage the forest effectively from single use of sustained supply of timber to multiple-use of forestry including maintaining of the environmental stability. Malaysia continues to strongly support international efforts to promote and ensure sustainability in forest management which can be an effective option to increase carbon sequestration as a potential to mitigate climate change.

TABLE 10. Trend of forest area under sustainable forest management in Malaysia (FRA 2015)

	Forest area (1000 hectares)			
	1990	2000	2005	2010
Forest area under sustainable forest management	12,600	14,400	14,400	14,301

URBAN FORESTRY

Urban forestry covers the woodlands/forests, groups of trees (trees in parks, garden, university area), and individual trees (streets and derelict corners) located in the urban and sub-urban areas (FAO 2016). According to Ward and Johnson (2007), urban forest is a diversity and combination of woody and other vegetation that cover the urban area. Urban forests play a crucial role in mitigating global warming and climate change by sequestering excessive atmospheric CO_2 emitted from transportation, industry and house hold activities in the urban and city area. Urban forestry improves the quality of life for the urban people and enhance the environmental footprint of a city. Urban forests help to filter the polluted air (Nowak et al. 2013), sequester atmospheric CO_2 in Malaysia (Kanniah 2016), manage storm water to reduce flash floods (FAO 2016), enhance wildlife biodiversity (Karuppannan et al. 2014), reduce urban heat (Zölch et al. 2016) and increase property values (Siriwardena et al. 2016). Due to the rising cities and demand for more lands, urban green areas in Malaysia have been undergoing destruction and degradation even though their numerous benefits (Kanniah et al. 2015). Some cities have initiated various efforts to increase their tree canopy cover. Akmar et al. (2011) reported that among the major cities in Klang Valley, Peninsular Malaysia, Putrajaya have the highest portion of greenspace (37%), while Subang Jaya has the lowest portion (7.3%) (Table 11).

Urban forests can reduce carbon emission up to 18 kg CO_2 $year^{-1}$ $tree^{-1}$ and which can compare with 3 to 5 forest trees of similar size and health (Ferrini & Fini 2011). More green spaces and plantation can be developed in Malaysia as new urban parks because urban forestry can greatly reduce the air temperature and increase relative humidity which could provide thermal comfort to the urban people. Urban forestry also reduces the usage of air conditions that helps to reduce GHGs emitted from them. To mitigate climate change, urban forestry can be a significant option to increase carbon sink by reducing pollution and air temperature in Malaysia.

TABLE 11. Greenspace status in Klang Valley, Peninsular Malaysia (Akmar et al. 2011)

Cities	Inhabitants	Area of greenspace (ha)	% of total city area	m^2 of greenspace per inhabitant
Kuala Lumpur	1,887,674	2,436	15.5	12.9
Putrajaya	50,000	4,931	37	986.2
Petaling Jaya	631,212	9,720	8	154.0
Subang Jaya	1,000,000	16,180	7.3	161.8
Shah Alam	584,340	29,030	12.9	496.8
Klang	1,004,194	5,730	16.1	57.1

WOOD BASED BIO-ENERGY

Bio-energy is a new trend which can be produced from forest biomass. Wood based bio-energy can reduce carbon emissions if the bio-energy replaces fossil fuels (Dymond 2012). In most forest industries, wood waste is left to decay. So, there is a significant potential resource for generating bioelectricity from the wood waste. This offers a mitigation option for reducing carbon emissions from biomass decay, and avoiding emissions from the fossil fuels that would have been used to generate electricity otherwise. Sathre and O'Conner (2008) reported that, bio-energy use can be a substitution of fossil fuel in Malaysia. Using wood based bio-energy can reduce the dependency of fossil fuel which can increase the climate change mitigation potential in Malaysia where about 76% of lands are covered by dense tropical forests and agricultural fields (Mekhilef et al. 2011). Malaysia has a great potential of renewable energy due to the production of a large volume of wood mass. Estimated amounts of wood residues generated by the forestry industries in Malaysia are presented in Table 12.

TABLE 12. Quantity of residues generated by the forestry industries in Malaysia (Mekhilef et al. 2011)

Sources of wood residue	Quantity (Million m^3)
Logging residues	5.1
Primary manufacturing residues	2.92
Plywood residues	0.91
Secondary residues	0.9
Total	9.83

ENHANCED NATURAL REGENERATION

When forests re-grow, the carbon stored in tree biomass also increase over the time. This re-growth can occur without planting trees rather than a natural process of regeneration. This is a cost-effective method of restoring forests and to reach climate change mitigation goals through carbon sequestration. Enhancing natural regeneration is faster and cheaper than any other option in terms of increasing forested area and the carbon storage as well. Natural regeneration in a secondary forests over time could sequester most of the carbon dioxide which was emitted through the deforestation on that area. Successful regeneration in lowland dipterocarp forest is a common feature in Malaysia. Good quality stands regenerated quickly in Sarawak forests which were harvested with proper management and thinning operations. However, the amount of naturally regenerated forest areas in Malaysia is decreasing by years (Table 13) due to the disturbance on natural forest. The rate of natural regeneration can be improved by increasing the amount of reserve or protected forest land in Malaysia that could be a low-cost option for mitigating climate change.

TABLE 13. Trend of naturally regenerated forest land area in Malaysia (FRA 2015)

	Forest area (1000 hectares)			
	1990	2000	2005	2010
Naturally regenerated forest	16,600	16,112	15,497	14,829

AGROFORESTRY

Over the past four decades, agroforestry has become recognized as an integrated approach to sustainable land use because of its production and environmental benefits (Nair et al. 2009). Since agroforestry is mostly practiced by subsistence farmers in developing countries, there is an attractive opportunity for those farmers to benefit economically from agroforestry. Thus, a lot of expectation has been raised about the role of agroforestry as a strategy for climate change mitigation through enhancing the carbon sink that removes atmospheric carbon dioxide. Agroforestry is becoming an attractive option for climate change mitigation because of its different dimensions of carbon emission cycle. Firstly, it sequesters carbon in vegetation and soils. Secondly, it reduces the need for slash and burn or shifting cultivation for agriculture, which influences deforestation. Thirdly, the wood products produced under agroforestry systems serve as substitute for similar wood products harvested from the natural forest unsustainably. Fourthly, agroforestry practices provide financial supports to the farmers, it reduces the incentive for further extraction from the natural forest for the purpose of livelihood (Makundi & Sathaye 2004).

Agroforestry practices in Malaysia involve agrisilviculture, silvopastural and agrosilvopastural combination with forest species, agricultural crops, livestock and aquaculture. Agroforestry development in Malaysia tended towards commercial agroforestry. Commercial agroforestry was first launched in Malaysia in the 1920s, where rubber trees were planted in coffee plantations (NajibLotfy & Mahmud 1999).

Among the agroforestry systems that have been developed in Malaysia are direct inter-row integration, block planting, perimeter or border planting, and hedge planting system. There is a wide scope of agroforestry in Malaysia that could play a crucial role for climate change mitigation.

SHORT ROTATION TROPICAL TREE PLANTATION

Due to the potentiality of very high growth rates, afforestation programs are encouraged in the tropical regions. There also seems to be a vast area of land available and suitable for plantation program in the tropical countries like Malaysia. Tree planting could improve an area including soil improvement, biodiversity conservation and carbon storage (Schroeder 1992). However, there is a lot of tropical well-known and commonly grown plantation species which are relatively short-lived. Most of them have rotations of less than 20 years. These short rotation tropical tree species can be planted in both of the urban and rural areas as an option to store carbon. The main benefit of planting short rotation tree species is that people can get financial outcome within a short time and carbon remain locked in the furniture made from the harvested short rotation tree species. These short rotation species can be planted again in the same place after harvesting. So, the place always remain covered with trees which constantly absorb atmospheric carbon dioxide. The short rotation tropical tree plantation can provide economic benefits with satisfying the timber demand of a country. Hence, plantation of short rotation tropical trees can be an option to mitigate climate change in Malaysia.

REDD+ INITIATIVES

The Intergovernmental Panel on Climate Change (IPCC) reported that deforestation causes 17% of Global GHG emissions, which is also the main source of GHG emissions in developing countries (Cerbu et al. 2011). Therefore, in the effort to mitigate climate change from deforestation and forest degradation, the United Nations Framework Convention on Climate Change (UNFCCC) has considered a new initiative, led by forest-rich developing countries, that calls for economic incentives to help facilitate reductions in emissions from deforestation in developing countries. Reducing emissions from deforestation and forest degradation-plus (REDD+) stands for efforts to reduce emissions from deforestation and forest degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries. REDD+ has seen as a cost-effective mitigation strategy to reduce GHG emissions in the tropical countries (Stern, 2007). Though REDD+ in Malaysia is still at the infant stage but there is a huge potential of REDD+ activities in Malaysia includes enhancement of carbon stocks, avoiding deforestation, forest protection and conservation, wildlife conservation and improving degraded forests through sustainable forest management.

DISCUSSION AND CONCLUDING REMARKS

Terrestrial ecosystems play a significant role in the global carbon cycle. Forests capture and store atmospheric carbon dioxide in vegetation, soils and tree biomass. Forests account for almost half of the global terrestrial carbon pool, and if vegetation is considered alone (excluding soils) they hold about 75% of the living carbon (FAO 2006). Tropical forests store on average about 50% more carbon per unit area than forests outside the tropics. Thus, tropical forests could play a particularly important role to mitigate global climate change.

Malaysia's forest lands have the potential to sequester carbon, which can contribute to a reduction in GHG emission. Different mitigation options are available in the forestry sector of Malaysia. These forestry options can be considered for reconciling carbon storage by reducing deforestation and forest degradation to mitigate climate change but no single option is sufficient by itself. The mitigation options discussed in this paper are diverse, and some options could be implemented together. Effective implementation of the potential and cost-effective options is needed to mitigate climate change through maximum carbon sequestration with minimum cost. Effective implementation of the potential mitigation options depends on policies and co-operation at all scales, and can be enhanced through integrated responses that link mitigation with other environmental objectives.

The most cost-effective mitigation options in forestry are afforestation, sustainable forest management and reducing deforestation, with large differences in their relative importance across regions (IPCC 2014). A few portion of the total natural forest land in Malaysia has declared as protected and reserve forest. Climate change mitigation potential could be increased by declaring rest of the natural forest land as conserved or protected forest. There is enough plain land, deforested and degraded land in Malaysia to implement afforestation, reforestation and urban forestry enormously. The range of potential mitigation options in the forest sector is quite wide. This review shows that, the effective potential mitigation options in the forestry sector could be forest protection and conservation followed by afforestation, reforestation, sustainable forest management and urban forestry. Many countries and regions have tended to focus largely on one or two options in their implementation and policy measures. However, there are some barriers due to lack of information about the costs and benefits of different options and uncertainties about the feasibility of implementing various policy measures. A very few economic analysis of climate change mitigation options in the forestry sectors have focused on the estimation of the cost effectiveness (costs or net benefits per tC) of mitigation options. Boer (2001) showed that, the potential of each option to avoid emission or sequester C per ha varied considerably. The difference in mitigation potential depends mainly on the type of mitigation options, rate of biomass increment which depends on site conditions and management, and length of biomass accumulation or rotation age.

This article concludes with several findings. Firstly, there is a huge scope to mitigate climate change through the forestry sector of Malaysia. Secondly, there is enough land in Malaysia which can be declared as protected/conserved land or reserved forest to enhance carbon sink. Thirdly, afforestation and reforestation rate is increasing every year in Malaysia which is a hope to increase mitigation potential. Fourthly, Though Malaysia is committed in implementing sustainable forest management there is no increment of the total forest land under the consideration of sustainable forest management with the recent years. Fifthly, urban forestry is getting popularity with increasing city areas in Malaysia. It will help to improve the climatic and environmental condition of urban areas. Sixthly, usage of wood based bio-energy has a huge chance to be a potential mitigation option in Malaysia. Finally, it can be concluded that, there is a huge gap between climate change mitigation options and the economics of climate change to make the mitigation process cost-effective. To fill up this research gap, it needs to conduct economic studies to test the feasibility of potential mitigation options in the forestry sector of Malaysia based on the following questions:

1. What are the roles of each mitigation options to mitigate climate change?
2. What are the characteristics of the potential mitigation options?
3. How much emissions reduction can be achieved through these mitigation options?
4. What is the cost effectiveness of each mitigation options?
5. What is the total cost of implementing these mitigation options?
6. Which mitigation options are economically viable?
7. What is the economic valuation of biomass carbon sequestrated by each mitigation options?

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