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Spatial assessment of ecosystem functions and services for air purification of forests in South Korea

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ABSTRACT

Ecosystem functions can be understood as the quantified amount of an ecosystem's role in a natural process, while ecosystem services are the requantification of the ecosystem functions by factoring in environmental conditions and human needs based on social perspectives. In this study, differences between ecosystem functions and services were presented in terms of air purification of a forest ecosystem. Forest volume growth was employed to quantify the pollutant absorption capacity of a forest and was indicated by the natural functions (NF) for air purification by a forest ecosystem. Forest ecosystem services can be requantified from the forest functions by adding the air pollutant and population densities. Air pollutant density was applied to the assessment of the environmental services (ES) of forest ecosystems. Furthermore, the environmental social services (ESS) of forest ecosystems were assessed by including population density considerations. We simulated differences in NF, ES, and ESS in relation to pollutant and population density; while NF was spatially quantified without a close relationship to air pollutant and population density, ES and ESS reacted to environmental and social condition more sensitively. These results imply that the ecosystem services of forest resources for air purification are high where the pollutant and population densities are high, while the ecosystem functions of forest resources for air purification depend solely on forest conditions and not on the density changes of air pollutants and population. This study suggests that the differences in NF, ES, and ESS are important factors to be understood and considered in the decision-making process for ecosystem services. When considering human needs and surrounding environmental conditions, the results suggest that decision makers should utilize the ES and ESS concepts, which reflect both population and pollutant density along with additional human-related factors.

1. Introduction

The concept of ecosystem services is now broadly applied in complex decision making; it includes various methods and standards, yet the optimal method of assessment is still a work in progress (Collins et al., 2010; Costanza et al., 1998, 2006; Daily, 1997; de Groot et al., 2002). In contribution toward such assessments, many attempts have been made to investigate specific functions and services of ecosystems. A set of standards for classifying and assessing ecosystem functions and services in a region-specific approach has been suggested (Costanza et al., 1998; de Groot et al., 2010; Maes et al., 2013; Ruckelshaus et al., 2015; TEEB, 2010).

However, ecosystem services have not been clearly distinguished from ecosystem functions (Carpenter et al., 2009; Chung and Kang, 2013; Collins et al., 2010). An ecosystem function usually refers to the combination of processes and structures of an ecosystem, and it can represent the potential capacity to deliver ecosystem services. Accordingly, ecosystem functions are occasionally referred to as "functions of nature" (Costanza et al., 1998; de Groot et al., 2010; Maes et al., 2011). Unlike ecosystem functions, ecosystem services can be defined human benefits from obtaining goods and services from the ecosystem. Therefore, ecosystem services reflect human demand and are driven by perception of ecosystem service classification and economic evaluation

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(Ahn, 2013; Costanza et al., 1998; de Groot et al., 2010; Rosenthal et al., 2015; Ruckelshaus et al., 2015). Ecosystem services imply access and demand by humans, so they are used to assess ecosystem goods and benefits through methods of economic valuation. In the absence of human beneficiaries, ecosystem functions are not ecosystem services; in other words, ecosystem services reflect both environmental conditions and human needs (Costanza et al., 1998; de Groot et al., 2010; Fisher et al., 2009; Maes et al., 2011). Although there have been clear definitions of ecosystem functions and services, there is still confusion in the assessment of ecosystem functions and services (Collins et al., 2010). That is, in previous studies, unit prices have been simply multiplied by certain units of quantified ecosystem functions to translate the benefits of ecosystem functions into economic value (Chung and Kang, 2013; de Groot et al., 2002). Therefore, presently, what is referred to as ecosystem services are basically ecosystem functions expressed in units of currency (Rosenthal et al., 2015; Ruckelshaus et al., 2015). Information about ecosystem functions and services have also been visualized through mapping to help aid in management decisions (Burkhard et al., 2012; Costanza et al., 1998; Daily, 1997; de Groot et al., 2002; Millennium Ecosystem Assessment, 2005; TEEB, 2010; UK National Ecosystem Assessment, 2011). However, the mapping and spatial modeling of ecosystem functions and services are still limited by model selection, data preparation, scaling decisions, and validation. These limitations in the spatial modeling of environmental conditions and human needs are caused the dynamics in social activities and the response of both ecosystem functions and services (Burkhard et al., 2012; Crossman et al., 2013; Jeon et al., 2013; Leh et al., 2013; Schägner et al., 2013). Therefore, the spatial assessment of ecosystem services considering environmental conditions and social needs as well as natural functions is vital for further realistic environmental policy and decision making but still challenging process.

In this study, the differences between ecosystem functions and services were examined through the assessment of air purification (pollutant sequestration function), specifically, SO_2 and NO_2 sequestration, which is usually known as a regulating function and service of forests (Millennium Ecosystem Assessment, 2005; Ninan and Inoue, 2013; TEEB, 2010). Based on the methodologies of this assessment, this study determined the natural functions (NF) as the ecosystem functions and environmental services (ES) and environmental social services (ESS) as the ecosystem services. In addition, three sets of spatial maps of ecosystem functions and services were prepared for facilitating spatio-temporally adequate decision-making processes.

2. Materials and methods

2.1. Study area

The Republic of Korea (South Korea) was the main study area, with a specific focus on forest areas, which cover around 64% of the land area. Korean forests are approximately 38% coniferous, 47% broadleaf, 12% mixed forests, and 3% other types. The main age class was the 3–4 age class (21–40 years), and the overall volume per hectare was 126.73 m^3/ha (Figs. 1 and 2; Choi et al., 2014; Nam et al., 2015).

2.2. Methods

Trees and other vegetation in forests absorb air pollutants through their leaf surfaces and reduce pollutant dispersion; this process of absorption is linked with CO_2 sequestration by photosynthesis. Accordingly, air pollutant absorption can be considered as a NF of forest ecosystems. A high NF can imply a high level of ecosystem functions, but the NF of a forest ecosystem may not directly represent its ecosystem service. In other words, spatial NF assessment results can be directly interpreted to ecosystem services in some cases (Frélichová et al., 2014; Ninan and Inoue, 2013), however, some previous studies of ecosystem services used weighted economic values driven by humans (Alam et al., 2016; Burkhard et al., 2012). Thus, the lower level NF area with high economic value could have possibility to exceed more ecosystem service value than the high level NF area. Therefore, the ecosystem services of forest ecosystems should be assessed by considering environmental conditions and human needs.

The demand for good air quality increases when people are exposed to poor air quality caused by rising air pollutant emission; on the other hand, demand for good air quality decreases when

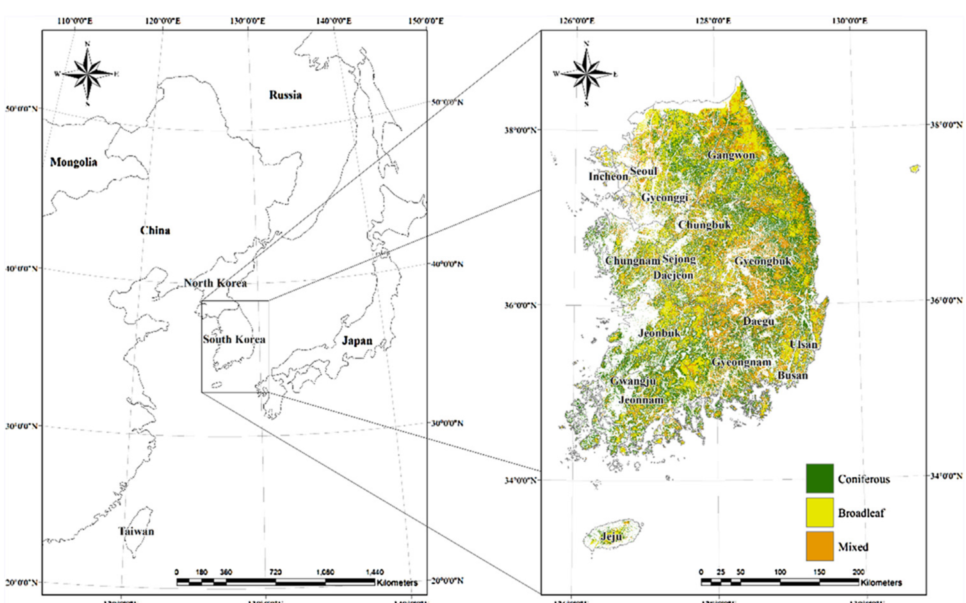

Fig. 1. Forest area in South Korea.