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Impacts of Mt. Bongeui on Atmospheric Purification in Chuncheon

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Abstract

Mt. Bongeui is a neighborhood park of 66.4 ha as a major natural landscape resource located in the center of Chuncheon City. This study quantified the reduction of carbon, SO_2, NO_2, O_3, and $PM_{2.5}$, and the production of O_2 to explore the role for Mt. Bongeui to contribute to annual atmospheric purification. The main forest types and age classes of the study site included age-class III broadleaved forest at 35.8%, age-class VI coniferous forest at 17.2%, and age-class IV broadleaved forest at 15.7%. The annual atmospheric purification effect per unit area was as follows: 7.6 t carbon/ha/yr, 16.6 kg SO_2/ha/yr, 40.4 kg NO_2/ha/yr, 41.5 kg O_3/ha/yr, 53.7 kg $PM_{2.5}$/ha/yr, and 20.2 t O_2/ha/yr. The economic value of these effects was equivalent to about 12.9 million KRW/ha/yr. The study site annually offset carbon emissions of about 300 citizens, SO_2 emissions of 220 citizens, and NO_2 emissions of 92 citizens in Chuncheon. It also played an important role in annually producing 1.5% of the amount of O_2 necessary for the respiration of Chuncheon's total population. This study pioneers in comprehensively quantifying the atmospheric purification effect and could be useful in guiding the planning and management to improve the effect.

Key Words: carbon, pollutants, oxygen, economic value, offset

Introduction

Globally, the consumption of fossil fuels has continuously increased the concentration of air pollutants, such as SO_2, NO_2, O_3, and $PM_{2.5}$, as well as carbon, which is the main cause of climate change. The increase in air pollutants has a negative impact on natural ecosystems and socio-economic systems (MOE 2014). Therefore, various efforts have been internationally made to reduce the emission of air pollutants including carbon (Cheongwadae 2016; Cheongwadae 2017; GIR 2017).

Mt. Bongeui is a neighborhood park located in the center of Chuncheon City, Korea. The park contributes to improving the quality of urban environment, such as air pollution control, heat island mitigation, and wildlife inhabitation. However, there is no information on environmental benefits of the park, and the expansion of the city presently threatens damage to the park.

The purpose of this study is to quantify the atmospheric purification effect of Mt. Bongeui to suggest the base information necessary for planning and management. The gaseous and particulate materials considered in computing the effect were the reduction of carbon, SO_2, NO_2, O_3, and $PM_{2.5}$, and the production of O_2. This study pioneers in tackling the complexities associated with comprehensively quantifying the materials, including carbon and $PM_{2.5}$, which are recently emerging as environmental problems.

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Materials and Methods

Sampling and survey

A total of 73 sample survey points were selected through a systematic sampling method on a 1:5,000 forest type map and aerial photographs. A grid of 2 cm spacing, which could reflect all the forest types and age classes of the study site, was established and all these points were sampled. For sample survey points, an on-site investigation was performed on the forest structure, including tree species, stem diameter, crown width, tree height, and stratum using the quadrat method (size: 10×10 m) from August to September 2017.

Quantifying atmospheric purification effects

The atmospheric purification effect per unit area by forest type and age class was quantified applying a quantitative model at the single-tree level by species to the result of forest structure survey. Annual carbon absorption was estimated using a quantitative model (Jo 2001; Jo and Ahn 2003; Jo and Ahn 2013) derived through the annual measurement of the CO_2 exchange rate. Annual absorption of SO_2, NO_2, and O_3 was calculated using a quantitative model (Jo 2001) derived from the absorption velocity ratios of SO_2, NO_2, or O_3/CO_2. Annual $PM_{2.5}$ deposition was computed using the dry deposition model (Jo 2001; Nowak et al. 2013) based on deposition velocity, total leaf area, and resuspension ratio by wind speed. Annual O_2 production was quantified based on the photosynthesis formula (Lieth 1963), which indicates the absorption of 6 moles of CO_2 and the emission of 6 moles of O_2. The atmospheric concentrations of these pollutants were applied based on data measured over the last three years (2014-2017) in Chuncheon City or nearby areas.

Analysis of economic value and emission offset

The atmospheric purification effect of the study site was converted into an economic value using the treatment and abatement cost by atmospheric matter: approximately 400 thousand KRW/t for carbon and O_2, 3,700 thousand KRW/t for SO_2, 15,200 thousand KRW/t for NO_2 and O_3, and 10,150 thousand KRW/t for $PM_{2.5}$ (Murray et al. 1994; GCCSI 2017; KPRC 2017). The annual average energy consumption of Chuncheon citizens for the last three years (Chuncheon 2017) was computed to explore the role of the study site in offsetting carbon and air pollutants. The amount of annual carbon and air pollutant emissions from the energy consumption was estimated applying the emission factors by energy type such as electricity, oil, and gas (NIER 2012; KEA 2016).

Results and Discussion

Forest type and age class

The total area of Mt. Bongeui is 66.4 ha. The most common forest types were broadleaved forest at 60.6%, followed by coniferous forest at 27.6% and mixed forest at 11.8%. By age class, age class III was predominant at 43.1%, followed by age class IV at 28.7% and age class VI at 17.2%. Tree density varied in the range of 9.1 to 13.7 trees/100 m^2 depending on forest type and age class. The stem diameter distribution at breast height of the tree was as follows: less than 10 cm with about 34%, 10-20 cm with 36.1%, and 20-30 cm with 18.1% (less than 30 cm with 88.2%). The major tree species with high mean importance values included *Quercus mongolica* (35.1%), *Pinus densiflora* (30.9%), and *Prunus sargentii* (6.2%).

Atmospheric purification effects

The annual atmospheric purification effect per unit area of the study site increased as the age class rose. For the same age class, the effect was greater in broadleaved forests than in coniferous forests (Table 1). However, annual $PM_{2.5}$ deposition was larger in coniferous forests than in broadleaved forests. Age-class VI coniferous forest, the oldest age at the study site showed the greatest atmospheric purification effect per unit area: 9.7 t carbon/ha/yr, 24.6 kg SO_2/ha/yr, 60.0 kg NO_2/ha/yr, 61.6 kg O_3/ha/yr, 156.2 kg $PM_{2.5}$/ha/yr, and 25.9 t O_2/ha/yr.

Previous studies (Jo 2001; Jo et al. 2002; Jo and Ahn 2013) reported that the annual atmospheric purification effect per unit area of age-class IV broadleaved forest distributed in the central area of Korea, including the Namsan Nature Park in Seoul, was 6.8-7.6 t carbon/ha/yr, 17.1-23.7 kg SO_2/ha/yr, and 44.2-48.2 kg NO_2/ha/yr. The absorption values of the study site were similar to or up to 1.3 times larger than those in the previous studies. The annual atmospheric purification effect for the total area of the study site was as follows: 478.5 t carbon/yr, 1,048.1 kg SO_2/yr, 2,556.4 kg NO_2/yr, 2,625.5 kg O_3/yr, 3.4 t $PM_{2.5}$/yr, and 1,276.0 t O_2/yr (Table 2).

Table 1. Atmospheric purification effects per unit area by forest type and age class

Matter*	Coniferous				Broadleaved			Mixed	
	III	IV	V	VI	II	III	IV	III	IV
C	4.6±0.2	6.5±0.4	7.9±0.4	9.7±0.7	3.8±0.3	7.5±0.3	8.9±0.3	5.6±0.3	7.6±0.5
SO_2	7.5±1.1	16.1±1.4	19.6±1.4	24.6±1.1	6.9±0.7	14.5±0.6	21.7±1.1	10.7±0.7	16.4±0.6
NO_2	18.3±2.8	39.2±3.3	47.8±3.5	60.0±2.8	16.8±1.7	35.4±1.5	52.8±2.8	26.2±1.7	40.1±1.5
O_3	18.8±2.8	40.2±3.4	49.0±3.6	61.6±2.9	17.3±1.8	36.4±1.5	54.2±2.8	26.9±1.7	41.1±1.5
$PM_{2.5}$	49.7±2.4	77.6±6.9	116.7±2.2	156.2±15.8	7.9±0.9	19.7±1.5	33.9±4.2	34.9±1.1	58.2±4.7
O_2	12.3±0.4	17.3±1.0	21.1±0.9	25.9±1.9	10.1±0.9	20.0±0.8	23.7±0.8	14.9±0.9	20.3±1.4

*Unit: t/ha/yr for C and O_2, and kg/ha/yr for the other matter.

Table 2. Capacity and economic value of atmospheric purification by matter

Matter	Unit area (ha)		Total area	
	Capacity[a]	Value (ten thousand ₩/ha/yr)	Capacity[b]	Value (million ₩/yr)
C	7.6	302	478.5	191
SO_2	16.6	6	1,048.1	4
NO_2	40.4	61	2,556.4	39
O_3	41.5	63	2,625.5	40
$PM_{2.5}$	53.7	55	3.4	35
O_2	20.2	808	1,276.0	511

[a]Unit: t/ha/yr for C and O_2, and kg/ha/yr for the other matter; [b]Unit: t/yr for C, $PM_{2.5}$ and O_2, and kg/yr for the other matter.

Emission offset and implication

The annual emissions of carbon, SO_2, and NO_2 per capita from energy consumption in Chuncheon City were 1.6 t/yr, 4.7 kg/yr, and 27.7 kg/yr, respectively. Mt. Bongeui annually offset carbon emissions of about 300 citizens, SO_2 emissions of 220 citizens, and NO_2 emissions of 92 citizens in Chuncheon. The study site also annually produced 1.5% of the amount of O_2 necessary for Chuncheon's total population (280 thousand), based on the annual O_2 requirement for respiration of 0.3 t per capita (Nowak et al. 2007). Thus, the study site played an important role in improving the urban air quality.

The economic value per unit area of the annual atmospheric purification effect equaled approximately 3 million KRW/ha/yr for carbon, 60,000 KRW/ha/yr for SO_2, 610,000 KRW/ha/yr for NO_2, 630,000 KRW/ha/yr for O_3, 550,000 KRW/ha/yr for $PM_{2.5}$, and 8 million KRW/ha/yr for O_2 (Table 2). The total economic value for the entire study area of the effect was equivalent to about 820 million KRW/yr. The economic value for O_2 and carbon comprised 62.3% and 23.3% of the total, respectively. These economic values can be useful in securing the budget required for managing the study site.

The economic value of the annual atmospheric purification effect per unit area by forest type and age class appeared in the order of 18 million KRW/ha/yr for age-class VI coniferous forest and 15 million KRW/ha/yr for age-class IV broadleaved forest. High priority of the management should be placed on conservation of these forest types and age classes with greater levels of atmospheric purification. The area of the study site important as the urban forest has been reduced with the expansion of the city (Jo 2003). It is essential to limit the development activities by establishing a buffer zone around the periphery of the study site. The poor growth of trees reduces the atmospheric purification effect. The normal growth of trees should be ensured through such means as supplementary planting, thinning, or the control of insects and diseases, such as pine creeper and oak wilt disease. It is important to publicize the atmospheric purification value of the study site and to boost citizens' participation and interest. This study comprehensively considered various gaseous and particulate materials in quantifying the atmospheric purification. The results of the study are expected to contribute to the sharing of relevant information with the world as well as the study site.

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