Identification of landscape multifunctionality along urban-rural gradient of coastal cities in South Korea

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Abstract

In order to reflect ecosystem services in environmental policies, it is necessary to assess multiple ecosystem services as well as the correlations among them in complex urban landscapes. Although landscape multifunctionality based on different land use statuses and intensity cause variations in the ecosystem services of complex urban landscapes, research that connect the urban landscape multifunctionality in terms of ecosystem services and urbanization processes is limited. In this study, we assessed ecosystem services and their correlations using correlation and principal component analysis. Then, we identified the urban landscape multifunctionality using ecosystem service bundles with diversity and capacity indices in two coastal cities of South Korea. Subsequently, five landscapes were categorized according to ecosystem services, which reflected landscape multifunctionality in accordance with urbanization levels. The provision of ecosystem services is affected by levels of urbanization from coast areas toward forest areas with increase in diversity and capacity indices. This study contributes to realistically examining the dimensions of regional ecosystem services within complex landscapes with land use changes. The results will support effective management plans and could be applied to other landscapes at various spatial scales.

Keywords Ecosystem service bundle · Urbanization · Spatial pattern · Correlation · Urban landscape

Introduction

According to a report by the United Nations (2015), 54% of the world population resides in urban areas, and it has been predicted that by 2050, two-thirds of the population will reside in urban areas by the year. Although expansion of urban areas may indicate a disengagement from nature, such areas still rely on various ecosystem services from non-urban ecosystems (Gómez-Baggethun and Barton 2013). The contribution and importance of urban ecosystem services towards the wellbeing of urban dwellers, urban sustainability, and resilience to environmental change is being increasingly demonstrated (Kremer et al. 2016). Sustainability and resilience in urban area is determined by management in ecosystem services provided by urban and peri-urban environments as a complex socio-ecological system (Alberti et al. 2003; McPhearson et al. 2014).

Urban and peri-urban ecosystems are composed of a series of landscapes that mixed natural and cultural landscapes providing multiple ecosystem services (O'Farrell and Anderson 2010). A capacity of landscapes to provide to multiple ecosystem services is defined as landscape multifunctionality (Mastrangelo et al. 2014). Because landscapes provide various ecosystem services rather than one specific service at the same time, landscape multifunctionality should be assessed to identify multiple provisions of ecosystem services (Bolliger et al. 2011; Helming and Wiggering 2003; Brandt and Vejre 2004). However, assessment of landscape multifunctionality in terms of ecosystem services remains limited although urban and peri-urban areas provide various ecosystem services (Haase et al. 2014b).

The main driver of change in the provision of urban ecosystem services is human-induced land use change (Kareiva et al. 2007). Intensive land use in core urban areas and extensive land use in peri-urban areas results in complex landscapes

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with urban-rural gradients, these gradient are identified as spatial variations in landscapes from rural areas to cities resulting from urbanization and causing changes in ecosystem service provisions (McDonnell and Pickett 1990). As this process occurs, assessment of urban ecosystem services should be expanded to include peri-urban and outskirt areas within urban administrative boundaries (Larondelle and Haase 2013). Levels of urbanization which lead to urban-rural gradients in specific areas also affects regional landscape (Antrop 2004), in turn affecting the types of ecosystem service provision (Baró et al. 2017). Urbanization processes alter supply levels of ecosystem services. Accordingly, management of urban ecosystems should consider levels of these services in terms of urban-rural gradients. Identification of interactions among ecosystem services are especially necessary for urban ecosystem management as it predicts changes in ecosystem services according to urbanization processes.

Interactions among ecosystem services are evaluated as bundles, trade-offs, and synergies (Gonzalez-Ollauri and Mickovski 2017). In an ecosystem service bundle, various services appear temporally and spatially bounded as a result of the landscape multifunctionality (Raudsepp-Hearne et al. 2010). Such multifunctionality is affected by the structure and changes in the ecosystem; changes in one ecosystem service provided by regional ecosystems are likely to affect other ecosystem services (Bennett et al. 2009). A trade-off is thus defined as the increase in one ecosystem service resulting in the loss of another ecosystem service, while a synergy is indicated by an increase in another ecosystem service (Haase et al. 2012). Studies evaluating correlations among multiple ecosystem services have assessed trade-offs and synergies among ecosystem services for efficient ecosystem management (Bennett et al. 2009; Lavorel et al. 2011; Haase et al. 2012; Maes et al. 2012; Howe et al. 2014). Raudsepp-Hearne et al. (2010) categorized bundles by identifying regions with similar ecosystem service distributions and assess trade-offs and synergies among ecosystem services. Since then, several studies have applied these concepts and methodologies to identify regional characteristics of ecosystem services. Such practices have included the use of 1) diversity indices (Queiroz et al. 2015); 2) policy scenarios (Hanspach et al. 2014); 3) temporal change analysis (Renard et al. 2015); and 4) driving factors affecting ecosystem services (Derkzen et al. 2015; Meacham et al. 2016). Particularly, research has progressed to evaluate the relationship between landscape multifunctionality and provision of multiple ecosystem services. Moreover, this allows for analysis of the correlation between the identification of trade-offs and synergies (Dobbs et al. 2014; Yang et al. 2015; Baró et al. 2017). However, there remains a lack of research that assesses landscape multifunctionality with ecosystem services with regard to the urban-rural gradient in complex landscapes with different urbanization levels.

This study assessed landscape multifunctionality in complex urban landscapes; the main objectives were to (a) produce bundles and analyze correlation among ecosystem services, (b) categorize sub-regions based on types of ecosystem services, and (c) evaluate landscape multifunctionality with different ecosystem service provision according to levels of urbanization. Finally, we identify the urban ecosystem services provided by various landscapes along urban-rural gradient in order to improve ecosystem service management.

Methodology

Study site

This study was conducted in Ansan and Siheung, which are coastal cities with industrial complexes in South Korea. Ansan covers an area of 151km^2 and has a population of 744,356 residents across 25 districts. As of 2017, Siheung city had an area of 136km^2 with 17 districts and a population of 438,298 residents. While industrial and sub-urban residential complexes were built on the coast in the 1970s to develop national industrial complexes in this region, the outskirts of inland areas are restricted development zones. Land use in Ansan is divided into coastal industrial complexes and core urban districts with farming areas and forests on the outskirts. Siheung has wetlands near coastal urban districts and farming areas that were produced by reclaiming wetlands. Small urban districts are present in areas around neighboring cities, producing a fragmented land use (Fig. 1).

Assessment of ecosystem services

Ecosystem services were categorized as provisioning, regulating, supporting, or cultural services (Millennium Ecosystem Assessment 2005). Because identification of landscape multifunctionality were progressed based on spatial assessment of ecosystem services, we selected ecosystem service indicators in accordance with the regional characteristics and methodological availabilities in district levels (Table 1).

Food production service is generally estimated by crop production in agricultural areas. We applied the area of crop land to estimate the capacity of crop production by calculating the ratio of crop land in each district from a land cover map of 2014 with 30 m resolution. This map provides information on agricultural areas classified as rice paddy, dry-field, greenhouse, or orchards. We calculated the area ratio of agricultural areas in one district.

Livestock production service can be estimated from the number density of stock farm areas. We used the land cover map of 2014 to identify ranch areas and calculated area of
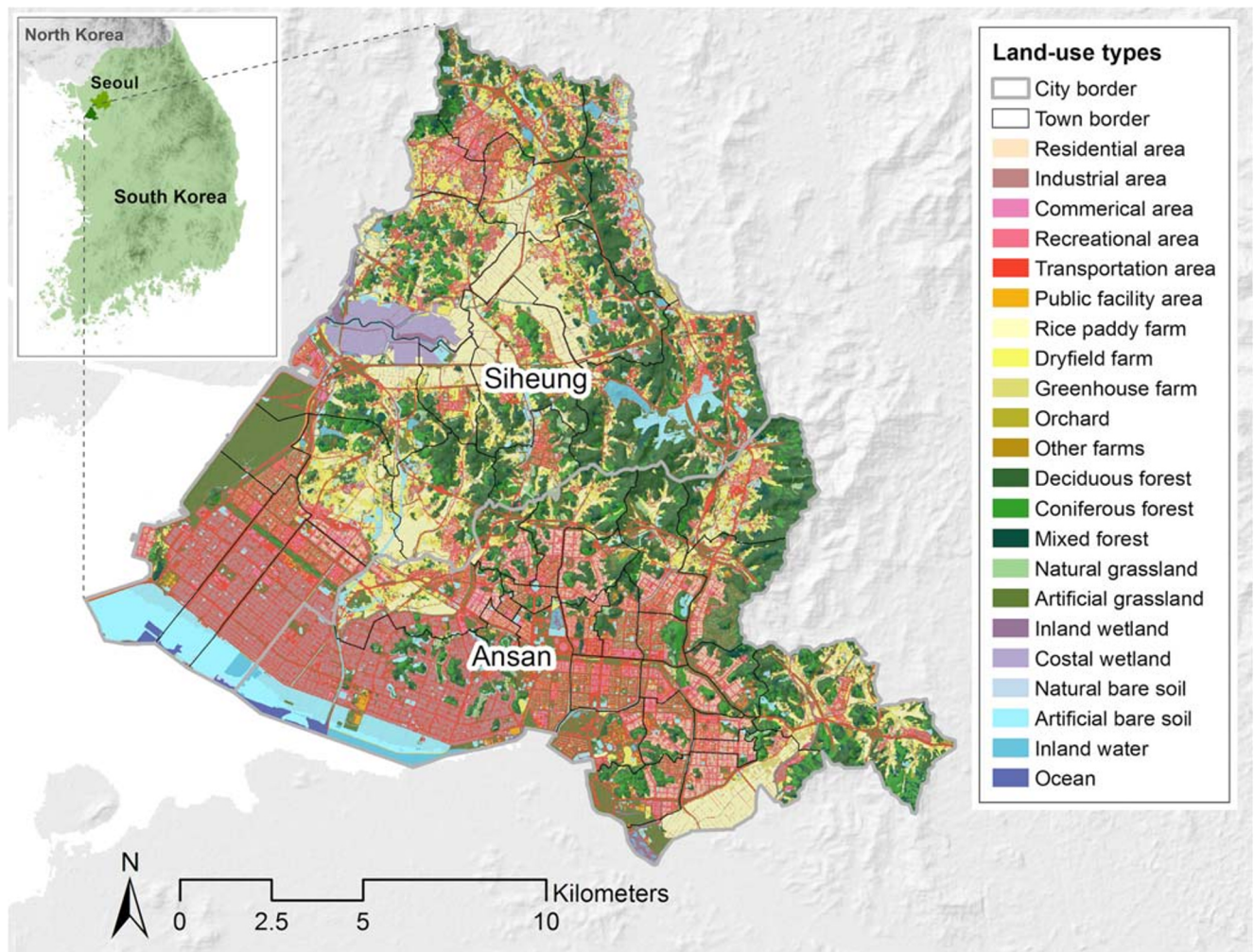
Fig. 1 Land use status belonging to the study area (Ansan and Siheung cities, South Korea)

ranch in each district. Then, we evenly distributed the total number of major livestock (pigs, cows, and chickens) of cities according to the area of ranchland in each district.

Air quality control was evaluated based on the amount of absorption of main pollutants such as nitrogen oxide (NO_2) and sulfur dioxide (SO_2) (Baró et al. 2014). We estimated amount of pollutants based on absorption of NO_2 and SO_2

according to the vegetation status, which was calculated by the Korea Forest Research Institute (2017). The institute found that 1 ha of forests could absorb 52 kg of NO_2 and 24 kg of SO_2 annually (Korea Forest Research Institute 2017). We applied the amount of pollutant absorption to the area of forest, urban green spaces, and orchards of each land cover map of 2014.

Table 1 Ecosystem service indicators used in the study

Type	Ecosystem service	Indicator	Unit	Reference
Provisioning	Food production	Area of farmland	Area ratio of farmlands	Raudsepp-Hearne et al. (2010)
	Livestock production	Number density in stock farm area	Number/ha	Maes et al. (2012)
Regulating	Air quality control	NO_2 and SO_2 sequestration	Ton/ha/year	Korea Forest Research Institute (2017)
	Climate control	Carbon stock	tCO_2/ha	Roh et al. (2016)
	Erosion control	Annual soil retention	Ton/ha/year	Laterra et al. (2012)
Cultural	Recreation	Recreation Potential Index	Mean value	Paracchini et al. (2014)
	Cultural accessibility	Recreation opportunity spectrum	Mean value	Paracchini et al. (2014); Jeon et al. (2018)
Supporting	Biodiversity	Bird species	Number of observed birds/km^2	Rho and Choung (2006)

Climate control was evaluated based on the amount of the aboveground and belowground carbon storage using the InVEST carbon model with major carbon pools (Sharp et al. 2017). We use the land cover map of 2014 and carbon pools based on Roh et al. (2016), which provided carbon pool values according to land cover status and compared results on carbon stock estimation with national forest inventory data.

Erosion control was evaluated based on the revised universal soil loss equation (RUSLE) model (Renard et al. 1997), which calculates annual soil retention potentials. The RUSLE model, which was developed to estimate annual soil loss potential, was used to calculate soil retention based on differences in soil loss potentials between current land cover and hypothesized land cover with bare soil (Laterra et al. 2012). We calculated soil loss by combining 1) a rainfall erosivity factor 5735 MJ/ha/year in Ansan City and 5755 MJ/ha/year in Siheung City, as calculated by Risal et al. (2016); 2) a soil erosivity factor ranging from 0.001 to 0.086 ton/ha/, as investigated by the Ministry of Environment (2012); 3) a slope length and slope angle factor based on a Digital Elevation Model (DEM); and 4) cover management and support practice factors as estimated by the National Disaster Management Institute (2012).

Recreation was calculated using the Recreation Potential Index (RPI) based on influencing factors on recreation behavior by combining degree of naturalness, protected areas, and attractiveness of water resources (Paracchini et al. 2014). The degree of naturalness was calculated from the hemeroby index in accordance with landscape and vegetation types. We estimated the hemeroby index following Walz and Stein (2014), who calculated the index from classification of land cover status. Protected areas were extracted in areas from wildlife conservation area designated by the Ministry of Environment, South Korea. Attractiveness to water source was estimated by bathing water quality, distance to water sources, and coastal protected areas (Paracchini et al. 2014). We used data on the quality and stream networks of river water from K-water to estimate water quality and distance to water sources; coastal protected areas were excluded due to an absence of protected areas in the research site.

Cultural accessibility is the potential benefit areas concerning cultural services (Ala-Hulkko et al. 2016). It was evaluated by revising the Recreation Opportunity Spectrum (ROS), which was introduced by Paracchini et al. (2014), to reflect the values of major ecological assets where cultural ecosystem services are provided (Jeon et al. 2018). We selected 101 ecological assets from workshops with local environmentalists in the research sites. Then, we estimated accessibility to those ecological assets from the local populations.

Biodiversity that reflect variability of living organisms is a supporting service and could be estimated by numbers of observed species in specific areas (Queiroz et al. 2015). In particular, bird observations, which are simple to performing using systematic survey methods, have been utilized for biodiversity and habitat evaluations in South Korea (Kim et al. 2002). We used data from the 3rd nationwide environment survey results, which collected bird sightings from 2006 to 2013 (National Institute of Ecology 2017) and made bird habitat evaluations using numbers of observed birds.

Relationship among ecosystem services

Ecosystem service bundles were established to evaluate landscape multifunctionality for environmental management (Kareiva et al. 2007; Raudsepp-Hearne et al. 2010). In this study, an ecosystem service bundle was produced using values of each ecosystem service per unit area in the districts of research sites. As assessment of multiple ecosystem services progressed with different indicators, we normalized values between 0 and 1 for multiple ecosystem services. Then, we visualized a bundle graph of all ecosystem service indicators (Table 1) by star plots using the R ggplot2 package (Wickham 2016).

Trade-offs and synergies between ecosystem services can be assessed through correlation analysis (Jopke et al. 2015). When the correlation coefficient between two ecosystem services is positive, it corresponds to a synergy. However, when this coefficient is negative, it is regarded as a trade-off. When the correlation coefficient, $r \geq \pm 0.5$, there is a strong correlation, while $\pm 0.5 > r > \pm 0.3$ indicates an intermediate correlation (Raudsepp-Hearne et al. 2010; Jopke et al. 2015). Correlation analysis was conducted and the correlations among ecosystem services based on the assessment results of each ecosystem service per district were identified. Principal component analysis (PCA) was used to evaluate the synergies and trade-offs between ecosystem services by using a bioplot and assessment of components that cause differences in ecosystem services (Maes et al. 2012; Rodríguez et al. 2015).

Assessment of landscape multifunctionality

Cluster analysis categorizes regions into groups with similar ecosystem services, assesses their spatial distributions (Mouchett et al. 2014), and evaluates the similarity and concentration of ecosystem services for each administrative district. K-mean clustering algorithm was used to group regions that provide similar ecosystem services (Raudsepp-Hearne et al. 2010). This type of clustering analysis enabled grouping of districts with similar ecosystem service patterns and categorization of landscape types with respect to land use to evaluate landscape multifunctionality. We conducted cluster analysis to categorize district groups according to types of landscapes with characteristics of ecosystem services.

Landscape multifunctionality is assessed based on the capacity and diversity of all ecosystem services (Raudsepp-Hearne et al. 2010; Stürck and Verburg 2017). Total Ecosystem Service Values (TESV) evaluates the capacity of multiple ecosystem services as a summarization of ecosystem services (Maes et al. 2012). The Simpson diversity index, which is used for evaluation of quantitative diversity of species, also assesses the diversity of multiple ecosystem services as landscape multifunctionality (Raudsepp-Hearne et al. 2010; Queiroz et al. 2015). In this study, we used both TESV and the Simpson diversity index to assess the capacity and diversity of ecosystem services for each district. R (R Development Core Team 2017) was used for conducting the correlation analysis and PCA. The R cluster package (Maechler et al. 2018) was used for cluster analysis and the vegan package (Oksanen et al. 2018) was used to calculate diversity of ecosystem services.

Results

Assessment of ecosystem services

The result revealed that crop production was high in reclaimed agricultural areas located in central areas of the research site and livestock production is high in outskirt districts (Fig. 2a and b). Regulating services were predominant in forest areas of the outskirts; air quality control and erosion control were high in the western forest, while climate control was relatively high in the northern forest (Fig. 2c, d and e). Recreation was similar across all districts; however, cultural accessibility was higher in the southwestern core urban areas (Fig. 2f and g). Biodiversity was high in coastal areas near mud flats and generally low in inland areas (Fig. 2h).

Relationship among ecosystem services

Seven strong positive correlations and two negative correlations between different ecosystem services ($r > \pm 0.5$), and four intermediate positive correlations and five intermediate negative correlations between different ecosystem services ($\pm 0.5 > r > \pm 0.3$) were found from correlation analysis (Fig. 3a). Correlations between crop production and recreation had the strongest positive correlation ($r = 0.8^{**}$) while correlations between recreation and cultural accessibility had the strongest negative correlation ($r = -0.62^{**}$). While there was a positive correlation between regulating services (air quality, climate, and erosion control) and recreation (between $r = 0.31^{*}$ and 0.69^{**}), cultural accessibility had a negative correlation with crop production ($r = -0.44^{**}$) and recreation. Recreation had the strongest correlation with other services (between $r =$

0.31^{*} and 0.8^{**}), whereas species diversity had the weakest correlation with others (between $r = -0.13$ and -0.32^{*}). In the PCA results, principal component 1 had an explanatory power of 44.9% and cultural accessibility and species diversity were high in urbanized areas while other services were high in farming areas and forests. Principal component 2 had an explanatory power of 17.9% and indicated ecosystem services with high values around tidal flats and western coastal areas. Principal component 3 explained 13.7% of interactions of ecosystem services indicating a geographic division between central and surrounding districts (Fig. 3b).

Identification of landscape types

Five optimal clusters were identified from cluster analysis to categorize regional landscapes according to ecosystem service provision (Fig. 4a). Cluster 1 included 7 districts named as agricultural forests that were mixed with farming areas and forests. This cluster provides high provisioning, regulating, and recreation services, but low cultural accessibility and species diversity. Cluster 2 included 10 districts, all agricultural areas, which are mainly located in the northern reclaimed lands. This cluster provides high crop production and recreation but few other services. Cluster 3 included 9 districts encompassing core urban areas in the southern part of the research site. It provides cultural ecosystem services in addition to air quality control as it is near urban green spaces, rivers, and the coast. However, it provides lower provisioning services in comparison with other regions owing to a lack of farming areas. Cluster 4 included 4 districts, namely urban forests distributed around urban areas and provides regulating and cultural services but lack provisioning services. Cluster 5 included 4 districts composed of industrial areas; the presence of industrial facilities differentiates it from cluster 3, which has residential and commercial areas. It provides high species diversity as it is located on the coast, but lacks other services.

Capacity and diversity of ecosystem services were assessed depending on landscape multifunctionality classified as clusters. Both diversity and capacity were high in the western and northern forests, and low in coastal areas (Fig. 4b). However, northern regions with a high proportion of farming areas have low diversity compared with capacity, whereas central mixed agricultural forest areas have high diversity compared with capacity.

Landscape multifunctionality with regard to urbanization was evaluated for each landscape type with provision of ecosystem services (Fig. 5). A Level of urbanization was high while the ecosystem services were low in industrial and urban areas situated near the cost. The ecosystem service capacity was higher for inland forest areas, which have lower level of urbanization.
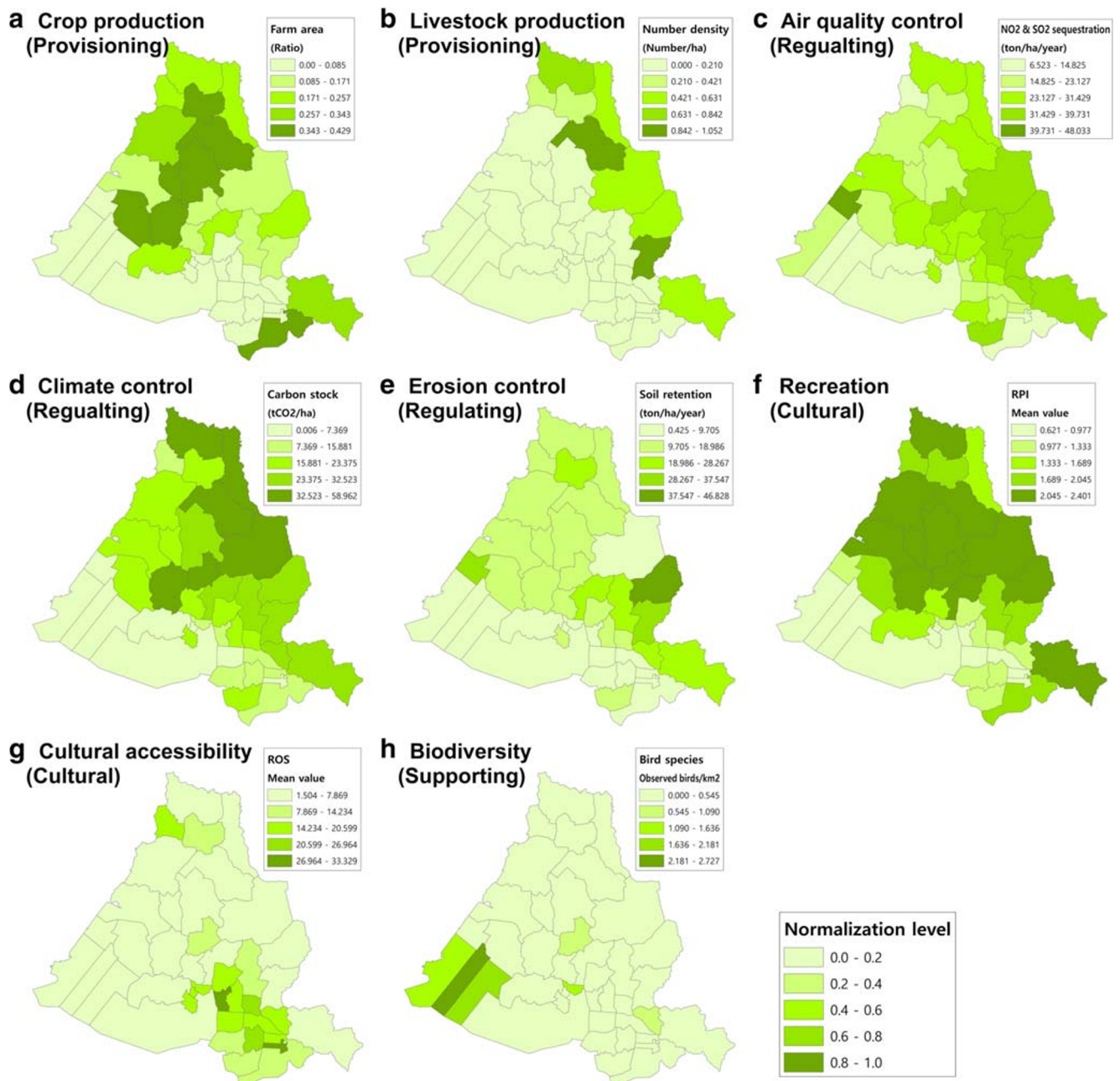
Fig. 2 Results of ecosystem service assessment and their normalization from 0 to 1 of 42 districts

Discussion

Regional features in ecosystem service correlations

We estimated multiple ecosystem services and assessed their correlations in coastal cities. There are positive correlations among regulating services that are generally observed in research on ecosystem service correlations (Maes et al. 2012; Yang et al. 2015; Jopke et al. 2015; Rodríguez-Loinaz et al. 2015). However, some results indicate that the correlations among ecosystem services reflected the characteristics of a research site.

Unlike prior research, which found that crop production and regulating services have a negative correlation as a trade-off (Raudsepp-Hearne et al. 2010; Yang et al. 2015; Baró et al. 2017), we found that crop production has an intermediate or weak positive correlation with regulating services (between $r = 0.1$ to 0.37) (Fig. 3a). This is result of our research site being categorized into core urban areas and outlying agricultural districts. Consequently, crop production levels appeared in concert with the regulating services provided by agricultural forests. A positive correlation between crop production and recreation potential ($r = 0.8$) also reflects regional characteristics because access to water resources is a
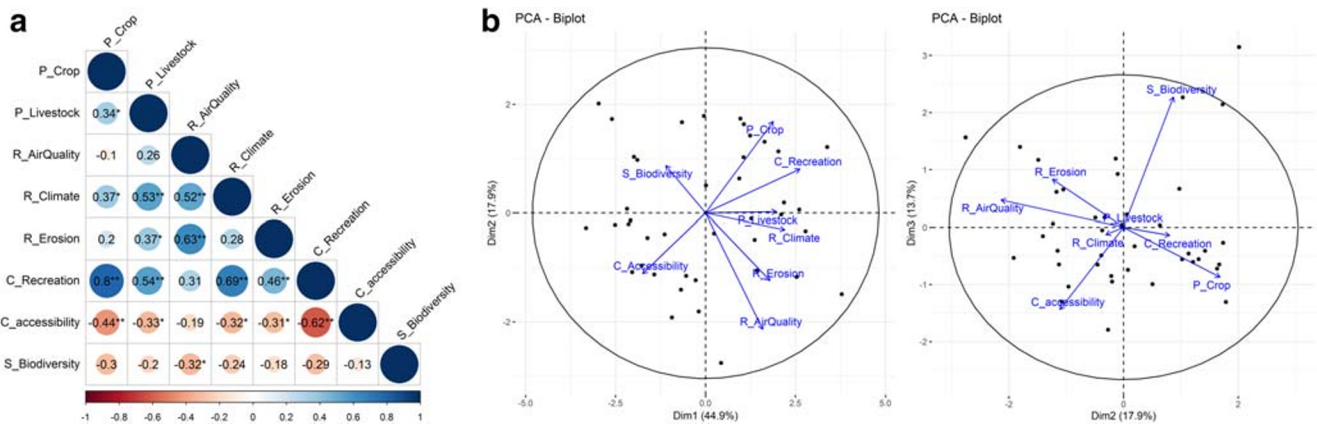
Fig. 3 Results of (**a**) correlation analysis and (**b**) principal component analysis (PCA) among multiple ecosystem services at the district level (P_Crop: crop production, P_Livestock: livestock production, R_AirQuality: air quality control, R_Climate: climate control, R_Erosion: erosion control, C_Recreation: recreation, C_Accessibility: cultural accessibility, S_Diversity: species diversity) (for ** p value <0.01, * p value <0.05)

significant factor for rice paddies and for the recreation potential index. Furthermore, rice paddies in the area have high cultural value because the farming areas are near mud flats and tidelands formed over 500 years ago and a famous ecological park with cultural, educational, and ecological experience programs (Jeon and Kim 2012). Such farming areas have a high cultural value resulting in a positive correlation between crop production and recreation, suggested by Baró et al. (2017).

Our results also indicate that species diversity is negatively correlated with other ecosystem services (between $r = -0.13$ and -0.32) (Fig. 3a), unlike the general patterns of biodiversity and ecosystem services described by Duncan et al. (2015). Birds in South Korea are mainly marine and migratory birds

that inhabit coastal and estuary areas (Yoo and Lee 1998) and there have been attempts to convert reclaimed lakes to wetlands to increase habitat quality for these diverse species near industrial complexes (Jeong 2001; Hur et al. 2005). Therefore, biodiversity based on bird appearance had a negative correlation with other ecosystem services that were high in agricultural and inland forest areas.

Ecosystem service management in multifunctional urban landscapes

Urbanization processes are related to changes in landscape multifunctionality of the study area. Industrial complexes were developed in coastal areas because of their high
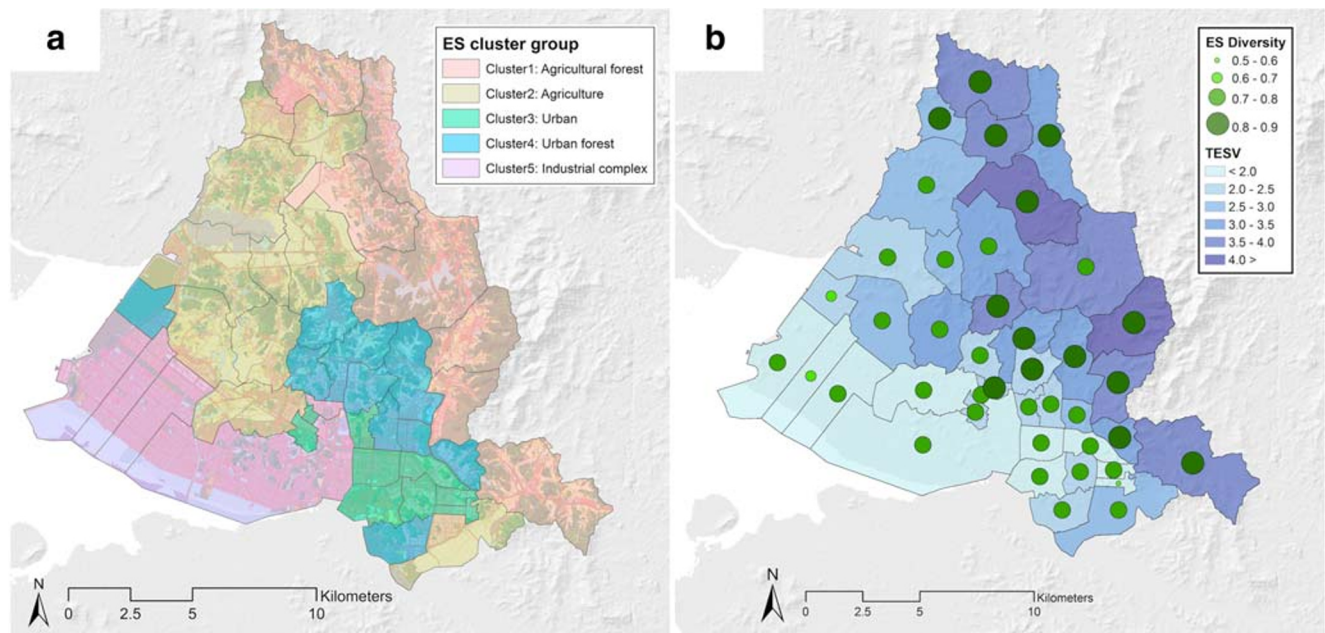

Fig. 4 Clustering results for the ecosystem services (**a**) and comparison of ecosystem service capacity (Total Ecosystem Service Value: TESV) and diversity (Simpson diversity index) of districts (**b**)
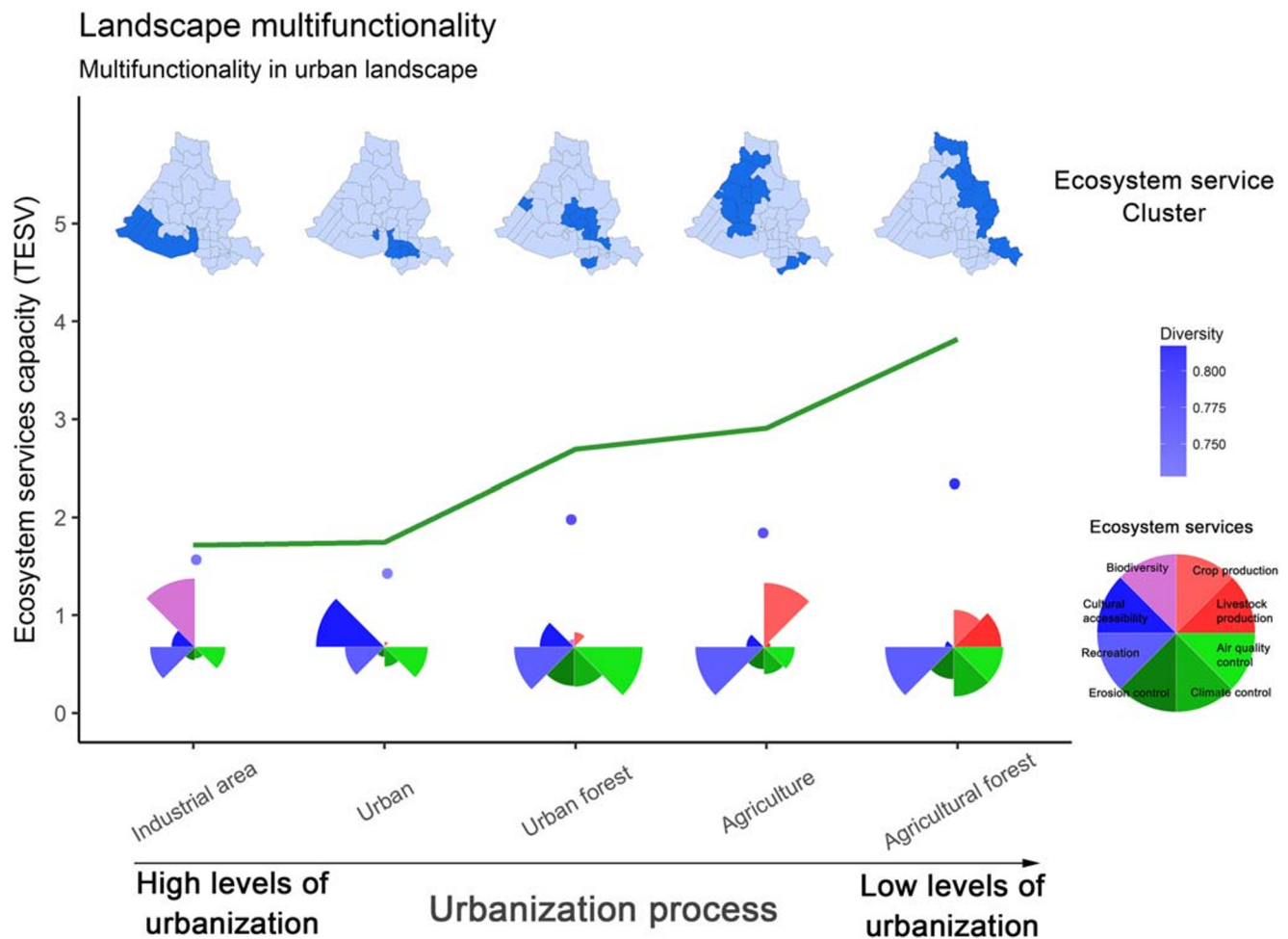
Fig. 5 Landscape multifunctionality reflected in ecosystem service provision and levels of urbanization

accessibility to Seoul City. Subsequently, commercial and residential areas were built to support workers in industrialized areas (Jeong 2006). Urbanization has consistently progressed from coastal areas to inland forest areas. Meanwhile, different levels of urbanization and multifunctional landscapes were formed through urban-rural gradients within cities. Identification of landscapes according to levels of urbanization and ecosystem services can help regional environmental management.

Rather than focusing on individual ecosystem services based on distinct types, landscape management considers service provisions of multiple ecosystems. Spatial planning in industrial (cluster 1) and urban (cluster 2) districts with low landscape multifunctionality could be progressed in terms of urban regeneration and greening by encouraging reforestation within urbanized areas; this would increase regulating and cultural services in a way similar to urban gardens (Camps-Calvet et al. 2016; Dennis and James 2017). In urban forest districts (cluster 3), ecosystem service management could be combined with reforestation of marginal lands near current forest to increase regulating services (Ziter et al. 2013). In agriculture districts (cluster 4), landscape management could

be progressed with eco-tourism policies that utilize ecological assets such as ecological parks and mud flats near rice paddies; promoting cultural ecosystem services for tourists provides both provisioning and cultural services (Tempesta et al. 2010; Winkler and Nicholas 2016). As prioritization areas that provide ecosystem services can achieve sustainable urban development (Woodruff and BenDor 2016; Albert et al. 2016; Langemeyer et al. 2016; Nin et al. 2016), currently conserved areas in agricultural forest districts (cluster 5) should be managed consistently and maintain complex landscapes for ecosystem service provisions. For effective management of ecosystem services, these suggestions can be applied to other urbanizing areas based on feature of landscape multifunctionality.

Landscape features and district's ecosystem services can vary according to continuous urbanization processes. Accordingly, landscape management should balance ecosystem services with urban development (Niemelä et al. 2010; O'Farrell and Anderson 2010; Ahern 2013). Although we suggested effective management of ecosystem services, urban expansion to peri-urban areas is highly likely due to growth of subway systems. Increased urbanization may alter current

landscape features and ecosystem services. According to levels of urbanization, our results can predict changes in ecosystem services and landscape features by identifying ecosystem service bundles. In contrast, our identification of districts can be applied to current environmental management plans, which alter landscapes features and capacity of ecosystem services. For example, urban reforestation program can shift district's types from urban to urban forest. In so doing, they are able to increase regulating services. Therefore, our approaches can support decision-making for effective management of regional ecosystem services by predicting potential changes of ecosystem services based on landscape changes.

Limitations of the study

Regional assessment of ecosystem service bundles has limitations in terms of data and appropriateness of ecosystem services (Queiroz et al. 2015). As indicators are selected based on availability and suitability at a research site, not all complexities and interactions in ecosystems can be reflected. Although, we selected ecosystem services based on methodological availability, limitations remained in accurately assessing ecosystem services. For example, a lack of data and credible references meant that we only assessed the amount of pollutant absorption by forest areas due to methodology-related uncertainty although farmlands and grassland may also contribute to pollutant absorption. Ecosystem service assessment for administrative units may be useful for management; however, if the spatial scale differs, the correlations and characteristics of ecosystem services may change (Stürck and Verburg 2017). If one city has a high proportion of agricultural areas compared with peri-urban areas, even if crop production is low in the region, it is still higher than in other urban areas in the vicinity. This may be solved by the quantification of maximum and minimum threshold values on ecosystem service provisions. As the correlations among ecosystem services and the relationship between the total capacity and diversity are not always consistent, and multifunctionality evaluation indices have limitations, the results should be interpreted carefully (Stürck and Verburg 2017) and novel approaches to assess ecosystem service bundles are also necessary for ecosystem management (Queiroz et al. 2015).

Conclusion

We assessed ecosystem services and categorized districts in two coastal cities in South Korea to identify landscape multifunctionality with regard to levels of urbanization. The result showed that agricultural areas and forests provide higher levels of ecosystem services and diversity than do industrial and urban areas near the coast. The potential amount

of ecosystem service provision can be expected to decline so long as urbanization and urban intensification continue. As urbanization influences the supply of ecosystem services, there is a need for urban planning that considers the provision of ecosystem services from landscape multifunctionality reflecting interactions in socio-ecological systems (Kroll et al. 2012; Dupras and Alam 2015). Decision-makers should understand the spatio-temporal dynamics of socio-ecological systems, including trade-offs and synergies among various services. Thus, assessment of ecosystem services based on temporal land use changes and intensification of urban ecosystems can aid to effective strategic planning (Haase et al. 2014a, 2014b). As such, the identification of landscape multifunctionality is necessary to gain an understanding of urban ecosystems. Our results also indicate that levels of urbanization affect ecosystem service provision; therefore, landscape planning and ecosystem management should be considered together within regional land management policies. Our perspective on identification of landscapes, which is based on ecosystem service provision, can be applied to other urbanizing or urbanized landscapes where the provision of ecosystem services is being considered.

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