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The CO_2 Reduction Potential Calculation through the Urban Park Construction

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ABSTRACT

This study is to identify quantitatively the function of carbon dioxide emissions reduction due to temperature and energy reduction according to direct carbon dioxide storage, shade provision, and evaportanspiration of urban park. According to the result of study, landscape tree indicated high carbon dioxide storage effect compare to bush, in which broadleaf tree indicated higher storage function than coniferous tree. It is believed to be the storage of carbon dioxide can be increased by increasing the composition rate of forest plants in the urban park. According to the direct estimation result of carbon dioxide storage in terms of example area, storage of carbon dioxide is estimated to be "seoul a zone" 476,818.8 kg·CO_2/㎡·yr, "anyang b zone" 186,435.7 kg·CO_2/㎡·yr, "daejeon c zone" 262,826 kg·CO_2/㎡·yr, "kwangju d zone" 231,657.8 kg·CO_2/㎡·yr. The carbon dioxide storage per unit area estimated to be "seoul a zone" 3.4 kg·CO_2/㎡·yr, "anyang b zone" 5.0 kg·CO_2/㎡·yr, "daejeon c zone" 2.6 kg·CO_2/㎡·yr, "kwangju d zone" 5.6 kg·CO_2/㎡·yr. The result of indirect carbon dioxide reduction effect estimated to be "seoul a zone" 291,603.4 kg·CO_2/㎡·yr, "anyang b zone" 165,462.4 kg·CO_2/㎡·yr, "daejeon c zone" 141,719.2 kg·CO_2/㎡·yr, "kwangju d zone" 154,803.4 kg·CO_2/㎡·yr. Carbon dioxide reduction potential amount through the urban park was increased to 1.6 times to 1.8 times when calculated to the indirect effect.

KYEWORDS

Urban Tree,
CO_2 Storage,
Temperature Reduction,
Cooling Load Reduction

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1. Introduction

Changes in the use of land such as urban development at global level instigate the emmission of 1.6 gigatons of carbon dioxide into the atmosphere every year despite the effort of United Nations Framework Convention on Climate Change (IPCC, 2000). It is estimated that 35% of the entire carbon dioxide had been discharged by human and due to changed usage of land such as urbanization or road development into the air for the last century (Turner et al., 2007). S. Korea also declared in the general meeting for the members of the 15th Conference of the Parties to the UN Framework Convention on Climate Change (UNFCCC), which was held in Copenhagen in December 2009, it will have reduced greenhouse gas emission by 30% (BAU basis) in 2020. In april, 2010, the country legislated and enacted Basic Act on Low Carbon Green Growth and has been making efforts to reduce greenhouse gas emission at the national level. Local governments set a mandatory target to reduce greenhouse gas emission and has to report the performance of the reduction to the central government every year (Lee, J.H., Lee, G.G, 2012). Because of this elevated awareness, the increase of carbon dioxide content in the atmosphere is causing considerable worry from the viewpoint related to global warming and, meanwhile, attention is giving to the capacity of park green spaces to absorb and store carbon dioxide (Laitat et al., 2000; Watson et al., 2000).

In recent years, direct CO_2 absorption by urban forest trees and indirect CO_2 absorption through cooling energy

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conservation during summer are getting more important as an alternative to tackle the issues of climatic change and energy consumption. The direct carbon reduction effect by urban forest trees is the most effective way to reduce carbon emission in terms of economy and technology (Ayman and El-Sayed, 2011; Daniel et al., 2011; Dimas and Gavriel, 2008). And it has been reported that vegetation reduces the emission of carbon (indirect absorption) into the atmosphere through the conservation of cooling energy in buildings during summer season, which is possible due to the shading and evapotranspiration (Cho, H.G., Lee, G.E., 2000). The calculation of carbon dioxide absorption by the green spaces factors in urban park requires very specific data of current status and basic research data regarding types of trees planted in the park and their growth characteristics. However, such data are limited only to a few of studies (Cho, H.G. et al., 1998; Jeong, H.D., 2009; Park, E.J., and Kang, K.Y., 2009). Furthermore, few studies have been conducted on the calculation of indirect carbon dioxide absorption through cooling/heating energy conservation.

Accordingly, the present study pays a due attention to urban park as an important CO_2 sink in a city and tries to yield a formula to calculate direct carbon dioxide absorption effect by urban park and indirect carbon dioxide absorption through cooling energy conservation. Based on the calculated direct and indirect effects of carbon dioxide reduction, this study aims to demonstrate the effectiveness of urban park for the reduction of carbon dioxide.

2. Theoretical Review

2.1 Construction and Scale Standard of Urban Park

Urban park is one constructed or designated to protect natural landscape in urban area and improve citizens' health, rest and emotional welfare in their urban life according to the Act of Urban Park and Green Space. It is classified into neighborhood park and theme park and managed accordingly. The location and size of urban park are decided in consideration of the use by neighborhood, type of use, population size of users, population allocation plan and demand analysis. Urban park is stipulated to be as big as 6㎡ per person. Mini park, historic park, cultural park and waterfront park are not subject to size requirement while children's park is specified by law to be over 1,500㎡; neighborhood park has to be 10,000 to 100 million㎡; and sports park and urban agriculture park has to be wider than 10,000㎡. Green volume in a park is legislated to conform to Clause 5 (by the size of development project) the Act of Urban Park and Green Space. According to the current laws, they do not set a standard for the function of urban park regarding carbon absorption, but it can be significantly considered that urban park can play a very significant role and function as a large-scale carbon sink, neutralizing carbon dioxide in a city.

2.2 Studies on the Absorption of Carbon Dioxide by Trees

Of the studies regarding the absorption and storage of carbon dioxide of trees, Cho, H.G. et al (2003) carried out a study on CO_2 absorption of urban green spaces in Chuncheon City and found out that carbon storage per unit breast area (cm^2) is 3.54kgC/㎡ on average and that unit coverage (㎡) is average 3.547kgC/㎡. Cho, H.G. and Cho, H.D (1998) calculated annual CO_2 absorption of major urban landscape tree species. According to them, annual CO_2 absorption of trees per unit area turned out to be 1.6-1.71t/ha/yr in natural area while that in in-town area was 0.56-0.71t/ha/yr. Kim, W.J. and Kim, U.S. (2010) reported in their study that the forests in Seoul area have 41.4tC/ha of CO_2 storage of per unit area and urban park has about 17.3tC/ha of CO_2 storage, which is 1/3 of that of forest. Cho, H.G. et al (2003) examined the improvement effect of urban green spaces on atmospheric environment and revealed that the average CO_2 storage of planted tree per unit area was 19.4t/ha; the annual CO_2 absorption 2.2t/ha/yr; and SO_2 and NO_2 storage were 1.9kg/ha/yr and 5.0kg/ha/yr, respectively. Park, E.J. and Kang, K.Y. (2010) calculated the carbon storage of 9 key species of trees of 90 kinds of trees planted on the avenues in Kyunggi Province. In the research, they found out that CO_2 absorption of 769,505 trees subject to the experiment was 30,693tCO_2/yr; CO_2 absorption of 4,602 fine trees was 35tCO_2/yr. Nowak and Crane (2002) reported that the urban trees in New York City stored a total of 120 tons of carbon and absorbed 770,000 tons of carbon dioxide annulary. Mcpherson et al. (2007) found out that planting a million trees in LA absorbed 28,571tCO_2 on annual average and 0.029tCO_2/tree/yr per tree. Moore (2009) estimated that one urban tree directly absorbed 29kgCO_2 in LA and 8.9~3.6kg in New York annually on average. But few studies have been conducted to calculate CO_2 storage of urban park, which is a major CO_2 sink in a city and to know its CO_2 storage by a variety of species of trees.

2.3 Studies on Indirect Carbon Dioxide Reduction Capacity by Trees

Studies have been performed on the indirect effect of CO_2 reduction by the green spaces of urban park through the conservation of cooling energy. McPherson and Rowntree (1993) examined 12 cities in the United States to show that a tree (7.6m tall) conserved 100-400 kw of cooling energy annually. Placing in consideration a variety of factors such as temperature reduction by tree green spaces and the increase of wind velocity, respectively, Ca V.T. et al (1998) reported in their research upon Sacramento region that the reduction of atmospheric temperature by 1.0 ℃ in industrial areas could reduce the energy consumption of air-conditioner by 6.5% for residential purpose and by 6.7% for commercial use. Simpson (2002) revealed in his simulation test that shading plants changed the load of cooling and heating in a building by reducing incident rays. Donovan, G.H. (2009) reported that urban trees reduced energy consumption because they were close to buildings and thus directly reduced carbon dioxide emitting from the burning of fossil fuels. Mchale et al. (2007) said that direct absorption of carbon dioxide by the growth of urban trees in 4 cities, Colorado, was 75 ~ 100kgCO_2 per tree and the trees indirectly inhibited the emission of carbon dioxide by forming shades over buildings and reducing the consumption of cooling energy in a building. Cho, H.G. and Lee, G.E. (2000) reported that CO_2 absorption by urban green spaces set off total CO_2 emission by 6 ~ 7% every year through tree planting management, soil decomposition, reduced energy consumption in Chuncheon and Kangryung City. In addition, Cho, H.G. and Ahn, T.H. (2010) found out that large shading trees facing west and east reduced cooling energy consumption by 1 to 2 % depending on the shape of building and region. Kim, D.H. (2011) revealed that when urban forest in neighborhood increased by 1m^2 per person, it conserved electric energy by 0.02MWh on national average and reduced midday temperature by 1.15℃ in major metropolitan cities during summer. Although those studies have been conducted on the effect of urban trees on energy conservation, not many have performed on the conversion of the effect into indirect carbon dioxide reduction effect. In short, some of studies have paid attention to the CO_2 storage and reduction of cooling energy by trees planted in urban areas, but the present study found out that there are few studies that focused on both direct CO_2 storage and the reduction of cooling energy consumption that works eventually for indirect CO_2 reduction by trees in urban park, which is a representative CO_2 absorber.

3. Research Scope and Target Areas

3.1 Research Scope

To reduce CO_2 by park & green spaces in a city that emits more than 80% of whole greenhouse gas, it is necessary to measure direct and indirect CO_2 storage from the planning stage of a park and to make a plan to assign park & green spaces properly enough to increase the amount of CO_2 reduction.

This study aimed to measure direct CO_2 storage and indirect potential amount of CO_2 reduction of a new urban park to be constructed, rather than of existing one. To this end, the present study set its research scopes as follows: first, it reviewed related literatures to know the formulas to calculate potential CO_2 storage and came up with CO_2 storage equations that reflect the size and ecological characteristics of trees planted in a new urban park. Second, it drew out the equations for indirect CO_2 reduction that occurs from the conservation of building cooling energy by urban park. Third, it calculated potential CO_2 reduction by urban park, being based on the direct and indirect CO_2 reduction equations.

Within its spatial scope, this study set the urban parks located in Seoul A zone, Anyang B zone, Daejeon C zone and Kwangju D zone sector, which are scheduled to be constructed for urbanization facilities, to calculate direct and indirect CO_2 reduction by urban park. To estimate the direct and indirect CO_2 reduction by urban park in those areas, it was necessary to get information of individual tree in the areas, so that the study measured the dimensions of the trees on the basis of standard landscape drawings and specifications of new urban park and used them for analysis.

3.2. The Summary of Planted Trees in the Research Target Areas

In the examination of the species of trees to be planted in the target area (Table 1), it turned out that the largest number of the species of trees (57 species) plans to be planted in neighborhood park and is followed by waterfront park (48 species), children's park (29 species) in Seoul A zone. In Anyang B zone, the largest number of trees in terms of the number of species is scheduled to be painted in cultural park (49 species) and is followed by neighborhood park (19 species) and children's park (14 species) in order. In Daejeon C zone, 62 species is scheduled to be planted in neighborhood park while children's park is going to have 40 different kinds of trees. In Kangju D zone, it turned out that 42 species of trees is scheduled to be planted in neighborhood park and is followed by children's park (35 species) and mini park (10 species).This comparison shows that relatively more species of trees are going to be planted in neighborhood park than other types of urban parks. In terms of the number of trees by research area, it was confirmed that neighborhood park (148,265) is going to have the largest number of trees planted in Seoul A zone while mini park (4,054) is going to have the smallest number of trees. For the number of trees by shape, broad-leaved trees (2,886 trees) and coniferous trees (91,148 trees) are relatively more planned than other types in Seoul A zone. In Anyang B zone, neighborhood park (34,233 trees) is going to have the largest number of trees planted while children's park (2,511) is going to have the smallest number of trees. For the number of trees by shape, broad-leaved trees (1,678) is planned twice more than coniferous trees (560) in Anyang B zone. In Daejeon C zone as well, neighborhood park (66,260) is scheduled to have the largest number of trees while the smallest number of trees was planned for children's park (13,411). For the number of trees by shape, broad-leaved trees (2,602) are planned 2.9 times more than

Table 1. Overview of the planting of study site

Site	Park Classification	Planting area (m²)	Planting species(Species)				Planting populations(Tree)				Planting density(tree/m²)		
			Tree coniferous	Tree broadleaf	Shrub coniferous	Shrub broadleaf	Tree coniferous	Tree broadleaf	Shrub coniferous	Shrub broadleaf	Tree	Shrub	Total
Seoul A site	Neighborhood park	128,606	5	31	1	20	966	1,735	1,540	144,024	0.1	1.1	1.2
	Children's park	3,303	3	17	-	9	101	325	-	38,310	0.1	11.6	11.7
	Waterfront park	8,903	1	27	1	19	41	762	130	31,602	0.1	3.6	3.7
	Mini park	1,062	2	10	1	6	40	64	1,400	2,550	0.1	3.7	3.8
	Subtotal	141,874	11	85	3	54	1,148	2,886	3,070	216,486	0.1	1.6	1.7
Anyang B site	Neighborhood park	14,219	1	10	1	7	52	484	490	7,510	0.0	0.6	0.6
	Culture park	21,420	4	31	2	12	413	1060	3740	29020	0.1	1.5	1.6
	Children's park	777	3	6	-	5	60	81	-	2,370	0.2	3.1	3.2
	Mini park	624	2	3	-	4	35	46	-	3,870	0.1	6.2	6.3
	Subtotal	37,040	10	50	3	28	560	1,671	4,230	42,770	0.0	0.9	0.9
Daejeon C site	Neighborhood park	93,637	7	27	2	26	644	2,305	300	63,011	0.0	0.7	0.7
	Children's park	5,567	3	24	-	13	194	297	-	12920	0.1	2.3	2.4
	Subtotal	99,204	10	51	2	39	838	2,602	300	75,931	0.1	0.9	1.0
Kwangju D site	Neighborhood park	36,594	3	27	-	12	711	1,028	-	62,465	0.1	1.7	1.8
	Children's park	3,827	3	19	-	13	237	172	-	3,580	0.1	0.9	1.0
	Mini park	649	1	7	-	2	11	50	-	330	0.1	0.5	0.6
	Subtotal	41,070	7	53	0	27	959	1,250	-	66,375	0.0	0.7	0.7

coniferous trees (888) in Daejeon C zone. Kwangju D zone also showed the similar trends in terms of the total number and type of trees to be planted. Neighborhood park (3,580) is scheduled to have the largest number of trees while the smallest number of trees is planned for mini park (330). Meanwhile, more broad-leaved trees (1,250) are scheduled to be planted than coniferous trees (959).

4. Calculation Model of Potential CO_2 Reduction and Hypothesis

4.1 Research Model

To examine direct CO_2 storage capacity by the trees and green spaces in a urban park, which is a major CO_2 sink, and indirect CO_2 reduction through the conservation of cooling energy by urban park, the present study reviewed previous studies regarding the calculations of CO_2 storage by trees planted in parks and set a research model that can calculate direct and indirect potential CO_2 reduction by the trees planted in the new urban parks (see Figure 1).

Based on the model, hypotheses were established as followed.

H 1: The trees planted and green spaces formed in a new urban park will store CO_2 and, by doing so, function as a key CO_2 sink for a city.

H 1-1: It will be possible to measure CO_2 storage if CO_2 storage formula can be derived from the dimensions (diameter at breast height for landscape tree) and number of tree for bush tree) of trees specified in the landscape drawing of a new park.

H 2: The trees planted and green spaces formed in a new urban park will indirectly function to store CO_2 through by reducing the consumption of cooling energy and thus reducing CO_2 emitted from the burning of fuel.

H 2-1: It will be possible to measure indirect potential CO_2 reduction if CO_2 reduction formula can be derived from the reduction of cooling energy by trees specified in the landscape drawing of a new park and indirect CO_2 reduction equation according to it.

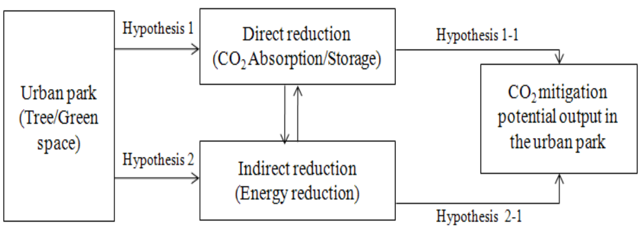

Fig. 1. Research Model

4.2 Calculation of CO_2 Storage and Hypothesis

CO_2 storage per individual tree is generally calculated using biomass allometric equation by species. In Korea, the equation has been known only for some species of urban tree. Cho, H.G. (1999) calculated each of biomass allometric equation of *Pinus densiflora*, *Pinus koraiensis*, *Quercus mongolica*, *Populus tomentiglandulosa* T. Lee, *Rhododendron schlippenbachii*, *Rhododendron mucronulatum* and *Lespedeza bicolor var. japonica* NAKAI . Cho, H.G. and Ahn, T.H. (2001) used an infrared gas analyzer to measure CO_2 exchange rate and derived a formula to calculate annual carbon dioxide absorption. However, domestic researches are limited to some species of landscape trees and shrubs, so that it is hard to find a suitable biomass allometric equation in applying to diverse species of trees.

Cho, H.G. (2001) and Lee, K.G. (2003) summarized the existing equations and developed a simplified CO_2 storage formula that uses the diameter of a tree as variable (diameter at breast height for landscape tree and diameter at root for shrub). The formula is a clue to calculating CO_2 storage using the dimensional information of a tree. However, a landscape drawing for park or others contains root diameter of landscape tree and crown width for shrubs, so that it is hard to apply the formula. Accordingly, the present study altered the formula into a regression model that sets as variable root diameter for landscape tree and number of tree for shrub so as to make it possible to measure CO_2 storage on the basis of the dimensional information of trees from the landscape drawing of a new park. To acquire necessary data, the study measured both the root diameter and breast diameter of 216 coniferous trees (6 species) and 131 broad-leaved trees (15 species) planted in Bundang Park and compared them to develop a formula that uses root diameter as variable. For shrubs, 120 coniferous shrubs (3 speceis) and 156 broad-leaved shrubs(10 species) were measured for their root diameters. Since the results showed that the gap between maximum and minimum root diameters wasn't significant, it did not make difference in the output of the regression equation using root diameter as variable. Therefore, the study premised that 2cm is an average root diameter and converted it to a formula to calculate CO_2 reduction per tree. CO_2 storage by urban park was estimated on the basis of the converted equation that can produce CO_2 storage by using the dimensional information of trees in the landscape drawing (Equation 1).

$$A_{T1} = -1.3582 + 1.9676 DAG^{\text{Root diameter}} \ (\text{kgCO}_2/\text{tree})$$
$$A_{T2} = -1.0471 + 1.7149 DAG^{\text{Root diameter}} \ (\text{kgCO}_2/\text{tree})$$
$$A_{S1} = 0.2346 \times Nmber\ of\ trees \ (\text{kgCO}_2/\text{tree})$$
$$A_{S2} = 0.3615 \times Nmber\ of\ trees \ (\text{kgCO}_2/\text{tree}) \quad (1)$$

Here, A_{T1} is CO_2 storage formula of broad-leaved tree; A_{T2} is CO_2 storage formula of coniferous tree; A_{S1} is CO_2 storage formula of broad-leaved shrub; A_{S2} is CO_2 storage formula of coniferous shrub.

4.3 Calculation of Indirect CO_2 Reduction and Hypothesis

Urban park & green spaces is known to lower temperature in neighboring area and reduce cooling energy consumption by providing shades and evapotranspiration. According to the study of Yoon, M.H. and Ahn, D.M. (2009), temperature reducing effect by green spaces reached up to 500 meters in radius from the green spaces and the temperature gap between green spaces boundary and the urban area was 0.3℃ at minimum and 1.7℃ at maximum. It was demonstrated in the study that 1℃ reduction of temperature by evapotranspiration and shading of urban green spaces can conserve residential cooling energy consumption annually by about 9% per unit and 1℃ reduction was turned out to produce 2 times greater conservation effect (Cho, H.G. and Ahn, T.W., 1999). Based on the finding, the present study attempted to estimate indirect CO_2 reduction effect, besides direct CO_2 storage by urban park & green spaces, through the reduced cooling energy consumption in neighboring areas to urban park, which is due to the evapotranspiration and shading provided from the park. To understand indirect CO_2 reduction by the construction of urban park, a comparison of electric consumption for cooling energy during summer can be made between an area without urban park nearby and one near to it. However, the main objective of the present study is to estimate direct and indirect CO_2 reduction by a new urban park to be constructed. Therefore, it is impossible to directly measure the amount of electricity used for air-conditioning in an area where a new park will be built nearby because the usage of adjacent land to the park hasn't been decided. For this reason, the study set the effect area of temperature reduction by the construction of a new park and converted the concerning area into development area (by applying residential and commercial floor area ratio) to estimate the electric consumption during summer in the development area. And it analyzed electric conservation through temperature reduction and converted it to CO_2 reduction.

To be more specific, this study first reviewed and summarized the results of the studies (Mcpherson, 2007; Yoon, M.H. and Ahn, D.M., 2009) in an attempt to analyze the CO_2 reduction effect on the neighborhood of a new urban park. And it set the effect range of temperature reduction by urban park & green spaces on the neighborhood (100 meters in radius) (Equation 2). It supposed that the area of (neighboring) land to be used (the study premised that the neighborhood of the new urban park is used mostly for residential and commercial purpose) is as wide as the size of the effect range of temperature reduction by urban park & green spaces. Floor space ratio (Won Unit) was applied differently by region and usage (Korea Research Institute for Human Settlements, 2010) to calculate building floor space ratio by land usage (Equation 3). Energy consumption was calculated by usage and then electricity use ratio related to cooling energy of total building energy consumption during summer was applied to Equation 4. It was again converted to the electric consumption for air-conditioning out of the total electric consumption during summer using Equation 5 in order to calculate cooling energy consumption (by air-conditioner) by building usage and building size. Based on it, Equation 6 was applied to compute cooling energy conservation (reduction of air conditioning cooling load) results from temperature reduction by the construction of urban park & green spaces. Then carbon emission coefficient, which is big as the reduction, was applied to Equation 7 to estimate the final reduction of CO_2 emission.

① Effect Range of Temperature Reduction = Urban Park × 100m in Radious (2)

· Reviewed and used the results of the studes (Mcpherson(2007) and Yoon and Ahn (2009))

② Development Area by Land Usage = (Equation 1) × Building Floor Space Ratio by Land Usage (3)

· Residential Area: Seoul (single-unit: 150%, multi-unit: 250%)
Anyang (single-unit: 185%, multi-unit: 280%)
Daejeon (single-unit: 150%, multi-unit: 250%)
Kwangju (single-unit: 150%, multi-unit: 250%)

· Commercial Area: Seoul (central: 1,000%, non-central: 800%)
Anyang (central: 1,087%, non-central: 913%)
Daejeon (central: 1,300%, non-central: 1,100%)
Kwangju (central: 1,300%, non-central: 1,100%)

· Reviewed and used the results of the study (Korea Research Institute for Human Settlements, 2010)

③ The Amount of Electricity Used by Usage = The Unit Amount of Electricity Used by Usage (Won Unit) × 0.0391 (4)

· The amount of electricity used by usage: single-unit - 7.2kgoe/㎡, multi-unit - 10.2kgoe/㎡, commercial facility - 28.0kgoe/㎡

· Reviewed and used the results of the study (LHI, 2011)

④ The Amount of Electricity Used for air Cooling by Usage = (Equation 4) × 0.099 (5)

· Electricity used for air-conditioner takes 9.9% of total electricity consumed, used the results of the study (Korea Energy Economics Institute, 2010)

⑤ Amount of Cooling Load Reduced by Urban Park & green spaces = (Equation 5) × 9.0% reduction per ℃ (6)

· Reviewed and used the results of the study (Mcpherson, E, G..,1988 and Ca, V. T., 1998)

⑥ Indirect CO_2 Reduction by Urban Park & green spaces = (Equation 6) × 0.424kgC/kw×3.67 (7)

· Carbon Emission Coefficient from Electricity by Usage: 0.424kgc/kw (Korea Energy Economics Institute, 2010)

Annual CO_2 storage in urban park is calculated with carbon storage of individual tree multiplied by 44/12 (Jeong, H.D., 2009)

5. Results and Discussion

5.1. Calculation of Direct CO_2 Storage of Urban Park

1) CO_2 Storage by the Shape of Tree

The trees in Seoul A zone consists of coniferous tree (1.0%), broad-leaved tree (1.8%), coniferous shrub (5.7%) and broad-leaved shrub (91.5%). And CO_2 storage by the shape of tree turned out as follows: coniferous tree (121,798.2 kg·CO_2/yr), broad-leaved tree (212,042.6 kg·CO_2/yr), coniferous shrub (4,069.3 kg·CO_2/yr) and broad-leaved shrub (186,220.8 kg·CO_2/yr). It was found here that landscape trees took lower portion in the total tree composition of the urban parks but contributed more significantly to CO_2 storage than shrubs.

The trees in Anyang B zone consists of coniferous tree (1.1%), broad-leaved tree (3.6%), coniferous shrub (1.5%) and broad-leaved shrub (93.8%). And CO_2 storage by the

Table 2. Comparison of CO_2 storage capacity of each properties of trees(unit :kgCO_2)

Classification		Tree coniferous	Tree broadleaf	Shrub coniferous	Shrub broadleaf
Seoul A site	Neighborhood park	97,036.9	122,649.6	2,041.2	123,889.3
	Children's park	12,175.5	26,078.1	-	32,954.2
	Waterfront park	3,719.8	5,187.2	1,855.7	2,193.4
	Mini park	8,866.0	58,127.7	172.3	27,183.9
	Subtotal	121,798.2	212,042.6	4,069.3	186,220.8
Anyang B site	Neighborhood park	2,416.0	22,688.6	421.7	6,459.9
	Culture park	38,122.7	70,957.0	4,994.0	24,963.0
	Children's park	4,278.3	5,296.1	-	2,038.7
	Mini park	2,883.8	2,959.7	-	3,329.0
	Subtotal	47,700.8	101,901.4	5,415.7	36,790.6
Daejeon C site	Neighborhood park	44,385.4	119,009.7	258.1	54,202.1
	Children's park	15,063.0	18,793.9	-	11,113.7
	Subtotal	59,448.4	137,803.6	258.1	65,315.8
Kwangju D site	Neighborhood park	54,702.6	84,102.3	-	-
	Children's park	15,963.9	15,022.7	-	3,079.6
	Mini park	718.7	4,052.8	-	283.8
	Subtotal	16,682.6	19,075.5	-	3,363.4

shape of tree turned out as follows: coniferous tree (47,700.8 kg·CO_2/yr), broad-leaved tree (101,901.4 kg · CO_2/yr), coniferous shrub (5,415.7 kg·CO_2/yr) and broad-leaved shrub (36,790.6 kg·CO_2/y). It was found here that broad-leaved tree took much lower portion in the total tree composition but contributed relatively more to CO_2 storage than broad- leaved shrub. The trees in Daejoen C zone consists of coniferous tree (1.9%), broad-leaved tree (3.7%), coniferous shrub (0.2%) and broad-leaved shrub (94.4%). And CO_2 storage by the shape of tree turned out as follows: coniferous tree (59,448.4 kg·CO_2/yr), broad-leaved tree (101,901.4 kg·CO_2/yr), coniferous shrub (258.1 kg·CO_2/yr) and broad-leaved shrub (65,315.8 kg·CO_2/yr). It was found here that broad-leaved tree took 2.5 times lower portion in the total tree composition but contributed 2.6 times more to CO_2 storage than broad-leaved shrub. The trees in Kwangju D zone consists of coniferous tree (16.1%), broad-leaved tree (22.7%) and broad-leaved shrub (61.1%). And CO_2 storage by the shape of tree turned out as follows: coniferous tree (16,682.6 kg·CO_2/yr), broad-leaved tree (19,075.5 kg·CO_2/yr) and broad-leaved shrub (3,363.4 kg·CO_2/yr). The target areas also showed the similar trend of the contribution to CO_2 storage by tree shape. Broad-leaved tree took relatively lower portion in the total tree composition but contributed more to more to CO_2 storage than shrubs. This data shows that it is likely that CO_2 storage capacity will be greater if the portion of landscape trees in those urban parks increases of the total tree composition. Therefore, it is necessary to increase the composition ratio of landscape trees to raise CO_2 storage.

2) CO_2 Storage by Urban Park (Type)

In CO_2 storage by urban park in Seoul A zone, it was known that neighborhood park (345,617.4 kg·CO_2/yr) having the broadest area of planted trees had the highest CO_2 storage and was followed by waterfront park (85,367.3 kg·CO_2/yr). Looking into CO_2 storage per unit area without considering areal effect, mini park (10.6 kg·CO_2/m²·yr) and children's park (10.5 kg·CO_2/m²·yr) had relative high level of CO_2 storage per unit area. Contrarily, neighborhood park (2.7 kg·CO_2/m²·yr) turned out to have low CO_2 storage due to its relatively low planting density of trees per unit area. CO_2 storage by park in Anyang B zone showed that cultural park (139,000.4 kg·CO_2/yr), of which area of planted trees is the biggest of other orban parks in the area, had the highest CO_2 storage and was followed by neighborhood park (26,650.1 kg·CO_2/yr). Looking into CO_2 storage per unit area without considering areal effect, children's park (14.9 kg·CO_2/m²·yr) and mini park (14.7 kg·CO_2/m²·yr) had higher level of CO_2 storage per unit area. On the contrary, neighborhood parks (1.9 kg·CO_2/m²·yr) turned out to have low CO_2 storage due to its relatively low planting density of trees per unit area. In CO_2 storage by park in Daejeon C zone, it was known that neighborhood park (345,617.4 kg·CO_2/yr), of which area of planted trees is the biggest of other urban parks in the area, had the highest CO_2 storage and children's park had 44,970.6 kg·CO_2/yr of CO_2 storage. However, when CO_2 storage was looked into per unit area without considering areal effect, children's park (8.1 kg·CO_2/m²·yr) turned out to have relatively high level of CO_2 storage per unit area. In the meantime, it was proved that neighborhood park (2.3 kg·CO_2/m²·yr) had low CO_2 storage due to its relatively low planting density of trees per unit area.

Table 3. Direct CO_2 storage capacity of each city park

Classification		Planting density (tree/m²)	Average CO_2 storage capacity per one tree (CO_2/tree)	Amount of CO_2 storage (kgCO_2)	CO_2 storage capacity per unit area (kgCO_2/m²)
Seoul A site	Neighborhood park	1.2	2.2	345,617.4	2.7
	Children's park	11.7	0.7	34,541.1	10.5
	Waterfront park	3.8	2.9	11,293.0	10.6
	Mini park	3.7	2.6	85,367.3	9.6
	Subtotal	5.1	2.1	476,818.8	3.4
Anyang B site	Neighborhood park	0.6	3.3	26,650.1	1.9
	Culture park	1.6	4.0	139,000.4	6.5
	Children's park	3.2	4.8	11,612.7	14.9
	Mini park	6.3	2.2	9,172.5	14.7
	Subtotal	2.9	3.6	186,435.7	5.0
Daejeon C site	Neighborhood park	0.7	3.3	217,855.4	2.3
	Children's park	2.4	3.3	44,970.6	8.1
	Subtotal	1.6	3.3	262,826	2.6
Kwangju D site	Neighborhood park	1.8	2.9	192,536.7	5.3
	Children's park	1.0	8.4	34,065.9	8.9
	Mini park	0.6	12.8	5,055.2	7.8
	Subtotal	1.1	8.0	231,657.8	5.6

CO_2 storage by park in Kwangju D zone showed that neighborhood park (192,536.7 kg·CO_2/yr) with broadest area of planted trees had the highest CO_2 storage capacity and was followed by children's park (34,065.9 kg·CO_2/yr) and mini park (5,055.2 kg·CO_2/yr). Looking into CO_2 storage capacity per unit area without considering areal effect, children's park (8.9 kg·CO_2/㎡·yr) had higher level of CO_2 storage per unit area. On the contrary, neighborhood parks (5.3 kg·CO_2/㎡·yr) turned out to have low CO_2 storage due to its relatively low planting density of trees per unit area. CO_2 storage per unit area was estimated from 1.9 kg·CO_2/㎡·yr at minimum to 10.6 kg·CO_2/㎡·yr at maximum. This comparatively considerable gap indicates that CO_2 storage capacity can be enhanced through the management of planting density of trees. Comparing with other CO_2-related factors in previous studies, these CO_2 storage capacities turned out to be lower than 15.1 kg·CO_2/㎡·yr of CO_2 absorption rate in natural forest (Cho, H.G., 1995) and 10.3 kg·CO_2/㎡·yr of CO_2 absorption rate in urban park (Park, E.J. and Kang, K.Y,, 2009) but similar to 6.3 kg·CO_2/㎡·yr in urban park (Kim, H.J. and Kim, U.S., 2010) and higher than 0.154 kg·CO_2/㎡·yr in urban arboretum and 0.251 kg·CO_2/㎡·yr in Urban forest (Jeong, 2009)

Combining these results, it was confirmed that it is more effective to increase tree size and planting density per unit area than whole size of a park to enhance the effect of CO_2 storage in urban park.

5.2. Direct CO_2 Reduction Effect by Urban Park

1) CO_2 Storage by the Shape of Tree

Table 4 shows the results from the calculation of indirect CO_2 reduction according to reduced cooling energy load by urban park. In Seoul A zone, it was estimated that a total of 291,603.4 kg·CO_2/yr (residential: 50,073.8 kg·CO_2/yr; commercial 241,529.6 kg·CO_2/yr) will be indirectly reduced. In Anyang B zone, it was estimated that a total of 165,462.4 kg·CO_2/yr (residential: 14,209.8 kg·CO_2/yr; commercial 151,252.6 kg·CO_2/yr) will be indirectly reduced. It was also calculated that a total of 141,719.2 kg·CO_2/yr (residential: 12,302.8 kg·CO_2/yr; commercial 129,416.5 kg·CO_2/yr) will be indirectly reduced in Daejeon C zone. In Kwangju D zone, it was proved that a total of 154,803.4 kg·CO_2/yr (residential: 11,979.0 kg·CO_2/yr; commercial: 142,824.4 kg·CO_2/yr) will be indirectly reduced. Like this, CO_2 reduction effect by urban park increase 1.8 times more when indirect CO_2 reduction is combined with the effect. Since urban park can reduce CO_2 emission as well as provides fresh climate through temperature reduction in its neighboring areas, it has considerable implication to urban environment control. Therefore, it seems necessary to consider climate control and CO_2 reduction effect together with usability when urban park is designed and drawn.

Table 4. Indirectly CO_2 emissions capacity by the Urban parks

Classification		Power consumption (kw)	Air conditioning power consumption (KW)	Cooling load reduction (KW)	Indirect CO_2 reduction (kgCO2)
Seoul A site	Residential area	1,964,604.5	194,495.9	32,208.5	50,073.8
	Commercial areas	9,476,273.6	938,151.1	155,357.8	241,529.6
	Subtotal	11,440,878.1	1,132,647	187,566.3	291,603.4
Anyang B site	Residential area	539,901.6	53,450.3	9,140	14,209.8
	Commercial areas	5,746,905.6	568,943.7	97,289.4	151,252.6
	Subtotal	6,286,807.2	622,394	106,429.4	165,462.4
Daejeon C site	Residential area	480,072.5	47,527.2	7,913.2	12,302.8
	Commercial area	5,050,147	499,964.6	3,244.1	129,416.5
	Subtotal	5,530,219.5	547,491.8	91,157.3	141,719.2
Kwangju D site	Residential area	455,158.3	45,060.6	7,705.4	11,979.0
	Commercial areas	5,426,684.9	537,241.8	91,868.4	142,824.4
	Subtotal	5,881,843.2	582,302.4	99,573.8	154,803.4

6. Conclusion

6.1 Significance

Upon a urban park that is an very important CO_2 sink in a city emitting more than 80% of greenhouse gas, the present study attempted to and succeeded in answering the following research questions by inventing the equations to calculate direct CO_2 storage capacity and indirect potential CO_2 reduction through the conservation of cooling energy on the basis of the dimensional information of trees to be planned according to the landscape drawing and specification of a new urban park development: Is it possible that CO_2 reduction capacity is calculated reflecting both direct CO_2

storage capacity from trees planted in a urban park and indirect CO_2 reduction through temperature reduction by the park? Is it possible to calculate direct and indirect potential CO_2 reduction capacity by the trees and green spaces in a urban park? If possible, how much CO_2 is reduced by the urban park?

6.2. Findings

Until now, the formulas used to calculate CO_2 storage capacity have used diameter at breast of a tree for landscape tree and diameter at root (source) of tree for shrub. Therefore, they are not suitable to apply to trees in a new urban park. However, the present study has developed equation that can calculate CO_2 storage capacity using root diameter for landscape tree and number of tree for shrub (see Equation 1 above). In addition, it analyzed the amount of electricity saved through temperature reduction by the construction of a urban park and developed the equations of potential CO_2 reduction that converts the conserved amount of electricty into amont of CO_2 reduced (see Equation 2 to 7 above).

According to the results of the calculations of direct and indirect CO_2 reduction capacity by an urban park, landscape trees have higher level of CO_2 storage capacity than shrubs by the shape of tree. Of the same landscape trees, broad-leaved trees have higher level of CO_2 storage capacity than coniferous trees. Therefore, it was found out that CO_2 storage of a urban park can be enhanced by increasing the portion of broad-leaved trees in the composition of trees to be planted in the park. In addition, it was known that CO_2 storage capacity varies very much by urban park: 186.435.7 kg·CO_2/㎡·yr (Anyang B zone) at minimum and 476,818.8 kg·CO_2/㎡·yr (Seoul A zone) at maximum). When indirect CO_2 storage effect is combined in calculation, it turned out that total potential CO_2 reduction capacity increases 1.6 times to 1.8 times more by integrated CO_2 storage effect by an urban park. Accordingly, it seems to be more effective to increase the planting density and tree size than broadening the size of the park to increase CO_2 reduction effect in a city. Moreover, this study identified that a urban park functions to mitigate urban heat island effect, reduce the consumption of building cooling energy and eventually reduce CO_2 emission. Therefore, an attentive consideration should be given to the multifaced effects of urban park as city environment controller when it is planned and designed.

6.3. Implications

This study calculated CO_2 storage capacity by target park on the basis of the formulas derived from direct CO_2 storage equations that can be applied to a new urban park to come in future. The estimated results showed similar phenomenon in CO_2 storage per unit area by park. It was demonstrated that the new equations based on tree height, root diameter and number of tree can be applied to a urban park to be newly built. In addition, The study drew out a formula that can calculate indirect CO_2 reduction capacity and applied it to know indirect CO_2 reduction effect by park in target areas. The combined effect of direct and indirect CO_2 reduction capacity turned out to be 1.6 to 1.8 times greater than direct CO_2 reduction capacity alone. Therefore, this result supports the existing studies that suggest urban park is indirectly effective in restraining CO_2 emission through the reduction of a building cooling energy consumption. Here, we could test the applicability of indirect potential CO_2 reduction capacity equation.

6.4. Limitation and Future Research

Every species of trees has different growth characteristics, so has different CO_2 absorption and storage capacity. However, CO_2 storage equations invented in the present study couldn't reflect these points fully. Accordingly, efforts need to come further to calculate CO_2 storage capacity by species because each species of trees have different CO_2 storage capacity. Futhermore, advancement needs one more step to be taken further over CO_2 storage capacity by the shape and type of trees to tree-planting design technique to increase CO_2 storage effect of trees to be planted in a park. Moreover, actual amount of energy in use by buildings near a urban park should be examined to analyze indirect CO_2 reduction effect by the park more objectively and followed by empirical study on the effect range and extent of temperature reduction by urban park & green spaces. Last, the present study conducted the estimation of CO_2 storage capacity at the point of planting trees. Therefore, time-series simulation analysis is also needed in future study.

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