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Development of a Prediction Model for NVOC Concentration with Changing Microclimate in *Camellia Japonica* Temple Forest

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This study aimed to make an efficient estimation of the concentration of NVOC with changing climate conditions in the forests possessed by Buddhist temple for the purpose of landscape preservation and procurement of material and operating expenses for Buddhist temple in Korea. To complement economic and technical issues of existing NVOC measurement techniques, the study conducted a total of 48 survey and analysis sessions from May 2016 to June 2016 in *Camellia japonica* forest, representing the climate of warm temperate zone. The comparison of the NVOC construction in *Camellia japonica* forest in summer showed 51% of α–pinene (1.79 μg/m^3), followed by 19% of β–pinene (0.68 μg/m^3). The analysis of daily NVOC concentration showed that it was the highest during the sunrise and the concentration increased when the photo–environment changed and when there was a smaller effect of wind velocity. The study also presented a concentration prediction model with varying microclimate conditions using a multiple regression analysis. The regression analysis on the estimated concentration and the observed data demonstrated that the proposed model had a higher explanatory force at 84.5%. This study offered scientific evidence which can inform the management of ‘Buddhist temple forests’ along with forest environment in general, helping to promote public welfare and meditation space.

Key words: *Buddhist temple forest, Camellia japonica, Forest healing, NVOC, Phytoncide*

INTRODUCTION

Since the outbreak of new viruses that cause highly infectious pandemics among humans, such as SARS, MERS, and 2009 H1N1 influenza epidemics, and COVID–19 pandemics, people have been increasingly interested in healthy living surrounded by nature (Tollefson, 2020; Slater *et al*., 2020; Stanhope *et al*., 2020; Zabini *et al*., 2020). Although having comfortable lives through industrialization and urbanization, people paradoxically are both disconnected from nature and more exposed to many stressful environments. Exposure to stressful environments like noise, anxiety about accidents, effects of environmental pollution and complex lifestyle are crucially effective to human’s mental and physical health. Not only that, they may cause social problems (Tafet and Bernardini., 2003; Marin *et al*., 2013). AVOC (Anthropogenic Volatile Organic Compound) existing within urban atmosphere have been emitted through industrial facilities, architecture materials and vehicle. Some of them in itself present either harmful toxic or carcinogenesis and mutation traits for health (WHO, 2015). With the increasing number of senior citizens and patients with chronic diseases and lifestyle diseases, there is an increasing need for spaces in nature that accommodate physical and mental stability (Kim *et al*., 2016). In 1982, the Ministry of Agriculture, Forestry and Fisheries of Japan created the term ‘forest bathing’ which is defined as making contacts with the forest or taking in its atmosphere, and this serves as a way to achieve individual’s state of physical and mental relaxation (Park *et al*., 2010). Furthermore, it was observed that phytoncide reduced sympathetic responsiveness under restraint stress, highlighting benefits of phytoncide in prevention of stress–induced hypertension (Kawakami *et al*., 2004). Forest environment encouraged activity of human natural killer (NK) cell, percentage of NK cells and intracellular anti–cancer proteins in lymphocytes, and this increased NK activity lasted for more than a week in both male and female subjects after several stays in forests (Li *et al*., 2009). Therefore, physiological and psychological studies on forest healing environments have increased. In regard to this, temple forests, a significant ecological and scenic resource has been receiving great attention. Temple Forest in Korea can be defined as “a forest possessed by Buddhist temple for the purpose of landscape preservation and procurement of material and operating expenses for Buddhist temple.” Temple forest takes up 1.3% (83,000 ha) of the entire Korean forest with well–preserved natural ecology. Moreover, the landscape is in good condition and well–preserved due to Buddhist view of the world and its symbolism. In recent years, temple forest in Korea serves as a way of meditation and healing space for people through activities including temple–stay and ecological education.

The purpose of this study is to evaluate the possibility of temple forests in Korea as a healing environmental space in order to meet the social demand for a natural space for physical and mental stability. There have been some economic difficulties in measurement and analysis

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of NVOC which is one of the forests healing factor, including analysis expenses, specimen and other technical problems such as different concentration value depends on analysist or measurer's skill. Thus, the investigation has taken place with the intention to draw an effective estimation of change in concentration of NVOC in the microclimate environment by looking at Seonunsa temple forest in Korea as a research object, where *Camellia japonica* L., an evergreen broad–leaved tree, is widely dispersed.

MATERIALS AND METHODS

Study site

Seonunsa Camellia japonica forest, Mountain Seonun Provincial Park in Korea

The study site is a temple forest located in seonunsa *Camellia japonica* forest, a mountain seonun Provincial Park (35° 29' 37.2" N, 126° 34' 43.9" E, 16.5 ha), Korea. The temple forest was located in grand rocks which brings its beautiful scenery. The temple was founded in A.D.577, 24th year of King Weeduk, baekje Dynasty. The *Camellia japonica* forest, which has been officially designated by Korean natural memorial, is legally preserved by the government. Major characteristics of *C. japonica* are thick leaves, high water content and ignition resistance, so it was used to form as fire break forest to protect temples in the past. Nowadays, it receives great attention as a space of natural education and landscape preservation besides forest's primary functions in Korea. This study focuses on measurements of *C. japonica* forest that are known to have various therapeutic effects including meditation and healing space (Akihisa *et al.*, 1997; Park *et al.*, 2002; Jung *et al.*, 2007). The vegetation status of surveyed stand is shown in Table 1.

Measurement factors

NVOC

Volatile organic compounds (VOC) are either liquid or gaseous organic compounds that have boiling points below 100°C and are easily evaporated into the atmosphere. The study concentrated on methods for analyzing NVOC. Majority of NVOC emitted in forests are generated by trees. Medical studies researching the effects of NVOC and how to cope with the diseases they cause have been published internationally (Yatagai *et al.*, 1995; Trapp *et al.*, 2001; Tani *et al.*, 2002; Wang *et al.*, 2006; Tani and Kawawata, 2008; Yang *et al.*, 2011; Wang *et al.*, 2012). Terpene compounds, a type of NVOC emitted by trees, are produced from multiple base units of isoprene, which contains five carbon and eight hydrogen atoms. Terpenoids, a common and large NVOC group, comprise hemiterpenes, monoterpenes and sesquiterpenes. Emission inventories show that isoprene and monoterpenes are the most prominent compounds. These compounds are usually strong smelling, rarely water soluble and found in plants, in animals and microorganisms (Kesselmeier and Staudt, 1999). In the study, 25 species of monoterpenes and sesquiterpenes (99%, Sigma–Aldrich, USA) including α–pinene, β–pinene and camphene were selected for the analysis. There are few tests to confirm the results of both the analysis device and the procedures. First, this study used 25 species of standard materials such as α–pinene and β–pinene to obtain the calibration curve. Using the calibration curve to calculate each element's mass number and the square of its rate of diluting standard materials, it was found out that the majority of the materials has a linearity greater than 0.997, e.g., α–pinene (R^2 = 0.997), β–pinene (R^2 = 0.998) and d–limonene (R^2 = 0.999). The experiments using these materials also have a high reproducibility with respect to the coefficient of determination, which is suitable for the analysis.

Microclimate Environment

Concentration of NVOC changes depends on interaction of inner factors: genetic factor and biochemical factor and outer factors: biological factors of animals, plants and microorganism and non–biological factors including temperature, sunlight, relative humidity and wind velocity (Monson *et al.*, 1994; Peñuelas and Joan, 2003; Niinemets *et al.*, 2004; Baghi *et al.*, 2012). The concentration appears to be changing by species of tree and microclimate. NVOC's concentration and its emitted mechanism are correlated by various factors which may lead to inadequate outcomes with accurate mechanism. Thus, the research aims to investigate the relationship between NVOC's concentration occurred in *C. japonica* forest (an evergreen broad–leave tree representing warm–temperate forest) by focusing on one of the mechanism factors, microclimate.

Vegetation survey

In order to study the geographic conditions of the subjects, we studied their aspect, altitude and slope using GIS (Fig 1) and used the quadrat method to study vegetation. The research object is located at an elevation of 240 m with an average slop grade greater than 15° which is a falling slop. Its sedimentary form is creep and forest soil is brown forest soil. There was no state of erosion and the forest has high humidity, less wind exposure and its aspect are southeast from mountain valley. A 20 m × 20 m quadrant was established at the NVOC measurement site, and plant species were divided into three categories which are tree layer, subtree layer and shrub layer to conduct a plant sociological survey. Records of the average tree height and crown projection charts of the tree layer were prepared. A log–wood survey of the tree species measuring ≥ 2 cm in diameter at breast height (DBH) in the study site was performed. Temple forest, the research area covered with arborescent *C japonica* L. which is approximately 6 m high and 14 cm of diameter of breast height. While the origin of inflow of *C. japonica* remains unclear, it has been developed and maintained with continuous management and preservation efforts since its settlement. It is observed that the species consisting vegetation are 34 families, 34 geneses, 37 species. The area is also covered with various types of evergreen plants such as *Camellia sinesis* L., *Hedera rhombea* (Miq.) Siebold & Zucc. ex

Table 1. Vegetation Status of Seonunsa *Camellia japonica* forest

Scientific name	Family	Life form	red list	rare plant	regional species
Ampelopsis heterophylla	Vitaceae	N			
Asplenium incisum	Aspleniaceae	H			
Athyrium niponicum	Aspleniaceae	G			
Boehmeria spicata	Uriticaceae	Ch			
Camellia japonica	Theaceae	M			I
Humulus japonicas	Cannabaceae	Th			
Celtis sinensis	Ulmaceae	MM			
Cocculus trilobus	Menispermaceae	N			
Commelina communis	Commelinaceae	Th			
Corydalis incisa	Fumariaceae	Th			
Cyrtomium fortunei	Dryopteridaceae	H			I
Dioscorea japonica	Dioscoreaceae	G			
Dioscorea septemloba	Dioscoreaceae	G			
Gynostemma pentaphyllum	Cucurbitaceae	H			I
Hedera rhombea	Araliaceae	MM			I
Liriope platyphylla	Liliaceae	G			
Millettia japonica	Leguminosae	M	LC	VU	V
Nanocnide japonica	Urticaceae	H			I
Ophiopogon japonicas	Liliaceae	G			
Oplismenus undulatifolius	Gramineae	H			
Orixa japonica	Rutaceae	M			I
Osmorhiza aristata	Umbelliferae	G			
Oxalis corniculata	Oxalidaceae	Ch			
Paederia scandens var. scandens	Rubiaceae	Ch			
Persicaria filiformis	Polygonaceae	G			
Persicaria senticosa	Polygonaceae	Th			
Phaenosperma globose	Gramineae	H			Ⅲ
Phryma leptostachya var. asiatica	Phrymaceae	G			
Phytolacca americana	Phytolaccaceae	G			
Plantago asiatica	Plantaginaceae	H			
Sanicula chinensis	Umbelliferae	Th			
Sasa borealis	Gramineae	N			
Smilax sieboldii	Liliaceae	N			
Solanum lyratum	Solanaceae	Ch			
Trachelospermum asiaticum	Apocynaceae	M			
Viola albida var. chaerophylloides	Violaceae	H			
Zingiber mioga	Zingiberaceae	G			

Life form: Th: therophyes, G: geophytes, H: hemicryptophytes, Ch: chamaephytes, N: nanophanerophytes, M: micropanerophytes, MM: megaphanerophytes.

Red list: LC (least concerned species for IUCN).

Rare plant: VU (vulnerable plant species for Korean Forest Service and Korea National Arboretum, 2008).

Floristics special plants: Hierarchical degree (V~I) following distribution range: V (taxa distributed isolating or discontinuous), I (taxa distributed at least three subprovinces) (Ministry of Environment Republic of Korea, 2006)

Bean, *Trachelospermum asiaticum* (Siebold & Zucc.) Nakai and *Euonymus fortune var. radicans* (Siebold & Miq.) Rehder. Vegetation structure of *C. japonica* L. in the area forms a pure forest, *Hedera rhombea* (Miq.) Siebold & Zucc. ex Bean, *Camellia sinensis* L., *Liriop platyphylla* F. T. Wang & T. Tang are also prevalent in the area with high cover degree. Gochang county in north jeolla province, Korea where seonunsa is located (35° 30' N) is one of the northernmost regions where *C. japonica* is distributed. Vegetation of adjacent areas is consisted of summer green forest meanwhile seonunsa *C. japonica* forest forms evergreen forests types and generates the region's own vegetation landscape. It also controls microclimate of understory crown which supports advancement of local creatures and warm–temperate plant through the development of vegetation ever-

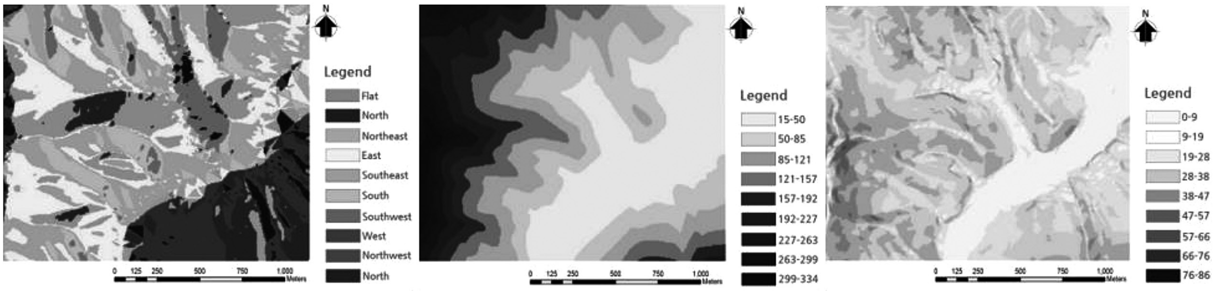

Fig. 1. The classification map of the surveyed area types.

green forest physiognomy with constant progress during winter time (Box and Fujiwara, 2014).

Measurement methods

NVOCs

The adsorption tube method was used to collect samples. Tubes (Makers, USA) filled with Tenax TA (150 mg) and Carbotrap 2B were used for adsorption. The sample capture device was a mini pump (MP–∑30KN, SIBATA, Japan) and the calibration was proceeded by a calculation of the adsorption error prior to the use of the flow meter. A total 9 L of NVOC volume was collected at a flow rate of 150 mL/min. The sampling equipment was installed on a tripod, 1.5 m from the ground, and the average value was calculated through duplicate sampling at every location. Disposable polyethylene gloves and antibacterial masks were used to prevent artificial errors when in contact with the tube during the installation. After sampling, the sample tubes were maintained at a temperature below 4°C and analyzed within 48 h. The samples were subjected to qualitative and quantitative analyses using a gas chromatography–mass spectrometer (7890N–5975, Agilent, USA) with a thermal desorption system (GC–MSD, Gerstel TDS, Gerstel, Germany). The substances adsorbed by the adsorption tube were concentrated in a low–temperature cryofocusing device, which intakes high–purity helium gas at a velocity of 1 mL/min from a thermal desorption device. The device desorbed the gas for 3 minutes at 210°C and maintained its temperature at –30°C. The substances were then subjected to thermal desorption for 3 minutes at 220°C, infused into a GC spectrometer and detected using an MSD.

Microclimate

The direction and slope of the site were measured in terms of locational environment. A setup was designed to ensure that a portable multifunction meter (Poly MI 6401, METREL, Slovenia) recorded the physical features of the site environment (temperature, humidity, wind velocity, dew point, globe temperature, air current and wet–bulb globe temperature) at intervals of 1 minute. The meter was installed at a height of 1.5 m in equilibrium on a tripod approximately 1 m from a mini pump and digitalized measurement results were saved and then converted for the analysis. The results were analyzed using the Sensor Link Pro program (METREL, Slovenia). The data was saved 5 minutes before and after each measurement were excluded from the analysis to minimize measurement errors.

Data Analysis

The data were analyzed for total of 52. However, 4 samples were excluded from the analysis because they that were detected as high concentration by unspecific factors were considered as robustness. All statistical analyses were performed using Statistical Package for Social Science software, Version 23 (IBM Corp., SPSS Inc., NY, USA). In this study, Pearson's correlation coefficient was used as a main correlation analysis because it is most commonly used to statistically measure the level of correlation among the variables. Among the regression analysis, stepwise regression analysis method was used because it only contains the variables that are able to affect dependent variable into the equation. In order to certify the multiple regression model's significance, VIF coefficient was used to check multicollinearity.

RESULTS

Characteristics of NVOC at *Camellia japonica* forest

The comparison of the NVOC construction in *Camellia japonica* forest in summer showed 51% of α–pinene (1.79 μg/m^3) followed by 19% of β–pinene (0.68 μg/m^3), as shown in Table 2. The other majority NVOC emitted camphene (0.19 μg/m^3), camphor (0.16 μg/m^3), d–limonene (0.12 μg/m^3), δ–3–carene (0.05 μg/m^3), γ–terpinene (0.04 μg/m^3), p–cymene (0.04 μg/m^3), eucalyptol (0.04 μg/m^3), α–terpinene (0.03 μg/m^3), myrcene (0.02 μg/m^3), bornyl acetate (0.02 μg/m^3), terpinolene (0.02 μg/m^3), linalool (0.01 μg/m^3), cedrol (0.003 μg/m^3) and α–humulene (0.002 μg/m^3). Comparative analysis on TNVOC (Total NVOC) concentration of emitted various tree species showed *Pinus densiflora* (14.21 μg/m^3), *Abies holophylla* (4.66 μg/m^3), *Pinus koraiensis* (4.31 μg/m^3), *Camellia japonica* (3.71 μg/m^3), *Chamaecyparis obtusa* (1.92 μg/m^3), *Larix kaempferi* (1.12 μg/m^3), *Cinnamomum camphora* (0.55 μg/m^3), *Machilus thunbergii* (0.40 μg/m^3), as shown in Fig. 2. *C. japonica* L. is included in the tea family, one of the representative species of evergreen broad–leaved trees and widely spread in warm–temperate zones. Therefore, *C. japon-*

Table 2. The characteristics of concentration of NVOCs component in *Camellia japonica* forest

Structure Material	Concentration (μg/m^3)	Structure Material	Concentration (μg/m^3)
α–pinene	1.79	δ–3–carene	0.05
camphene	0.19	p–cymene	0.04
β–pinene	0.68	myrcene	0.02
sabinene	0.29	cedrol	0.003
α–terpinene	0.03	camphor	0.16
limonene	0.12	linalool	0.01
eucalyptol	0.04	bornyl acetate	0.02
γ–terpinene	0.04	α–humulene	0.002
terpinolene	0.02	–	–

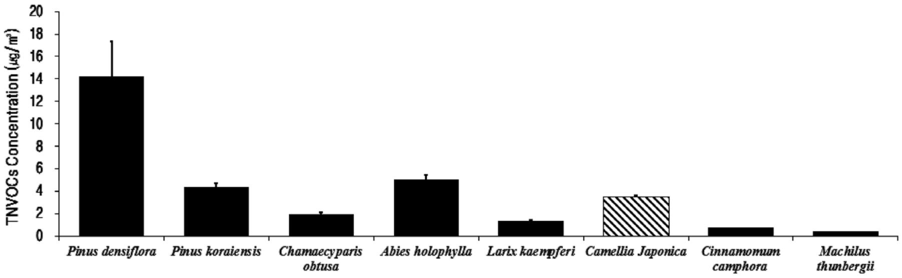

Fig. 2. The variations of TNVOCs at the surveyed area.

ica forest is considered as more possible healing space as concentration of phytoncide is higher compared to coniferous forests such as *A. holophylla*, *P. koraiensis* and *C. obtuse*.

The intraday variation of NVOCs concentration at *Camellia japonica* forest

To evaluate the changes in NVOC concentration during the day in *C. japonica* forest, NVOC were measured three times (sunrise, culmination and sunset) at each point of the study site. Four study sites were set up at 50 m intervals according to the geographical characteristics in the shape of a 'L'. The NVOC concentration detected from *C. japonica* increased over time from the sunrise to sunset (Fig. 3). Nineteen substances in total including α–pinene and β–pinene were detected in

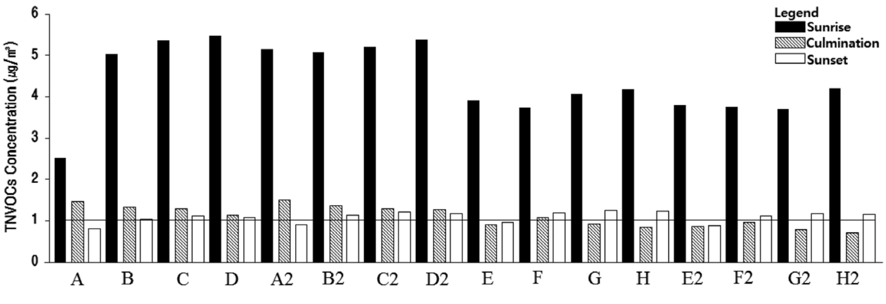

Fig. 3. The variations of TNVOCs at *Camellia japonica* forest.
A, B, C, D: results of primary measuring areas.
A2, B2, C2, D2: the day after's measuring results of primary measuring areas.
E, F, G, H: results of additional measuring areas.
E2, F2, G2, H2: the day after's measuring results of additional measuring areas.

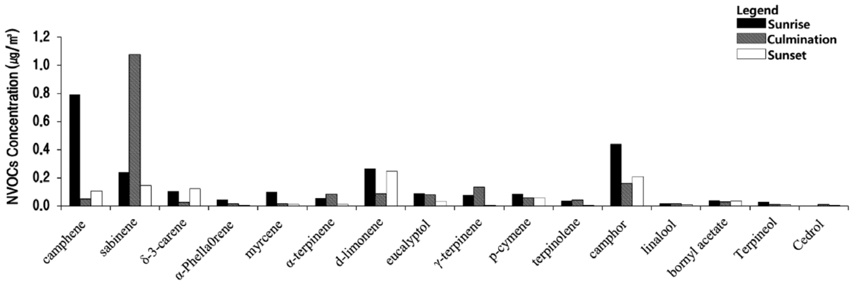

Fig. 4. Intraday record of concentration of NVOCs.

which α–pinene and β–pinene were detected at high concentrations during the sunrise. Thus, based on a thorough investigation on other substances that were detected at low concentration, it was confirmed that sabinene, γ–terpinene etc. were detected at high concentrations during culmination (Fig. 4). Therefore, reactivity to the photo–environment was considered as low.

Relationship between NVOCs and microclimate at *Camellia japonica* forest

To maintain the accuracy of the measured values, data taken from the first 5 minutes of each measurement were excluded. As a result, a negative linear relationship was confirmed between NVOC and wind velocity where wind velocity decreased with increasing in concentration of NVOC (Fig. 5). A positive linear relationship was confirmed with the temperature and humidity, showing that they increased with increasing in concentration of NVOC (Fig. 6 and 7). Microclimates and materials showing abnormal values in correlation analysis were excluded, and the excluded factors were analyzed, followed by reanalysis.

Prediction model for NVOCs concentration in *Camellia japonica* forest

This study conducted a multiple regression analysis to create NVOC concentration prediction model for changes in microclimate environment (Table 3). To verify the independence of the residuals, the durbin–watson values were evaluated; a value of 1.748 was obtained which shows no autocorrelation. The variance inflation factor (VIF) in this study was 3.681–5.013 and it indicates no multicollinearity issues. The results of the study site analysis presented a significant regression model with an F value of 80.169. The R^2 was as high as 84.5%, confirming that the regression model of the concentration prediction of NVOC in *C. japonica* forest has significant explanatory power. Analysis of variance (ANOVA) showed a significantly high P value of 0.000 and the explanatory power of the regression model equation was high. For temperature, the value of B was 0.394 and the test statistic was confirmed to have a significant effect with a t value of 4.599 and significance probability of 0.000. Due to the fact that the standardized *beta* value is 0.610, the concentration of NVOC increased by 0.610 (61.0%) when the temperature increased by 1°C. In further analysis, the value of B was analyzed as –0.002 and the test statistic was confirmed to have a significant negative effect with a t value of –3.429 and significant probability of P of 0.001. Because of the standardized *beta* value of –0.390, the concentration of NVOC decreased by –0.390 (39.0%) when illuminance increased by 1%. For wind velocity, the value of B was –0.602 and the test statistic showed that the t value was –2.781 and significance probability was 0.008 which is significant. Because the standardized *beta* value was –0.365, the concentration of NVOC decreased by –0.365 (36.5%) when wind speed increased by 1%. In order to predict concentration of NVOC in the *C. japonica* for-

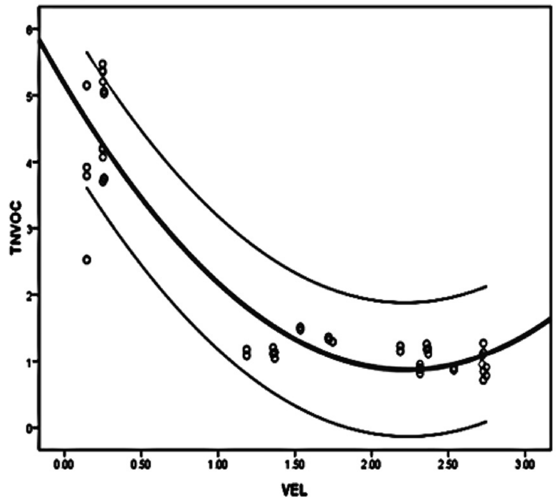

Fig. 5. The Correlation between NVOCs concentration and wind velocity in *Camellia japonica* forest.

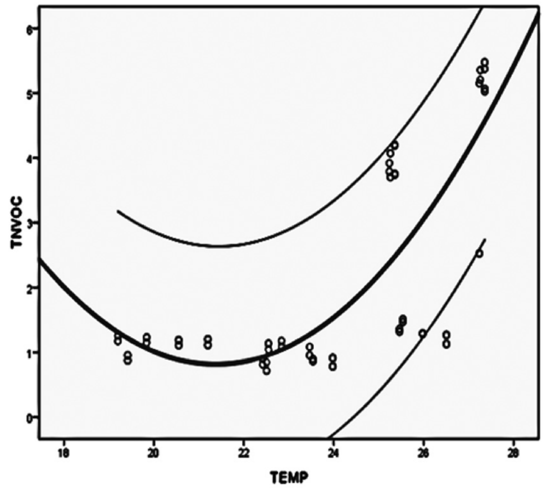

Fig. 6. The Correlation between NVOCs concentration and temperature in *Camellia japonica* forest.

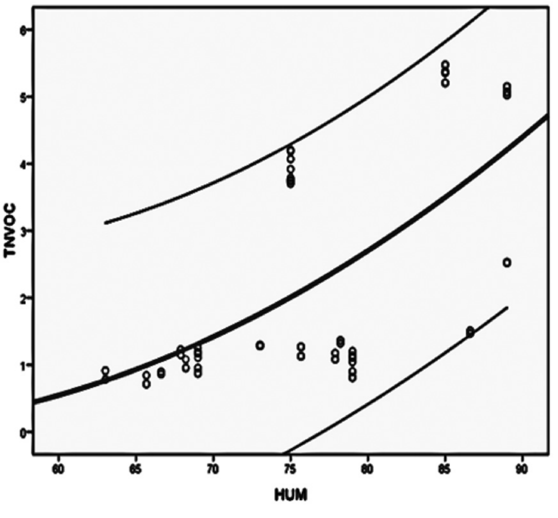

Fig. 7. The Correlation between NVOCs concentration and humidity in *Camellia japonica* forest.

Table 3. Result of multiple regression analysis for *Camellia japonica* forest

Variables	SD	Beta	*t*	VIF	R^2	*F*	D–W
Constant	2.187		–2.607		.845	80.869 (.000)	1.748
Vel	.217	–.365	–2.781	4.904			
Temp	.086	.610	4.599	5.013			
Illm	.001	–.390	–3.429	3.681			

Vel: Wind velocity, Temp: Temperature, Illm: Illumination.

est, independent variables influencing the concentration were selected from the microclimate by correlation analysis, followed by multiple regression analysis to create the following equation model:

$$\text{MNCF} = -5.7 + 0.394 \times \text{TEMP} - 0.602 \times \text{VEL} - 0.002 \times \text{IllM}$$

Where, MNCF = Model of NVOC concentrations from *C. japonica* forest, TEMP = temperature, VEL = wind velocity and IllM = illumination. However, this prediction model was confined within narrow microclimate range limits.

DISCUSSION

To achieve sustainable development of temple forests, this study was conducted to evaluate scientifically potential of these forests as a healing space with cultural value. Temple forest in Korea serves as a way of meditation and healing space for people. Additionally, the significance of warm temperate forest environment due to climate change was analyzed. To complement economic and technical issues of existing NVOC measurement techniques, the study conducted a total of 52 survey and analysis in a *Camellia japonica* forest. Analysis of the NVOC emitted at the study site showed that 19 types of substances were detected. The comparison of the NVOC construction in *C. japonica* forest showed 51% of α–pinene (1.79 μg/m^3), followed by 19% of β–pinene (0.68 μg/m^3), 8% of sabinene (0.29 μg/m^3). Higher ratio of α–pinene is known for effective reduction and resistance on stress, microbial, oxidant, cancer, depressant, insecticidal (Juven *et al.*, 1994; Gustafson *et al.*, 1998; Cox *et al.*, 2000; Lambert *et al.*, 2001; EH *et al.*, 2003; McKay *et al.*, 2003; Kawakami *et al.*, 2004; Yamaoka *et al.*, 2005; Mercier *et al.*, 2009; Lima *et al.*, 2010; Menezes *et al.*, 2010; Matsuo *et al.*, 2011; Lee *et al.*,2012; Mishra *et al.*, 2012; Wang *et al.*, 2012). β–pinene was known for effective reduction in the hypotension, tachycardia (Gavrilov *et al.*, 2010; Menezes *et al.*, 2010). Some compositions differed from those in previous coniferous forest studies (Kim *et al.*, 2013; 2014; 2015). This may affect chemical characteristics of the *Camellia japonica* NVOC and have species effects. Intra–day measurement of changes in NVOC concentrations found out that concentrations were higher after the sunset, when the boundary layer of the atmosphere contracted, stabilized and the photo–environment changed. This is consistent with the result showing that the atmosphere is stable and not mixed well in night time compared to during the day time when it is perished by rapid reactions with oxidants such as O_3 in the atmosphere, although there may have be some differences in concentration changes between the atmosphere in forests and the air above the canopy (Harrison *et al.*, 2001, Cerqueira *et al.*, 2003). In addition, NVOC concentrations increased when photo–environment changed and wind velocity was less affected. Among the detected substances, sabinene, camphor and myrcene were highly concentrated during culmination, and thus showing lower reactivity with the photo–environment than other substances. The correlation between NVOC concentration and microclimate demonstrates that higher temperature and humidity were associated with a higher NVOC concentration whereas higher wind velocity resulted in a lower concentration. In this study, a prediction model for NVOC concentration of *C. japonica* was proposed considering the concentration changes related to the microclimate, and regression analysis showed an explanatory power as high as 84.5%. Domestic wild *C. japonica* L. is generally odorless and used in daily life as extruded oil of seeds and petals. However, it emits a relatively high concentration of NVOC and therefore, additional studies are required to analyze these emitted NVOC. Our data provides a foundation for developing forest healing programs in temple forests. However, this study has some experimental limits. For example, the model is only able to predict the concentration in certain microclimate conditions. First, pure forests are more widely spread out than mixed forests are in Korea. Also, uneven–aged forests have more complicated composition than do even–aged forests, so it is needed to develop a new concentration models of NVOC based on various criteria. Second, because the mechanism factors of occurrence interact each other, it is needed to check the correlation between the various internal and external factors like biomass, leaf area, flowering, PAR, soil, stand age, density of standing trees, evapotranspiration. Third, it is needed to monitor seasonal NVOC concentrations for each forest floor because this study monitored other research sites only for spring and summer. Lastly, NVOC study can result in various conclusions depending on the operators. The measuring processes for NVOC concentration in Korea are mostly on the basis of indoor air quality processes without specific guidelines. Therefore, it is necessary to set up a standard process through the feedbacks from the experts for air or forest analysis. This study developed a model to effectively predict NVOC concentration. We hope that the model will be used to predict NVOC concentration in sites that are managed as 'Buddhist temple Forests', and thus contribute to well–being of public.

AUTHOR CONTRIBUTIONS

G. Kim carried out the field experiment of the research and wrote the statistical analysis and the manuscript. B. J. Park co–designed the experiment and performed the field experiment. S. Koga conceived the experiment, participated in its design, coordination and tree species identification and helped to draft the manuscript. All authorities assisted in editing of the manuscript and approved the final version.

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