

PRELIMINARY ESTIMATION OF CARBON SEQUESTRATION POTENTIAL OF TIMBER TREE PLANTATIONS IN SELECTED RESEARCH STATIONS IN PENINSULAR MALAYSIA

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The REDD+ is an important tool not only for carbon sequestration potential in natural forests, but also to exploit the enhancement of carbon stocks and sequestration potential in tropical timber tree plantations. To date baseline information on the role of timber species, age group, site variations and environmental factors which control sequestration potential is scarce in Peninsular Malaysia. Thus, this study was to determine the aboveground biomass sequestration potential between 2021 to 2023 on selected forest plantations sites and to estimate the potential price of carbon credits for forest plantations. The mean annual increments of the plantations were determined and the aboveground and belowground biomass change were computed for the study period according to stock change method between two timelines. Aboveground biomass and belowground biomass (roots) changes stand at 0.08-1.60 Mg C ha⁻¹ yr⁻¹ and 0.02-0.43 Mg C ha⁻¹ yr⁻¹, respectively. The total aboveground biomass changes for the timber plantations ranged from 0.10 to 6.72 Mg C ha⁻¹ yr⁻¹ where a mean value of 2.69 CO₂e ha⁻¹ yr⁻¹ reported. It is projected that carbon credits that can be sold would range between USD 0.20- 3.68 CO₂e ton ha⁻¹ yr⁻¹ based on a value of USD 4.7 CO₂e ton. The results of this research suggest that tree species, age, management practices, and environmental factors control the carbon accumulation rates and changes of tree plantations.

Keywords: planted forest, carbon accumulation, biomass, stock change method, tropics

INTRODUCTION

Global forests sequester close to 662 Pg C in plant biomass and soils (FAO 2020) and play an important role in mitigating the ever increasing atmospheric CO₂ concentration. It was reported that 7% of the world's forest is planted forest (Pugh et al. 2019). Planted forests hold significant potential for carbon sequestration both in biomass and soils, serving as valuable tools in combating climate change (Yu et al. 2020, Zhang et al. 2020). These forests were intentionally established by planting trees, primarily for timber production, ecological restoration, or for other purposes such as for aesthetic values. The capacity of planted forests to sequester carbon varies depending on factors such as tree species, soil type, age, management practices, natural disasters such as fire and pest and diseases as well as environmental conditions. Additionally, the carbon stored in harvested wood products can provide long-term carbon storage if properly managed via the life cycle assessment tool. Overall, maximising the carbon sequestration

potential of planted forests requires sustainable management practices, including appropriate species selection, silvicultural techniques and protection against disturbances such as pests, diseases and wildfires.

REDD+, which stands for Reducing Emissions from Deforestation and Forest Degradation, is an initiative under UNFCCC aimed at mitigating climate change by addressing deforestation and forest degradation in developing countries. The "+" in REDD+ signifies additional activities beyond just reducing emissions, including conservation, sustainable management of forests, and enhancement of forest carbon stocks (Grafton et al. 2021). REDD+ is to create financial incentives for developing countries to protect their forests from deforestation and forest degradation, thereby reducing greenhouse gas emissions and conserving biodiversity. These financial incentives can come from various sources, including international funds, or bilateral agreements. Additionally, mitigation

action from forest can also use the various carbon standards to produce carbon credits. In the local scene, Bursa Malaysia has initiated the Bursa Carbon Exchange (BCX) as a platform to trade carbon credits. Carbon credits derived from nature-based solutions and technologies that avoid, reduce or remove GHG emissions will be considered (Bursa Malaysia & MGTC 2023). Currently, the National Carbon Market Policy is in the pipeline to support the implementation of compliance and voluntary carbon markets (Ministry of Natural Resources, Environment and Sustainability 2024)

Nevertheless, some studies have found that the function of forests as sinks is reaching saturation. European forests are increasingly attaining maturity, with older age classes and lower per hectare growth which resonates with lesser CO₂ uptake (Nabuurs et al. 2013). As such, future mitigation potential may exploit afforestation, reforestation and restoration strategies as part of the REDD+ strategy. Planted forests can play a crucial role by contributing to the overall carbon sequestration efforts by providing opportunities for countries to enhance their carbon sinks and achieve emission reduction targets. Malaysia has set a target to achieve carbon neutrality by the year 2050 (Fan et al. 2023). This indeed requires a strategy to explore the role of planted forest in emission reductions and sink enhancements. In the long run, planted forests can serve as sites for sustainable forest management practices and contribute to local livelihoods and biodiversity conservation. Planted forests represent complementary approaches in addressing climate change, promoting sustainable forest management and aid in the decision making processes on forest management (Jeyanny et al. 2022).

Usually, a thorough understanding of the role of ecosystems in carbon cycles can be elucidated with accurate calculation of carbon sequestration (He et al. 2022) which is unavailable to date. A combination of managed planted forests with climate change mitigation strategies, is direly needed so that countries can maximise their potential to mitigate climate change, conserve biodiversity, and achieve sustainable development goals. In the South East Asian region, Cambodia has obtained payments for REDD+ and Malaysia has fulfilled all the

required criteria for REDD+ for natural forest conservation. Malaysia reported a value of 97, 470 million tCO₂ for the period between 2006- 2010 for the sustainable management of forest activities (Parotta et al. 2022). In 2020, Vietnam's Ministry of Agriculture and Rural Development (MARD) signed an agreement with the World Bank's Forest Carbon Partnership Facility (FCPF) for up to USD 51.5 million to cover Vietnam's efforts to reduce carbon emissions from deforestation and forest degradation between 2020 and 2025 (Pham et al. 2015, World Bank 2024). Indonesia was awarded its first payment by Norway and the Green Climate Fund (GCF) for having reduced emissions in 2017. Norway promised to pay USD 56 million and the GCF agreed to disburse approximately USD 103.8 million (Pham et al. 2015). The approvals of neighbouring countries will hopefully create the awareness on REDD+ initiatives at national scale in future by exploiting the role of planted forests.

Results from earlier research have indicated the capacity of planted forest to produce high levels of biomass that can be a significant contribution to carbon stocks. Jeyanny et al. (2012) showed that a 4 year old *Acacia mangium* can sequester 39.28 Mg C/ha in the planted forests of Ulu Sedeli, Johor. Ho et al. (2021) reported a value of 8- 23Mg C/ha for 7 year old *Hopea odorata* planted in different localities. However, these values despite report the carbon stocks did not evaluate the carbon sequestration potential of planted forests.

The current literature review on carbon sequestration potential of plantation forests is scanty especially in Peninsular Malaysia. Most forest plantations are situated in the East Malaysian region. A recent report showed that there is an increment of plantation forests from 0.071 million ha in 1990 to 0.582 million ha in 2014 (Raihan et al. 2021). In the latest statistics, forest plantation stands at 0.724 million ha in Malaysia (Timber Trade Portal 2024).

In order to gauge the capacity of planted forests in carbon dynamics, it is important to establish a baseline information on the potential of C sequestration in planted forest, which is ever increasing. Thus, several forestry research stations which has on-going efforts in research and development of suitable timber species were selected for this purpose.

Our main objective was to

- i. To determine the aboveground biomass sequestration potential present between 2021 to 2023 on selected forest plantations in FRIM research stations in Peninsular Malaysia
- ii. To estimate the potential price of carbon credits for forest plantations established in FRIM research stations in Peninsular Malaysia

MATERIAL AND METHODS

Study sites

The study site and the baseline information of the plantations are given in Table 1. The stands planted here had minimal silvicultural practices such as pruning and thinning, an act of removing biomass. This was so as to determine the survival ability of tree species at varying sites governed by environmental conditions. The trials were mainly to forecast the resilience of trees in harsh and limited conditions. The present study was focussed on the biomass measurements of trees selected for three consecutive years under the 12th Malaysian Plan project. The sites were chosen to represent the diverse environmental conditions of Peninsular Malaysia, namely Jeli and Setiu in the East Coast, Bukit Hari in the central region, Selandar and Segamat in the southern part of the Peninsular Malaysia. The stands possess varying differences of planting age and species and serve as a baseline information for forestry planters. Most of the sites were established on flat to undulating terrain to ease silvicultural activities. Soils were deep, well drained, stone free with low to moderate organic matter content. The sites were cleared using machineries before planting. Neither prescribed burning or soil movement were done prior to planting. During planting, trees from the selected species (Table 1) were chosen at 1 to 1.5 meters tall and planted into planting hole. Planting holes were filled with 100-150 g of CIRP, with 50-100 g of organic composts and the NPK 15:15:15 compound fertiliser applied twice a year every 6 months at the rate of 150- 200 g/tree. Additionally, the plot in Setiu received a dose of 10 kg of rice husk biochar in the planting hole during planting. No extreme pruning and thinning was carried out except for the *Antoshorea roxburghii* trees planted in Bukit Hari, Selangor in 2012. It underwent minimal thinning in 2021. The information on soil types, forest species, planting dates, spacing

grid, area planted and the climatic factors were shown in Table 1. Most of the soils fall under the Rengam and Tai Tak soil series (Typic Paleudult) except for coastal soils of BRIS (Beach Ridges Interspersed with Swales) which is Jambu soil series (Typic Tropohumid) in Setiu, Terengganu.

Meteorological data

Data on mean temperature and rainfall were collected for all sites from the period of 2020 – 2023 from freely available data source from the link given (<https://weatherandclimate.com/malaysia>). The trend shows that the monthly average air temperature for all the sites ranged between 24- 33°C (Table 1). Generally, the mean annual rainfall ranged between 2,173- 2,529 mm in most sites except for Setiu, Terengganu which recorded a value about 2,832 mm.

Mean annual DBH increments

The periodic annual DBH increment (P_{obs}) was calculated as:

$$P_{obs} = [(d_{t+k} - d_t) / k] \times t \quad (1)$$

where

P_{obs} = observed periodic annual diameter increment (cm year⁻¹)

d_{t+k} = DBH at the end of growth period (cm)

d_t = DBH at the beginning of growth period (cm)

k = length of growth period (days)

t = 365 days

The periodic annual DBH increment were computed between the year 2021 to year 2023 and expressed as an average of all annual increments over the growth period and tabulated in Table 2.

Above and belowground biomass estimation

Aboveground biomass were determined using allometric equations which were common in tropical forests, based on Chave et al. (2005). Equations are suitable for moist tropical forests, receiving 1500-4000 mm annual rainfall.

The equations used for aboveground biomass are as follows:

Table 1 Baseline information on site, species, climate of selected forestry research stations of Peninsular Malaysia

Location	GPS Coordinates	Soil type	Species	Planting date	Planting spacing	Mean annual rainfall (mm)	Mean temperature (°C)	Area planted (ha)
Segamat, Johor	N2° 35' 05.3" E102° 58' 17.9"	Rengam	<i>Antoshorea roxburghii</i>	2018	4 × 3	2,173	24-32	1.53
Segamat, Johor	N2° 35' 03.6" E102° 58' 16.1"	Rengam	<i>Antoshorea roxburghii</i>	2018	4 × 3	2,173	24-32	3.68
Selandar, Melaka	N2° 25.488' E102° 23.590'	Tai Tak	<i>Eucalyptus hybrid</i>	2013	4 × 4	2,409	26-31	0.50
Selandar, Melaka	N2° 25.443' E102° 23.574'	Tai Tak	<i>Endospermum diadenum</i>	2016	4 × 4	2,409	26-31	0.64
Bukit Hari, Selangor	N3° 13.236' E101° 36.547'	Rengam	<i>Antoshorea roxburghii</i>	2012	4 × 3	2,529	24-33	1.42
Bukit Hari, Selangor	N3° 13.273' E101° 36.437'	Rengam	<i>Eucalyptus pellita</i>	2011	4 × 3	2,529	24-33	0.20
Bukit Hari, Selangor	N3° 13.304' E101° 36.780'	Rengam	<i>Endospermum diadenum</i>	1998	4 × 3	2,529	24-33	2.20
Setiu, Terengganu	N5° 32.222' E102° 52.071'	Jambu	<i>Antoshorea roxburghii</i>	2017	4 × 3	2,832	25-31	0.25
Setiu, Terengganu	N5° 32.293' E102° 52.144'	Jambu	<i>Antoshorea roxburghii</i>	2018	4 × 4	2,832	25-31	1.70
Jeli, Kelantan	N5° 39.281' E101° 41.101'	Tai Tak / Rengam	<i>Antoshorea roxburghii</i>	2018	4 × 4	2,410	29-32	1.40
Jeli, Kelantan	N5° 39.336' E101° 41.128'	Tai Tak / Rengam	<i>Endospermum diadenum</i>	2014	4 × 4	2,410	29-32	0.64

Table 2 Above and belowground biomass change and carbon sequestration potential of planted forests in selected research stations of Peninsular Malaysia

Location	Species	Planting date	Annual stem DBH increment cm yr ⁻¹	Annual belowground biomass change ton C ha ⁻¹ yr ⁻¹	Annual aboveground biomass change ton C ha ⁻¹ yr ⁻¹	Annual total biomass change ton C ha ⁻¹ yr ⁻¹	Annual CO ₂ e ha ⁻¹ yr ⁻¹	Value (USD), USD 4.7 CO ₂ e ha ⁻¹ yr ⁻¹	Area planted (ha)	Total (USD)
Segamat, Johor	<i>Antoshorea roxburghii</i>	2018	1.15	0.13	0.60	0.73	2.68	12.59	1.53	19.27
Segamat, Johor	<i>Antoshorea roxburghii</i>	2018	2.26	0.23	0.72	0.95	3.49	16.39	3.68	60.30
Selandar, Melaka	<i>Eucalyptus hybrid</i>	2013	1.05	0.04	0.18	0.22	0.81	3.79	0.5	1.90
Selandar, Melaka	<i>Endospermum diadenum</i>	2016	2.10	0.43	1.14	1.57	5.76	27.08	0.64	17.33
Bukit Hari, Selangor	<i>Antoshorea roxburghii</i>	2012	1.03	0.23	1.60	1.83	6.72	31.57	1.42	44.82
Bukit Hari, Selangor	<i>Eucalyptus pellita</i>	2011	0.88	0.40	0.66	1.06	3.89	18.28	0.2	3.66
Bukit Hari, Selangor	<i>Endospermum diadenum</i>	1998	0.33	0.05	0.09	0.14	0.51	2.41	2.2	5.31
Setiu, Terengganu	<i>Antoshorea roxburghii</i>	2017	0.70	0.06	0.16	0.22	0.81	3.79	0.25	0.95
Setiu, Terengganu	<i>Antoshorea roxburghii</i>	2018	1.10	0.26	0.76	1.02	3.74	17.59	1.7	29.91
Jeli, Kelantan	<i>Antoshorea roxburghii</i>	2018	0.67	0.04	0.18	0.22	0.81	3.79	1.4	5.31
Jeli, Kelantan	<i>Endospermum diadenum</i>	2014	1.22	0.02	0.08	0.10	0.37	1.72	0.64	1.10
Mean			1.14	0.17	0.56	0.73	2.69	12.64	1.29	17.26
Min			0.33	0.02	0.08	0.10	0.37	1.72	0.20	0.95
Max			2.26	0.43	1.60	2.03	6.72	31.57	3.68	60.30
Median			1.05	0.13	0.60	0.73	2.68	12.59	1.40	5.31
CV			50.92	86.36	87.25	173.61	82.82	82.82	79.73	116.02
SE			0.17	0.04	0.15	0.19	0.67	3.16	0.31	6.04

Aboveground Biomass (kg)

$$= \rho \times \exp (-1.499 + 2.148 \times \ln \text{dbh} + 0.207 \times (\ln (\text{dbh}))^2 - 0.0281 - (\ln (\text{dbh}))^3)$$

Where dbh constitutes the diameter at breast height and ρ is wood specific gravity. DBH was measured for the study period from 2021 to 2023. Species level average ρ were obtained from the Global Wood Density Database (Zanne et al. 2009). The equation was fitted into for each tree. Each plantation was represented by 20 replicates of trees and this value was totalled to obtain the above ground biomass of carbon and extrapolated to one hectare to facilitate follow up calculations. The belowground (roots) biomass was determined using the equation:

Belowground biomass (kg)

$$= \text{Exp} (-1.0587 + 0.8836 \times \ln \text{ABD})$$

The values were treated similarly for calculation according to the aboveground biomass.

Above and belowground biomass change

Once the above and belowground biomass were computed, the change in carbon stocks in living biomass was estimated according to stock change method as outlined by the IPCC (2006) guideline according to equation 3.2.3 between the year 2021 and year 2023. The estimated carbon stocks between two periods were computed according to carbon stock change per unit area. Detailed information of minimal thinning was not ascertained for the Bukit Hari plot, thus, it was assumed none. The below equation was used whereby

$$\Delta C = \frac{Ct2 - Ct1}{t2 - t1}$$

The ΔC is the annual carbon stock change in living biomass (Mg C yr^{-1}), $Ct1$ and $Ct2$ are carbon stocks at $t1$ (2021) and $t2$ (2023). The values were further multiplied with the molecular weight of carbon dioxide of 44/7 to report in $\text{Mg CO}_2 \text{ yr}^{-1}$. The values were further multiplied with the current market price for voluntary carbon market price of USD 4.7/ tCO_2 for REDD+ credit scheme (United Nations and Environment Programme 2023) are reported in Table 2.

RESULTS AND DISCUSSION

Annual stem dbh increment

The data for annual stem DBH increments were recorded from the year 2021-2023, according to the timeline of the funding provided. The mean stem increment was 1.14 cm yr^{-1} overall for the mixed plantations. However, the highest mean stem increment was recorded for *Antoshorea roxburghii* (2018) in Segamat, Johor ($2.26 \text{ cm} \pm 0.17$) and *E. diadenum* planted in Selandar, Melaka ($2.26 \text{ cm} \pm 0.17$). Trees which were planted in the late 1990's experienced slow growth rate (0.33 cm yr^{-1}) as for the *E. diadenum* plot in Bukit Hari. Values reported for *A. roxburghii* concurs with Hardiansyah et al (2015) whereby another species, naturally regenerating *Rubroshorea leprosula* from the same meranti group showed MAI of between $1.4\text{-}2.7 \text{ cm yr}^{-1}$ slightly concurring with our mean stem increment (1.14 cm yr^{-1}). Growth rates usually increased rapidly at the initial stage (sapling) then slowed down at the mature stage (tree) usually after reaching 10 cm DBH to form a plateau. Growth rates can also be influenced by the El-Nino effects which can reduce tree growth and photosynthesis, leading to higher respiration rates (Cavaleri et al. 2017) which was not monitored in this study. During the entire duration from planting to current growth (1998-2018), droughts and elevated temperatures were significant in year 1997-1998, 2000, 2010, and 2016 (Muhammad et al. 2024) influencing growth. Abd Rahman et al. (2016) reported that the *R. curtisii* and *R. leprosula* had only showed MAI of between $0.55\text{-}0.78 \text{ cm yr}^{-1}$ once reaching maturity as the trees were planted in the 1990's and 2000. Apparently, Osunkoya et al. (2007) and King et al. (2005) stated that the wood density has a negative proportion to the annual growth rate of trees, implying, trees with higher wood density have slower growth rates. However, this was not visible in our plots due to the variations related to site-specificity.

Annual total aboveground biomass change

The values for above ground biomass stocks were not presented here as the focus was on carbon sequestration potential. Numerous studies were published reporting on above

ground biomass stocks according to age, species and environmental conditions which can be found in Adam & Jusoh 2018, Jeyanny et al. 2019, Hung et al. 2020, Jeyanny et al. 2021. The average carbon density in Malaysian forests is estimated at 157.5 ton C ha⁻¹ in 2020 (Raihan et al. 2021). Generally, the above ground biomass and below ground biomass stocks for all the species from year 2021- 2023 ranged from 1.14 – 7.43 Mg C ha⁻¹ and 0.53- 1.93 Mg C ha⁻¹ respectively (data not shown). The derivation of the changes between 3 consecutive years were reported whereby changes were in the range of 0.02-0.43 Mg C ha⁻¹ yr⁻¹ for roots, 0.08-1.60 Mg C ha⁻¹ yr⁻¹ for aboveground biomass (Table 2). The total aboveground biomass changes for the mixed plantations ranged from 0.02 to 1.83 Mg C ha⁻¹ yr⁻¹. Thus, the mean value for annual total biomass changes for the mixed plantations stands at 0.73± 0.19 CO₂e ha⁻¹ yr⁻¹. The highest annual CO₂e ha⁻¹ yr⁻¹ was reported for *A. roxburghii* planted in Bukit Hari, Selangor in year 2012, at 6.72 CO₂e ha⁻¹ yr⁻¹. The lowest whereas was for the *E. diadenum* planted in 2014 in Jeli, Kelantan at 0.37 CO₂e ha⁻¹ yr⁻¹. Values for *A. roxburghii* in Bukit Hari coincides with the thinning practice which was done in 2022. Thinning exercise will eventually remove crown cover, allow more sunlight and reduce competition for growth in the plot, which simultaneously accelerate growth of the trees giving higher increments in biomass and tree heights (Yu et al. 2020) and enhancing C stocks. This was also apparent in 4 year old *Acacia mangium* plantation after 2nd rotation where thinning increased soil C and N values that may have assisted in nutrient assimilation for tree growth (Vijayanathan et al., 2011). Unfortunately, studies related to carbon sequestration potential of planted forests are scarce in Malaysia and a past study by Shepherd & Montagnini (2001) showed that carbon sequestration potential of mixed plantations in the humid tropics range between 0.8 to 3.5 Mg C ha⁻¹ yr⁻¹ for selected species which underwent thinning practices. Another study by Pan et al. (2011) showed that tropical regrowth of forest can sequester about 1.64 Mg C ha⁻¹ yr⁻¹. Studies have shown that secondary tropical forests which regenerate naturally after removal of initial forest cover can sequester carbon at the rate of 0.4-6.3 Mg C ha⁻¹ yr⁻¹ for the first 20 years of natural regrowth (Silver et al. 2001, Poorter et al.

2016). These studies depict the closest reference to the work produced by the current study.

In contrary, a study by Hamdan (2021) displayed that the carbon sequestration potential of inland Dipterocarps fell between 0.01 – 0.02 Mg C ha⁻¹ yr⁻¹ assuming that these trees experienced a MAI of between 0.3- 0.5 cm⁻¹ yr⁻¹ in natural forests for trees based on 30 cm DBH. Despite this information is useful for natural inland forests, these values are far lower compared to this study where planted forests were studied with both fast growing and slow growing species, factored in variations on stem diameter and ages. The mixed plantations displayed varying values according to species, age, and localities in this study, thus the high CV obtained (Table 2). Besides that, other factors that contribute to this vast variation are wood density and growth rates (King et al. 2005, Osunkoya et al. 2007). Hamdan (2021) further reiterated that trees with slow growth rates and higher wood density, will tend to have slower carbon sequestration values but will store more carbon stocks compared to trees with low wood density and fast growing species. This is because wood density, trunk volume and biomass are interconnected (Phillips et al. 2019), and will reciprocally affect the carbon stocks as well as carbon stock change for a given period of time. Faster growing species were cited to sequester more carbon but have shorter life spans and lower maximum biomass (Dutcă et al. 2009).

Voluntary carbon market

Carbon markets is the mechanism for private finance to support avoided deforestation and forest restoration. United Nations reported that trading in credits from forestry and land-use projects in the voluntary carbon market reached almost USD 1.7 billion, for more than 285 million tCO₂e (United Nations Environment Programme 2023). The average price of REDD+ credits on voluntary carbon markets has increased from \$3.9/tCO₂ in 2019 to \$4.7/tCO₂ in 2021. Afforestation, reforestation, and improved forest management projects typically earn higher prices due to the higher costs involved in inputs and establishment. Furthermore the current National Climate Change Policy 2.0 in Malaysia also advocates the increment of soil carbon sequestration via reforestation, afforestation

and sustainable agricultural practices to realise mitigation measures (Ministry of Natural Resources, Environment & Sustainability, 2024). The volume of carbon traded on the voluntary carbon market is expected to increase 5 to 15 times by 2030. Busch et al. (2019) estimated that an increase in the carbon price from USD 20/tCO₂ to USD 50/tCO₂ would potentially increase global forest sequestration from 5.7 to 15.1 GtCO₂ over the 2020-2050 period. These are positive progress for countries like Malaysia to further enhance their forest plantations for REDD+. Based on the conservative value of USD 4.7 CO₂e ton ha⁻¹ yr⁻¹ pricing (United Nations 2024), it is projected that the range of carbon credits that can be sold would range between USD 1.72- 31.57 CO₂e ton ha⁻¹ yr⁻¹ depending on the variation of species type and area covered according to this study. Assuming an annual growth rate of 3%, Austin et al. (2020) projected a mitigation potential of 0.8 to 6.0 GtCO₂ over the period between 2015-2055 with carbon pricing between USD 5-100/tCO₂ with the largest share for the global forest sector contributed from the tropics. Thus, there is a vast potential for carbon sequestration of planted forests in Malaysia, provided that all aspects of the variables controlling C sequestration is accounted for.

CONCLUSION

Aboveground biomass and belowground biomass (roots) changes estimated for 3 consecutive years stands at 0.08-1.60 Mg C ha⁻¹ yr⁻¹ and 0.02-0.43 Mg C ha⁻¹ yr⁻¹, respectively. Thus, the total aboveground biomass change for the mixed plantations ranged from 0.10 to 2.03 Mg C ha⁻¹ yr⁻¹ where a mean value of 2.69 CO₂e ha⁻¹ yr⁻¹ reported. The values obtained are governed by factors such as environmental conditions, age of stand, species, wood density, growth rates and management practices. Based on the conservation value of USD 4.7 CO₂e ton ha⁻¹ yr⁻¹ pricing, It is projected that the range of carbon credits that can be sold would range between USD 0.20- 3.68 CO₂e ton ha⁻¹ yr⁻¹ based on a value of USD 4.7 CO₂e ton ha⁻¹ yr⁻¹. The current study supports the need to expand the quantification of carbon sequestration potential of planted

forests in the Malaysian forests. The current study also calls for site-specific and environmental factors investigations that control the carbon sequestration potential of various timbers. Besides, this study assists forest managers on decision making processes on selection of suitable timber species that can be utilised for afforestation and reforestation strategies that may realise the country's goal towards climate change mitigation. We foresee that this pioneer work will support initiatives related to carbon credits in future.

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