RESEARCH ARTICLE

MEDIA KONSERVASI
SCIENTIFIC JOURNAL IN CONSERVATION OF NATURAL RESOURCES AND ENVIRONMENT

Life Cycle Assessment Approach for Tracing the Impact of Recreational Activities in Green Open Spaces, South Tangerang - Indonesia

Luthfia Ainur Rahma[a], Rachmad Hermawan[b] and Eva Rachmawati[b]

[a] Study Program of Tropical Biodiversity Conservation, IPB University, Bogor 16680, Indonesia
[b] Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, Bogor 16680, Indonesia

Article Info:
Received 07 May 2024
Revised 29 July 2024
Accepted 07 August 2024

Corresponding Author:
Rachmad Hermawan
Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, Bogor 16680, Indonesia
E-mail: rachmadhe@apps.ipb.ac.id

Abstract

South Tangerang has green open spaces currently widely used for community recreation, namely City Park 1 BSD and City Park 2 BSD. Recreational activities can contribute to environmental impacts. Life Cycle Assessment is an approach used to trace the impact of each recreational activity. This research aims to inventory inputs and outputs, calculate the magnitude of emissions based on impact categories, and formulate impact control scenarios for recreational activities in green open space, South Tangerang. The main data collected were the characteristics and activity patterns of visitors. At each recreational activity stage, the input type is identified, and the magnitude of emissions is calculated using the basic formula: Emissions = activity data x emission factor. The next stage is interpreting the results by formulating impact control scenarios. The identified inputs are gasoline and diesel fuel, electrical energy, urine, soap, and organic and inorganic solid waste. Emissions of transportation activities are CO_2, N_2O, CH_4, SO_2, and NO_2; emissions of organic waste processing are N_2O and CH_4; emissions of inorganic waste processing are CH_4; emissions of electricity use are CO_2, SO_2, and NO_2; as well as emissions of using toilets and soapy water are CH_4 and PO_4^{3-}. Recreational activities in City Park 1 BSD produce greater emissions than in City Park 2 BSD, with hotspots in visitor transportation. Impact control can be carried out using two scenarios: limiting motorized vehicles' use and reducing plastic waste.

Keywords: green open space, life cycle assessment, recreation

1. Introduction

The dynamics of life's demands in big cities and the high work intensity can cause boredom. This condition will be exacerbated by various environmental problems such as air pollution, traffic jams, and environmental discomfort so that it can cause a decline in people's health, both physically and psychologically [1–3]. Recreation is one way to overcome these various problems [4–6]. Recreation in free time can be a source of happiness [7]. Recreation is important in maintaining or improving a person's health by balancing work and relaxation, promoting respiratory circulation and better digestion. Recreation reduces the potential for lifestyle-related diseases such as fatigue and obesity through stress management and meditation [8]. Apart from that, recreation also contributes to a person's emotional stability by providing increased relaxation and calm, creative activities so that it can increase work productivity [9,10].

One of the recreation destinations for city residents is green open space (GOS), which can provide a comfortable, fresh environment and as a means for carrying out enjoyable activities. GOS also has the function of controlling air pollution, beautifying the city environment, regulating water management and wildlife habitat, providing environmental education, and increasing environmental comfort [11,12]. South Tangerang is a buffer area for Jakarta that can potentially be affected by various environmental problems that occur in Jakarta [13,14]. The population of South Tangerang is 1,378,466, the majority of whom are officers or employees [15]. South Tangerang has GOS that are widely used, including City Park 1 BSD and City Park 2 BSD. Currently, the two GOS are used by the community for sports, taking photos, and community gatherings. The area of GOS in South Tangerang in 2010 was 6,070 ha, while in 2020 it was 4,224 ha [16].

Recreation is a series of activities starting from residence to the recreation destination, namely GOS, carrying out recreational activities in GOS, and returning to residence. This activity can produce exhaust emissions, chemical residues, solid waste, liquid waste, originating from transportation, accommodation, food waste, drink waste, energy consumption and human waste [17,18]. The recreation sector is responsible for around 8% of the digital carbon footprint, with around 60% of this being due to transportation for recreation [19]. Air pollution caused by transportation from recreation is in the form of NOx, $PM_{2.5}$, PM_{10}, CO and SO_2 emissions [20]. Various exhaust gas emissions and chemical residues can contribute to global warming, ozone depletion, acidification, eutrophication, and photochemical oxidation [19].

South Tangerang has an unhealthy air quality index [21]. In addition, water pollution in rivers in South Tangerang was also found, including light pollution to heavy pollution due to domestic waste [22]. As environmental pollution increases and its contribution to global environmental problems, efforts are needed to control negative impacts in various sectors, including recreation [23,24]. One approach that can be used to trace the environmental impacts of various stages of recreational activities is Life Cycle Assessment (LCA). This approach is a compilation and evaluation of inputs, outputs, and potential environmental impacts during their life cycle, so that the stages of recreational activities that can reduce their potential impacts can be identified [25,26]. The research aims to conduct an inventory of inputs and outputs, calculate the magnitude of emissions based on impact categories, and formulate scenarios for controlling the impact of recreational activities in GOS, South Tangerang.

2. Materials and Methods

2.1. Research Location and Time

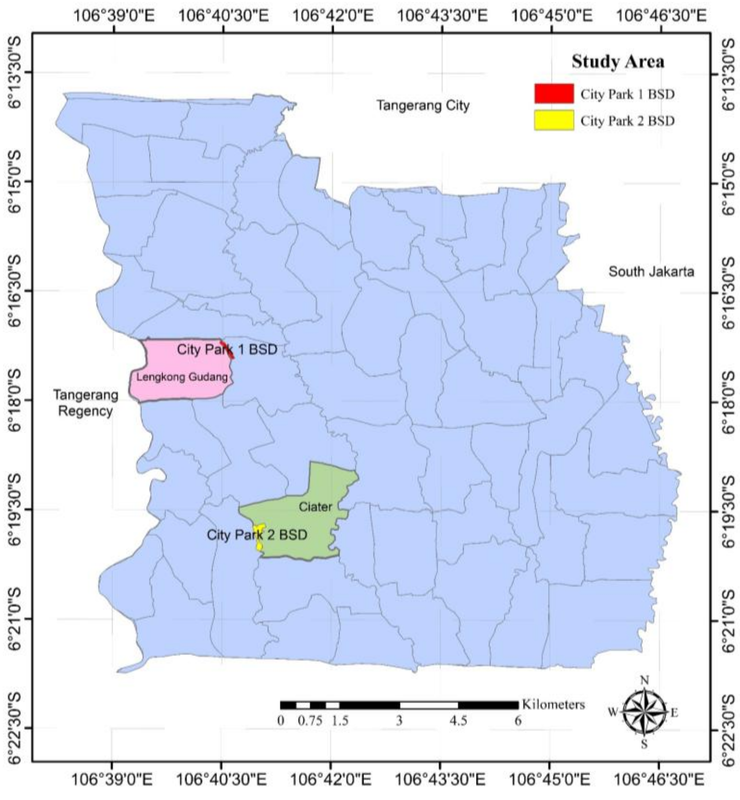

Figure 1. Research site map in City Park 1 BSD and City Park 2 BSD, South Tangerang.

The research was conducted at City Park 1 BSD and City Park 2 BSD in February–April 2024. City Park 1 BSD is located on Letnan Sutopo Street, Lengkong Gudang Timur Village, Serpong District, South Tangerang with an area of 2.6 ha. City Park 2 BSD is located on Tekno Widya Street, Ciater Village, Serpong District, South Tangerang with an area of 9 ha (Figure 1).

2.2. Tools and Instruments

The tools used to collect visitor data is a hand counter. Data analysis using Microsoft Excel software. The research instruments used were questionnaires and interview guides for data collection.

2.3. Data Collection

D Data The main data were the characteristics and patterns of visitors' recreational activities at City Park 1 Bumi Serpong Damai (BSD) and City Park 2 BSD. Data on visitor characteristics includes age, gender, occupation, education, regional origin, and intensity of visit. Data and information on recreational activity patterns include means of transportation visitors use, forms of recreational activity, food and drink waste, and toilet use.

Data collection was carried out by interviews using questionnaires. Accidentally sampling determined respondents, namely visitors who happened to be at the research location and were considered appropriate as data sources [27]. The criteria for respondents are ≥ 17 years of age and currently carrying out recreational activities directly in GOS. The number of respondents was determined using the Levy and Lemeshow [28] formula, assuming that a maximum of 50% of South Tangerang residents recreation in the two GOSs. Determination of the number of respondents is as follows:

$$n = \frac{Z^2_{(1-\alpha)} \text{ x p x } (1-p)}{d^2} = \frac{(1.96)^2 \text{ x } 0.50 \text{ x } (1-0.50)}{(0.10)^2} = 96 \approx 100 \text{ respondents} \quad (1)$$

Where n is number of samples; z is confidence level 95% (α = 5%) = 1.96; p is maximum estimate 50% = 0.50; and d is sampling error 10% = 0.10.

Based on calculations, the minimum number of respondents was 100 for both GOSs, but in practice the number of respondents for City Park 1 BSD was 51 and City Park 2 BSD was 52. The number of visitors was counted using a hand counter for one hour in the morning, afternoon and evening on Saturdays and Sundays with three repetitions and on national holidays with one repetition. Data and information were collected through field observations, literature studies, and interviews with GOS managers.

The system boundary used in the research is "Cradle to Grave". The stage begins with visitors leaving the residence for the GOS and then carrying out recreational activities in the GOS until returning to the residence (Figure 2). While in GOS, visitors produce waste by using the toilet, soap, eating, and drinking. Organic and inorganic waste from eating and drinking is transported to the Cipeucang Final Disposal Site (FDS) at 9.7 km from City Park 1 BSD and 4.5 km from City Park 2 BSD, which is managed using the open dumping method or open storage in media land.

2.4. Percentage of Respondents' Characteristics and Recreation Activity Patterns

The respondent is someone who provides answers to questions related to research on the required data. Data on the characteristics of respondents required are age, gender, occupation, education, regional origin and intensity of visits. Data on characteristics and patterns of respondents' recreational activities were calculated in percentage using the equation:

$$\text{Characteristic/activity percentage} = \frac{\text{Number of respondents with certain characteristics/activities}}{\text{Number of all respondents}} \text{ x } 100\% \quad (2)$$

2.5. Estimating the Number of Visitors

Estimating the number of visitors is carried out to determine the level of interest of visitors in visiting RTH. This data is used to calculate the annual visitor emission value for each RTH. The estimate of the number of visitors in a year is obtained from multiplying the number of visitors per day by the number of weekend days plus multiplying the number of visitors per day by the number of national holidays for one year for 2024.

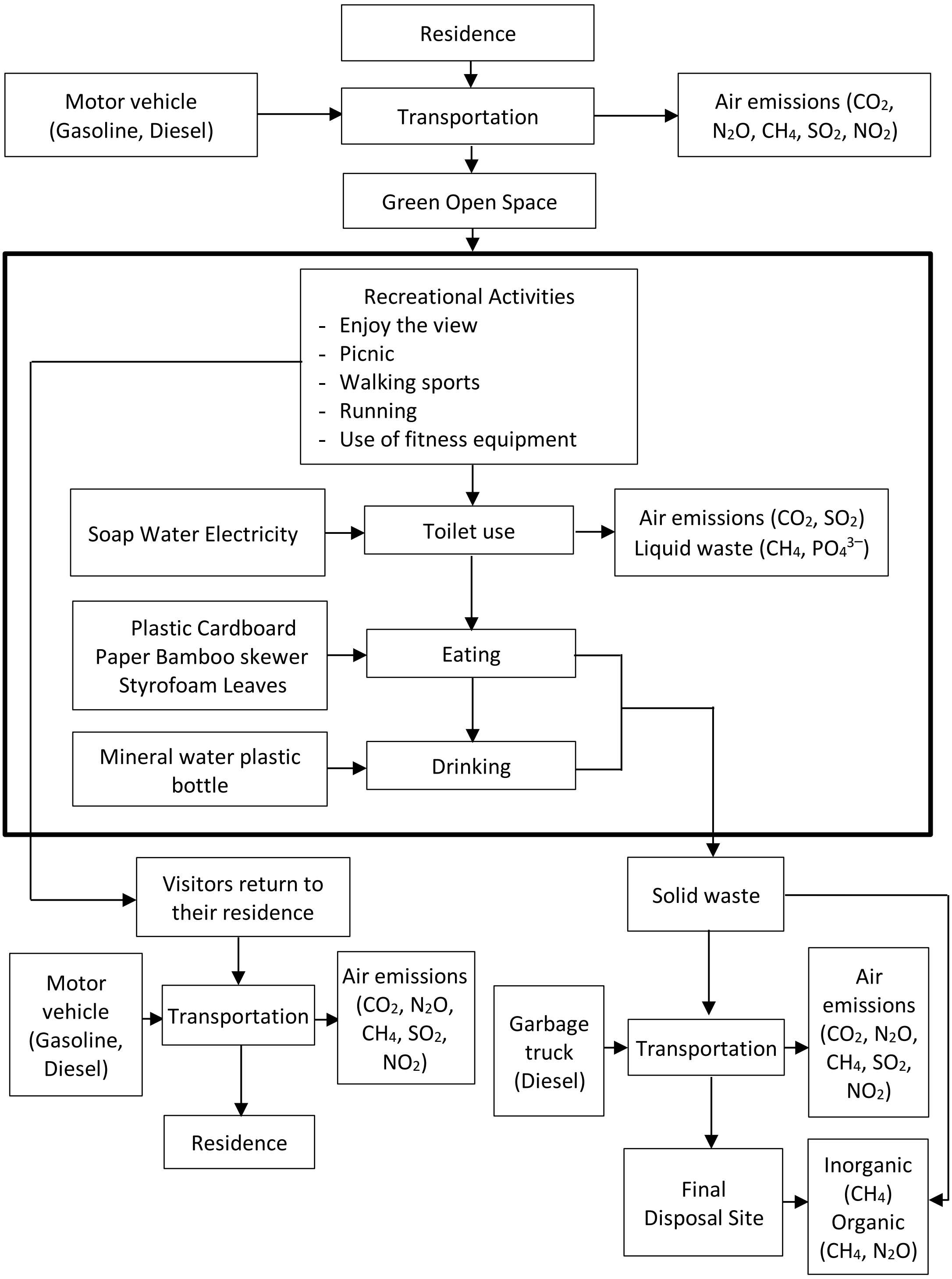

Figure 2. Flow diagram of recreational activities.

2.6. Input and Output Inventory

The LCA stages refer to ISO 14040:2016 [29]. This stage inventories the types of input from each stage of recreational activities that produce impacts in the form of emissions (output). Restrictions on recreational activities range from residence, transportation to GOS, until returning to residence.

2.7. Quantitative Calculation of Environmental Impact

Quantitative calculations of environmental impacts are only carried out up to the characterization stage. The calculation of the number of green house gases emissions was carried out after knowing the type and amount of input for each activity as well as the type of emissions (output) produced. Quantitative calculations use the following basic formula:

$$\text{Emissions} = \text{activity data x emission factor} \quad (3)$$

Types of emissions are classified into impact categories, then emission magnitude data is characterised using conversion factors based on impact categories. Quantitative calculations of environmental impacts are limited to the Global Warming Potential (GWP), acidification, and eutrophication impact categories [17,25,30]. The emissions calculated are total respondents' emissions, emissions per person per visit, and emissions per year.

2.8. Global Warming Potential (GWP)

The types of pollutants that can cause GWP are CO_2, N_2O, and CH_4. Sources of pollution that cause GWP come from electricity, fuel, inorganic solid waste, organic solid waste, and liquid waste. The emission magnitude the GWP inventory refers to IPCC [31].

2.8.1. Electricity

Electricity is used as energy for recreational facilities. Facilities that use energy such as lights can emit CO_2 emission. The following equation obtains emissions produced by electrical energy [31]:

$$CO_2 \text{ Emissions} = QL \times 0.84 \text{ kg } CO_2/\text{kWh} \quad (4)$$

Where QL is electricity consumption (kWh).

2.8.2. Fuel

The use of fuel can produce CO_2, N_2O, and CH_4 emission. Fuel is used for visitor transportation. IPCC [31] stated the emission magnitude of transportation can be obtained from the following equation with emission factors according to the fuel type (Table 1).

$$CO_2 \text{ Emissions} = QF \times NK \times FE \quad (5)$$

Where QF is fuel consumption (L), NK is calorific value ($TJ\ L^{-1}$), and FE is emission factor ($kg\ CO_2\ TJ^{-1}$).

$$N_2O \text{ Emissions} = QF \times NK \times FE \quad (6)$$

Where QF is fuel consumption (L), NK is calorific value ($TJ\ L^{-1}$), and FE is emission factor ($kg\ N_2O\ TJ^{-1}$).

$$CH_4 \text{ Emissions} = QF \times NK \times FE \quad (7)$$

Where QF is fuel consumption (L), NK is calorific value ($TJ\ L^{-1}$), and FE is emission factor ($kg\ CH_4\ TJ^{-1}$).

Table 1. Default emission factor of road transport

Emissions	Diesel	Gasoline*
CO_2	74,100 kg CO_2 TJ^{-1}	69,300 kg CO_2 TJ^{-1}
N_2O	3.9 kg N_2O TJ^{-1}	3.2 kg N_2O TJ^{-1}
CH_4	3.9 kg CH_4 TJ^{-1}	33 kg CH_4 TJ^{-1}
Calorific value	36 x 10^{-6} TJ L^{-1}	33 x 10^{-6} TJ L^{-1}

*Includes pertamax and pertalite. Source: IPCC [31].

2.8.3. Inorganic solid waste

Solid waste is generated from recreational activities in the form of the use of packaging such as plastic spoons, plastic bottles, and styrofoam. Inorganic solid waste produces CH_4 emissions. The conversion value of CH_4 emissions is 0.035 CH_4 ton^{-1} of solid waste for tropical climate conditions as follows [31]:

$$CH_4 \text{ Emissions} = TSW \times 0.035\ CH_4/ton \quad (8)$$

Where TSW is Total Solid Waste (ton); and 0.035 is conversion value of CH_4 emissions of climate zone tropical [31].

2.8.4. Organic solid waste

Organic waste is produced from recreational activities such as leftover food/drink ingredients. Organic solid waste produces CH_4 and N_2O emissions. The conversion value of CH_4 emissions is 0.4 CH_4 ton^{-1} of organic waste for tropical climate conditions as follows [31]:

$$CH_4 \text{ Emissions} = TOW \times 0.4\ CH_4/ton \quad (9)$$

Where TOW is Total Organic Waste (ton); and 0.4 is conversion value of CH_4 emissions climate zone tropical [31].

$$N_2O \text{ Emissions} = TOW \times N \times 0.07\ gr\ N_2O/kg\ N \quad (10)$$

Where TOW is Total Organic Waste (kg); and N is N content (%): paper = 0.60% [32], bamboo skewer = 1.71% [33], banana leaves = 2.11% [34].

2.8.5. Liquid waste

Liquid waste results from using soapy water in the toilet. Liquid waste produces CH_4 emissions. Determination of the magnitude of CH_4 emissions uses the following equation [31]:

$$CH_4 \text{ Emissions} = V_{LC} \times C \times 0.25\ kg\ CH_4/kg\ COD \quad (11)$$

Where V_{LC} is liquid waste volume (L); and C is COD value (mg L^{-1}): urine = 770 mg L^{-1} [35], soap = 547 mg L^{-1} [36].

GWP emission values are obtained from the conversion of CO_2, N_2O, and CH_4 to CO_2eq. Conversion value is obtained through comparison. The comparison of GWP emission values is as follows [31]: 1 kg CO_2 = 1 kg CO_2eq; 1 kg N_2O = 298 kg CO_2eq; 1 kg CH_4 = 25 kg CO_2eq.

2.9. Acidification

The types of pollutants that can cause acidification are SO_2 and NO_2. Acidification is one of the environmental impacts caused by human activities. Sources of pollution that cause acidification come from the use of electricity and fuel.

2.9.1. Electricity [37]

$$SO_2 \text{ Emissions} = QL \times 8.1\ g\ SO_2/kWh \quad (12)$$

Where QL is electricity consumption (kWh).

$$NO_2 \text{ Emissions} = QL \times 4.17\ g\ NO_2/kWh \quad (13)$$

Where QL is electricity consumption (kWh).

2.9.2. Fuel [38]

$$SO_2 \text{ Emissions} = QF \times NK \times 59.61\ kg\ SO_2/TJ \quad (14)$$

Where QF is fuel consumption (L) and NK is calorific value (TJ L^{-1}) (Table 1).

$$NO_2 \text{ Emissions} = QF \times NK \times 1.322\ kg\ NO_2/TJ \quad (15)$$

Where QF is fuel consumption (L) and NK is calorific value (TJ L^{-1}) (Table 1).

The acidification emission value is obtained from the conversion of SO_2 and NO_2 to SO_2eq by comparison [39]: 1 kg SO_2 = 1 kg SO_2eq; 1 kg NO_x = 0.7 kg SO_2eq.

2.10. Eutrophication

The types of pollutants that can cause eutrophication are NO_2 and PO_4^{3-}. Sources of pollution that cause eutrophication come from the use of electricity, fuel, and liquid waste.

2.10.1. Electricity [37]

$$NO_2 \text{ Emissions} = QL \times 4.17 \text{ g } NO_2/\text{kWh} \tag{16}$$

Where QL is electricity consumption (kWh).

2.10.2. Fuel [38]

$$NO_2 \text{ Emissions} = QF \times NK \times 1.322 \text{ kg } NO_2/\text{TJ} \tag{17}$$

Where QF is fuel consumption (L) NK is calorific value (TJ L^{-1}) (Table 1)

2.10.3. Liquid waste [31]

$$PO_4^{3-} \text{ Emissions} = V_{LC} \times C \times 0.022 \text{ kg } PO_4^{3-}/\text{kg COD} \tag{18}$$

Where V_{LC} is liquid waste volume (L); and C is COD value (mg L^{-1}): urine = 770 mg L^{-1} [35], soap = 547 mg L^{-1} [36].

The eutrophication emission value is obtained from the conversion of NO_2 and PO_4^{3-} to PO_4^{3-}eq by comparison [39]: 1 kg PO_4^{3-} = 1 kg PO_4^{3-}eq; 1 kg NO_x = 0.13 kg PO_4^{3-}eq.

2.11. Interpretation of Result

The results interpretation stage is carried out to identify hotspots that are of concern to be controlled or reduced. Hotspots are activities that have the greatest impact on the environment. Then formulate scenarios/recommendations for alternative activities that can reduce the environmental impact of recreational activities.

3. Results

3.1. General Condition

City Park 1 BSD is located on Jalan Letnan Sutopo, Lengkong Gudang Timur Village, Serpong District, South Tangerang, with a 2.6 ha area established in 2004. The location of City Park 1 BSD is on the side of Jalan Letnan Sutopo, so it is easily accessible by vehicle. However, the location is not traversed by public transportation. Tree species were dominated by shade plants, with a total of 365 individual trees in 46 species [40]. Facilities at City Park 1 BSD include the main entrance gate with signage, a parking area, a plaza with a small stage, a children's recreation and play area as well as an educational park, seating, a sports area with fitness equipment, a skatepark area, jogging track, bridge, toilet, and prayer room.

City Park 2 BSD is located on Jalan Tekno Widya, Ciater Village, Serpong District, South Tangerang, and it has 9 ha, consisting of 7 ha of open space and 2 ha of rivers. City Park 2 BSD was established in 2006. The topographic condition of City Park 2 BSD varies relatively from flat to quite steep, around 2–25%. The average daily noise level was 50.71 dB with a sunlight intensity of 1,282.7 lux. The average air temperature was 28.4 °C and the average humidity was 74% with a wind speed of 0.7 m s^{-1} [41]. Tree species were dominated by shade plants with 722 trees in 40 species [40]. Facilities at City Park 2 BSD include a parking area, bridge, welcome area, amphitheater, plaza, gazebo, seating, prayer room, toilet, jogging track, sports area with fitness equipment, children's play area, skatepark area, food court, sitting area, lake view deck, and gateball field. The problems faced are the illegal buildings of street vendors and the accumulation of rubbish [42].

3.2. Respondent Characteristics

Respondents were visitors who carried out recreational activities at City Park 1 BSD and City Park 2 BSD. Respondent characteristics were similar between the two GOS locations. Most respondents were adults (19–44 years) with 36 each (70.59%) in City Park 1 BSD and 35 (67.32%) in City Park 2 BSD. Adult visitors need interaction between physical exercise and using GOS environmental services for health [43]. In addition, physical activity in GOS in the medium to long term can make a person fitter and have an ideal body weight [44]. Women constitute most visitors, 28 (54.90%) at City Park 1 BSD with 27 (51.92%) at City Park 2 BSD. Women prefer carrying out social activities in GOS [45].

Most respondents' last education in City Park 1 BSD was Junior High School/equivalent and High School/equivalent, 15 (29.41%). In contrast, most respondents' last education in City Park 2 BSD was High School/equivalent, 27 (51.92%). The respondents' occupations were dominated by students, with 22 person (43.14%) and 26 person (50%), respectively. Students busy with academic activities, both in the classroom and outside, can experience fatigue and decreased mental health, so it is necessary to improve students' physiological and psychological health and the perception of quality of life through recreation in GOS [46].

Most respondents came from South Tangerang, as many as 31 person (60.78%) in City Park 1 BSD and 23 person (44.23%) in City Park 2 BSD. South Tangerang GOS is an alternative location for exercise or picnics that is cheap, comfortable and has easy accessibility. Most visits to City Park 1 BSD were once a month, as many as 21 person (41.18%), while City Park 2 BSD was dominated by once a week, as many as 15 person (28.85%). Most respondents visited City Park 1 BSD and City Park 2 BSD to carry out recreational activities in the form of picnics, 20 (39.22%) and 18 (34.62%).

3.3. Inventory Analysis

Inventory analysis includes inputs and outputs released into the environment during the life cycle. Most respondents used motorized vehicles, as many as 29 (58.86%) in City Park 1 BSD and 42 (80.77%) in City Park 2 BSD. Most respondents use motorbikes for ease of parking and efficiency. Respondents using motorbikes with two passengers were 21 (41.18%) in City Park 1 BSD and 31 (59.62%) in City Park 2 BSD. Most of the vehicles used were petrol-fueled, as many as 46 respondents (90.20%) in City Park 1 BSD and 47 respondents (90.38%) in City Park 2 BSD. Most respondents used 1,500 cc with 14 (27.45%) in City Park 1 BSD, while in City Park 2 BSD, the majority had 125 cc with 19 (36.54%). Cubic centimeter (CC) describes the capacity (volume) of the cylinder in a motor vehicle engine. The larger the cylinder capacity, the greater the exhaust gas emissions tend to be [47]. All respondents (100%) in City Park 1 BSD did not use vehicles for recreational activities in GOSs, while in City Park 2 BSD there were 49 respondents (94.23%).

Most respondents did not use the toilet in city parks, with 32 (62.75%) in City Park 1 BSD and 42 (80.77%) in City Park 2 BSD, respectively. This is because, on average, respondents to city parks only come for a short time, so they do not need a toilet. Most respondents did not wash their hands with soap during activities in GOSs, as many as 44 (86.27%) in City Park 1 BSD and 50 (96.15%) in City Park 2 BSD. Visitors generally use hand sanitizer or wet wipes to clean their hands.

Respondent input data was taken based on recreational activity patterns. Inputs of recreational activities include gasoline and diesel fuel, electrical energy, urine, soap, and organic and inorganic solid waste (Table 2).

Table 2. The magnitude of respondents' recreational activity input

No.	Activity	Input	Unit	City Park 1 BSD	City Park 2 BSD
1	Transportation				
a	Visitor	Gasoline	litre	28.38	17.39
	(Home-GOS; Round Trip)	Diesel	litre	0.51	0
b	Waste disposal (GOS-FDS)	Diesel	litre	4.27	1.98
2	Activities in GOS				
a	Eating and drinking	Organic solid waste	kg	0.003	0.73
		Inorganic solid waste	kg	0.96	0.91
b	Toilet use	Urine	litre	5.87	2.67
		Soap	litre	0.05	0.01
		Electricity	kWh	0.36	0

The outputs produced are CO_2, N_2O, CH_4, SO_2, NO_2, and PO_4^{3-} (Table 3). The greater the amount of input brought in, the higher the emissions that will be produced. The biggest input is the use of transportation by visitors.

Table 3. The magnitude of emissions from respondents' recreational activities

No.	Activity	Emission type	Unit	The magnitude of emissions		Emission total
				City Park 1 BSD	City Park 2 BSD	
1	Transportation					
a	Visitor (Home- GOS; Round Trip)	CO_2	kg CO_2	49.99	43.89	93.88
		N_2O	kg N_2O	2.31×10^{-3}	2.03×10^{-3}	4.34×10^{-3}
		CH_4	kg CH_4	2.34×10^{-2}	2.09×10^{-2}	4.43×10^{-2}
		SO_2	kg SO_2	4.30×10^{-2}	3.78×10^{-2}	8.07×10^{-2}
		NO_2	kg NO_2	9.53×10^{-4}	8.37×10^{-4}	1.79×10^{-3}
b	Waste disposal (GOS-FDS)	CO_2	kg CO_2	11.39	5.28	16.67
		N_2O	kg N_2O	5.99×10^{-4}	2.78×10^{-4}	8.77×10^{-4}
		CH_4	kg CH_4	5.99×10^{-4}	2.78×10^{-4}	8.77×10^{-4}
		SO_2	kg SO_2	9.16×10^{-3}	4.25×10^{-3}	1.34×10^{-2}
		NO_2	kg NO_2	2.03×10^{-4}	9.42×10^{-5}	2.97×10^{-4}
2	Activities in GOS					
a	Eating and drinking					
	Organic solid waste	CH_4	kg CH_4	1.25×10^{-3}	0.29	0.29
		N_2O	kg N_2O	3.70×10^{-6}	3.17×10^{-4}	3.21×10^{-4}
	Organic solid waste	CH_4	kg CH_4	3.36×10^{-2}	3.17×10^{-2}	6.53×10^{-2}
b	Toilet use					
	Urine	CH_4	kg CH_4	1.13×10^{-3}	5.14×10^{-4}	1.64×10^{-3}
		PO_4^{3-}	kg PO_4^{3-}	9.95×10^{-5}	4.52×10^{-5}	1.45×10^{-4}
	Soap	CH_4	kg CH_4	6.20×10^{-6}	1.40×10^{-6}	7.50×10^{-6}
		PO_4^{3-}	kg PO_4^{3-}	5.00×10^{-7}	1.00×10^{-7}	7.00×10^{-7}
	Electricity	CO_2	kg CO_2	0.30	0	0.30
		SO_2	kg SO_2	2.92×10^{-3}	0	2.92×10^{-3}
		NO_2	kg NO_2	1.50×10^{-3}	0	1.50×10^{-3}

3.4. Contribution of Recreational Activities to Environmental Impacts

Global warming potential emissions from recreation are in the form of CO_2, N_2O, and CH_4 [31]. The largest type of emission is CO_2. The magnitude of emissions of the main gases causing GWP in City Park 1 BSD and City Park 2 BSD are as in Table 4.

Table 4. The magnitude of emissions causing GWP from respondents' recreational activities in City Park 1 BSD and City Park 2 BSD

Emission type	Source impact	City Park 1 BSD	City Park 2 BSD
		(kg CO_2eq)	
CO_2	Electricity	0.30	0
	Visitor transportation fuel	49.99	43.89
	Waste disposal transportation fuel	11.39	5.28
N_2O	Visitor transportation fuel	0.69	0.60
	Waste disposal transportation fuel	0.18	8.28×10^{-2}
	Organic solid waste	1.11×10^{-3}	9.45×10^{-2}
CH_4	Visitor transportation fuel	0.59	0.52
	Waste disposal transportation fuel	1.50×10^{-2}	6.95×10^{-3}
	Inorganic solid waste	0.84	0.79
	Organic solid waste	3.13×10^{-2}	7.29
	Urine	2.83×10^{-2}	1.28×10^{-2}
	Soap	1.54×10^{-4}	3.42×10^{-5}

Acidification emissions from recreational activities are in the form of SO_2 dan NO_2. The largest type of emission is SO_2. The magnitude of emissions that cause acidification from respondents' recreational activities in City Park 1 BSD and City Park 2 BSD is as in Table 5.

Table 5. The magnitude of emissions that cause acidification from respondents' recreational activities in City Park 1 BSD and City Park 2 BSD

Emission type	Source impact	City Park 1 BSD	City Park 2 BSD
		(kg SO_2eq)	
SO_2	Electricity	2.92 x 10^{-3}	0
	Visitor transportation fuel	4.30 x 10^{-2}	3.78 x 10^{-2}
	Waste disposal transportation fuel	9.16 x 10^{-3}	4.25 x 10^{-3}
NO_2	Electricity	1.05 x 10^{-3}	0
	Visitor transportation fuel	6.67 x 10^{-4}	5.86 x 10^{-4}
	Waste disposal transportation fuel	1.42 x 10^{-4}	6.60 x 10^{-5}

Eutrophication emissions from recreational activities are in the form of PO_4^{3-} dan NO_2. The largest type of emission is NO_2. The magnitude of emissions that cause eutrophication from respondents' recreational activities in City Park 1 BSD and City Park 2 BSD is as in Table 6.

Table 6. The magnitude of emissions that cause eutrophication from respondents' recreational activities in City Park 1 BSD and City Park 2 BSD

Emission type	Source impact	City Park 1 BSD	City Park 2 BSD
		(kg PO_4^{3-}eq)	
PO_4^{3-}	Urine	9.95 x 10^{-5}	4.52 x 10^{-5}
	Soap	5.00 x 10^{-7}	1.00 x 10^{-7}
NO_2	Electricity	1.95 x 10^{-4}	0
	Visitor transportation fuel	1.24 x 10^{-4}	1.09 x 10^{-4}
	Waste disposal transportation fuel	2.64 x 10^{-5}	1.23 x 10^{-5}

3.5. Interpretation of Results

The final stage in the LCA study is interpretation stage. Recreational activities in City Park 1 BSD contribute to GWP of 64.05 kg CO_2eq, followed by acidification of 5.69 x 10^{-2} kg SO_2eq, and eutrophication of 4.45 x 10^{-4} kg PO_4^{3-}eq. Recreational activities in City Park 2 BSD have a total GWP impact value of 58.57 kg CO_2eq, followed by acidification of 4.27 x 10^{-2} kg SO_2eq, and eutrophication of 1.66 x 10^{-4} PO_4^{3-}eq. Overall, the impact values of GWP, acidification, and eutrophication in City Park 1 BSD are greater than in City Park 2 BSD (Table 7). The largest main source of emissions (hotspots) resulting from the impact of GWP, acidification, and eutrophication is the use of transportation by visitors, with the GWP impact being the largest value. GWP is the largest impact compared to other impacts with transportation as the largest contributor to environmental impacts [17].

Table 7. GWP, acidification, and eutrophication emission magnitude from recreational activities in City Park 1 BSD and City Park 2 BSD

Impact category	Unit	Emission magnitude	
		City Park 1 BSD	City Park 2 BSD
GWP	kg CO_2eq	64.05	58.57
Acidification	kg SO_2eq	5.69 x 10^{-2}	4.27 x 10^{-2}
Eutrophication	kg PO_4^{3-}eq	4.45 x 10^{-4}	1.66 x 10^{-4}

The estimated number of visitors at City Park 1 BSD is 57,890 persons year^{-1}, while at City Park 2 BSD it is 54,669 persons year^{-1}. The average emissions from each visitor in one visit and the annual emission value at City Park 1 BSD and City Park 2 BSD have the greatest GWP impact compared to acidification and eutrophication (Table 8). Visitors to City Park 1 BSD tend to emit greater emissions than City Park 2 BSD.

Table 8. GWP, acidification, and eutrophication emission magnitude from recreational activities in City Park 1 BSD and City Park 2 BSD

Impact category	Unit	Emission magnitude			
		City Park 1 BSD		City Park 2 BSD	
		Emissions per person per visit (kg per person per visit)	Emissions per year (kg $year^{-1}$)	Emissions per person per visit (kg per person per visit)	Emissions per year (kg $year^{-1}$)
GWP	kg CO_2eq	1.26	72,702.07	1.13	61,520.87
Acidification	kg SO_2eq	1.12×10^{-3}	64.57	8.20×10^{-4}	44.84
Eutrophication	kg PO_4^{3-}eq	6.30×10^{-6}	0.37	1.10×10^{-6}	6.06×10^{-2}

4. Discussion

4.1. Contribution of Recreational Activities to Environmental Impacts

Global Warming Potential (GWP) is a measure of the impact of various Greenhouse Gases (GHG) on warming the earth. Increasing GHG emissions in the atmosphere create a blanket around the earth, blocking the escape of heat from solar energy that is not reflected outside the earth [48]. The increase in anthropogenic greenhouse gas emissions significantly contributes to rising temperatures on the earth's surface which causes global warming, rising sea levels, increasing atmospheric storms, changes in wind patterns, rain and hydrological cycles which disrupt the environment [49,50].

CO_2 emissions contribute the most to GWP in City Park 1 BSD and City Park 2 BSD. The biggest contributor to CO_2 emissions comes from using fuel in visitor transportation. Then, CH_4 emissions also show a greater impact than N_2O. The largest GWP impact generator based on its emission source is City Park 1 BSD, respectively, from the largest, namely transportation used by visitors and managers who require fuel, inorganic solid waste, electricity, organic solid waste, urine, and soap.

The largest sources of emissions in City Park 2 BSD are visitor transportation fuel, organic solid waste, waste disposal transportation fuel, inorganic solid waste, urine, soap, and electricity. Most of the organic and inorganic solid waste disposed of by visitors is only one unit. In contrast, liquid waste depends on the intensity of soap and toilet use, which is rare, so the GWP impact value is relatively low. The largest carbon footprint value in recreational activities is visitor transportation compared to food, accommodation, and recreational activities [51].

Acidification is one of the environmental impacts caused by human activities which produces SO_2 and NO_x emissions [52]. Acidification is caused by the leaching of heavy metals in soil and water which increases the concentration of hydrogen ions, thereby lowering the pH. The negative impact is disruption of the food network between animals and plants, both on land and in waters [53]. In addition, when acidification occurs, many organisms must add energy to maintain acid-base balance, metabolism, and other biological functions, thereby affecting growth, reproduction, and survival [54].

SO_2 emissions contribute more than NO_2 as a cause of acidification in City Park 1 BSD and City Park 2 BSD. The highest SO_2 value is influenced by the presence of fuel in the transportation visitors use. The largest producers of acidification impacts based on their emission sources are City Park 1 BSD and City Park 2 BSD, respectively, namely visitor transportation, waste disposal transportation, and electricity. City Park 2 BSD has no electricity emission value because it does not use electricity during the day, whereas City Park 1 BSD uses 2 lights for the toilet.

Eutrophication is a phenomenon in waters where nutrients are excess due to chemicals from fertilizers or wastewater discharge, thereby triggering rapid algae growth. The main pollutants that cause eutrophication are PO_4^{3-} and NO_x. Increasing PO_4^{3-} and NO_x in the environment causes the activity of microorganisms also to increase, resulting in increased oxygen consumption [54]. This causes the red tide phenomenon due to a surge in nutrients, thereby depleting oxygen in the water (hypoxia) and decreasing water quality [55].

NO_2 emissions have a higher eutrophication impact on the environment than PO_4^{3-} in both city parks. This is due to the use of fuel, which causes higher NO_2 pollution than liquid waste. The largest producers of eutrophication impacts based on their emission sources are City Park 1 BSD, respectively from the largest to the largest, namely visitor transportation, urine, electricity, waste disposal transportation, and soap. City Park 2 BSD has a eutrophication impact based on emission sources, namely visitor transportation, urine, waste disposal transportation, soap, and electricity.

4.2. Recommendations for Environmental Impact Control Scenarios

4.2.1. Scenario 1: Restrictions on motor vehicle use

The use of fossil fuel transportation impacts the environment in the form of GWP, acidification, and eutrophication. The increasing number of motorized vehicles in urban areas results in a decrease in the quality of urban life in the form of decreased air quality, increased stress due to traffic jams, and reduced physical health due to spending more time in vehicles [56]. The control scenario implemented is that visitors who live ≤ 5 km away can use bicycles as vehicles when visiting city parks with the reduced impacts of GWP, acidification, and eutrophication as in Table 9.

Table 9. Reducing the impact of GWP, acidification, and eutrophication from Scenario 1

Impact category	Data	Emission value	
		City Park 1 BSD	City Park 2 BSD
GWP (kg CO_2eq year^{-1})	Calculation	58,194.37	47,324.93
	Scenario 1	56,037.06	45,816.27
	Reduced impact	2,157.31	1,508.66
	Percentage	3.71%	3.19%
Acidification (kg SO_2eq year^{-1})	Calculation	49.51	40.31
	Scenario 1	47.67	39.02
	Reduced impact	1.84	1.28
	Percentage	3.71%	3.19%
Eutrophication (kg PO_4^{3-}eq year^{-1})	Calculation	0.14	0.11
	Scenario 1	0.14	0.11
	Reduced impact	5.22×10^{-3}	3.65×10^{-3}
	Percentage	3.71%	3.19%

The impact of GWP, acidification, and eutrophication on City Park 1 BSD decreased by 3.71%, while City Park 2 BSD experienced a reduction of 3.19%. Besides reducing various environmental impacts, cycling can benefit the user's health. Physical bicycle activity can reduce the risk of physical and psychological disease [57,58].

4.2.2. Scenario 2: Plastic waste reduction

Plastic is a familiar and easily available material, such as food and drink packaging, in everyday life. The high demand for plastic will cause the amount of plastic waste to increase. South Tangerang Mayor Regulation Number 83 of 2022 concerning Reducing Plastic Waste states that the community is expected to implement plastic waste reduction actively. One way to do this is using environmentally friendly shopping bags, bringing drinking bottles, and avoiding buying food and drinks in plastic packaging. The reduction in GWP impact from the plastic waste reduction scenario for recreational activities in City Park 1 BSD and City Park 2 BSD is presented in Table 10.

The reduction in the GWP impact in City Park 1 BSD is very significant at 94.78%, while in City Park 2 BSD, there will be a decrease of 9.71% (Table 10). City Park 2 BSD has a lower percentage because most visitors use organic materials as food packaging than inorganic materials (plastic). Guidance and supervision of the prohibition on using single-use plastic shopping bags in the environment must be carried out [59]. Small businesses or people selling in GOSs must provide environmentally friendly shopping bags. Education for the public on the use of environmentally friendly materials must be provided so that it becomes a habit and even a culture [60]. In addition, reducing plastic waste can also be done with a policy from eating places or drink sellers that do not use plastic straws or cutlery and replace them with more environmentally friendly materials such as paper, bamboo, and stainless steel.

Table 10. Reducing the impact of GWP from Scenario 2

Impact category	Data	Emission value	
		City Park 1 BSD	City Park 2 BSD
GWP (kg CO_2eq year^{-1})	Calculation	989.03	8,593.86
	Scenario 2	51.64	7,759.57
	Reduced impact	937.39	834.29
	Percentage	94.78%	9.71%

5. Conclusions

Inputs (materials) inventoried from recreational activities are gasoline and diesel fuel, electrical energy, urine, soap, and organic and inorganic solid waste. The outputs of transportation activities are CO_2, N_2O, CH_4, SO_2, and NO_2; emissions of organic waste processing are N_2O and CH_4; emissions of inorganic waste processing is CH_4; emissions of electricity use are CO_2, SO_2, and NO_2; as well as emissions of using toilets and soapy water are CH_4 and PO_4^{3-}. Recreational activities in City Park 1 BSD produce greater emissions than in City Park 2 BSD. Hotspots are the means of transportation used by visitors. Controlling this impact can be done by calling for restrictions on motorized vehicles for those living ≤ 5 km from green open space and reducing plastic waste.

Author Contributions

LAR: Writing & Editing; **RH:** Conceptualization, Review & Editing**; ER:** Analysis, Review.

Conflicts of Interest

There are no conflicts to declare.

Acknowledgements

The author appreciates the management of City Park 1 BSD, City Park 2 BSD, the Environmental Service of South Tangerang City, the National and Political Unity Agency of South Tangerang City, and the Tropical Biodiversity Conservation Study Program.

References

1. Rakhshandehroo, M.; Yusof, M.J.M.; Arabi, R.; Parva, M.; Nochian, A. The Environmental Benefits Of Urban Open Green Spaces. *Alam Cipta* **2017**, *10*, 10–16.
2. Kim, Y.; Manley, J.; Radoias, V. Air Pollution and Long Term Mental Health. *Atmosphere* **2020**, *11*, 1–12, doi:10.3390/atmos11121355.
3. Bakolis, I.; Hammoud R.; Stewart R.; Beevers S.; Dajnak D.; MacCrimmon S.; Broadbent M.; Pritchard M.; Shiode N.; Fecht, D.; et al. Mental Health Consequences of Urban Air Pollution: Prospective Population-Based Longitudinal Survey. *Social Psychiatry and Psychiatric Epidemiology* **2020**, *56*, 1587–1599, doi:10.1007/s00127-020-01966-x.
4. Hanani, E.S. The Study on Value of Recreational Sports Activity of Urban Communities. *Jurnal Kesehatan Masyarakat* **2017**, *12*, 96–101, doi:10.15294/kemas.v12i2.5813.

5. Chu, Y.; Li, D.; Chang, P. Effects of Urban Park Quality, Environmental Perception, and Leisure Activity on Well-Being Among the Older Population. *International Journal of Environmental Research and Public Health* **2021**, *18*, 1–14, doi:10.3390/ijerph182111402.
6. Kurniati, R.; Kurniawati, W.; Ristianti, N.S.; Syahri, E.K. Strategies for sustainable urban tourism in Kampoeng Batik, Semarang, Indonesia. *Journal of the International Society for the Study of Vernacular Settlements* **2023**, *10*, 1–23.
7. Kang, L.; Yang, Z.; Han, F. The Impact of Urban Recreation Environment on Residents' Happiness—Based on A Case Study in China. *Sustainability* **2021**, *13*, 1–14, doi:10.3390/su13105549.
8. Ambreen, R.; Ahmad, W.; Ali, Y.; Israr, M.; Manan, A. Impacts of Outdoor Recreation, on Health & Wellness of the People. *Journal of Positive School Psychology* **2022**, *6*, 635–642.
9. Gulam, A. Recreation- Need and Importance in Modern Society. *International Journal of Physiology, Nutrition and Physical Education* **2016**, *1*, 157–160.
10. Wajchman-Switalska, S.; Grabowska-Chenczke, O.; Wozniak, M. Exploring the Patterns of Recreational Activity among Urban Green Spaces in Poland. *Sustainability* **2023**, *15*, 1–16, doi:10.3390/su15065425.
11. Wang, R.; Zhao, J.; Meitner, M.J.; Hu, Y.; Xu, X. Characteristics of Urban Green Spaces in Relation to Aesthetic Preference and Stress Recovery. *Urban Forestry & Urban Greening* **2019**, *4*, 6–13, doi:10.1016/j.ufug.2019.03.005.
12. Ali, S.; Sulistiowati, R.; Wulandari, C.; Riniarti, M. Maximizing the Social-Economy Impacts of Urban Green Space in Several Cities in Indonesia. *IOP Conf. Series: Earth and Environmental Science 2021* **2021**, *918*, 1–8, doi:10.1088/1755-1315/918/1/012007.
13. Artianti, D.; Satiawan, PR. Penentuan tipologi permukiman di kawasan pinggiran Jakarta (Studi kasus: Kota Tangerang Selatan). *Jurnal Teknik ITS* **2020**, *9*, 209–215, doi:10.12962/j23373539.v9i2.56252.
14. Izzatuljannah, H.F.; Zakiah, A. Isu Polusi Udara Di Kota Tangerang Selatan. In Seminar Karya & Pameran Arsitektur Indonesia: Heritage Management in Time of Crisis (SAKAPARI) Ke-7, Yogyakarta, Indonesia, 20 February 2021; pp. 64–76.
15. Badan Pusat Statistik Kota Tangerang Selatan. *Kota Tangerang Selatan Dalam Angka 2023*; Badan Pusat Statistik Kota Tangerang Selatan: Tangerang Selatan, Indonesia, 2023.
16. Fitri, R.; Seanders, O.; Fauzi, R.; Pangaribowo, R.L. Analisis Ketersediaan Ruang Terbuka Hijau Di Kota Tangerang Selatan. *Jurnal Arsitektur Lansekap* **2022**, *8*, 119–126, doi:10.24843/JAL.2022.v08.i02.p13.
17. Campos, C.; Gallego, M.; Villanueva, P.; Laso, J.; Dias, A.C.; Quinteiro, P.; Oliveira, S.; Albertí, J.; Fullana-i-Palmer, P.; Melon, L.; *et al.*. Life Cycle Assessment to Address the Environmental Impacts of Tourism in A Spanish Tourist Destination: The case of Rias Baixas (Galicia) Holidays. *Science of the Total Environment* **2023**, *896*, 1–11, doi:10.1016/j.scitotenv.2023.166242.
18. Ahirwar, V.; Gupta, R.; Kumar, A. Impacts of Tourism on Development of Urban Areas in Indian Cities: A Systematic Literature Review. *Journal of Environmental Management and Tourism* **2023**, *14*, 2993–3005, doi:10.14505/jemt.v14.8(72).02.
19. Candia, S.; Pirlone, F. Tourism Environmental Impacts Assessment to Guide Public Authorities Towards Sustainable Choices for the Post-COVID Era. *Sustainability* **2022**, *14*, 1–16, doi:10.3390/su14010018.
20. Zhang, J.; Lu, Y. Exploring the Effects of Tourism Development on Air Pollution: Evidence from the Panel Smooth Transition Regression Model. *International Journal of Environmental Research and Public Health* **2022**, *19*, 1–19, doi:10.3390/ijerph19148442.
21. IQAir. Peta global interaktif konsentrasi $PM_{2,5}$ 2022 menurut kota. 2022. Available online: https://www.iqair.com/id/world-air-quality-report (accessed on 9 January 2024).
22. Meisyanti.; Rahmawati, K.J. Strategi Komunikasi Lingkungan dalam MENGATASI PENCEMARAN Air Sungai Cisadane. *Jurnal Komunikasi* **2021**, *13*, 69–88, doi:10.24912/jk.v13i1.9307.
23. Andari, R. Developing A Sustainable Urban Tourism. *The Journal: Tourism and Hospitality Essentials Journal* **2019**, *9*, 27–30, doi:10.17509/thej.v9i1.16986.
24. Tian, Y. Study on the Impact of Carbon Emission Pollution on Urban Tourism Environment. *Engineering Reports* **2022**, *5*, 1–8, doi:10.1002/eng2.12641.
25. Herrero, C.C.; Laso, J.; Cristóbal, J.; Fullana-i-Palmer, P.; Albertí, J.; Fullana, M.; Herrero, Á.; Margallo, M.; Aldaco, R. Tourism under a life cycle thinking approach: A Review of Perspectives and New Challenges for the Tourism

Sector in the Last Decades. *Science of the Total Environment* **2022**, *845*, 1–14, doi:10.1016/j.scitotenv.2022.157261.

26. Moutik, B.; Summerscales, J.; Graham-Jones, J.; Pemberton, R. Life Cycle Assessment Research Trends and Implications: A Bibliometric Analysis. *Sustainability* **2023**, *15*, 1–45, doi:10.3390/su151813408.
27. Putra, R.P.H.; Defit, S.; Sumijan. Analisis Sistem Antrian dalam Meningkatkan Efektivitas Pelayanan Menggunakan Metode Accidental Sampling. *Jurnal Sistim Informasi dan Teknologi* **2022**, *4*, 70–75, doi:10.37034/jsisfotek.v4i2.127.
28. Levy, S.; Lemeshow, S. *Sampling of Populations: Methods and Applications*; John Wiley & Sons: Hoboken, New Jersey, USA, 2008.
29. Standar Nasional Indonesia. *SNI ISO 14040 Manajemen Lingkungan — Penilaian Daur Hidup — Prinsip dan Kerangka Kerja*; Badan Standardisasi Nasional: Jakarta, Indonesia, 2016.
30. Veselkova, A. Life-Cycle Assessment of International Vacation Packages. Thesis, Norwegian University of Science and Technology, Trondheim, Norway, 2014.
31. Intergovernmental Panel on Climate Change (IPCC). *IPCC Guidelines for National Greenhouse Gas Inventories*; Institute for Global Environmental Strategies (IGES): Kanagawa, Japan, 2006.
32. Wulandari, N.K.R.; Madrini, I.A.G.B.; Wijaya, I.M.A.S. Efek Penambahan Limbah Makanan terhadap C/N Ratio pada Pengomposan Limbah Kertas. *Jurnal Beta (Biosistem dan Teknik Pertanian)* **2020**, *8*, 103–112, doi:10.24843/JBETA.2020.v08.i01.p13.
33. Negara, D.N.K.P.; Nindhia, T.G.T.; Surata, I.W.; Sucipta, M. Potensi Bambu Swat (*Gigantochloa verticillata*) sebagai Material Karbon Aktif untuk Adsorbed Natural Gas (ANG). *Jurnal Energi dan Manufaktur* **2016**, *9*, 174–179.
34. Suriani, H. Pengaruh Pemberian Pupuk Kompos Daun Pisang (*Musa paradisiaca* L) terhadap Pertumbuhan Tinggi Tanaman Sawi Hijau (*Brassica juncea* L). *Journal on Education* **2023**, *5*, 15409–15416.
35. Ursada, R.; Bagastyo, A.Y. Kombinasi Elektrodialisis dan Presipitasi dalam Recovery Amonium dan Fosfat Dari Limbah Urin. *Jurnal Teknik ITS* **2021**, *10*, 76–81, doi:10.12962/j23373539.v10i2.65107.
36. Wahyudi.; Mustafa.; Harjanto.; Samosir, D. Analisis Laju Alir Umpan terhadap Penurunan COD dan TSS Limbah Cair Pembuatan Sabun dengan Metode Biofilter Aerob. *Prosiding Seminar Nasional Teknologi Industri X* **2023**, *10*, 189–194.
37. Putt, D.P.S.; Bhatia, P. *Working 9 to 5 on Climate Change: an Office Guide*. World Resource Institute: Washington DC, USA, 2002.
38. Australian Institute for Petroleum. *Oil and Australia, Statistical Review*; Petroleum Gazette: Australia, 1996.
39. Heijungs, R.; Guinee, J.B.; Huppes, G.; Lankreijer, R.M.; Haes, H.A.; Sleeswijk, A.W.; Ansems, A.M.M.; Eggels, A.M.M.; Duin, V.; Goede, H.W. *Environmental Life Cycle Assessment of Products - Guidelines and Backgrounds*; Centre of Environmental Science (CML): Leiden, The Netherlands, 1992.
40. Isnaniyah, R. Evaluasi Tingkat Kenyamanan dan Estetika Taman Kota BSD City Tangerang Selatan. Undergraduate Thesis, Bogor Agricultural University, Bogor, Indonesia, 2021.
41. Putri, S.A. Potensi Healing Forest di Taman Kota 2 Bumi Serpong Damai City, Tangerang Selatan. Undergraduate Thesis, Bogor Agricultural University, Bogor, Indonesia, 2023.
42. Asti, A.P.; Wirawati, S.; Tjung, L.J. Strategi Pengelolaan Taman Kota sebagai Destinasi Wisata (Objek Studi: Taman Kota 2 BSD, Kota Tangerang Selatan). *Jurnal STUPA* **2021**, *3*, 3413–3424, doi:10.24912/stupa.v3i2.12899.
43. Khansa, S.M.; Dewi, O.C.; Salsabila, N.D.; Viriezky, V. Reviewing the Role of Green Open Spaces' Feature in Promoting Physical Activity. *IOP Conf. Series: Earth and Environmental Science 2023* **2023**, *918*, 1–6, doi:10.1088/1755-1315/918/1/012007.
44. Jakicic, J.M.; Powell, K.E.; Campbell, W.W.; Dipietro, L.; Pate, R.R.; Pescatello, L.S.; Collins, K.; Bloodgood, B.; Piercy, K.L. Physical Activity and the Prevention of Weight Gain in Adults: A Systematic Review. *Medicine & Science in Sports & Exercise* **2019**, *51*, 1262–1269, doi:10.1249/MSS.0000000000001938.
45. Ayuningtyas, A.H.; Setiawan, R.P. Perbedaan Karakteristik Kunjungan ke Ruang Terbuka Hijau di Masa Pandemi Covid-19: Studi Kasus Taman Kota di Kota Bekasi. *Jurnal Perencanaan Pembangunan Wilayah dan Perdesaan* **2022**, *6*, 165–175, doi:10.29244/jp2wd.2022.6.2.165-175.

46. Migl, W.; Mathis, H.; Spencer, M.; Hernandez, R.; Maddock, J.E. Undergraduate College Students' Awareness and Perception of Nature - A Photovoice Study. *BMC Public Health* **2023**, *23*, 1–8, doi:10.1186/s12889-023-17455-0.
47. Pambayun, N.A.Y.; Sukoco.; Suyanto, W.; Sudarwanto. Konsep Modifikasi untuk Meningkatkan Daya Mesin Sepeda Motor. *Jurnal Pendidikan Vokasi Otomotif* **2018**, *1*, 38–53, doi:10.21831/jpvo.v1i1.21782.
48. Al-Yasiri, Q.; Géczi, G. Global Warming Potential: Causes and Consequences. *Academia Letters* **2021**, *3202*, 1–10, doi:10.20935/AL3202.
49. Ai, K.; Yan, X. Can Green Infrastructure Investment Reduce Urban Carbon Emissions: Empirical Evidence from China. *Land* **2024**, *13*, 1–18, doi:10.3390/land13020226.
50. Kementerian Lingkungan Hidup. *Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional Buku 1*; Kementerian Lingkungan Hidup: Jakarta, Indonesia, 2012.
51. Cao, R.; Mo, Y.; Ma, J. Carbon Footprint Analysis of Tourism Life Cycle: the Case of Guilin from 2011 to 2022. *Sustainability* **2022**, *15*, 1–17, doi:10.3390/su15097124.
52. Marendra, F.; Rahmada, A.; Prasetya, A.; Cahyono, R.B.; Ariyanto, T. Kajian Dampak Lingkungan pada Sistem Produksi Listrik dari Limbah Buah Menggunakan Life Cycle Assessment. *Jurnal Rekayasa Proses* **2018**, *12*, 85–97, doi:10.22146/jrekpros.36425.
53. Kim, T.H.; Chae, C.U. Environmental Impact Analysis of Acidification and Eutrophication due to Emissions from the Production of Concrete. *Sustainability* **2016**, *8*, 1–20, doi:10.3390/su8060578.
54. Falkenberg, L.J.; Bellerby, R.G.J.; Connel, S.D.; Fleming, L.E.; Maycock, B.; Russell, B.D.; Sullivan, F.J.; Dupont, S. Ocean Acidification and Human Health. *International Journal of Environmental Research and Public Health* **2020**, *17*, 1–18, doi:10.3390/ijerph17124563.
55. Xia, R.; Zhang, Y.; Critto, A.; Wu, J.; Fan, J.; Zheng, Z.; Zhang, Y. The Potential Impacts of Climate Change Factors on Freshwater Eutrophication: Implications for Research and Countermeasures of Water Management in China. *Sustainability* **2016**, *8*, 1–17, doi:10.3390/su8030229.
56. Sidjabat, S. Sepeda sebagai Alat Transportasi Ramah Lingkungan. *Jurnal Manajemen Bisnis Transportasi dan Logistik* **2016**, *3*, 117–122, doi:10.54324/j.mbtl.v3i1.926.
57. Laird, Y.; Kelly, P.; Brage, S.; Woodcock, J. *Cycling and Walking for Individual and Population Health Benefits*; Public Health England: London, England, UK, 2018.
58. Green, S.; Sakuls, P.; Levitt, S. Cycling for Health Improving and Mitigating the Climate Crisis. *Canadian Family Physician* **2021**, *67*, 739–742, doi:10.46747/cfp.6710739.
59. Peraturan Wali Kota Tangerang Selatan Nomor 83 Tahun 2022 Tentang Pengurangan Plastik Sampah. 2022.
60. Kusumo, R.A.B.; Charina, A.; Sukayat, Y.; Mukti, G.W. Kajian Edukasi Ramah Lingkungan dan Karakteristik Konsumen serta Pengaruhnya terhadap Sikap dan Perilaku Ramah Lingkungan. *Jurnal Ilmu Keluarga & Konsumen* **2017**, *10*, 238–249, doi:10.24156/jikk.2017.10.3.238.