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Estimating CO_2 Storage and Absorption of Trees in Urban Parks: Case Study of Daejeon-si, Republic of Korea

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Many countries worldwide are experiencing natural disasters that have not been experienced in the past owing to abnormal weather caused by climate change, resulting in considerable economic damage and human casualties. Global warming, which is the increase in Earth's temperature due to the greenhouse effect primarily caused by carbon emissions to the atmosphere, is considered as the main cause. Thus, various international agreements are being promoted to reduce carbon emissions. The Republic of Korea (ROK) is also abiding with these international agreements and enacting and enforcing related and fundamental laws in response to international trends. To reduce carbon emissions, the management and composition of existing and new carbon sinks are being highlighted, and urban park green areas play an essential role as existing carbon sinks. Research is needed to understand how urban parks can contribute to carbon neutrality and the importance of local government units that manage these urban parks. Therefore, in this study, we aim to quantitatively analyze the current status of CO_2 storage and absorption of trees in urban parks on the basis of tree survey data obtained from representative urban parks located in Daejeon-si, the target site of this study. The methodology for analyzing the amounts of CO_2 storage and absorption was applied in two ways by referring to previous studies, and the reliability of the results was reviewed to confirm the appropriate methodology. In addition, on the basis of the amounts of CO_2 storage and absorption per unit area of the park derived through analysis, the amounts of CO_2 storage and absorption of trees in urban parks for the entire city of Daejeon-si were estimated. As a result of this study, the amounts of CO_2 storage and absorption of 1931 ha of 557 established parks, parks under construction, and unconstructed parks in Daejeon-si were calculated as 492096 tCO_2/ha and 18498 tCO_2/ha/y, respectively. The storage and absorption of CO_2 per unit area in this study are expected to be used as data for climate change response, carbon neutrality measures, and decision-making.

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1. Introduction

Climate change and the greenhouse effect are currently two of the most serious environmental concerns in the world, and efforts to reduce greenhouse gas emissions related to climate change, including the UNCHE (1972), UNCED (1992), Kyoto Protocol (2005), Bali Roadmap (2007), 34th G8 Summit (2008), Durban Platform (2012), and Paris Climate Agreement (2015), have been promoted through various international agreements. The Paris Climate Agreement (2015), which the UN General Assembly recently adopted as a new system to replace the Kyoto Protocol (2005), imposes a reduction obligation on all parties, unlike existing agreements centered on advanced countries.(1) As the Republic of Korea (ROK) government declared carbon neutrality in 2020, the importance of carbon sinks in cities has been highlighted.(2)

Urban green spaces, including trees and soil, play vital roles as carbon sinks to delay or mitigate the effects of climate change as they take in atmospheric carbon and contribute to soil carbon accumulation during the growth of park trees. The dependence of ROK on overseas energy imports is 96.5%, making it difficult to respond to the new climate system only by reducing carbon emissions owing to energy saving.(3) Therefore, there is a need for a plan to expand carbon sinks through the efficient creation and management of urban green spaces, breaking away from the conventional energy-saving.

In many foreign countries, inventories that include tree species, specifications, and management of tree planting in urban green spaces have been established. Computer programs such as i-Tree, which can quickly evaluate the multivariable benefits of urban green spaces, have been developed and used to establish guidelines and policies for creating urban green spaces. In the case of ROK, research on the primary unit and measurement model required for evaluating the multiple benefits of each urban green space type is reinforced. It is necessary to develop an evaluation method for various benefits (temperature reduction, resource production, flood control, etc.) that conforms to the characteristics and structure of domestic urban green spaces and an optimal composition and management technology to enhance these benefits.

Amid the growing importance of urban green spaces, various studies are being conducted to analyze the CO_2 storage and absorption of trees in urban parks. In ROK, several studies were conducted to analyze the CO_2 storage and annual CO_2 absorption of belt trees for land use in the early 2000s,(4–6) and since then, more studies have been conducted to evaluate the CO_2 absorption of trees in urban parks.(7–12) However, there were limitations in that the study subjects were focused on some tree species, and the amounts of CO_2 storage and absorption varied depending on the region; thus, continuous future research is required.

After examining previous studies,(13,14) we found that the analyses conducted in ROK, unlike overseas studies, are insufficient for estimating the amounts of CO_2 storage and absorption at the level of administrative districts such as urban units. This is because the studies conducted in ROK mainly focused on improving the accuracy of CO_2 uptake measurement for specific tree species. To achieve carbon neutrality, it is necessary to determine the amounts of CO_2 storage and absorption of trees in the city as a whole and a method to improve it. Therefore, even if the accuracy is somewhat low, research is necessary to prepare a basis to help city-level, carbon-neutral decision-making.

In this study, the following research goals were set. First, the current CO_2 storage and absorption status was quantitatively analyzed using tree survey data from representative urban parks in Daejeon-si. Second, on the basis of the CO_2 storage and absorption information derived for trees in representative urban parks, we tried to calculate the CO_2 storage and absorption of all the trees in the urban parks existing in Daejeon-si. In this process, the CO_2 storage and absorption in the three types of urban park (established parks, under-construction parks, and undeveloped parks) were compared and reviewed to derive the quantitative effect of trees in urban parks on CO_2 storage and absorption. The results of this study can be utilized as primary data for decision-making when establishing measures to respond to climate change locally and achieve carbon neutrality.

2. Methods

2.1 Scope of study

The spatial scope of this study is Daejeon-si, located in the south-central part of Chungcheong-do at a latitude of 36.35111 and a longitude of 127.385. Like other local governments units, Daejeon-si established a greenhouse gas reduction roadmap in 2018, starting with the 2015 greenhouse gas emission trading system.(15) Daejeon-si is steadily promoting policy measures for greenhouse gas generation and reduction by participating in the national greenhouse gas reduction policy. The "2050 Carbon Neutral" declaration aims to make net greenhouse gas emissions "zero" by 2050 with five key points: greenhouse gas reduction for buildings, transportation, energy, civic cooperation, and offsetting greenhouse gases among urban forests (Fig. 1).

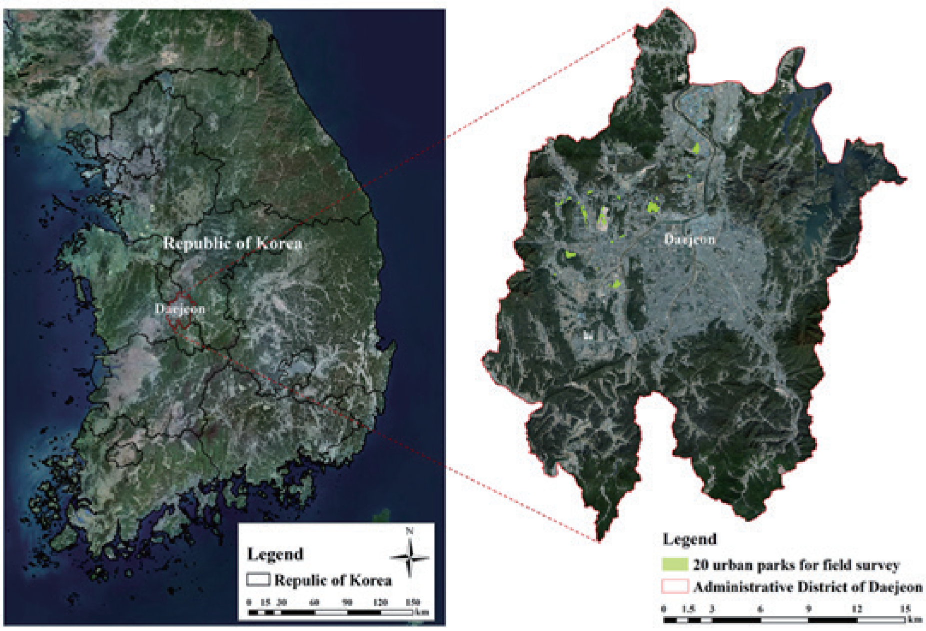

Fig. 1. (Color online) Study site.

The temporal range of the study was set to 2021, the year in which tree survey data were obtained from urban parks in Daejeon-si. The detailed scope of the research analysis is 20 urban parks where tree surveys were conducted. On the basis of the CO_2 storage and absorption figures of urban parks derived from the results of this study, three types of park existing in Daejeon-si, namely, undeveloped parks, under-construction parks, established parks, were studied to understand the amounts of CO_2 storage and absorption of trees in urban parks throughout the city (Fig. 2). The purpose of analyzing the three types of park is as follows. To improve the amounts of CO_2 storage and absorption in Daejeon-si, we will support decision-making on park management by comparing the amounts of storage and absorption and by managing existing parks, quickly completing the parks under construction, and creating new parks.

In this study, the Forest Service(16) method was used instead of the CO_2 absorption estimation method provided by the Intergovernmental Panel on Climate Change (IPCC). The reason was that the method provided by IPCC is an internationally standardized method. Accordingly, it was considered that there was a limit to reflecting the regional characteristics of ROK. Therefore, by using the research methodology developed in ROK, we intended to apply a methodology suitable for the tree habitat conditions of the target site.

2.2 Database of trees in urban parks

Information on trees in urban parks in ROK is insufficient to estimate CO_2 storage and absorption. Currently, statistical data on urban parks and green areas across the country exist, but it is challenging to calculate emission factors because there is no information on the number of trees, species, and forest age. In the case of Daejeon-si, tree survey information on 20 representative urban parks is being established through park information collection research. As of 2021, tree information on 20 urban parks out of a total of 557 urban parks is being investigated (Parks and Greenery Division, Daejeon-si, 2021). It takes considerable time and budget to investigate every park; thus, tree survey information was collected on only 20 out of 557 parks.

Through field surveys, information necessary for estimating CO_2 storage and absorption was collected. The data investigated were the scientific name of the species, the number of individuals by species, and the diameter at breast height (DBH) by species. The following table shows tree survey data from two urban parks out of 20 (Table 1). The amounts of CO_2 storage and absorption per park area were calculated on the basis of information from 20 urban parks.

2.3 Calculating the amounts of CO_2 storage and absorption of trees in 20 urban parks

In this study, previous research was conducted to calculate the amounts of CO_2 storage and absorption of trees in urban parks. In ROK, there has been a lack of research on developing methodologies for calculating the amounts of CO_2 storage and absorption of different tree species in urban areas. In cities, studies have been conducted mainly on single or limited species.(17) Overseas, studies were conducted to calculate the carbon absorption capacity of trees using I-tree.(18–20) In ROK, a study was also conducted to calculate the carbon absorption of trees using I-tree.(21)

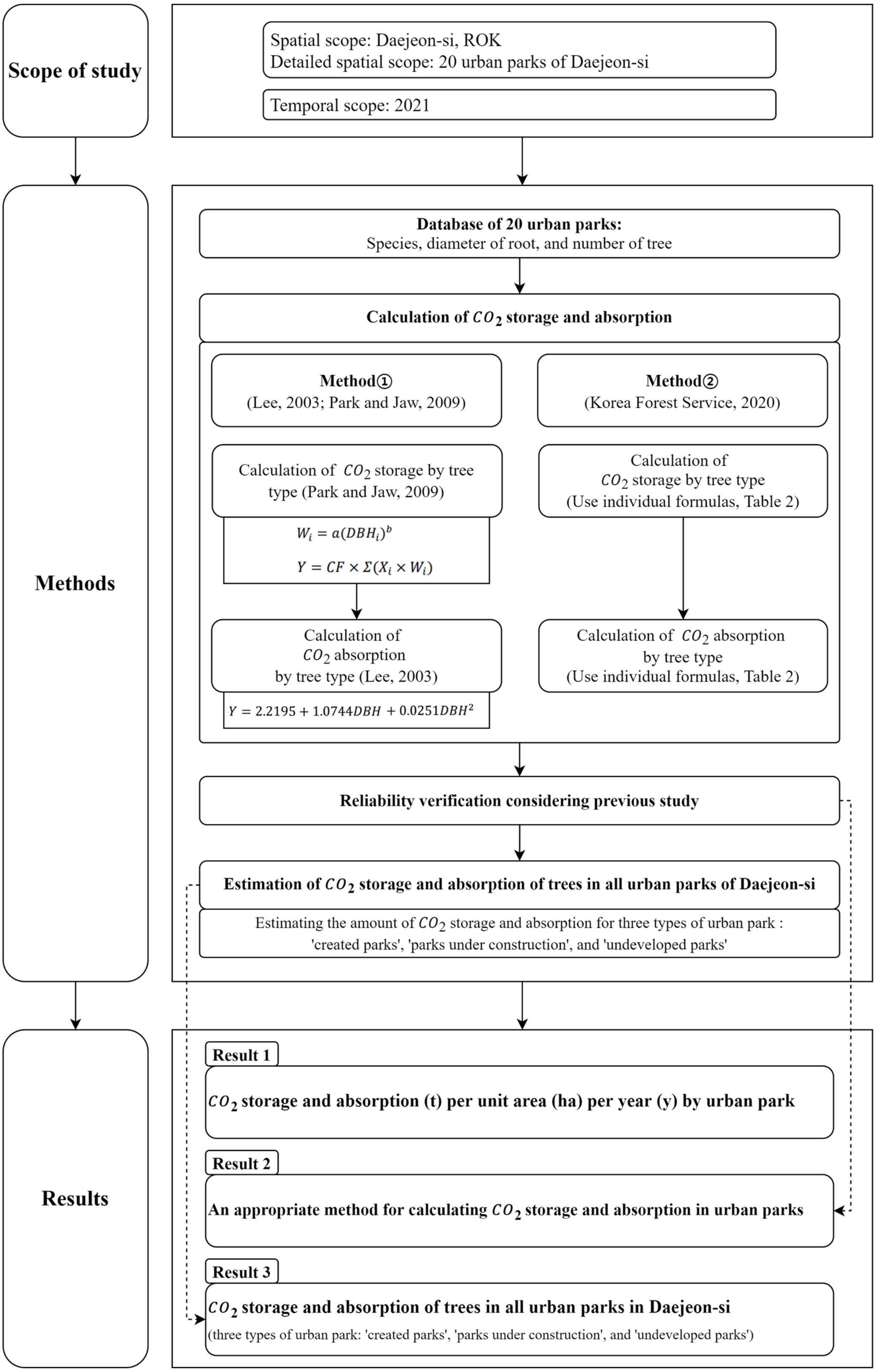

Fig. 2. Research flow chart.

Table 1
Examples of tree survey data from urban parks.

Park name	Division	Pine	Oak	Scholar	Maple	Acacia
Wanggol Neighborhood Park	Number of trees	34	15	40	15	—
	Mean value of diameter at breast height (cm)	31.2	12.5	18.3	12.5	—
	Park area (m^2)			21894.5		
	Planting area (m^2)			17746.8		
Cheongbyeoksan Mountain Neighborhood Park	Number of trees	59570	66	207	138	13524
	Mean value of diameter at breast height (cm)	20.8	16.6	10.0	8.3	12.5
	Park area (m^2)			206604.1		
	Planting area (m^2)			184165.2		

After reviewing the references, we used two methodologies of previous studies that can be used to calculate the amounts of CO_2 storage and absorption by using field survey data from urban parks in Daejeon-si. Method 1 is based on the research of Lee(22) and Park and Jaw(23) and Method 2 is based on the information provided by the ROK Forest Service (Tables 2 and 3). In these two ways, the CO_2 storage and absorption of trees in the 20 green park areas that completed the survey on the construction of green parks in Daejeon were calculated. By applying a methodology based on different previous studies, uncertainty was considered, and the amounts of CO_2 storage and absorption of the trees planted in all the urban parks in Daejeon-si were calculated using a highly reliable methodology.

To estimate the amount of CO_2 storage in green park areas, Park and Jaw used Method 1, and the ROK Forest Service research results were applied in Method 2. For CO_2 storage, the amounts of biomass and CO_2 storage were calculated using the DBH according to Park and Jaw's method in Method 1. In the case of DBH used in the calculation formula, since there is no DBH in the provided park and green data, the standard that the root diameter is 1.2 times larger than the DBH according to the ROK landscape design standards was inversely calculated (multiplied 0.83) to derive the diameter value. The derived DBH used the average value of each species, and accordingly, the amount of biomass was calculated as the average value, and the CO_2 storage amount was derived as the average value. In the case of Method 1, the same formula was applied to all the trees when calculating the amounts of biomass and CO_2 storage since there is no separate formula for each tree.

Method 2 provides a quantitative model formula that can be used to calculate the amount of CO_2 stored by tree species. The calculation formula of the ROK Forest Service is derived from a study on 22 tree species inhabiting the city. Therefore, it was considered suitable for application to the subject of this study. In the case of Daejeon-si, the quantitative model formula for each pine, cherry, fir, leaf, zelkova, and maple tree was used, and the same quantitative model formula developed for tree leaves and tree evergreens without individual calculation formulas was applied. In the case of the quantitative formula, the same survey information as in Method 1 was used, so the DBH used in the calculation formula was employed as the average value.

Table 2
Comprehensive formula for calculating amount of CO_2 storage in previous studies.

Division		Formula	Note
Method 1	Biomass amount (Park & Jaw, 2009)	$W_i = a(DBH_i)^b$	·a, b: Relative growth coefficient ·DBH_i: Average diameter at breast height (cm) of the representative tree species i
	CO_2 storage amount (Park & Jaw, 2009)	$Y = CF \times \Sigma(X_i \times W_i)$	·Y: Amount of tree CO_2 storage in the target green area (kg/tree) ·CF: Carbon conversion coefficient for biomass (0.5) ·X_i: Representative tree species (i number of trees) ·W_i: Average diameter at breast height (cm) of the representative tree species i
Method 2	Metered-type CO_2 storage amount (Korea Forest Service, 2020)	·Pine: $\ln Y = -3.1140 + 2.4430{*}\ln DBH$ ·Fir: $\ln Y = -2.2126 + 2.0814{*}\ln DBH$ ·Zelkova: $\ln Y = -2.4708 + 2.3862{*}\ln DBH$ ·Maple: $Y = -23.2064 + 4.8538{*}DBH$ ·Cherry: $\ln Y = -2.8265 + 2.4181{*}\ln DBH$ ·Fringe: $\ln Y = -2.7512 + 2.4952{*}\ln DBH$ ·Deciduous: $\ln Y = -2.5274 + 2.3431{*}\ln DBH$ ·Evergreen: $\ln Y = -3.313 + 2.5098{*}\ln DBH$	·$\ln Y$: CO_2 storage amount (kg/tree) ·Y: CO_2 storage amount (kg/tree) ·DBH: Diameter at breast height (cm)

Table 3
Comprehensive formula for calculating CO_2 absorption in previous studies.

Division		Formula	Note
Method 1	CO_2 absorption (Lee, 2003)	$Y = 2.2195 + 1.0744DBH + 0.0251DBH^2$	·Y: CO_2 absorption of vegetation (kg/tree/y) ·DBH: Diameter at breast height (cm)
Method 2	Metered-type CO_2 absorption (ROK Forest Service, 2020)	·Pine: $\ln Y = -2.6720 + 1.5251{*}\ln DBH$ ·Fir: $\ln Y = -3.1386 + 1.6158{*}\ln DBH$ ·Zelkova: $\ln Y = -2.8177 + 1.7715{*}\ln DBH$ ·Maple: $Y = -0.9608 + 0.1535{*}DBH$ ·Cherry: $\ln Y = -3.0939 + 1.7702{*}\ln DBH$ ·Fringe: $\ln Y = -2.2695 + 1.7554{*}\ln DBH$ ·Deciduous: $\ln Y = -2.6119 + 1.5686{*}\ln DBH$ ·Evergreen: $\ln Y = -3.7807 + 1.9347{*}\ln DBH$	·$\ln Y$: Annual CO_2 absorption (kg/tree/y) ·Y: Annual CO_2 absorption (kg/tree/y) ·DBH: Diameter at breast height (cm)

For the estimation of the amount of CO_2 absorption, Method 1 used the equation of Lee and Park and Jaw. In the case of Lee's calculation formula in Method 1, ROK was divided into central and southern regions, and the calculation formula for each province was applied differently. Since Daejeon-si belongs to the southern region of ROK, the calculation formula for the southern region was used. In Method 2, like the CO_2 storage calculation equation derived from the ROK Forest Service, the individual calculation equation was used for the tree species that provide the quantitative model equation. For other tree species, the same quantitative model equation developed for tree leaves and tree evergreens was used. Estimating the amount of CO_2 absorption consists of four steps for each tree species: (1) DBH calculation, (2) biomass calculation, (3) CO_2 storage calculation, and (4) CO_2 absorption calculation.

2.4 Estimation of amounts of CO_2 storage and absorption of trees in all urban parks of Daejeon-si

To estimate the amounts of CO_2 storage and absorption of trees in all parks in Daejeon-si, the amounts of CO_2 storage and absorption per unit area were calculated for 20 urban parks. There are 557 urban parks in Daejeon-si, with a total area of 1931 ha. By multiplying the corresponding area by the amounts of CO_2 storage and absorption per unit area (ha) of an urban park, we tried to estimate the amounts of CO_2 storage and absorption of trees in all the city parks in Daejeon-si. Daejeon-si has three types of urban park: established, under construction, and undeveloped. In this study, we intend to calculate and present the amounts of CO_2 storage and absorption for each of the three types so that Daejeon-si can be used as a reference in the creation and planning of urban parks to achieve carbon neutrality.

3. Results and Discussion

3.1 Tree survey by urban park

The tree survey results for each park in Daejeon-si are shown in Table 4. Through an on-site survey in Daejeon-si, the name of the species, the number of populations by species, and the DBH were investigated. Since the number of trees planted varies from park to park, data were derived differently from each park.

3.2 CO_2 storage and absorption of trees in urban parks

The current status of CO_2 storage and absorption calculated using tree survey data from urban parks is as follows. The average CO_2 storage (t) and absorption (t) per unit area according to the park area and planting area for 20 urban parks were calculated. In Method 1, the annual absorption per unit area of the park area was 30.05 tCO_2/ha, and the storage amount derived was 334.96 tCO_2/ha. The annual absorption per unit area of the planted area was 42.21 tCO_2/ha, and the storage amount derived was 470.54 tCO_2/ha (Table 5). This CO_2 storage amount gathered in this study was determined by applying the CO_2 conversion factor (44/12).

The average result of Method 2 (ROK Forest Service, 2020) shows that the annual absorption per unit area of the park area is 9.58 tCO_2/ha, the storage is 254.84 tCO_2/ha, the annual absorption per unit area of the planted area is 13.45 tCO_2/ha, and the storage is 358.00 tCO_2/ha (Table 6).

3.3 Reliability verification considering previous studies

To judge the reliability of the study results, a comparison with previous studies was conducted. There were a few studies on the amounts of CO_2 storage and absorption of trees in urban parks at the city level, but there is no study on the target site, Daejeon-si. Therefore, among the studies of the ROK Forest Service, which is in charge of forest-related affairs in ROK,

Table 4
Examples of tree data based on field survey for six parks.

Park name	Division	Pine	Oak	Scholar	Maple	Acacia
Wanggol Neighborhood Park	Number of trees	34	15	40	15	—
	Mean value of diameter at breast height (cm)	31.2	12.5	18.3	12.5	—
	Park area (m^2)			21894.5		
	Planting area (m^2)			17746.8		
		Pine	Oak	Scholar	Maple	Acacia
Cheongbyeoksan Mountain Neighborhood Park	Number of trees	59570	66	207	138	13524
	Mean value of diameter at breast height (cm)	20.8	16.6	10.0	8.3	12.5
	Park area (m^2)			206604.1		
	Planting area (m^2)			184165.2		
		Pine	Meta	Oak(1)	Oak(2)	—
Sorasil Neighborhood Park	Number of trees	699	1220	8110	324	—
	Mean value of diameter at breast height (cm)	27	12.5	8.3	20.8	—
	Park area (m^2)			21564.4		
	Planting area (m^2)			16303.9		
		Pine	Scholar	Oriental	Oak	Maple
Gilmabong Neighborhood Park	Number of trees	139	62	62	62	33
	Mean value of diameter at breast height (cm)	27	7.5	7.5	9.5	8.3
	Park area (m^2)			12989.6		
	Planting area (m^2)			8617.8		
		Pine	Pitch	Oak	Maple	W Pine
Durubong Neighborhood Park	Number of trees	1132	2265	345	124	619
	Mean value of diameter at breast height (cm)	50	50	29.1	16.6	20.8
	Park area (m^2)			105972.8		
	Planting area (m^2)			90999.8		
		Pitch	Acacia	Kobus	—	—
Geumseong Neighborhood Park	Number of trees	806	166	54	—	—
	Mean value of diameter at breast height (cm)	29.1	14.5	14.5	—	—
	Park area (m^2)			18442.8		
	Planting area (m^2)			14211.6		

the reliability was judged by estimating the amount of CO_2 absorption per unit area of the forest areas of Daejeon-si. According to a study by the ROK Forest Service, the amount of CO_2 absorption per unit area of the forest areas in Daejeon-si was 7.2 tCO_2/ha/y. According to Method 1 applied in this study, the CO_2 absorption per unit area of urban parks was 30.05 tCO_2/ha/y, and the results were about 4.17 times higher than those in previous studies. Meanwhile, according to Method 2, the absorption of CO_2 per unit area of urban parks was 9.58

Table 5
CO_2 storage and absorption of trees in 20 urban parks (Method 1).

Urban park		Area (ha)	CO_2 storage and absorption (tCO_2)		CO_2 storage and absorption per unit area (tCO_2/ha)	
			Annual absorption	Storage	Annual absorption	Storage
1	Sangdae	0.39	7.64	95.218	19.59	244.15
2	Cheongbyeok Mountain	18.41	1525.37	15764.30	82.86	856.29
3	Toegogae	3.79	72.77	879.30	19.20	232.01
4	Haksan	0.74	72.59	1303.69	98.09	1761.74
5	Sorasil	1.63	149.80	908.32	91.90	557.25
6	Janghyeon	0.95	16.19	177.00	17.04	186.32
7	Gilmabong	0.86	7.73	68.78	8.99	79.98
8	Durubong	9.09	395.34	5765.61	43.49	634.28
9	GeumSeong	1.42	36.16	429.47	25.46	302.44
10	Wanggol	1.77	3.28	35.99	1.85	20.33
11	Gungdong	1.99	5.90	59.49	2.96	29.89
12	Dullegi	14.48	536.84	6070.29	37.07	419.22
13	Daegol	4.36	30.35	319.158	6.96	73.20
14	Jukdong	8.33	308.04	3298.17	36.98	395.94
15	Duresamgol	1.32	30.01	411.67	22.73	311.87
16	Haerang	3.85	42.47	550.71	11.03	143.04
17	GoraeDeul	0.80	4.28	33.92	5.35	42.40
18	Doryong	1.77	17.81	190.17	10.06	107.44
19	JangSoo	0.11	0.88	5.19	8.00	47.18
20	Eungubi	1.49	10.22	124.20	6.86	83.36
Average					42.21	470.54

tCO_2/ha/y, which was about 1.33 times higher than those in previous studies. Therefore, the equation for calculating CO_2 absorption of Method 2 is more suitable than that of Method 1 for calculating the CO_2 storage and absorption of trees in urban parks.

After analyzing the reason for the overestimation of CO_2 absorption in Method 1, the equation for calculating the amounts of biomass and CO_2 storage of trees must be employed to calculate the amount of CO_2 absorption, which did not take into account the characteristics of each tree because the same equation was applied to all trees. In the equation for calculating the amount of CO_2 absorption, as in the equation for calculating the amount of CO_2 storage, such an overestimated result appeared since the same equation was used for all trees, not the equation for each tree. In the case of Method 2, unlike Method 1, there is an equation for calculating the amounts of CO_2 storage and absorption of each tree. The equation is subdivided according to the DBH range of each tree. For this reason, it is considered that the results of the CO_2 storage and absorption amounts of Method 2 were adequately derived.

3.4 CO_2 storage and absorption of trees in all urban parks in Daejeon-si

Using the results of CO_2 storage and absorption per unit area of trees in urban parks derived in this study, we estimated the amounts of CO_2 storage and absorption of trees in all urban parks

Table 6
CO_2 storage and absorption in 20 urban parks (Method 2).

Urban park		Area (ha)	CO_2 storage and absorption (tCO_2)		CO_2 storage and absorption per unit area (tCO_2/ha)	
			Annual absorption	Storage	Annual absorption	Storage
1	Sangdae	0.39	2.09	111.86	5.36	286.82
2	Cheongbyeok Mountain	18.41	474.88	1709.13	25.79	92.84
3	Toegogae	3.79	21.37	964.01	5.64	254.36
4	Haksan	0.74	19.50	1025.16	26.35	1385.4
5	Sorasil	1.63	30.26	903.69	18.56	554.41
6	Janghyeon	0.95	5.15	201.543	5.42	212.15
7	Gilmabong	0.86	1.96	81.38	2.28	94.63
8	Durubong	9.09	141.47	8632.84	15.56	949.71
9	GeumSeong	1.42	13.56	541.90	9.62	384.33
10	Wanggol	1.77	0.84	38.65	0.47	21.84
11	Gungdong	1.99	1.57	74.47	0.79	37.42
12	Dullegi	14.48	182.39	7399.69	12.60	511.03
13	Daegol	4.36	8.27	396.26	1.90	90.89
14	Jukdong	8.33	104.98	4170.48	12.60	500.66
15	Duresamgol	1.32	11.48	564.870	8.70	427.93
16	Haerang	3.85	12.54	526.90	3.26	136.86
17	GoraeDeul	0.80	1.00	35.29	1.25	44.11
18	Doryong	1.77	6.33	238.33	3.58	134.65
19	JangSoo	0.11	0.18	4.90	1.64	44.55
20	Eungubi	1.49	3.43	141.24	2.30	94.79
Average					13.45	358.00

in Daejeon-si by Method 2. The total area of 557 urban parks in Daejeon-si is 1931 ha, the amount of CO_2 storage is 492096 tCO_2/ha, and the annual CO_2 absorption is 18498 tCO_2/ha/y. In this study, the amounts of CO_2 storage and absorption of trees in three types of urban park (established, under-construction, and unconstructed parks) were calculated so that Daejeon-si can be used as a reference in the creation and planning of urban parks to achieve carbon neutrality.

When the amounts of CO_2 storage and absorption for the three types were derived separately, the established parks had a storage amount of 227006 tCO_2/ha/y and an absorption amount of 8533 tCO_2/ha/y. The under-construction parks had a storage amount of 228762 t/ha/y and an absorption amount of 8599 tCO_2/ha/y. For the unconstructed parks, the storage amount was 36503 tCO_2/ha/y, and the absorption amount was 1372 tCO_2/ha/y.

The total CO_2 emission of Daejeon-si in the 2019 regional greenhouse gas inventory of the Greenhouse Gas Information Center of the Ministry of Environment is 5376000 tCO_2/y.[24] Compared with total emissions, the percentage of Daejeon-si urban parks contributing to absorption is 0.34%. This is a contribution considering only the amounts of CO_2 absorption and storage according to tree growth. Considering other green spaces within the city, higher contribution could be expected.

Since the amounts of CO_2 storage and absorption of trees in under-construction parks are higher than those of established parks, it is necessary that under-construction parks be completed as soon as possible to realize carbon neutrality in Daejeon-si by 2050. If tree planting is carried out through park creation in undeveloped areas, more CO_2 storage and absorption can be expected than in established parks, contributing to achieving carbon neutrality in Daejeon-si.

In addition, it is necessary to establish a detailed survey database of trees in urban parks to support the achievement of carbon neutrality in Daejeon-si. In particular, for a more accurate calculation of CO_2 storage and absorption amounts of trees, the urban parks' survey data of each tree and the actual DBH (converting the root diameter into DBH) are needed. In addition, urban parks can be actively used when considering the role and alternatives of urban green spaces to achieve carbon neutrality only when database updates and management are considered.

4. Conclusion

In this study, we calculated the amounts of CO_2 storage and absorption per unit area using tree survey data from representative urban parks in Daejeon-si. On the basis of this, the amounts of CO_2 storage and annual absorption were estimated for all urban parks in Daejeon-si. Among the two methodologies for estimating these amounts, Method 2 was identified as the most suitable method. In this study, we did not utilize tree survey data from all urban parks in Daejeon-si, and we estimated the amounts of CO_2 storage and absorption in Daejeon-si using information from some urban parks; thus, the accuracy of the estimation results is limited. In the future, it is necessary to increase the reliability of the estimation results by collecting tree survey information for more urban parks. Research to develop improved equations should also be continuously conducted. The results of this study can be used as bases for understanding the importance of securing and managing other urban parks and establishing a database to understand the current status of CO_2 storage and absorption. In addition, when the storage and absorption calculation method in this study are applied to urban parks and green areas in other regions, each local government can support the operation and decision-making of CO_2-neutral policies.

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