WRI INDONESIA

TECHNICAL NOTE

INDONESIA ZERO EMISSIONS APPLICATION (EMISI): METHODOLOGIES FOR CALCULATING URBAN TRANSPORT EMISSIONS AND TREE SEQUESTRATION

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EXECUTIVE SUMMARY

In recent decades, greenhouse gases (GHGs) and air pollutant emissions have increased due to land transport activities. This substantial growth has accelerated climate change and the deterioration of urban air quality, which have intensified serious hazards and have increased public health risks. Therefore, significant environmental action is urgently needed to mitigate the impact of climate change and air pollution on both the environment and human life. Globally, however, Indonesia has one of the largest populations of climate change deniers. Hence, it is crucial to establish a locally relevant platform—using Indonesia's emissions factors and profiles—that can educate and empower Indonesians to take action to mitigate their transportation impact on climate change. Therefore, the Indonesia Zero Emissions Application (EMISI) was developed to help users easily calculate and learn how to sequester their GHGs emissions, starting with urban commuting and transport activities.

This Technical Note describes the method within EMISI for calculating individual-level GHGs and air pollutant emissions from urban transport activities and then determining the necessary carbon sequestration through reforestation and afforestation. The application uses the bottom-up approach to calculate carbon dioxide, sulfur dioxide, carbon monoxide, fine particulate matter, and nitrogen oxides emissions to make them personal, science driven, and trackable; this helps users understand how their travel activities contribute to GHGs and air pollutant emissions. For emissions sequestration, EMISI uses guidelines and methodologies adopted from the Intergovernmental Panel on Climate Change and the Clean Development Mechanism. This shows users how they can sequester their GHGs emissions by planting trees; it also provides the required number of trees for a specific species planted in a specific location.

CONTENTS

WRI Technical Notes document methodology underpinning research publications, interactive applications, and other tools.

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This methodology could be adopted by various stakeholders in Indonesia—including government, nongovernmental and private organizations, communities, scientific experts, and the general public—helping them to embed it in their systems, develop their own calculators, and improve Indonesia's carbon sequestration knowledge as well as add value to other research and development purposes. Despite utilizing the best available data and models, the methodologies in this Technical Note have several limitations and room for future improvement.

INTRODUCTION

Rapid motorization, low public transport use, excessive travel, and massive congestion are among the main reasons why the transport sector has become one of the major producers of emissions and air pollution in Indonesia (Erou and Fadillah 2019; World Bank 2019). The proportion of total emissions from land transport sectors increased from 9 percent in 2010 to 12 percent in 2017 (MoEF 2019). Meanwhile, Indonesia has the highest percentage of climate change deniers among 23 nations, with 18 percent of its population still not convinced that human behavior plays a role in climate change (Hilman and Harvey 2019). This indicates that public understanding and responses to climate change issues are still limited in Indonesia. Failing to act on these issues will cause an irreversible chain reaction that results in ecosystem losses, food security risks, economic losses, and other potential disasters. At the same time, the increasing air pollution from urban commuting in Indonesian cities also leads to serious public health risks as well as declining productivity (Amalia et al. 2013). Thus, it is important to instill the Indonesian people with a stronger awareness of their transportation impact on the climate crisis and the sustainability of cities as well as to provide them with opportunities to conduct wider climate action.

Around the world, various government agencies and multinational companies have implemented programs to increase public awareness about transport emissions. These programs have used statistical measurements to personalize individual-level emissions. For instance, the Energy Efficiency and Conservation Authority of New Zealand developed a carbon dioxide (CO_2) emissions calculator for transport by using fuel consumption and fuel type data (EECA 2019). The International Civil Aviation Organization and Scandinavian Airlines System also built a CO_2 calculator for air transport (ICAO 2016; SAS 2019). Most of these existing calculators are relevant for developed countries, but none reflects developing countries, specifically Indonesia. A proper Indonesia-specific emissions calculator would add value to relevant Indonesian environmental policies by considering the country's unique sociodemographic and economic characteristics and its scientific numbers (e.g., emissions factors) (Brander et al. 2011; Hasan et al. 2012; MoEF 2010).

Therefore, the Indonesia Zero Emissions Application (EMISI) was developed to fill that gap, providing an easy-to-access educational tool for Indonesians to calculate their emissions and learn about their carbon footprint and its impact on their environment and communities. EMISI is mainly a mobile application because cell phones are one of the most accessible device types for Indonesians. As a result, it can facilitate a direct, quick call to action. As a platform, EMISI enables more individuals to track their personal emissions and then act to reduce them. The application also promotes carbon sequestration as a last resort, allowing users to calculate the total number of trees that would need to be planted. Although EMISI comprehensively provides the tools and mechanism of the calculation, reduction, and sequestration of an individual's transport emissions, this Technical Note specifically explains the scientific methodologies for all calculations in the application. The analysis follows the bottom-up approach used by the Intergovernmental Panel on Climate Change (IPCC) to calculate greenhouse gas (GHG) and air pollutant emissions (IPCC 2006). To calculate the emissions sequestration, EMISI uses the Clean Development Mechanism (CDM) methodology booklet (UNFCCC 2019) and the IPCC guideline (Aalde et al. 2006) for CO_2 removal.

This Technical Note focuses on calculating CO_2 as GHG emissions and carbon monoxide (CO), nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$), and sulfur dioxide (SO_2) as air pollutants, considering their substantial implication to climate change and air pollution. To make the solutions more locally relevant, reforestation (including afforestation and forest restoration) was chosen from various alternatives for sequestering CO_2 emissions because it is one of the most accessible and cost-efficient CO_2 removal strategies in Indonesia (Graham et al. 2016, 2017). Hence, the sequestration calculation in this Technical Note focuses on reforestation and analyzes a limited number of tree species and locations in Indonesia that have ongoing tree-planting activities. The tree biomass (aboveground and belowground) used in the sequestration estimation is based on Indonesia's best available data, latest possible model, and assumptions provided in national and international scientific publications. By including this calculation, EMISI also aims to help Indonesia integrate and enhance its citizens' individual tree emissions sequestration data for further research and development purposes.

METHODS

The method used in EMISI is designated to equip the application with accountable, Indonesia-specific emissions and sequestration calculations for the urban commuter sector; these calculations are generated from various national and international studies. This method consists of four parts, as illustrated in Figure 1: flow of user data input for travel characteristics, the GHG and air pollutant emissions calculation, data input for tree planting, and the tree-based sequestration calculation.

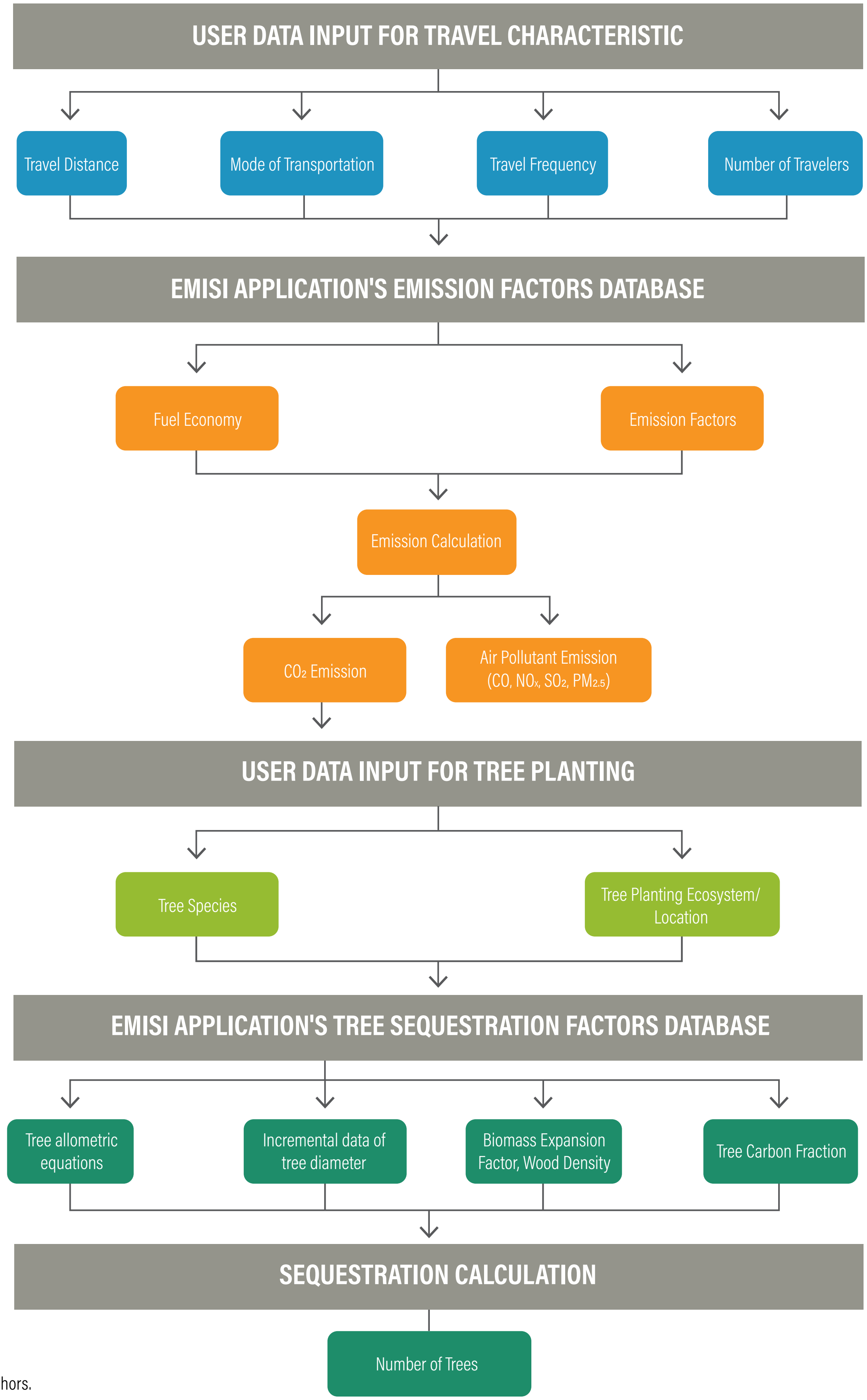
For the first part, which consists of input data for all transport emissions calculations, users need to input their travel characteristics, such as transport modes, trip frequency, and the number of people traveling together on private transport (i.e., car or motorcycle) and taxi (including car-based ride-hailing) modes. The transport modes provided in EMISI correspond to the actual available modes in Indonesian cities. Although private transport and public transport (i.e., bus and rail transit) are commonly used in various emissions calculators, EMISI also provides paratransit as one of the common transport modes in Indonesian cities (Joewono and Kubota 2007). The users' travel distance is generated using Google Maps application that is included in EMISI's programming, in which users input their journey's origin and destination.

The second part uses fuel-based and distance-based methods to calculate GHG and air pollutant emissions (Brander et al. 2011). These methods are based on literature about transport emissions calculations (Brander et al. 2011; IPCC 2006; Wang and Rakha 2017; Zadek and Schulz 2010) and consider Indonesian emissions factors (EFs) and fuel economy (Boedisantoso et al. 2019; Hasan et al. 2012; MoEF 2010, 2017; MoEMR 2017).

The third part collects user input data to determine their tree-planting activities. EMISI considers tree species and locations or ecosystems that are relevant to Indonesia's landscape and will be feasible for reforestation activities and sequestration calculations. Only CO_2 emissions are included in the sequestration calculation, following the natural ability of trees to sequester CO_2 by converting it into biomass.

The fourth and last part shows the tree-based carbon sequestration calculation to define the quantity and type of trees needed to sequester the user's CO_2 emissions from urban commuting. This part estimates the amount of CO_2 that can be removed by planting different types of trees. Using methods and factors generated by the IPCC guidelines and CDM methodology, EMISI can suggest both the species and number of trees that would need to be planted (Gorte 2009; Krisnawati et al. 2012).

Figure 1 | **The EMISI Method Framework**



Source: WRI authors.

Calculating Transport Activity Emissions

The Method for Calculating GHG and Air Pollutant Emissions

The IPCC's *Guidelines for National Greenhouse Gas Inventories* (2006) classifies transport activities as mobile sources of emissions. The guidelines categorize the emissions calculation methodology as either top-down or bottom-up (Song 2017; van Vuuren et al. 2009). As recommended by the IPCC (2006), which prefers an activity-based calculation, and while also considering that EMISI will gather data about individual citizens' travel characteristics, this Technical Note uses the bottom-up approach to calculate emissions.

The bottom-up approach can be calculated by using the fuel-based or the distance-based method (Zadek and Schulz 2010), and both methods use EFs to calculate GHG (CO_2) and air pollutant (CO, NO_x, $PM_{2.5}$, and SO_2) emissions. These factors express the calculated ratio between GHG and air pollutant emissions and activity data (i.e., fuel consumption and distance traveled). The distance-based method simply multiplies the distance traveled by an emissions factor, but the fuel-based method uses a two-step calculation. It begins by converting the distance traveled to energy consumption by multiplying it by the energy economy factors. The total emissions, then, are produced by multiplying the energy consumption by the EFs.

The formula for the fuel-based method to calculate GHG and air pollutant emissions is as follows:

$$\textit{Total emissions per person } (TEP_p) = \sum_{i=1}^{N} \frac{D_i}{FCF_{ij}} \, x \, \frac{EFs_k}{PT_i} \quad (1)$$

where i (i = 1, 2, . . . N) is the number of trips (i^{th}) captured; D_i is the total distance (kilometers) for the i^{th} trip; FCF_{ij} is the fuel economy factor for the transport mode (j) on the i^{th} trip in the units of kilometers per energy (i.e., liter or kilowatt-hour); EFs_k is the EF based on the type of fuel (k) or power plant/grid (w) in the units of kilogram-emissions per energy (i.e., liter or kilowatt-hour); and PT_i is the number of people traveling together on the i^{th} trip. The total emissions per person is the sum of the emissions calculated throughout the trip.

Below is the formula for the distance-based method to calculate air pollutant emissions:

$$\textit{Total emissions per person } (TEP_p) = \sum_{i=1}^{N} \frac{D_i \, x \, EFs_j}{PT_i} \quad (2)$$

where i (i = 1, 2, . . . N) is the number of trips (i^{th}) captured; D_i is the total distance (kilometers) for the i^{th} trip; EFs_j is the EF based on the transport mode (j) in the units of kilogram-emissions per kilometer; and PT_i is the number of people traveling together on the i^{th} trip. The total emissions per person is the sum of the emissions calculated throughout the trip.

The Determinants for Calculating GHG Emissions

To calculate the GHG (CO_2) emissions, the fuel-based method requires the energy consumption for every trip that users inputted into EMISI. Although users only inputted their trips' origin and destination—and then Google Maps generated the distance traveled—energy consumption is calculated by dividing the distance traveled by the energy economy factor. The energy economy factor for land transport is based on the type of transport mode (i.e., car, motorcycle, bus), as suggested by the IPCC (2006), and also on the national average number provided by Indonesia's Ministry of Environment and Forestry (MoEF) (2010). Specific energy economy factors for urban rail are derived from a study conducted by Wang and Rakha (2017) that modeled electricity consumption factors for urban rail in the United States based on the number of train cars per set (six and eight cars). The summary of such energy economy factors is provided in Table 1.

Table 1 | Energy Economy Factors

TRANSPORT MODES	ENERGY ECONOMY FACTORS	UNIT
Car (gasoline)[a]	9.8	km/liter
Van/minibus (gasoline)[a]	8	km/liter
Car (diesel)[b]	10.3	km/liter
Paratransit (gasoline)[a]	7.5	km/liter
Taxi (gasoline)[a]	8.7	km/liter
Medium bus (diesel)[a]	4.0	km/liter
Big bus (diesel)[a]	3.5	km/liter
Motorcycle (gasoline)[a]	28	km/liter
Electric urban rail (8 cars)[c]	0.0325	km/kWh
Electric urban rail (6 cars)[c]	0.0433	km/kWh

Note: kWh = kilowatt-hour.
Sources: a. MoEF 2010; b. IPCC 2006; c. Wang and Rakha 2017.

The calculated energy consumption is then multiplied by the EFs that corresponds to each fuel/energy type, as described in Table 2. Like the fuel consumption, EFs for CO_2 are based on fossil fuel consumption and electricity production. In particular, the fossil fuel EFs resulted from conversions, by multiplying EFs from MoEF (2017) and the Ministry of Energy and Mineral Resources (2017) local reference, in unit kg CO_2/terajoules with their heating value (TJ/liter). Meanwhile, the EFs for the electricity consumption of urban rail transit use Indonesian standards of electrical EFs for grid electricity by Brander et al. (2011).

Table 2 | CO_2 Emissions Factors

FUEL/ENERGY	CO_2 EMISSIONS FACTOR	UNIT
Automotive diesel oil [a,b]	2.68	kg CO_2/liter
RON 92 gasoline [a,b]	2.39	kg CO_2/liter
RON 88 gasoline [a,b]	2.41	kg CO_2/liter
Grid electricity [c]	0.774	kg CO_2/kWh

Notes: kWh = kilowatt-hour. The heating value for gasoline is $33x10^{-6}$ terajoules/liter; for diesel it is $38x10^{-6}$ terajoules/liter (MoEF 2012).
Sources: a. MoEF 2010; b. MoEMR 2017; c. Brander et al. 2011.

The Determinants for Calculating Air Pollutant Emissions

To calculate the air pollutant (CO, NO_x, $PM_{2.5}$, and SO_2) emissions, the distance-based method is used for all trips except those involving urban rail, which uses the fuel-based method. The required data is similar to the CO_2 emissions calculation method, although EFs used for calculating air pollutant emissions are based on the distance traveled and the mode of transport. The EFs for air pollutants are obtained from studies conducted by the MoEF (2010) and Boedisantoso et al. (2019), as shown in Table 3. The EFs from electricity are sourced from Hasan et al. (2012), who distinguish air pollutant EFs based on the type of fuel used in power plants in Indonesia. The EFs for $PM_{2.5}$ are sourced from Shrestha et al. (2013), who developed the *Atmospheric Brown Clouds (ABC): Emission Inventory Manual* for Asian cities.

To simplify the calculation, the following factors were excluded from the analysis because they would not have significantly changed the calculation results:

- Driving behavior in various conditions (i.e., congestion or free flowing)
- Vehicle engine maintenance as well as years of use after vehicle production

It is assumed that these factors had already been considered when the EFs or energy economy factors were produced. Moreover, to calculate GHG and air pollutant emissions per person for paratransit, bus, and urban rail modes, the number of passengers based on the existing capacity and load factor are simplified using the following assumptions:

- The load factor for all modes is assumed to be about 70 percent of its capacity.
- For paratransit and bus modes, the capacity is 14 and 73 people per vehicle, respectively, according to a study by Cervero (1991) and Trans Jakarta (Jakarta Bus Management Company) (Ghozali 2018).
- The urban rail capacity is 250 people per car, with a total of eight cars per train set, according to the Indonesian Commuter Rail Company (commuter railway operator) (Rudi 2015).

Table 3 | **Air Pollutant Emissions Factors**

VEHICLE TYPE / MODE OF TRANSPORT	EMISSIONS FACTORS			
	KG CO/KM	KG NO_X/KM	KG $PM_{2.5}$/KM	KG SO_2/KM
Motorcycle[a,b,c]	0.0140	0.00029	0.000032	0.000008
Car (gasoline)[a,b,c]	0.0400	0.0020	0.00005	0.000026
Car (diesel)[a,b,c]	0.0028	0.0035	0.00084	0.00044
Paratransit[a,b,c]	0.0431	0.0021	0.00006	0.000029
Bus[a,b,c]	0.0110	0.0119	0.00042	0.00093
ELECTRICITY EMISSIONS FACTOR BASED ON POWER PLANT	**KG CO/KWH**	**KG NO_X/KWH**	**KG $PM_{2.5}$/KWH**	**KG SO_2/KWH**
Coal[c,d]	0.0002	0.0052	0.000189	0.0139
Natural gas[c,d]	0.0005	0.0009	0.000140	0.0005
Fuel oil[c,d]	0.0002	0.0025	0.000055	0.0164

Notes: CO = carbon monoxide; kWh = kilowatt-hour; NO_x = nitrogen oxides; $PM_{2.5}$ = fine particulate matter; The heating value for gasoline is $33x10^{-6}$ terajoules/liter; SO_2 = sulfur dioxide. Terajoules converted to gigawatt-hours is 0.2778.
Sources: a. MoEF 2010; b. Boedisantoso et al. 2019; c. Shrestha et al. 2013; d. Hasan et al. 2012.

Furthermore, users also input their travel frequency in weekly units (trip/week). Therefore, assuming a month consistently consists of four weeks, to calculate the total emissions per person during a one-month period ($TEP_p\text{-}M$), TEP_p is multiplied by the total weekly frequency and number of weeks in a month that the trips are taken. Furthermore, given the fact that a year always consists of twelve months, to calculate the total emissions per person during a one-year period ($TEP_p\text{-}Y$), $TEP_p\text{-}M$ is multiplied by the number of months in the year when the trips are taken. To provide a more practical illustration, examples of these emissions calculations are provided in Appendix A. The appendix presents three cases involving different travel characteristics and modes that consider locally relevant trip chains that Indonesians perform during their daily travels. The first case illustrates a comparison of people using motorcycles for ride-hailing services and cars in their daily trip chain. The second case illustrates the trip chain using a combination of car and urban rail, and the third case illustrates the trip chain using a combination of motorcycle and bus.

The framework for calculating emissions described in this section has a wide range of applications, as suggested by the CDM methodology (UNFCCC 2019). Whereas some studies investigate emissions reduction for various public transport projects (ADB 2017; Yuan and Frey 2020), others estimate the impact of improved technologies for reducing emissions (Xylia et al. 2019) and the impact of new mobility services, such as car sharing and ride hailing, on the production of emissions (Jung and Koo 2018; Suatmadi et al. 2019). Therefore, this Indonesia-specific framework can provide a practical emissions-tracking methodology that can be adapted to platforms by various stakeholders in Indonesia, including government, nongovernmental and private organizations, and communities.

Calculating Emissions Sequestration

Among other measures, tree planting has been widely promoted as an effort to effectively remove atmospheric CO_2 to minimize the catastrophic effects of climate change (Buis 2019; Carrington 2019; Coppolino 2014; Rathi 2020). Besides CO_2, studies also found that trees can absorb air pollutants, but only physical interaction influences the dispersion and deposition of air pollutants, and the trees should be planted close to the source of pollution (Badach et al. 2020; Janhäll 2015). However, planting activities in EMISI are conducted in various locations and are not necessarily at the location where emissions were released. Therefore, tree-planting activities may not be an appropriate approach to sequester air pollutants, which will not be converted to CO_2 equivalents. Thus, this method only considers sequestration of CO_2.

The scale and purpose of the sequestration efforts vary from individual to large-scale tree planting and from reforestation to afforestation (Bäckstrand and Lövbrand 2006; Gorte 2009). EMISI estimates the number of planted trees based on total CO_2 emitted per user, calculated as follows:

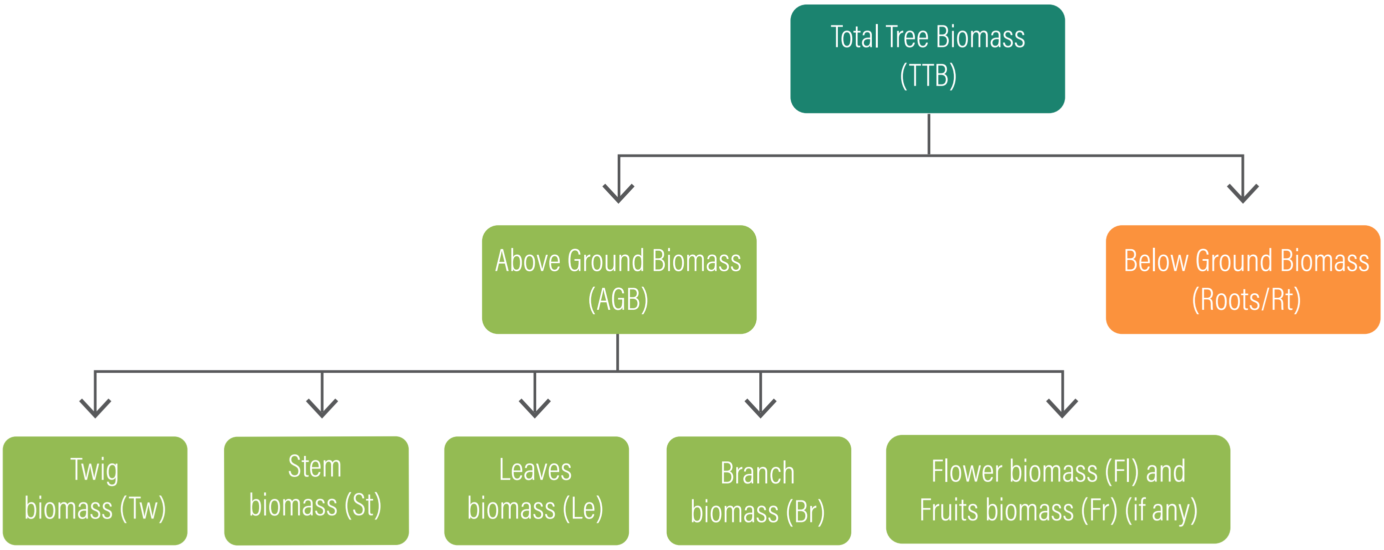
$$\textit{Number of trees} = \frac{TEP_p CO_2}{\textit{Estimated sequestered } CO_2 \textit{ per tree}} \qquad (3)$$

where TEP_p CO_2 refers to Equation 1, and estimated sequestered CO_2 (ESC) per tree is influenced by growth rate (stem diameter and height increment) of the tree and the ecosystem performance to uptake CO_2 (Röhling et al. 2016), which depends on tree species and ecosystem type (Bernal et al. 2018; Kirby and Potvin 2007). Tree species and ecosystem type of planting activities are important to achieve the optimum impact of tree planting for CO_2 removal. Moreover, standardizing seedling quality, maintaining environmental condition, and nurturing treatment are three factors affecting the growth and survival rate of planted trees and, hence, their capacity to remove CO_2 (Jaenicke 1999). Therefore, tree-planting activities within EMISI maintain these factors to reach optimum carbon sequestration capacity.

Carbon sequestration estimates can be calculated using the total change in several relevant carbon pools (namely, the stock difference method) or in carbon fluxes (the gain-loss method). The stock difference method considers carbon pools that include biomass (aboveground and belowground), dead organic matter (dead wood and litter), and soil organic matter. The gain-loss method uses a carbon input component (i.e., net primary production) and output components (heterotrophic respiration, methane and nitrous oxide emissions, fire and water flow emissions) (Basuki et al. 2019; Hergoualc'h and Verchot 2011). EMISI uses the stock difference method to estimate CO_2 removal from tree-planting activities because it is considered a generic methodology that is applicable to multiple land-use categories (Aalde et al. 2006).

According to method AR-AMS0007 of the United Nations Framework Convention on Climate Change (2019) regarding afforestation/reforestation on land other than wetlands, CO_2 removal is achieved by increasing carbon stocks in the following pools: mainly aboveground (AGB) and belowground biomass (BGB),

Figure 2 | **Tree Biomass Components That Can Be Estimated Using Tree Allometric Equations**



Source: WRI authors.

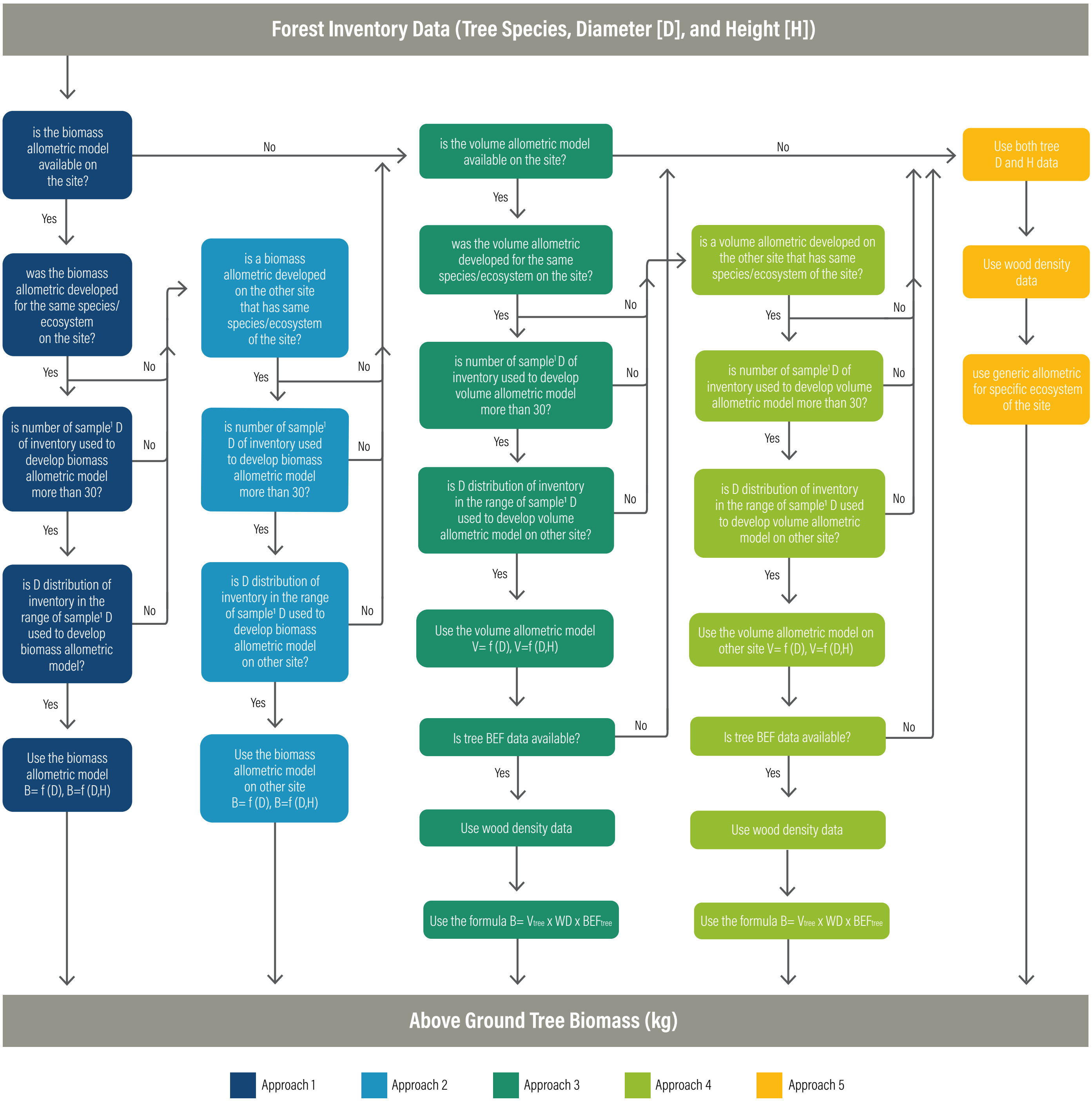
while deadwood, litter, and soil organic carbon are optional. Based on this, the calculation method used in EMISI will only consider AGB and BGB carbon pools in accordance with the CDM methodology booklet and the IPCC (Aalde et al. 2006). Changes in carbon stocks can be calculated using the global default value (Tier 1), nationally derived data (Tier 2), or the country-based methodology with specific equations/models in specific forest types (Tier 3) (Aalde et al. 2006).

EMISI aims to use the Tier 3 method using Indonesian-based tree allometric equations/models derived from locally relevant locations and ecosystems documented in *Allometric Models for Estimating Tree Biomass at Various Forest Ecosystem Types in Indonesia* (Krisnawati et al. 2012) and other recent literature about the Indonesian-based allometric model. Allometric equations estimate the biomass by correlating tree diameter and height with tree biomass components (Figure 2). The equations can also represent the function of diameter to total tree biomass (TTB) or the function of diameter to each component of tree biomass. In addition, the allometric equations can represent the function of diameter to tree volume (V), converted to biomass using wood density (WD), and the biomass expansion factor (BEF). Finally, the carbon stock is estimated by multiplying biomass with the carbon fraction coefficient.

However, allometric equations are not always available for all Indonesian tree species in specific ecosystems and locations. This is because developing species-specific allometric equations for Indonesia's highly diverse tropical forests is laborious, cost ineffective, and almost impossible (Paul et al. 2016). Tree-specific allometric equations also may produce errors and biases due to the small sample sizes, limited tree diameter ranges, and other factors that are not represented in the allometric, such as geographical, biophysical, and forest boundaries (Manuri et al. 2016). Therefore, some approaches have been developed to select the most suitable allometric equations according to defined standards, including the number of samples, the diameter ranges used to develop the allometric, the ecosystem type, and the location of tree samples. Consequently, carbon sequestration for some species might be calculated using a generic allometric equation for several ecosystem types in Indonesia because existing allometric equations do not meet the standard criteria. Examples of generic allometric equations include those developed by Chave et al. (2014) for tropical trees and Kusmana et al. (2018) for mangrove species.

The approaches used in this method have been adopted and modified from approaches developed by Krisnawati et al. (2012). Figure 3 illustrates the decision tree for selecting calculation approaches to estimate biomass based on the availability of a tree allometric that suits the defined criteria (number of samples and tree diameter ranges used to develop the allometric model). Five approaches are used in a consecutive order, from Approach 1 (most desirable) to Approach 5 (least desirable).

Figure 3 | **Decision Tree for Selecting Allometric Models to Estimate Tree Biomass**



Source: WRI authors.

Approach 1 is used to estimate tree biomass using allometric models for specific species and ecosystems that are available in the tree-planting location. However, if a biomass allometric model is not available for the species and ecosystem in a tree-planting location, the model for another location with the same species and ecosystem can be used; this is called Approach 2. Next, Approach 3 is used to estimate tree biomass using the volume allometric model available for the specific species and ecosystem in the tree-planting location. Similar to Approach 2, if the volume allometric equation is not available for the tree-planting location, the equation for another location can be used; this is Approach 4. Lastly, Approach 5 uses generic allometric equations that are available for specific ecosystem types in the tree-planting locations.

EMISI quantifies the required number of trees based on the tree species, ecosystem, and location, considering the presence of reforestation and restoration activities implemented by Indonesian conservation and restoration organizations. Table 4 provides the potential list of species to be planted by several organizations across Indonesia. This list is not limited and can be expanded in the future. Tree species are based on the needs of the restoration area and the communities who live nearby; hence, some species are for agroforestry purposes.

Table 4 | **List of Prospective Tree Species to Be Planted in Restoration Areas across Indonesia**

ECOSYSTEM TYPE	SPECIES	INDONESIAN COMMON NAME	ENGLISH COMMON NAME
Secondary mangrove forest	*Avicennia marina*	Bakau	White mangrove
	Rhizopora apiculata	Bakau	Mangrove
	Rhizopora mucronata	Bakau	Mangrove
	Rhizopora stylosa	Bakau	Mangrove
Secondary dryland forest	*Aleurites moluccanus*	Kemiri	Candle nut
	Alstonia scholaris	Pala	Nutmeg
	Archidendron pauciflorum	Jengkol	Stinky bean
	Artocarpus integer	Cempedak	Jackfruit
	Daemonorops draco	Jernang	Dragon's blood
	Durio zibethinus	Durian	Durian
	Eusideroxylon zwageri	Ulin/Bulian	Ulin
	Gnetum gnemon	Melinjo	Gnemon
	Lansium paraciticum	Langsat	Lanzones
	Parkia speciosa	Petai	Bitter bean
	Pinus merkussi	Pinus	Pine
	Shorea senoptera Burck	Tengkawang	Tengkawang
	Shorea spp.	Meranti	Meranti
	Syzygium aromaticum	Cengkeh	Clove
	Toona sureni	Surian	Surian

Source: WRI authors.

Table 5 provides examples for calculating carbon sequestration for several species that can be planted through the EMISI application's tree-planting program. Besides the selected allometric model chosen based on the five approaches, the following assumptions are also applied to calculate tree-based carbon sequestration:

- Planted trees are assumed to survive for 20 years (the default time frame by the IPCC to estimate carbon stock from land-use change activities) and/or to reach a minimum of 10 centimeters (cm) in diameter at the breast height (DBH).

- Conservative scenarios estimate an annual increment of 0.5 cm stem diameter (Rexon and Pearson 2010) and 0.5 meters (m) height (H); H increments vary between 0.5 and 0.9 m during the first 20 years (Bustomi et al. 2009) for dryland trees or 0.1 m for mangrove trees (Siregar 2007).

- The TTB is estimated using the allometric function (f) of stem diameter (D) to biomass for tree biomass components:
  - TTB = f (D) or TTB = AGB + BGB
  - AGB = f (D)
  - BGB/Roots (Rt) = f (D) or BGB = f(AGB)

- Wood density (WD) for each tree species is the mean of WD data provided in the Tree Functional Attributes and Ecological Database.[1]

- If the allometric equation for BGB/Rt is not available, the BGB is calculated using default shoot-root ratio (0.27), which is based on the 2006 IPCC guidelines.

- If a tree carbon fraction is not available for a tree species or ecosystem, the default value of 0.47 is used based on the 2006 IPCC guidelines.

Table 5 also shows that the CO_2 sequestration estimate falls between 50 and 150 kilograms (kg) of CO_2 per tree for five different tree species; the detailed total CO_2 sequestration calculation can be found in Appendix B. The estimate for sequestered CO_2 per tree is used to define the number of trees needed to sequester a user's travel-related emissions. Appendix C further illustrates the estimated number of trees needed per species to sequester different amounts of emissions in different cases.

Table 5 | Parameters and Data Needed to Estimate Tree Species CO_2 Sequestration Using Five Different Approaches

PARAMETERS	APPROACHES				
	APPROACH 1	APPROACH 2	APPROACH 3	APPROACH 4	APPROACH 5
Tree species	*Avicennia marina*	*Pinus merkussi*	*Eusideroxylon zwageri*	*Rhizopora apiculata*	*Artocarpus integer*
Tree diameter increment	0.5 cm per year[a]	0.5 cm per year[a]	0.5 cm per year[a]	0.5 cm per year[a]	0.5 cm per year[a]
Ecosystem	Mangrove forest	Dryland forest	Dryland forest	Mangrove forest	Dryland forest
Location	West Java	Aceh	South Sumatra	DKI Jakarta	Aceh
Allometric equation	$TTB = 0.291 \times D^{2.260}$ [b]	$TTB = 0.178 \times D^{2.586}$ *from different location* [b]	$V = 0.000101 \times D^{2.619}$ [b]	$V = 0.000107 \times D^{2.4}$ *from different location* [b]	$AGB = 0.0678 (D^2 \times WD \times H)^{0.976}$ [d]
Number of samples	47[b]	80[b]	262[b]	50[b]	>1000[d]
Diameter range for allometric equation	6.4–35.2 cm[b]	0.4–44 cm[b]	8-33 cm[b]	10–57.6 cm[b]	5–150 cm[d]
Biomass expansion factor (BEF)	Not applicable	Not applicable	1.49[b]	1.55[b]	Not applicable
Wood density (WD)	Not applicable	Not applicable	561.2 kg/m^3[c]	583.6 kg/m^3[c]	647.6 kg/m^3[c]
Tree carbon fraction (TCF)	0.47[b]	0.47[b]	0.47[b]	0.47[b]	0.47[b]
Biomass calculation	*TTB*	*TTB*	$AGB = V \times BEF \times W$; $BGB = 0.27 \times AGB$; $TTB = AGB + BGB$		$BGB = 0.27 \times AGB$; $TTB = AGB + BGB$
Carbon stock calculation	$\text{Carbon stock} = TTB \times TCF$				
CO_2 calculation	$CO_2e = \text{Carbon stock} \times \frac{44}{12}$				
Estimated sequestered CO_2 (ESC) per tree (kg)	91.3	51.1	146.8	94.1	100.1
Average ESC per tree per year (kg)	4.6	2.5	7.3	4.7	5

Notes: AGB = aboveground biomass; BGB = belowground biomass; TTB = total tree biomass.
Sources: a. Rexon and Pearson 2010; b. Krisnawati et al. 2012; c. Average WD is from the Tree Functional Attributes and Ecological Database, International Centre for Research in Agroforestry, http://db.worldagroforestry.org/; d. Chave et al. 2014.

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[1] See the Tree Functional Attributes and Ecological Database, International Centre for Research in Agroforestry, http://db.worldagroforestry.org/.

LIMITATIONS

Although EMISI educates and enables citizens to measure their transport-related GHG and air pollutant emissions along with the number of trees required for their sequestration, the method does have limitations. In developing countries, data availability has been a key barrier, as identified by Song (2017). The calculator focuses on developing the best estimates for Indonesian context; however, when local data are unavailable, the calculator uses data from global contexts to develop the next-best estimates. Recent and upcoming research data on the determinants for calculating emissions in Indonesia-specific cases, such as EFs and fuel consumption, will further improve future calculations. Therefore, these studies also encourage more detailed and localized data for those determinants due to demographic, economic, and infrastructure disparities across nations, affecting different behaviors and thus influencing the fuel consumption factor, among others.

The emissions sequestration calculation is estimated by using the best available tree allometric equation and tree increment prediction, which may contain errors and biases. The errors and biases are caused by several factors, including field measurement errors in producing allometric equations (Manuri et al. 2016). Another factor is that the allometric equation is limited in representing all factors that may affect the amount of tree biomass. For example, most local allometric equations only present correlations between tree diameter and biomass, which means other factors, such as tree height and age, are not represented. Moreover, the ability of trees to absorb CO_2 and to grow may also be affected by seedling quality, environment, and treatment, which lead to some uncertainties that cannot be counted in the allometric equation and tree growth. Even though EMISI aims to standardize these factors, uncertainties may still exist. Furthermore, tree growth, which is presented as the annual increment of tree diameter and height, is assumed to have linear growth per year. On the ground, this may not be entirely true and may result in errors and biases that are not measured in the calculation method as well. However, such an assumption is still applicable because this method is acceptable for the CO_2 removal calculation in the CDM methodology (Rexon and Pearson 2010). Another factor that can potentially lead to errors is the survival rate of trees; the EMISI application's tree-planting program reduces this factor by ensuring that all dying trees are replaced. This tree replacement process, however, may decrease the growth increment of the trees. Therefore, the assumption of tree growth is based on the lowest possible annual tree increment to compensate for the potential decline of tree increment due to tree replacement.

These potential errors and biases still cannot be defined directly in this calculation method due to unavailability of actual data for tree-planting activities. In the future, these potential errors and biases will be measured by comparing the projected and actual data to calculate the mean relative error, mean absolute relative error, and root mean square error. These error factors will then be used to further determine the best allometric equations and to improve the current allometric equation used for that specific tree species and planting location.

APPENDIX A: EXAMPLES OF GHG AND AIR POLLUTANT EMISSIONS CALCULATIONS

Table A1 | **Case 1: Using a Private Car or Motorcycle**

CO_2	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					CO_2 ($kgCO_2$/liter)		$kgCO_2$/trip/person		$kgCO_2$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/((C)*(E))	(G)	(H) = (F)*(G)
	1	Motorcycle	10	28	2.41	1	0.86	20	17.214
	2	Car	10	9.8	2.41	1	2.46	20	49.184

CO	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					CO (kgCO/km)		kgCO/trip/person		kgCO/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Motorcycle	10	28	0.014	1	0.14	20	2.800
	2	Car	10	9.8	0.04	1	0.4	20	8.000

NO_x	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					NO_x ($kgNO_x$/km)		$kgNO_x$/trip/person		$kgNO_x$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Motorcycle	10	28	0.00029	1	0.0029	20	0.058
	2	Car	10	9.8	0.0020	1	0.02	20	0.400

SO_2	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					SO_2 ($kgSO_2$/km)		$kgSO_2$/trip/person		$kgSO_2$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Motorcycle	10	28	0.000008	1	0.000026	20	0.002
	2	Car	10	9.8	0.000026	1	0.00026	20	0.005

$PM_{2.5}$	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					$PM_{2.5}$ ($kgPM_{2.5}$/km)		$kgPM_{2.5}$/trip/person		$kgPM_{2.5}$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Motorcycle	10	28	0.000032	1	0.00032	20	0.006
	2	Car	10	9.8	0.00005	1	0.0005	20	0.010

Table A2 | Case 2: Combination of Private Car and Commuter Line (Electricity-Based Train)

	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter) or (km/kWh)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
CO_2					CO_2 (kgCO_2/liter) or (kgCO_2/kWh)		kgCO_2/trip/person		kgCO_2/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/((C)*(E))	(G)	(H) = (F)*(G)
	1	Car	5	9.8	2.41	1	1.22959	20	24.592
	2	Train	25	0.03252	0.774	1,400	0.42501	20	8.500
CO	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter) or (km/kWh)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					CO (kgCO/km) or (kgCO/kWh)		kgCO/trip/person		kgCO/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Car	5	9.8	0.04	1	0.20000	20	4.000
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/((C)*(E))	(G)	(H) = (F)*(G)
	2	Train	25	0.03252	0.0002	1,400	0.00011	20	0.002
NO_x	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter) or (km/kWh)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					NO_x (kgNO_x/km) or (kgNO_x/kWh)		kgNO_x/trip/person		kgNO_x/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Car	5	9.8	0.002	1	0.01	20	0.200
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/((C)*(E))	(G)	(H) = (F)*(G)
	2	Train	25	0.03252	0.0052	1,400	0.00286	20	0.057
SO_2	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter) or (km/kWh)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					SO_2 (kgSO_2/km) or (kgSO_2/kWh)		kgSO_2/trip/person		kgSO_2/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Car	5	9.8	0.000026	1	0.00013	20	0.003
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/((C)*(E))	(G)	(H) = (F)*(G)
	2	Train	25	0.03252	0.0139	1,400	0.00763	20	0.153
$PM_{2.5}$	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter) or (km/kWh)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					$PM_{2.5}$ (kg$PM_{2.5}$/km) or (kg$PM_{2.5}$/kWh)		kg$PM_{2.5}$/trip/person		kg$PM_{2.5}$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Car	5	9.8	0.00005	1	0.00025	20	0.005
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/((C)*(E))	(G)	(H) = (F)*(G)
	2	Train	25	0.03252	0.000189	1,400	0.00010	20	0.002

Table A3 | **Case 3: Combination of Bus and Motorcycle**

	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
CO_2					CO_2 ($kgCO_2$/liter)		$kgCO_2$/trip/person		$kgCO_2$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/((C)*(E))	(G)	(H) = (F)*(G)
	1	Motorcycle	5	28	2.41	1	0.43036	20	8.607
	2	Bus	25	3.5	2.68	51	0.37535	20	7.507
CO	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					CO (kgCO/km)		kgCO/trip/person		kgCO/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Motorcycle	5	28	0.014	1	0.07000	20	1.400
	2	Bus	25	3.5	0.011	51	0.00539	20	0.108
NO_x	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					NO_x ($kgNO_x$/km)		$kgNO_x$/trip/person		$kgNO_x$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Motorcycle	5	28	0.00029	1	0.00145	20	0.029
	2	Bus	25	3.5	0.0119	51	0.00583	20	0.117
SO_2	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					SO_2 ($kgSO_2$/km)		$kgSO_2$/trip/person		$kgSO_2$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Motorcycle	5	28	0.000008	1	0.00004	20	0.001
	2	Bus	25	3.5	0.00093	51	0.00046	20	0.009
$PM_{2.5}$	Number of trips	Modes of transport	Distance (km)	Energy conversion (km/liter)	Emissions factor	Number of people traveling together	Emissions per person	Number of trips per month	Emissions per person
					$PM_{2.5}$ ($kgPM_{2.5}$/km)		$kgPM_{2.5}$/trip/person		$kgPM_{2.5}$/month/person
		(A)	(B)	(C)	(D)	(E)	(F) = ((B)*(D))/(E)	(G)	(H) = (F)*(G)
	1	Motorcycle	5	28	0.000032	1	0.00016	20	0.003
	2	Bus	25	3.5	0.00042	51	0.00021	20	0.004

Notes: CO = carbon monoxide; CO_2 = carbon dioxide; kWh = kilowatt-hour; NO_x = nitrogen oxides; $PM_{2.5}$ = fine particulate matter; SO_2 = sulfur dioxide.

APPENDIX B: SEQUESTERED CO_2 CALCULATION DETAILS USING FIVE APPROACHES

The tables below provide the calculation details for sequestered CO_2 per tree, where

- DBH = diameter at the breast height measured in cm;
- TTB = total tree biomass, calculated in kg using tree allometric equations;
- AGB= aboveground biomass, calculated in kg using tree allometric equations;
- BGB = below ground biomass, calculated in kg using tree allometric equations;
- carbon stock = the total sequestered carbon estimation, converted from TTB;
- CO_2e = the total sequestered CO_2 estimation, converted from carbon stock; and
- annual CO_2e = total sequestered CO_2 estimation annually.

Table B1 | **Approach 1: Estimated Sequestered CO_2 for *Avicennia marina* (White Mangrove) Planted in a Mangrove Forest**

Year	DBH (cm)	TTB (kg)	Carbon Stock (kg)	CO_2e (kg)	Annual CO_2e (kg)
2020	0.000	0.000	0.000	0.000	0.000
2021	0.500	0.061	0.029	0.105	0.105
2022	1.000	0.291	0.137	0.502	0.397
2023	1.500	0.728	0.342	1.254	0.752
2024	2.000	1.394	0.655	2.402	1.148
2025	2.500	2.308	1.085	3.978	1.576
2026	3.000	3.485	1.638	6.006	2.028
2027	3.500	4.937	2.321	8.509	2.503
2028	4.000	6.676	3.138	11.507	2.998
2029	4.500	8.713	4.095	15.016	3.509
2030	5.000	11.055	5.196	19.053	4.037
2031	5.500	13.712	6.445	23.633	4.580
2032	6.000	16.692	7.845	28.769	5.136
2033	6.500	20.002	9.401	34.474	5.705
2034	7.000	23.649	11.115	40.759	6.285
2035	7.500	27.640	12.991	47.637	6.878
2036	8.000	31.980	15.031	55.117	7.480
2037	8.500	36.676	17.238	63.210	8.093
2038	9.000	41.733	19.615	71.927	8.716
2039	9.500	47.157	22.164	81.275	9.348
2040	10.000	52.953	24.888	91.264	9.989
Total CO_2e at year 20 (kg)					**91.264**

Table B2 | Approach 2: Estimated Sequestered CO_2 for *Pinus merkussi* (Pine) Planted in Dryland Forest

Year	DBH (cm)	TTB (kg)	Carbon Stock (kg)	CO_2e (kg)	Annual CO_2e (kg)
2020	0.000	0.000	0.000	0.000	0.000
2021	0.500	0.019	0.009	0.032	0.032
2022	1.000	0.103	0.048	0.178	0.145
2023	1.500	0.279	0.131	0.481	0.304
2024	2.000	0.566	0.266	0.976	0.495
2025	2.500	0.980	0.461	1.690	0.714
2026	3.000	1.535	0.721	2.645	0.956
2027	3.500	2.242	1.054	3.865	1.219
2028	4.000	3.114	1.464	5.367	1.502
2029	4.500	4.160	1.955	7.170	1.803
2030	5.000	5.390	2.533	9.290	2.120
2031	5.500	6.814	3.202	11.744	2.454
2032	6.000	8.439	3.967	14.545	2.802
2033	6.500	10.275	4.829	17.709	3.164
2034	7.000	12.329	5.795	21.249	3.540
2035	7.500	14.609	6.866	25.178	3.929
2036	8.000	17.121	8.047	29.508	4.330
2037	8.500	19.874	9.341	34.252	4.744
2038	9.000	22.873	10.750	39.421	5.169
2039	9.500	26.125	12.279	45.027	5.605
2040	10.000	29.637	13.929	51.079	6.053
Total CO_2e at year 20 (kg)					**51.079**

Table B3 | Approach 3: Estimated Sequestered CO_2 for *Eusideroxylon zwageri* (Ulin) Planted in Dryland Forest

Year	DBH (cm)	Volume (m^3)	AGB (kg)	BGB (kg)	TTB (kg)	Carbon Stock (kg)	CO_2e (kg)	Annual CO_2e (kg)
2020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2021	0.500	0.000	0.023	0.006	0.030	0.016	0.060	0.060
2022	1.000	0.000	0.138	0.037	0.175	0.096	0.353	0.293
2023	1.500	0.000	0.399	0.108	0.506	0.278	1.021	0.668
2024	2.000	0.001	0.847	0.229	1.075	0.591	2.169	1.148
2025	2.500	0.001	1.519	0.410	1.929	1.061	3.891	1.722
2026	3.000	0.002	2.449	0.661	3.110	1.710	6.272	2.381
2027	3.500	0.003	3.667	0.990	4.657	2.561	9.392	3.120
2028	4.000	0.004	5.202	1.404	6.606	3.633	13.324	3.932
2029	4.500	0.005	7.081	1.912	8.993	4.946	18.138	4.814
2030	5.000	0.007	9.332	2.520	11.851	6.518	23.902	5.764
2031	5.500	0.009	11.977	3.234	15.211	8.366	30.679	6.777
2032	6.000	0.011	15.043	4.062	19.105	10.508	38.531	7.852
2033	6.500	0.014	18.551	5.009	23.560	12.958	47.517	8.986
2034	7.000	0.017	22.525	6.082	28.607	15.734	57.696	10.178
2035	7.500	0.020	26.986	7.286	34.272	18.850	69.122	11.426
2036	8.000	0.023	31.956	8.628	40.584	22.321	81.851	12.729
2037	8.500	0.027	37.454	10.113	47.567	26.162	95.936	14.085
2038	9.000	0.032	43.503	11.746	55.249	30.387	111.428	15.492
2039	9.500	0.037	50.120	13.532	63.653	35.009	128.378	16.950
2040	10.000	0.042	57.327	15.478	72.805	40.043	146.836	18.458
Total CO_2e at year 20 (kg)								**146.836**

Table B4 | **Approach 4: Estimated Sequestered CO_2 for *Rhizopora apiculata* (Mangrove) Planted in Peat Swamp Forest**

Year	DBH (cm)	Volume (m^3)	AGB (kg)	BGB (kg)	TTB (kg)	Carbon Stock (kg)	CO_2e (kg)	Annual CO_2e (kg)
2020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2021	0.500	0.000	0.028	0.007	0.035	0.019	0.071	0.071
2022	1.000	0.000	0.146	0.039	0.186	0.102	0.374	0.303
2023	1.500	0.000	0.387	0.104	0.491	0.270	0.990	0.616
2024	2.000	0.001	0.771	0.208	0.979	0.539	1.975	0.985
2025	2.500	0.001	1.317	0.356	1.673	0.920	3.375	1.399
2026	3.000	0.001	2.041	0.551	2.592	1.425	5.227	1.852
2027	3.500	0.002	2.954	0.798	3.752	2.064	7.567	2.340
2028	4.000	0.003	4.070	1.099	5.169	2.843	10.426	2.859
2029	4.500	0.004	5.400	1.458	6.858	3.772	13.832	3.406
2030	5.000	0.005	6.954	1.878	8.831	4.857	17.811	3.980
2031	5.500	0.006	8.741	2.360	11.101	6.106	22.389	4.578
2032	6.000	0.008	10.771	2.908	13.679	7.524	27.589	5.199
2033	6.500	0.010	13.052	3.524	16.576	9.117	33.432	5.843
2034	7.000	0.011	15.593	4.210	19.803	10.892	39.940	6.508
2035	7.500	0.013	18.401	4.968	23.369	12.853	47.132	7.192
2036	8.000	0.016	21.484	5.801	27.284	15.006	55.028	7.896
2037	8.500	0.018	24.848	6.709	31.557	17.357	63.646	8.618
2038	9.000	0.021	28.502	7.696	36.197	19.909	73.005	9.358
2039	9.500	0.024	32.451	8.762	41.213	22.667	83.120	10.115
2040	10.000	0.027	36.702	9.910	46.612	25.636	94.009	10.889
Total CO_2e at year 20 (kg)								**94.009**

Table B5 | Approach 5: Estimated Sequestered CO_2 for *Artocarpus integer* (Jackfruit Tree) Planted in Dryland Forest

Year	DBH (cm)	H (m)	AGB (kg)	BGB (kg)	TTB (kg)	Carbon Stock (kg)	CO_2e (kg)	Annual CO_2e (kg)
2020	0,000	0,500	0,000	0,000	0,000	0,000	0,000	0,000
2021	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000
2022	1,000	1,500	0,065	0,018	0,083	0,046	0,167	0,167
2023	1,500	2,000	0,191	0,052	0,243	0,133	0,489	0,322
2024	2,000	2,500	0,416	0,112	0,529	0,291	1,066	0,577
2025	2,500	3,000	0,769	0,208	0,977	0,537	1,970	0,903
2026	3,000	3,500	1,276	0,344	1,620	0,891	3,268	1,298
2027	3,500	4,000	1,964	0,530	2,494	1,372	5,030	1,762
2028	4,000	4,500	2,859	0,772	3,631	1,997	7,323	2,293
2029	4,500	5,000	3,988	1,077	5,064	2,785	10,214	2,891
2030	5,000	5,500	5,376	1,451	6,827	3,755	13,770	3,555
2031	5,500	6,000	7,049	1,903	8,952	4,924	18,055	4,286
2032	6,000	6,500	9,033	2,439	11,471	6,309	23,136	5,081
2033	6,500	7,000	11,352	3,065	14,417	7,930	29,078	5,941
2034	7,000	7,500	14,033	3,789	17,822	9,802	35,944	6,866
2035	7,500	8,000	17,100	4,617	21,717	11,944	43,800	7,856
2036	8,000	8,500	20,578	5,556	26,134	14,374	52,708	8,909
2037	8,500	9,000	24,492	6,613	31,105	17,108	62,734	10,025
2038	9,000	9,500	28,867	7,794	36,661	20,163	73,939	11,205
2039	9,500	10,000	33,727	9,106	42,833	23,558	86,388	12,448
2040	10,000	10,500	39,097	10,556	49,653	27,309	100,142	13,754
Total CO_2e at year 20 (kg)								**100.142**

APPENDIX C: NUMBER OF TREES CALCULATED FROM TOTAL EMISSIONS PER PERSON

The tables below provide three different travel cases to calculate the number of trees needed using five different tree species as examples (tree species in EMISI application are not limited to these five species). The tree species are varied based on the restoration needs, which are determined by several restoration and tree-planting organizations.

Table C1 | **Case 1: Using Private Car or Motorcycle**

Total Emissions per Person (TEP_p) (kg)	Tree Options	Estimated Sequestered CO_2 (kg)	Number of Trees
(A)	(B)	(C)	(D) = (A)/(C)
66.40	*Avicennia marina*	91.26	0.73
66.40	*Pinus merkussi*	51.08	1.30
66.40	*Eusideroxylon zwageri*	146.84	0.45
66.40	*Rhizopora apiculata*	94.01	0.71
66.40	*Artocarpus integer*	100.14	0.66

Table C2 | **Case 2: Combination of Private Car and Commuter Line (Electricity-Based Train)**

Total Emissions per Person (TEP_p) (kg)	Tree Options	Estimated Sequestered CO_2 (kg)	Number of Trees
(A)	(B)	(C)	(D) = (A)/(C)
33.09	*Avicennia marina*	91.26	0.36
33.09	*Pinus merkussi*	51.08	0.65
33.09	*Eusideroxylon zwageri*	146.84	0.23
33.09	*Rhizopora apiculata*	94.01	0.35
33.09	*Artocarpus integer*	100.14	0.33

Table C3 | **Case 3: Combination of Bus and Motorcycle**

Total Emissions per Person (TEP_p) (kg)	Tree Options	Estimated Sequestered CO_2 (kg)	Number of Trees
(A)	(B)	(C)	(D) = (A)/(C)
15.36	*Avicennia marina*	91.26	0.17
15.36	*Pinus merkussi*	51.08	0.30
15.36	*Eusideroxylon zwageri*	146.84	0.10
15.36	*Rhizopora apiculata*	94.01	0.16
15.36	*Artocarpus integer*	100.14	0.15

ABBREVIATIONS

AGB	Aboveground Biomass
BEF	Biomass Expansion Factor
BGB	Belowground Biomass
CDM	Clean Development Mechanism
CO	Carbon Monoxide
CO_2	Carbon Dioxide
D	Diameter
DBH	Diameter at the Breast Height
EF	Emissions Factor
EMISI	Indonesia Zero Emissions Application
ESC	Estimated Sequestered Carbon Dioxide
f	Function
GHG	Greenhouse Gas
H	Height
IPCC	Intergovernmental Panel on Climate Change
MoEF	Ministry of Environment and Forestry
NO_x	Nitrogen Oxides
$PM_{2.5}$	Fine Particulate Matter
Rt	Roots
SO_2	Sulfur Dioxide
TCF	Tree Carbon Fraction
TEP_p	Total Emissions Per Person
TTB	Total Tree Biomass
WD	Wood Density

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ABOUT WRI

The World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.