An Assessment of CO_2 Emission and Absorption in Response to Land-Cover Changes in the Seoul Metropolitan Area

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Abstract—**In order to cope with climate change, which has been becoming a global issue, there are measures such as fundamentally reducing energy use or converting energy sources into renewable energy, but this is difficult to apply due to limitations on human activities. Based on the guidelines provided by the IPCC, this study drew a countermeasure to climate change considering the emission and absorption of CO_2 by land use or land cover. Especially, by using the land-use change simulation technique to predict future land use, expected problems which are caused by urban development were prevented in advance. In addition, CO_2 emissions sources are classified into direct emissions and indirect emissions, and the extent to which each region contributes to greenhouse gas emissions is analyzed to provide alternatives that meet the characteristics of each region. Moreover, to calculate greenhouse gas emissions in the transportation sector, the network analysis of ArcGIS was used to calculate CO_2 emissions from vehicle's movements and to propose alternatives.**

Index Terms—**Climate change adaptation, CO_2 emission and absorption, direct-indirect emission, land use change simulation.**

I. Introduction

The climate change which is caused by emissions of greenhouse gases that raise the average temperature influences on the way of life including industry and economy by causing severe socio-economic losses. Since the Kyoto Protocol in 1997 aimed at reducing greenhouse gases was adopted, research on the observation, analysis and prediction of greenhouse gases has been carried out in a variety of ways to find fundamental solutions to the global warming problem [1]. There was a global agreement to provide a target for reducing GHGs (Green House Gases) emissions by 2020 to limit global warming to within 2℃ on Copenhagen Climate Change Conference (2009). In the same vein, IPCC provided guidelines for preparing carbon emission inventory and required to submit periodic carbon emission inventory. The Korean government declared that it would reduce GHGs emissions by 30% compared to business as usual (BAU) due to an urgent situation [2], indicating a higher global average temperature increase rate. In order to calculate greenhouse gas emissions, the energy use is applied to the IPCC's CO_2 conversion equation to prepare an inventory of carbon emissions, but there is a problem which is that the amount of natural emissions and absorption due to land use or land cover is overlooked. Therefore, it is necessary to develop and apply a methodology for estimating CO_2 emissions, which can be applied to both cities and towns, and includes natural emissions and absorption.

In this study, the present and future patterns of CO_2 emissions and absorption are predicted and measures are taken to reduce net CO_2 emissions. For this purpose, the IPCC guideline, which calculates the CO_2 emissions and absorption by energy use and land cover, is applied to calculate the amount of CO_2 emissions and absorption and analyze the spatial distribution which is based on the simulated the changes of energy use and land-cover of future. Through this, this study aims to prepare countermeasures in terms of urban planning and management according to the patterns of changes in CO_2 emissions and absorption by region and analyze their effects. Procedure for Paper Submission.

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II. Theoretical Review and Advanced Research

A. Analysis of CO_2 Emission and Absorption

The Greenhouse Gas Protocol Initiative divides greenhouse gas sources into direct and indirect sources. And in the case of Korea, under the Act on Low Carbon Green Growth, greenhouse gas emissions are divided into direct emissions that emit greenhouse gases (GHGs) generated by human activities, and indirect emissions that emit greenhouse gases (GHGs) by using electricity or heat supplied from others. Therefore, direct emissions are emissions from electricity and heat or steam production, emissions from physical or chemical processes, emissions from the transport of materials, products, waste, and fugitive emissions. And indirect emissions can be divided into emissions from power use and other indirect emissions from the extraction and production of purchased materials and fuels, transport-related activities, and waste disposal. In the case of greenhouse gas absorption sources, the IPCC 2006 Guidelines classify land use, land use change and forestry (LULUCF) as the absorption sources, and forests, agricultural land and grasslands are classified as the only sources of absorption in land use.

In most studies, the estimation of greenhouse gas emissions was made by dividing into households and industries through methods such as energy use, utilization of IO tables, and calculation of emissions from industrial processes [3]-[5], and for greenhouse gas absorption, estimations can be made based on the increase in biomass carbon accumulation for agricultural, grassland and forests presented in the IPCC 2006 [6].

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B. Analysis of Relationship between Urban Spatial Characteristics and Energy Usage

Research cases related to the creation of low-carbon cities are mainly concerned with the reduction of traffic energy consumption in compact cities. Fossil fuels, known as the main source of greenhouse gas emissions, are mainly used to produce various kinds of energy needed for urban life. The use of fossil fuels such as oil and gas for generating electricity, city gas for cooking and heating, and water supply facilities all result in the emission of greenhouse gases. These energy sources are characterized by different locations of use and emission, but the energy use of transportation directly emits greenhouse gases. For this reason, many cases have focused on the relationship between urban space and transport energy [7]-[13].

There are also a number of studies that focus on analyzing which types of cities contribute to energy use reduction through comparison with the current state of energy use and urban development patterns. In the study of Nam *et al*. [14], based on the results of the analysis of the relationship between consumption of energy sources and urban characteristics, energy policies were suggested that correspond to factors such as urban, industrial, transportation and income by urban type. Steemers [15] found that the use of electric energy increases as the floor area ratio increases, but the increase rate decreases as the density increases. Therefore, maintaining a high density above a certain level may have a positive effect on electricity usage. Lee & Oh [16] suggested urban forms with high energy consumption efficiency by using indicators that can represent urban spatial form. In that study, population and population density showed negative correlation with energy consumption efficiency, but total floor area and floor area ratio showed different results depending on the relationship between area of analysis and development density. Therefore, in order to increase energy efficiency, differentiated urban planning and management policies should be established according to spatial unit of planning and development characteristics. In addition, Kim *et al*. [17], urban forms that affect energy use in urban space are presented based on the relationship between urban form factors related to the physical size, the usage status, and activity intensity of the urban space and the CO_2 emissions from the use of electricity, urban gas, district heating, oil and water.

C. Urban Growth Simulation

As various urban problems are caused by rapid urban growth, prediction of the physical structure, shape and pattern of future cities is important to maintain the quality of life. As a result, the simulation model for urban growth has been attracting much attention since the 1950s. Since the 1970s, a complex system approach based on fundamental principles such as disorder theory and artificial life theory has been the mainstream for urban growth simulation [18]. This is a dynamic and clear time-space modeling technique that is actively studied due to conceptual similarities with the Raster GIS [18]-[21].

Recently, studies on the application of the Cellular Automata theory have been conducted. In the study of Jung *et al*. [22], urban growth types were classified as external growth, non-intellectual growth, and road-induced growth, and random number generation using urban areas, slopes and road networks by time period and the expected number of urban cells by forecast period were used to predict the spread of urban areas in the future. In addition, in order to overcome the disadvantage of Cellular Automata's inability to consider density, Choi and Yim [23] suggested a urban growth model considering density combined with a planar urban growth forecast based on Cellular Automata by allocating population changes per cell of developed cells.

D. Limitations of Existing Studies

Most of the previous studies did not distinguish between greenhouse gas emission sources and calculated the CO_2 emissions by applying the carbon emission factor to the amount of each energy source. However, because of the high percentage of oil consumed by traffic, estimating CO_2 emissions based on consumption at the point of sale is less accurate. In the case of electricity, it is meaningful that the power consuming area contributes to the CO_2 emission, but the actual CO_2 emission is generated in the power generating plant. Therefore, when creating alternatives or policies to reduce CO_2 emissions, it is necessary to distinguish between areas that actually emit CO_2 and areas that contribute to CO_2 emissions.

Further, the research to predict future CO_2 emissions and absorption was conducted using input-output models, macroeconomics models, CGE models, dynamic energy optimization models, etc. However, since it is difficult to accurately grasp the spatial location of CO_2 emissions and absorption sources and to take into account changes in land cover due to urban development, there is a limit to apply directly to the IPCC 2006 Guideline. In order to solve this problem, it is possible to analyze the spatial distribution of CO_2 emissions and absorption by land cover in accordance with the IPCC 2006 Guideline if a simulation model is applied to predict future changes in land cover. As a result, alternatives for reducing CO_2 emissions and enhancing absorption are presented separately by each space, and their effects can be verified.

III. METHODOLOGY

A. Analysis of CO_2 Emission and Absorption

This study is to predict changes in CO_2 emissions due to land use change, which is divided into three parts: estimation of energy use, prediction of land cover changes, and calculation of CO_2 emissions due to energy use and land cover (Fig. 1). First, the relationship between the characteristics of urban space and the amount of energy use is analyzed. CO_2 is emitted by energy use according to human activity, and the CO_2 emissions are calculated by analyzing the urban spatial characteristics and traffic volume that affect the consumption of each energy source of urban gas, oil and electricity. The regression equation derived of the analysis of energy use according to the urban spatial structure is used to estimate the energy consumption according to the future land cover change.

And CO_2 emissions from the transportation sector are calculated by applying the CO_2 emission coefficients by vehicle type per unit distance to the optimal path derived through network analysis, which is conducted by using the current OD data in 2009 and predicted OD data in 2030.

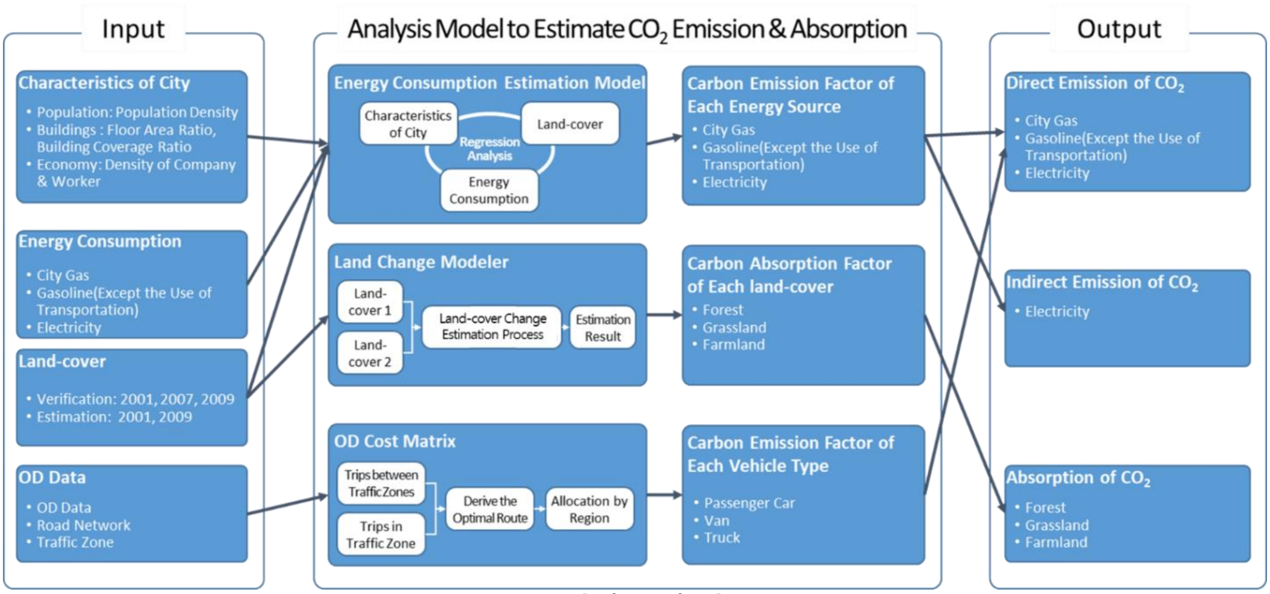

Fig. 1. The frame of analysis.

TABLE I: ENERGY USE ESTIMATION BY URBAN SPATIAL CHARACTERISTICS

Sector	Variables of Advanced Researches		Adaptation in this Research
Population & Economy	Population		Population Density
	Number of Households		Household Density
	Level of Employment	Economically Active Population	Density of Employee
		Number of Employee	
Land-use	Number of Houses		Residential Density
	Number of Companies		Density of Companies
	Area of Urbanized Area, Mixed Land-use		Area of Each Land-cover
	Ratio of Public Lands		-
	Development Density		Building Coverage Ratio, Floor Area Ratio, Average Height of Building of Each Land-cover
Transportation	Road Density	Trips	Trips Between Origin and Destination
		Area of Roads	Least Cost Route
Energy Use	Energy Use in Buildings		Energy Use of Buildings(City Gas, Gasoline, Electricity)
	Energy Use of Transportation		Energy Use of Transportation (Gasoline, Diesel, LPG)
Others	Scale of City		Area of City
			Large City or Not(Dummy)
	Terrain		Elevation, Slope

Second, future land cover changes is predicted. Land cover is an aggregate result of land and facilities, which are the physical components of a city, and is an important measure of the characteristics of citizens and activities, which are the social and cultural components of the city. In this study, the Land Change Modeler is used to simulate future land cover changes, where the land cover used in the simulations is subdivided or integrated to conform to the IPCC 2006 Guideline.

Third, the amount of CO_2 emissions and absorption due to land cover and energy use is calculated by direct emission, indirect emission, and absorption by each energy source, and then the spatial distribution of net CO_2 emissions is analyzed by utilizing them. Based on the results of the analysis, the measures for reducing CO_2 emissions in the future were also proposed and their effects were analyzed.

B. Analysis of Relationship between Urban Characteristics and Energy Usage

In this study, the analysis is performed based on the energy consumed in the end, but the coal whose utilization rates have been decreasing gradually and the regional heating including consumption of energy sources for generating heat energy are excluded from the analysis. Therefore, the energy sources used for analysis are electric power, gas, and oil. And in the case of oil, the consumption of oil used in the building and transportation are separated, and the former is analyzed by the regression model and the latter by the traffic volume calculation.

1) Analysis of relationship between urban spatial elements and energy consumption

Energy is consumed by human activities, and human activities are affected by various urban spatial characteristics such as terrain, land use or land cover and development density. Thus, cross-sectional analysis using the statistical regression model could be considered as a useful way to analyze the impact and extent of the spatial characteristics of city on energy use, and to find the factors that cause regional energy use differences among these characteristics.

In this study, multiple regression analysis was performed to estimate the coefficients of the energy use function. In the previous step to derive the regression equation, among the factors that represent the spatial characteristics of the city selected above, only the variables showing significant correlation through the correlation analysis with the energy usage were reflected in the regression formula. Correlation analysis and regression analysis were conducted on a total of 66 samples throughout the Seoul Metropolitan Area, and since energy consumption in large cities differed from other small and medium-sized cities, they were distinguished using dummy variables (Table I).

2) *Estimation of energy consumption by traffic volume*

In this study, the traffic volume and the minimum cost route of each vehicle type were analyzed based on the following assumptions in order to analyze the energy use of the transport sector using the traffic volume between zones of the OD data.

First, transportation between traffic zones is based on moving from the center of the traffic zone to the center of the other traffic zone.

Second, it is assumed that all the agents of traffic take the most ideal route, that is, the least cost route. The travel routes may be different depending on the traffic conditions or personal purposes, but since the individual routes of each passenger cannot be identified, the travel distance is calculated according to the assumption that all passengers chooses the optimal route.

The minimum cost path was analyzed using the OD Cost Matrix module, one of the network analysis modules of ArcGIS 10.2. The central point of the traffic zone provided by the National Traffic DB Center (www.ktdb.go.kr) was designated as the origin and destination point, and each point was located in the actual road network. The minimum cost path analysis was performed by inputting the distance and the reference speed for smooth communication by road type of network link as the weight of the resistance value. Afterwards, the minimum cost path analyzed for each type of vehicle was multiplied by the daily traffic volume and travel distance for each means of transportation, and the CO_2 emission factor by means of transportation was applied to calculate the final CO_2 emission amount (eq. 1).

$$\text{CO}_2\text{ Emission} = \text{Optimal Route(km)} \times {}^{\text{Traffic}}/_{\text{day}} \times \text{Carbon Emission Factor of each Vehicle Type}(\text{tCO}_2\ /\ km) \quad (1)$$

C. *Prediction of Urban Growth*

1) *Establishing the type of urban growth and deriving the factors*

The types of urban growth were divided into external growth which means that the non-urban area is transformed to the urban area by the influence of the nearby urban area, non-intellectual growth where non-urban area is transformed into a urban area by arbitrary probability, and road-induced growth where urban growth is more likely to occur as the area is close to the road [22]. In addition, based on the preceding study, land cover, distance from the urban areas, distance from the roads, slope and elevation were selected as factors for urban growth, and areas with slope of 25% or more, development restricted areas, and areas with legally restricted development were selected as factors limiting urban growth [18], [22], [24].

2) *Land cover change prediction model*

Land cover change simulation was performed using Land Change Modeler, a module of IDRISI, a raster-based GIS program developed by Clark Lab. of Clark University, USA. The prediction of land cover change using Land Change Modeler is as follows: First, the probability of each land cover change to another land cover is calculated based on the pattern of land cover change in the past. Second, the total amount of land cover change is calculated and allocated according to the past trend of land cover change probability. Finally, the ultimate change in land cover is achieved by resolving conflicts in the allocation of land cover. The simulation is performed in as many steps as the user enters, it is possible to perform a dynamic analysis in which the newly distributed land cover and previously planned infrastructure are utilized as new inputs in the target year (Fig. 2).

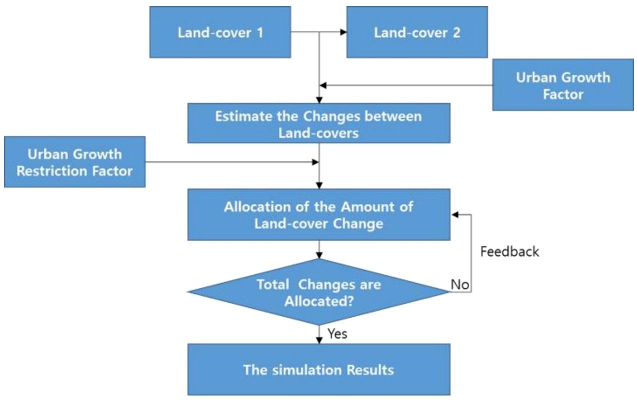

Fig. 2. Concept of land change modeler.

D. *Calculation the Amount of CO_2 Emission and Absorption*

CO_2 emissions can be calculated by applying Ton of Oil Equivalent (TOE) and Carbon Emissions Factor (CEF) for each energy use presented by the IPCC to each energy source (eq. 2).

$$E_c = \sum(e_i \times T_i \times C_i \times c) \quad (2)$$

E_c :Carbon Emission
e_i :Usage of Energy
T_i :TOE of Energy
C_i :Carbon Emission Factor of Energy
c : Molecular Weight of CO_2 /Molecular Weight of C(44/12)

1) *Estimation of CO_2 absorption by land cover*

The only carbon-absorbing sources presented by the IPCC 2006 Guideline are forests, grasslands and farmland at LULUCF. Thus, in this study, CO_2 absorption was calculated for forests, grasslands and agricultural land. For this purpose, the vegetation types were classified into coniferous forests, mixed forests, and broad-leaved forests, and CO_2 absorption coefficients according to each age-class were applied (Table II).

TABLE II: CARBON ABSORPTION FACTOR BY AGE-CLASS & TYPE OF TREE

Type of Tree	Carbon Absorption Factor by Age-class (t/ha/yr)					
	I	II	III	IV	V	VI
Needleleaf Tree	5.76	10.14	10.27	7.42	5.85	4.79
Mixed Forest	6.91	11.62	10.74	8.27	6.79	5.76
Broadleaf Tree	10.36	16.08	12.14	10.81	9.62	8.65

In the case of grassland, the estimation of CO_2 absorption by grassland is missing due to the problem of data acquisition in the 2013 National Inventory Report. However, in this study, the amount of CO_2 absorption by the grassland was calculated by citing the research result of Lee [25], which estimates the amount of CO_2 absorbed by the grassland area (eq. 3).

$$\text{CO}_2 \text{ Emission of Grassland} = 0.0471(\text{kg/m}^2) \times \text{Area of grassland}(\text{m}^2) \quad (3)$$

Finally, in accordance with the IPCC 2006 Guideline, the emission coefficient of temperate and wet weather areas where Korea belong to was applied to rice paddies, fields and orchards (Table III).

TABLE III: CARBON INCREMENT BY TYPE OF CROPS

Type of Crop	Carbon Increment (tC/ha/yr)
Fields and Paddies	5.0
Orchard	2.1

IV. CASE STUDY

In this study, case studies were conducted on the Seoul Metropolitan Area, where excessive concentration of the population caused many problems such as environmental, transportation, and housing. However, the islands that are not connected with land by roads were excluded from the analysis sites because separate growth rules are applied as independent spaces that are not influenced by land in predicting land cover change.

A. Analysis of CO_2 Emission and Absorption

1) Estimation of Energy Consumption according to urban Spatial Characteristics

To identify factors affecting energy use, the spatial characteristics and socio-economic factors and their correlation with energy use per unit area were analyzed. The regression equations by each energy source were derived for variables other than factors that are not significant or show a low correlation with the correlation coefficient of less than 0.4 (Table IV).

TABLE IV: RESULT OF REGRESSION

Classification		Unstandardized Coefficients		Standardized Coefficients	t	p-value	Model Summary	
		B	Standard Error				R^2	p-value
City Gas	(Constant)	-68854.475	18727.031		-3.677	.001	0.847	0.000
	Large City or Not (Dummy)	26145.057	9332.975	.115	2.801	.009		
	Area	8.938E-05	.000	.200	2.455	.018		
	Residential Density	2913.662	996.418	.804	2.924	.006		
	Density of Companies	-5432.307	2495.252	-.240	-2.177	.011		
	Building Coverage Ratio	4292.452	1865.332	.274	2.301	.035		
	Floor Area Ratio	223.310	94.003	.123	2.376	.023		
Gasoline (Except the Use of Transportation)	(Constant)	-4663.953	1537.622		-3.033	.004	0.652	0.000
	Large City or Not (Dummy)	15509.595	7272.140	.290	2.133	.038		
	Area	8.458E-06	.000	.080	2.125	.042		
	Residential Density	463.483	219.292	.544	2.114	.041		
	Density of Companies	-4291.559	1305.712	-.806	-3.287	.013		
	Density of Employee	666.424	249.573	.687	2.670	.033		
	Floor Area Ratio	94.110	43.236	.220	2.177	.037		
Electricity	(Constant)	8015.078	2607.384		3.074	.004	0.840	0.000
	Large City or Not (Dummy)	3606.279	1726.971	.070	2.088	.035		
	Area	-9.486E-06	.000	-.093	-2.138	.023		
	Residential Density	42.253	13.137	.051	3.216	.003		
	Density of Employee	504.320	67.360	.539	7.487	.000		
	Building Coverage Ratio	1277.167	534.726	.359	2.388	.021		
	Floor Area Ratio	-29.340	10.369	-.071	-2.830	.009		

2) Estimation of energy consumption according to urban spatial characteristics

The CO_2 emission of the transportation department is calculated by applying the CO_2 emission coefficient of vehicle type [5] to the result of multiplying the optimal route, which is analyzed by the OD Cost Matrix module of ArcGIS, by the traffic volume (eq. 4).

$$\begin{aligned} &CO_2\ \text{Emission from Transportation}(gCO_2) \\ &= \text{Traffic Volume}(trip/day) \times 365(day) \times \text{OptimalRoute}\ (km) \times \\ &CO_2\ \text{Emissions per Driving Distance by Vehicle Type}(gCO_2/km) \end{aligned} \quad (4)$$

As a result, it accounts for about 15.2% of the total 66,694,590 Kton CO_2 emissions in the Seoul Metropolitan Area and about 22.5% of the total direct emission of 105,892,807 Kton CO_2.

B. Urban Growth Prediction

In order to drive the Land Change Modeler, the distance from the road and the distance from the city to reflect the type of urban growth were used as input data, and development-restricted zones and the areas whose development was restricted by various regulations, such as development-restricted area, were designated as factors limiting regional growth. A comparison of the actual 2009 land cover and the predicted 2009 land cover based on the change trend from 2001 to 2007 showed a convergence of 78.76% that matched the type and location of land cover. Based on this, the results of predicting land cover in 2030 are as follows (Table V).

TABLE V: LAND-COVER CHANGE

ha(%)

From \ To	Residence	Industry	Commerce	Culture, Recreation	Public	Total
Agricultural Land	26,472.74 (27.63)	15,195.01 (15.86)	5,415.56 (5.65)	386.07 (0.40)	5,020.97 (5.24)	52,490.36 (54.78)
Forest	6,971.48 (7.27)	8,712.11 (9.09)	7,028.33 (7.33)	451.71 (0.47)	6,972.47 (7.28)	30,136.09 (31.45)
Grass Land	2,129.37 (2.22)	1,026.54 (1.07)	541.00 (0.56)	152.00 (0.16)	865.77 (0.90)	4,714.67 (4.92)
Bare-land	3,998.18 (4.17)	1,820.72 (1.90)	1,211.66 (1.26)	135.91 (0.14)	1,320.31 (1.38)	8,486.78 (8.86)
Total	39,571.77 (41.29)	26,754.38 (27.92)	14,196.56 (14.81)	1,125.69 (1.17)	14,179.52 (14.80)	95,827.90 (100.00)

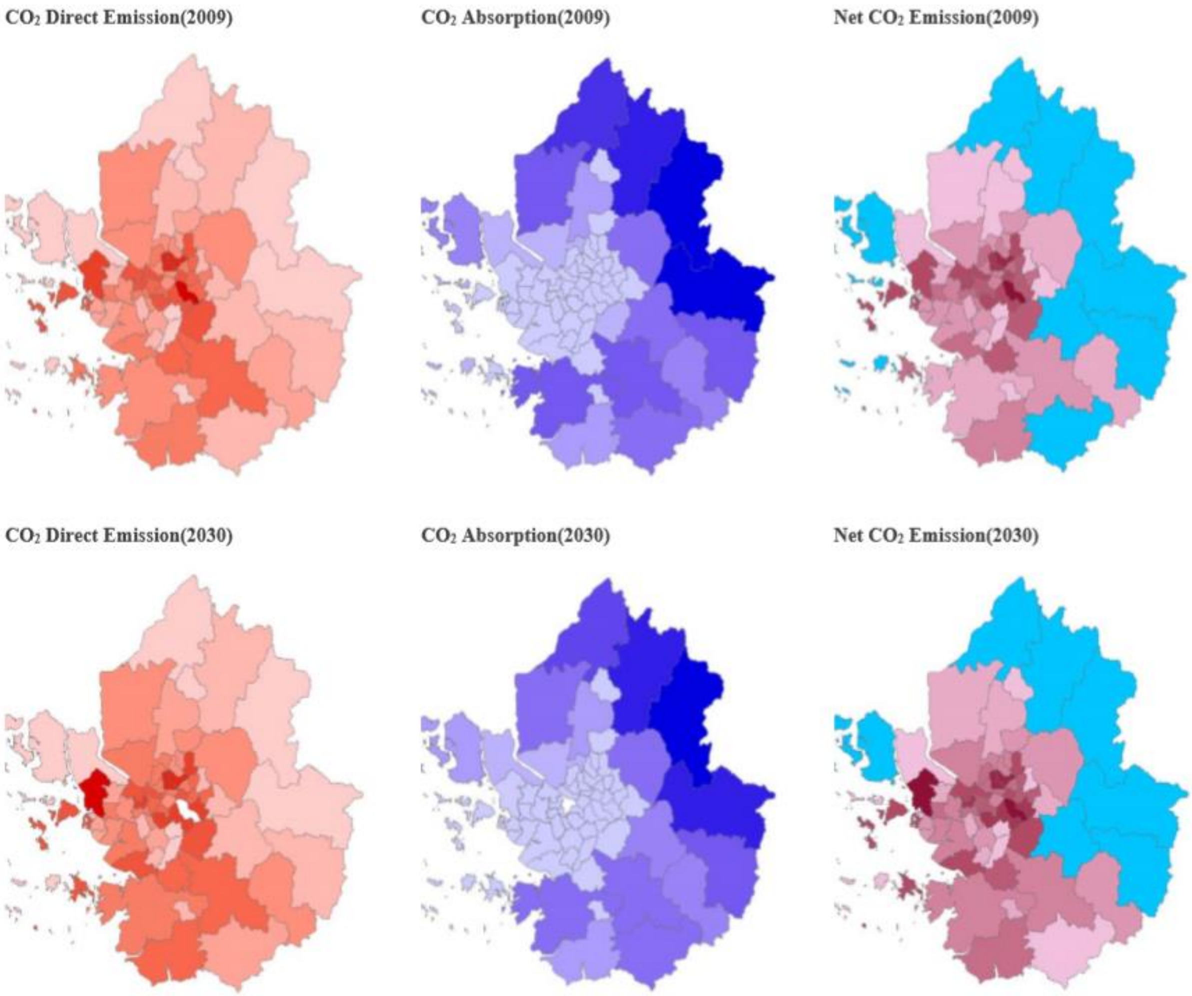

Fig. 3. Estimation Result of CO2 emission and absorption.

TABLE VI: SCENARIO TO REDUCE EMISSION & IMPROVE ABSORPTION OF CO_2

Quadrant	Goals		Scenarios	
	Emission	Absorption	Scenarios for each Quadrant	Common Scenario
I Quadrant	Reduce	-	• Restrict the Change of Land-cover to Residential, Commercial, Industrial Use • Keep Current Building Coverage Ratio & Floor Area Ratio of Residential, Commercial, Industrial Use	• Achieve 30% of Biotope Area Ratio on the New Development Area • Reduce Traffics by Encouraging the Use of Public Transportation
II Quadrant	-	-	-	
III Quadrant	-	Improve	• Restrict the Change of Forest, Grassland and Agricultural Land to other Land-cover	
IV Quadrant	Reduce	Improve	• Restrict the Change of Land-cover to Residential, Commercial, Industrial Use • Keep Current Building Coverage Ratio & Floor Area Ratio of Residential, Commercial, Industrial Use • Restrict the Change of Forest, Grassland and Agricultural Land to other Land-cover	

TABLE VII: EFFECTS OF THE SCENARIOS

(kton CO_2)

	2009 (A)	**2030 (B)**	**Adaptation of Scenarios**			
			Restrict Land-cover Changes & Development Density (C)	Achieve 30% of Biotope Area Ratio (D)	Encourage the Use of Public Trans-portation (E)	Total (F=B+C+D+E)
Direct Emission	129,753.6	147,646.1	-1,242.4		-428.7	145,975.0
Indirect Emission	27,095.7	31,058.4	-98.7			30,959.7
Absorption	19,849.1	17,816.3	276.0	338.2		18,430.5
Net Emission	109,904.5	129,829.8	-966.4			128,311.4

TABLE VIII: CO_2 EMISSION FROM ELECTRICITY GENERATION AND INDIRECT EMISSION

(kton CO_2)

	2009		2030		2030 (Adaptation of Scenarios)	
	CO_2 Emission from Electricity Generation	Indirect Emission of CO_2	CO_2 Emission from Electricity Generation	Indirect Emission of CO_2	CO_2 Emission from Electricity Generation	Indirect Emission of CO_2
Seoul	0.3	7,982.1	0.3	8,955.5	0.3	8,997.5
Incheon	24.0	3,843.6	26.3	4,473.3	26.3	4,810.5
Gyunggi	6.3	15,270.0	7.0	17,629.6	7.0	17,151.7
Total	30.6	27,095.7	33.6	31,058.4	33.6	30,959.7

C. Estimate the Amount of CO_2 Emissions and Absorption

CO_2 emissions and absorption were calculated by taking into account CO_2 emissions from energy use and transport, and CO_2 absorptions by land cover. Among them, CO_2 emissions from electricity use were not included in the calculation of net emission by dividing the emissions into indirect emission sources because the regions that emit the actual CO_2 for energy generation did not eventually match those that consume the energy (Fig. 3).

As a result of the analysis, it was found that agriculture and forests decreased and residential and industrial areas evidently increased in where relatively is not urbanized and located on the outskirts of Gyeonggi-do than those already developed in Seoul and Incheon. Thus, if urban development is carried out according to the trend so far, the net CO_2 emissions will increase 17.4% as CO_2 emissions increase and absorption decrease, which will result in a reversal of the country's greenhouse gas reduction target of 30% compared to BAU.

D. Analysis of the Effect of Reduction of CO_2 Emission and Improvement of Absorption

In this study, after establishing a goal to curb the increase in CO_2 emissions and reduction in absorption according to the change in CO_2 absorption and emission trends for each city, the improvement scenario was established for four areas:

land use, development density, ecological area ratio and public transportation (Table IV).

The change in land cover and traffic volume in 2030 were calculated based on the improvement scenario, and then CO_2 emission and absorption were calculated which resulted in a decrease of 5.3% of the net CO_2 emission increase (Table VII).

In the case of indirect emissions, electricity use by each city was analyzed as a contribution to CO_2 emissions from power plants located in the Seoul Metropolitan Area, assuming that all of the electricity produced in the Seoul Metropolitan Area was first consumed in there. The CO_2 emissions from power generation in the Seoul Metropolitan Area account for 0.112% of total indirect emissions in the Seoul Metropolitan Area, of which 78.43% are generated from Incheon (Table VIII).

In order to resolve the gap between the energy consumed area during electricity use and the area where CO_2 is generated by power generation, the emission trading system and the carbon tax can be applied to the workplace and local governments, respectively. In the case of the emission trading system, emission rights are imposed on major business sites, provided by the Kyoto Protocol, that emit greenhouse gases such as energy sectors, energy-intensive industrial processes, agriculture, and waste, but in the case of power plants, some of the emission rights can be allocated to major power-use businesses according to the amount of electricity used. In the case of carbon taxes, a method is applicable to invest the collected tax which is imposed based on the amount of electricity used in projects to reduce CO_2 emissions from the area where the plant is located.

V. Conclusion

Based on the IPCC 2006 Guideline, the amount of CO_2 emissions and absorption due to land cover was calculated for Seoul Metropolitan Areas, and the change of land cover was predicted using Land Change Modeler to examine future CO_2 emissions and absorption trends and to come up with alternatives. As a result of the analysis, if the urban development is carried out up to now, CO_2 emissions will increase and the amount of absorption will decrease, resulting in a 17.4% increase in CO_2 emissions, which is against the 30% reduction in the greenhouse gas reduction target. In order to address this problem, the followings were suggested: 1) reduce CO_2 emission sources and restrain the perishment of absorption sources, 2) increase CO_2 absorption sources by achieving 30% ecological area rate of new development site, and 3) increase public transportation sharing rate. As a result of verifying the effect after setting those as an alternative, it was found that 5.30% of the net CO_2 emission, which is increasing due to the current trend, can be reduced. As a result of the application of alternatives to only new development areas, it would have a greater effect if the expansion of the supply of new and renewable energy and other measures to increase energy efficiency were applied together. In addition, it is possible to induce reduction of greenhouse gas emissions by allocating emission rights and levying carbon taxes according to their contribution levels by identifying the extent to which they contribute to the generation of CO_2 based on the electricity use in each region.

This study is meaningful in that it proposed a response that is consistent with the spatial location and characteristics of each region in response to the climate change in terms of urban development and management measures by predicting the CO_2 emission and absorption patterns through simulations of future land cover changes based on the guidelines provided by the IPCC.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Sangheon Lee conducted the overall research, including data analysis and paper writing; all authors had approved the final version.

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