연구논문 「환경정책」 제28권 특별호 2020. 12: 97-116
DOI http://dx.doi.org/10.15301/jepa.2020.28.S.97
pISSN 1598-835X eISSN 2714-0601

Network Analysis of Ecosystem Service Valuation Trends in South Korea*

Hyeran Kim** · Jae-hyuck Lee*** · Hyuksoo Kwon****

Abstract: Ecosystem service valuations provide imperative data that is valuable for policy makers. However, the valuations are seldom adopted in national policymaking. In order to promote the use of ecosystem service valuations in policy and decision-making, a two-mode network analysis was conducted in order to investigate trends in ecosystem service valuation research in South Korea. According to the results, the "contingent valuation method" and "choice experiment" showed high connectivity with ecosystem type and service and were frequently employed by valuators. In contrast, the "net factor income" and "contingent ranking method" showed low connectivity and low frequency of use. The ecosystem types "forest", "farmland," and "coastal systems" showed high connectivity with the valuation methodologies and high frequency of use whereas "grassland" and "urban" showed low connectivity and frequency of use. The ecosystem services "aesthetic value/amenities/inspiration" and "recreation/ecotourism" showed high connectivity with the methodologies and high frequency of use whereas "forest products" and "natural resources" showed low connectivity and frequency of use. This study identified trends in ecosystem service valuation research in South Korea, and these trends can be used to guide the direction of future research and aid in the selection of methodologies according to ecosystem type and services.
Key Words: Two-Mode Network, Economic Valuation, Ecosystem Assessment, Meta-Analysis

I. Introduction

Ecosystem services are the benefits that nature provides to people (MEA, 2005). They directly and indirectly contribute to human well-being (Costanza et al., 1997) and have recently become an important concept

* This research was supported by the National Institute of Ecology.
** First author, M.A. in climatic economics, Chung-Ang University
*** Co-author, Research fellow, Korea Environment Institute
**** Corresponding author, Senior researcher, National Institute of Ecology

(Fisher et al., 2009; Seppelt et al., 2011; La Notte et al., 2017). They are used as tools for various policy decisions including sustainable management of natural resources, landscape planning, and natural environment conservation (De Groot et al., 2010; Chan et al., 2012; Maes et al., 2012; Martinez-Harms et al., 2015; Burkhard and Maes, 2017). Many researchers have evaluated ecosystem services from various perspectives, including by using mapping and economic valuation (Maes et al., 2012; Häyhä et al., 2015; Karabulut et al., 2016; Kremer et al., 2016; Rabe et al., 2016), payments for ecosystem services (Jack et al., 2008; Calvet-Mir et al., 2015), and various scenarios and models (Mexia et al., 2018; Redhead et al., 2018). Among these, economic valuation, which is the assessment of the monetary value of goods or services, is important not only for raising awareness and payments for ecosystem services; but also for spatial planning, for example, in urban and protected areas. Economic valuation of ecosystem services are limited as it leads to uncertainty (Johnson et al., 2012) or variations in the valuation results according to the applied conditions. Another limitation is the problem of double counting of ecosystem services (Hein et al., 2006; Fu et al., 2011). Despite these drawbacks, such valuations are useful for experts and the general public to intuitively understand, making them valuable tools in policymaking. Research into economic valuation of ecosystem services varies according to ecosystem type, service, and scale (Rabe et al., 2016; Barbier et al., 2011; Krieger, 2001; Nahuelhual et al., 2013; Manes et al., 2016; Quintas-Soriano et al., 2016). South Korea, a country that exhibits diverse ecosystems, currently has a strong research focus on ecosystem services, emphasizing the importance of considering ecosystem services in policymaking. However, actual plans and policies based on ecosystem service valuations are rare. Therefore, to enable ecosystem service

valuations to support planning and decision-making, this study examined the trends and gaps in research related to ecosystem types, ecosystem services, and valuation methodologies in South Korea. The Environmental Valuation Information System (EVIS) of South Korea was used to compile economic valuation data, and two-mode network analysis (NetMiner 4.0) analyzed the data. By identifying the ecosystem types and services that should be included in future assessments, this study should enable researchers to select and set development directions for future valuation research.

Ⅱ. Analysis Method

1. Study Location

This study was based in South Korea, a country boasting diverse ecosystems, including coasts, coastal wetlands, and forests. In response to the increasing global debate surrounding ecosystem services, South Korea hosted a knowledge and data technical support unit of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). And as well, an online environmental valuation database was compiled on this basis, to promote the use of valuation studies related to environmental goods for policymaking and decision-making. This database provided results of valuation studies conducted on both ecosystem types and services. In order to fully investigate ecosystem services in South Korea, this study conducted a meta-analysis of the results available on the online database.

2. Analysis Data and Method

Firstly, this study utilized the EVIS of the Korea Environment Institute (KEI) (〈Figure 1〉). EVIS is an online database, developed and operated by the KEI that provides basic information on the monetary value of ecosystems and environmental services. It includes information such as the valuation and environmental valuation targets derived from each study, with values estimated in monetary units. As of January 17, 2020, the site comprised information on 1,117 value estimates, derived from 278 ecosystem-related studies that were conducted between 1992-2019. This study used individual value estimates derived from each study in the EVIS database, to identify the relationships among valuation methodologies, ecosystem types, and ecosystem services.

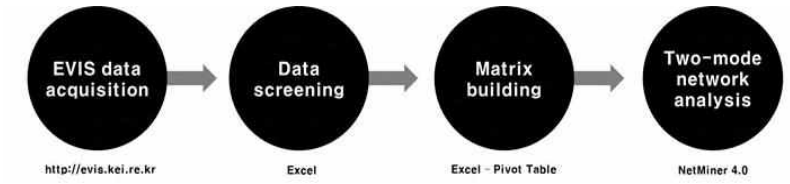
〈Figure 1〉 EVIS database for ecosystem services valuation studies, including ecosystem types, services, and study information

Secondly, unclear ecosystem types or valuation methodologies were excluded from the analysis, and duplicate ecosystem types were adjusted by referencing the literature. For example, the following cases were excluded from the analysis: cases where the ecosystem type was classified

as 'Other ecosystems', cases where the valuation method was classified as 'Other' or 'Value transfer' using valuations derived from other studies, and cases where only the value estimate's monetary unit was changed and the natural value derived from the study was the same (e.g., the total value was calculated by multiplying the area, or number of visitors of the study location, by the derived monetary unit). Furthermore, cases where the results of the economic and feasibility analysis were relevant to a particular project were excluded from the analysis. Additionally, where two or more ecosystem types were duplicated for one value estimate, they were adjusted to the closest ecosystem type, as determined from the literature. Even for cases in which the derived values were not distinguished by the ecosystem services (e.g., conservation value), the appropriate ecosystem services were used by referencing the related literature. This resulted in a total of 675 value estimates available for the analysis. Thirdly, this study constructed matrixes of valuation methodology-ecosystem types, and valuation methodology-ecosystem services. The ecosystem types and services were first classified with reference to previous literature (MEA, 2005; Costanza et al., 2014; De Groot et al., 2012). The ecosystem types were classified into urban, farmlands, forests, grasslands, rivers and lakes, coastal wetlands, and coasts. The ecosystem services were classified into provisioning services (crops, fishing, aquaculture, forest products, freshwater, natural resources, and biochemicals/medical and pharmaceutical resources), regulating services (air quality regulation, greenhouse gas regulation, natural hazard regulation, water quality regulation, and erosion control), cultural services (recreation/ecotourism, aesthetic value/amenities/ inspiration, educational value, spiritual/religious value, cultural heritage/ cultural diversity, and natural heritage/natural diversity), and supporting

services (provision of habitat and biodiversity). Excel pivot tables were then used to construct the matrixes. Lastly, this study used two-mode network analysis to confirm the relationship between ecosystem, ecosystem service, and valuation methodology, based on each value estimate. Network analysis can efficiently identify the relationship structure by visually illustrating the relationships. Moreover, two-mode network analysis was selected as it can illustrate the relationship between two entities of different natures (Borgatti, 2009; Borgatti and Everett, 1997; Lee et al., 2018). Thus, this study identified the characteristics of the current methodologies employed for ecosystem service valuation, using the relationship structure of the three entities. NetMiner 4.0 was used as the network analysis program. The analysis data was constructed and analyzed as follows (〈Figure 2〉).

〈Figure 2〉 Schematic of the analysis procedure employed in this study



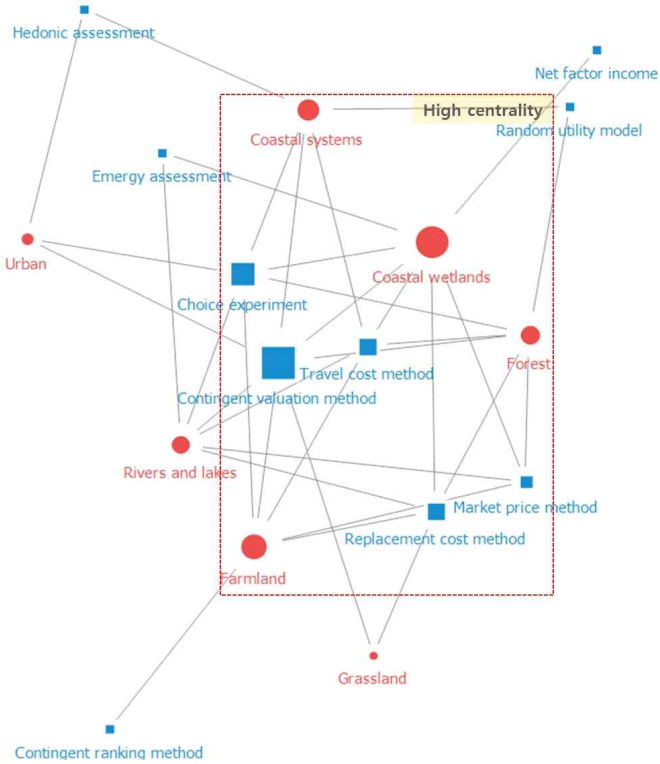
Ⅲ. Analytical Results

1. Ecosystem Type-Valuation Method Analysis

According to the analytical results shown in Figure 3 and Table 1, high connectivity was observed for the ecosystem types: 'coastal wetland', 'farmland', 'coastal systems', and 'forest', with the valuation methodologies: 'contingent valuation method', 'choice experiment', 'travel cost method',

and 'replacement cost method'. For 'forest', the recreation value was previously assessed using the 'contingent valuation method (Yoon and Kim, 1992; Han, 2003; Kim and Byeon, 2003)', and for 'farmland', the aesthetic value of rural villages was previously assessed using the 'choice experiment' method (Jeong, 2014). The ecosystem type-valuation method connectivities between 'grassland'/'urban' and 'net factor income'/'contingent ranking method' were relatively low. This was attributed either to the lack of diversity in methodology types used for the assessment of these ecosystems, or the evaluation of only some ecosystem types using these two methodologies. The most commonly used methodologies were 'contingent valuation method', 'choice experiment', 'travel cost method', and 'restoration cost method'. Indeed, 85.9% of the 675 value estimates were derived using these four evaluation methods. Conversely, 'net factor income', 'contingent ranking method', 'hedonic assessment', and 'emergy assessment' comprised 31 value estimates, or approximately 4.6% of the total. Among these, 'net factor income' and 'contingent ranking method' also exhibited low connectivity with ecosystem type. Along with 'forest', 'farmland', 'coastal systems' and 'rivers and lakes' contributed to 544 (80.6%) of the total value estimates. Among these, the three types excluding 'rivers and lakes', also showed high connectivity with the valuation methodologies. However, the total frequency of 'grassland' and 'urban' was 71, accounting for approximately 10.5%; they also exhibited low connectivity with the valuation methodologies. Furthermore, although the number of value estimates for 'urban' and 'coastal wetland' was similar, the network analysis demonstrated a large difference in terms of betweenness centrality. This can be attributed to a lack of diversity in the methodologies, which also indicated bias in the evaluation of ecosystem services.

〈Figure 3〉 Analysis between ecosystem types (red) and valuation methods (blue)



〈Table 1〉 Analysis between ecosystem types and valuation methods

Ecosystems	Two-mode normalized betweenness centrality	Frequency	Valuation methods	Two-mode normalized betweenness centrality	Frequency
Coastal wetlands	0.23	60	Contingent valuation method	0.24	287
Farmland	0.17	98	Choice experiment	0.15	169
Coastal systems	0.13	75	Travel cost method	0.09	55
Forest	0.11	201	Replacement cost method	0.08	69
Rivers and lakes	0.10	170	Market price method	0.04	28

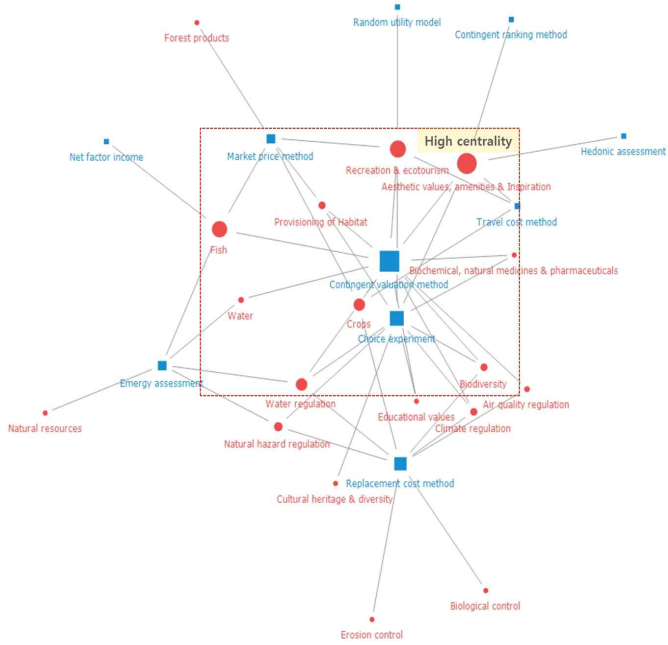
Urban	0.05	62	Random utility model	0.01	36
Grassland	0.00	9	Hedonic assessment	0.01	11
–	–	–	Contingent ranking method	0.00	13
–	–	–	Emergy assessment	0.00	6
–	–	–	Net factor income	0.00	1

2. Ecosystem Service-Valuation Method Analysis

According to the analytical results shown in Figure 4 and Table 2, high connectivity was observed for cultural services ('recreation/ecotourism' and 'aesthetic value/amenities/inspiration'), provisioning services ('fish'), and regulating services ('water quality regulation'), with the valuation methodologies 'contingent valuation method', 'choice experiment', 'replacement cost method', and 'market price method'. For 'recreation/ecotourism', the ecotourism value of coastal wetlands was previously assessed using the 'choice experiment' method (Chang et al., 2011) and for 'aesthetic value/amenities/inspiration', the landscape value of urban forests was previously assessed using the 'contingent valuation method' (Kim et al., 2010). In contrast, the connectivity of 'forest products'/'natural resources' (provisioning services), 'educational value', and 'cultural heritage/cultural diversity' (cultural services) with the valuation methodologies was rather low. This difference could be attributed to bias in the evaluation of specific ecosystem services. Additionally, when compared to other methodologies, 'net factor income', 'contingent ranking method', and 'hedonic assessment' showed low connectivity with the ecosystem services. This could be attributed to

their use for evaluating only some ecosystem services, which is similar to the analytical results between ecosystem type and valuation methodology. The most commonly used methodologies for evaluation were 'contingent valuation method', 'choice experiment', 'replacement cost method', and 'market price method', corresponding to 580 value estimates, or 85.9% of the total. Conversely, few value estimates were attributed to 'net factor income', 'contingent ranking method', and 'hedonic assessment', and their connectivity with ecosystem services was also low. In addition, the total number of value estimates for 'recreation/ecotourism', 'aesthetic value/amenities/inspiration', 'water quality regulation', and 'natural hazard regulation' was 474, which was approximately 76.7% of the total. Among these, the three types excluding 'natural hazard regulation', also showed high connectivity with the valuation methodologies. However, the number of value estimates for 'biological control', 'forest products', 'natural resources', and 'erosion control' totaled 10, comprising 1.5% of the total. Among them, 'forest products' and 'natural resources' showed low connectivity with the valuation methodologies. Additionally, 'water quality regulation' had the second-highest frequency of value estimates and showed a large difference in betweenness centrality based on the network analysis with 'aesthetic value/amenities/inspiration', which had the third-highest frequency. This is because 'water quality regulation' could only be derived for specific ecosystem types.

〈Figure 4〉 Analysis between ecosystem services (red) and valuation methods (blue)



〈Table 2〉 Analysis between ecosystem services and valuation methods

Ecosystem services		Two-mode normalized betweenness centrality	Frequency	Valuation methods	Two-mode normalized betweenness centrality	Frequency
Providing services	Fish	0.14	19	Contingent valuation method	0.38	287
	Crops	0.09	9	Choice experiment	0.25	169
	Natural resources	0.05	2	Replacement cost method	0.19	69
	Water	0.02	7	Market price method	0.11	28
	Biochemical, natural medicines & pharmaceuticals	0.00	14	Emergy assessment	0.11	6
	Forest products	0.00	1	Travel cost method	0.02	55
Regulating	Water	0.09	110	Random utility	0.00	36

	regulation			model		
services	Natural hazard regulation	0.05	44	Contingent ranking method	0.00	13
	Climate regulation	0.03	17	Hedonic assessment	0.00	11
	Air quality regulation	0.01	18	Net factor income	0.00	1
	Erosion control	0.00	6	-	-	-
	Biological control	0.00	1	-	-	-
Cultural services	Aesthetic values, amenities & inspiration	0.19	80	-	-	-
	Recreation & ecotourism	0.14	284	-	-	-
	Educational values	0.00	12	-	-	-
	Cultural heritage & diversity	0.00	11	-	-	-
Supporting services	Provision of habitat	0.03	32	-	-	-
	Biodiversity	0.03	8	-	-	-

Ⅳ. Discussion

This study investigated the trends in ecosystem services research in South Korea by using the value estimates' frequency and level of connectivity between the analysis targets through a network analysis of ecosystem types, ecosystem services, and valuation methodologies. Overall, the connectivity and frequency were proportional. These results indicated the following implications. Firstly, in terms of valuation methodology, the value estimates that used the statement preference methods such as 'contingent valuation method' and 'choice experiment' (Eom, 2001; Kwak et al., 2006; Rhee, 2007; Noh and Lee, 2012; Shin et al.,

2016) exhibited high connectivity with ecosystem type and service, accounted for 456 value estimates (67.6%). 'net factor income' and 'contingent ranking method' (Kwon and Yun, 2004; Yun and Kim, 2006), which showed low connectivity, comprised only 14 value estimates (2.1%). Due to the nature of environmental goods, they are not traded in markets. Rather, they are valued by creating a virtual market through methods such as the 'contingent valuation method' and by asking consumers their willingness to pay. As ecosystem services do not exist in markets, their values must be estimated virtually; therefore, these techniques are more widely used for evaluating ecosystem services. Additionally, the 'travel cost method' (Han and Cho, 2006; Pyo, 2017) is primarily used for valuing cultural services and is rarely used for other services. Hence, its connectivity with ecosystem services was low and it comprised only 8.1% of the total value estimates. Secondly, in terms of ecosystem type, 'coastal wetland', 'forest', 'farmland', and 'coastal systems' (Kang et al., 2006; Ryu and Lee, 2013) showed high connectivity with the valuation methodologies and comprised a high proportion of the total value estimates, whereas 'grassland' and 'urban' showed low connectivity and only accounted for 10.5% of the total. This suggests that the valuation of specific ecosystem types was biased. For example, 'forest' accounted for 29.7% of total value estimates, whereas 'urban' accounted for only 9.2%. Although the importance of evaluating 'urban' ecosystem services is growing, current research trends indicate that 'urban' valuations are still insufficient. Future studies must therefore evaluate a variety of ecosystem types, including these 'urban' ecosystems. Thirdly, in terms of ecosystem services, 'recreation/ecotourism', 'aesthetic value/amenities/inspiration', 'fish', and 'water quality regulation' all showed high connectivity with the valuation methodology

and comprised approximately 76.7% of the total value estimates. Conversely, connectivity was low for 'forest products', 'natural resources', 'educational value', and 'cultural heritage/cultural diversity'. These services, along with 'biological control' and 'erosion control', showed a low frequency of 1.5%. Provisioning services exhibited a lower frequency than other services, which was largely due to the formation of market prices (e.g., crops, forest products). Despite numerous recent issues regarding fine dust and climate change, there were few evaluations of 'air quality regulation' and 'greenhouse gas regulation', and their connectivity was also low. Given their importance, it is necessary to analyze these environmental issues and link them to ecosystem service valuations based on these analytical results. This study included only the valuation results of ecosystem services in South Korea. For example, regardless of its importance, 'pollination' could not be included in the analysis due to the lack of related valuation results. Consequently, this analysis did not cover all services provided by ecosystems. To address this limitation, further research is required on such services which have received minimal research attention.

Ⅴ. Conclusions

This study examined trends in ecosystem services valuation research in South Korea in order to support environmental policies and decision-making. Based on the value estimates derived from EVIS, two-mode network analysis was conducted between ecosystem types, ecosystem services, and valuation methodologies. According to the results, the connectivity and frequency of value estimates were high among specific

valuation methodologies ('contingent valuation method', 'choice experiment'), ecosystem types ('forest', 'farmland', 'coast'), and ecosystem services ('aesthetic value/amenities/inspiration', 'recreation/ecotourism'). In contrast, the methodologies 'net factor income' and 'contingent ranking method' exhibited low connectivity with ecosystem types and services, as well as low frequency. Furthermore, the ecosystem types 'grassland' and 'urban', and ecosystem services 'forest products' and 'natural resources', showed low connectivities with the methodologies, and low value estimation frequencies. This suggests that the valuation of certain ecosystem types and services is biased. Future studies must therefore assess ecosystem types and services that have previously received little research attention, in addition to ecosystem services reflecting solutions to recent environmental issues, and to research trends. Moreover, methodology selection and valuation should also consider the ecosystem type and service characteristics. By identifying the trends in valuation research, this study can help guide the direction of future valuation research and improve its applicability in policymaking. However, given the valuation characteristics of environmental goods, which are non-market goods, there are limitations for the usage frequency of stated preference methods. We hope that future studies will actively conduct valuations of ecosystem services using methodologies other than the stated preferred ones, thereby increasing the diversity of available values and enhancing the application of ecosystem services valuations to national policymaking.

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Hyeran Kim: She gained her master's degree in climatic economics at Chung-Ang University. Her research interests are ecosystem services assessments and climate change policies (hr2.kim@gmail.com).

Jae-hyuck Lee: Dr. Lee gained his Ph.D. degree in landscape architecture at Seoul National University. He is a research fellow at the Korea Environment Institute. His research interests are ecotourism and ecological community (jaehyuck@kei.re.kr).

Hyuksoo Kwon: Dr. Kwon gained his Ph.D. degree in landscape architecture at Seoul National University. He is a senior researcher at the National Institute of Ecology. His research interests are mapping ecosystem services and biodiversity offsets (ulmus@nie.re.kr).

Received: 09 November 2020
Revised: 12 November 2020
Accepted: 16 December 2020