Ecosystem Services in Forest Remnants

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Analyzing the landscape configuration factors where they are located can ensure a more accurate spatial assessment of the supply of ecosystem services. It can also show if the benefits promoted by ecosystems depend not only on the supply of these services but also on the demand, the cultural values, and the interest of the society where they are located.

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1. Introduction

The ecosystem services concept covers ecological, economic, and social aspects by emphasizing the values of nature for humans. Thus, this approach provides a suitable framework to address complex problems related to the sustainable use of resources that societies face today [1][2]. Ecosystem services can also be regarded as benefits derived from ecosystem functions, for which there is a demand. Thus, in this context, ecosystem services also embrace the goods derived from ecosystems [3]. Rapid urban expansion has turned natural ecosystems into semi-natural or artificial ecosystems [4][5][6], resulting in dramatic changes in both ecosystem structure and functions [7][8][9]. Life in cities needs increasing amounts of ecosystem services (ESs) in the form of food, drinking water, clean air, and recreation [10]. Simultaneously, urbanization is an increasingly important driver of land-use change, biodiversity loss, and ecosystem service deterioration [11][12][13][14]. The ESs therefore became vulnerable with the rapid alteration of ecological landscapes caused by urbanization [15][16][17]. In a context of generalized decline of ESs [18], putting in place governance systems that secure long-term delivery and use of ESs is one of the biggest challenges for cities in the 21st century [19][20][21].

In this context, urban planning can be associated with ecosystem services supply and demand: in supply, by estimating the potential of these services in terms of conservation, management, and deployment of green infrastructure, and in demand, through the organization of land use and cover, so that the demand matches the available supply [22].

In addition to this assessment based on supply and demand, ecosystem services can be approached through conceptual models that analyze them from the structural characteristics in the environment that ensure the production of these benefits [22][23]. This is because the capacity to provide ecosystem services can be, and is, also affected by the pressures acting on the ecosystem. These pressures are most often associated with the spatial distribution of the population and anthropic factors arising, in particular, from urbanization [22].

As these pressures vary, so does the ability to generate ecosystem services and the demand for them. The urbanization of a given region, for example, results in a drop in the supply of ecosystem services because of soil sealing, while at the same time, the demand for ecosystem services increases as the number of urban inhabitants grows [22][24].

Correctly understanding the correlation between supply and demand of ecosystem services is a very important condition to promote a sustainable management of such services, contributing significantly to improving human welfare [25][26]. However, in practice, choosing appropriate tools to address ecosystem services in planning is still difficult because they differ in their complexity, transferability, and time and data requirements [1]. For example, urban forests benefit cities with different ecosystem services, such as groundwater recharge, retention of particulate emitted by motors, surface runoff of rainwater, thermal comfort and local climate regulation, and carbon uptake [27].

In natural landscapes, but more especially in urban landscapes, the relationship and impact caused by measurable variables such as size, shape, and structure of natural habitat fragments on their ecological function are still unclear [28]. But the identification of spatial and temporal changes in the supply and demand of ecosystem services faces challenges; it is still necessary to incorporate relevant indicators that relate the supply and demand of ecosystem services, considering a spatial and temporal analysis [25].

Most of the operational tools that address the provision of ecosystem services present their outputs as spatial information or in a form easily connected to GIS software (ArcGIS, version 10.8.1, ESRI). This is very interesting, as it allows the location of hotspots of provision of these services, the analysis of synergies and trade-offs between them, or the spatial comparison of supply and demand, also revealing areas under pressure [2].

2. Ecosystem Services in Forest Remnants

Given this need to approach ecosystem services associated with spatial planning, especially urban planning, multicriteria decision analysis (MCDA) approaches have proven to be quite suitable [29][30][31][32][33][34]. This is because they allow the integration of ecological and socioeconomic aspects in planning related to changes in land use and land cover, in addition to allowing dealing with subjectivity and the different demands of stakeholders involved in the decision-making process [1].

It is worth remembering, however, that these indicators of the state of the ecosystem provide an incomplete picture of the overall level of service provision, especially in an urban setting where many services result from a combination of human and ecosystem inputs [22]. Although progress has been made in decision support systems (DSSs), choosing the appropriate tools to assess ecosystem services, aiming at a specific decision process, is still complicated because there are no clear guidelines for the implementation of these tools [2].

Recent times have seen progress in research about the mapping and evaluation of ecosystem services, but these studies have mostly focused on aspects of ecological change and economic valuation; the discussion has not included the perspective of beneficiaries, i.e., stakeholders and their perceptions. And these groups have different interests and preferences regarding ecosystem services [35].

Thinking about this growing demand to incorporate management factors in the valuation of ecosystem services, a study proposed an analytical framework to identify similarities and differences in social preferences and values associated with ecosystem services and recognized by key stakeholders [35]. It can be highlighted that there is a gap between scientific perception and human preference, and therefore, studies aimed at broadening and including knowledge about these services are needed [36].

As for the approach to ecosystem services integrated into the planning process, it is worth noting that the different types of ecosystem services currently have a patchy participation in these processes. What researchers do find is that in public policy sectors with long traditions in natural resource management, such as forestry, agriculture, and water, the ecosystem services approach is already fairly well established. These are also the sectors that involve the most usual operational tools in terms of ecosystem services valuation [2].

Therefore, it is now necessary to find new methods that take into account the unique characteristics and scale demands of the urban environment. They should also consider the diversity of stakeholders involved, their interests and ideas as a support tool for sustainable ecosystem management practices; this is essential, especially for guiding land-use policies, lessening land-use conflict, and promoting the building of an ecological civilization [28][35].

However, few studies have considered human needs, i.e., demand, in approaches to assessing ecosystem services [37]. This is quite inconsistent, according to the authors, since the very definition of ecosystem services was born from the search for human well-being and the focus on sustainable development [26]. In this regard, some new approaches have been established to structure the assessment of ecosystem services considering three concepts: (1) the capacity or potential to provide services (PS); (2) the flow of provision of these services (AS); and (3) the demand for such ecosystem services [22][25][35].

Nevertheless, studies show that there is an incompatibility between the supply and demand of ecosystem services, especially in urban, peri-urban, and expanding areas. And generally, areas with high demand for these services are those with the lowest supply, hence the imbalance [38]. Therefore, only through strategies that combine both supply optimization and demand reduction can the supply of these services be enhanced [37].

It can thus be noted that changes in the type of land use are among the main reasons for the decrease in the supply–demand relationship, since they directly affect the potential of ecosystem services and the flow of services. But more than that, especially when it comes to regulating ecosystem services, which are intrinsically related to demand, urban planning decisions significantly affect the provision of such services and how they are related to the benefits provided in the city environment [25].

As example, Cortinovis & Geneletti [22] considered seven regulating services (air purification, global climate regulation, moderation of extreme events, noise reduction, runoff and flood control, urban temperature regulation, and sewage treatment), and correlated them to common indicators in urban planning. Such indicators include population density, census data, locations, and presence of infrastructure. With this association, the researchers sought to understand what the demands of ecosystem services are, multiplying the intensity of ecological pressure and the amount of urban population or physical assets exposed [22].

This is because it is also important to consider that inequalities between the supply and demand of ecosystem services change over time, influenced by biotic factors such as richness and diversity, abiotic factors, such as geospatial factors, and by anthropic factors such as population growth, for example [38][39]. These are concepts that are usually associated with the spatiality of land-use and land-cover changes and can be used as tools for rural and urban development planning at both local and regional levels [22][25][35][38].

The actual magnitude of changes in the supply of ecosystem services and the relevance of considering these services in decision-making also depend on factors such as landscape configuration and geopolitical and management issues. In other words, considering these other factors would ensure a more precise and accurate spatial assessment of the supply of ecosystem services, as would considering that the benefits promoted by ecosystems depend not only on the supply of these services but also on demand, cultural values, and interest [40].

Furthermore, by focusing on the assessment of ecosystem services, based on the peculiar characteristics of each small basin or sub-basin and integrated with socioeconomic development planning, it will be possible to develop a much more effective ecosystem services management policy, since it will be based on a specific management model that is more appropriate for each landscape [41].

References

1. Grêt-Regamey, A.; Altwegg, J.; Sirén, E.A.; van Strien, M.J.; Weibel, B.; Grêt-Regamey, A.; Altwegg, J.; Sirén, E.A.; van Strien, M.J.; Weibel, B. Integrating ecosystem services into spatial planning—A spatial decision support tool. Landsc. Urban Plan. 2017, 165, 206–219.
2. Grêt-Regamey, A.; Sirén, E.; Brunner, S.H.; Weibel, B. Review of decision support tools to operationalize the ecosystem services concept. Ecosyst. Serv. 2017, 26, 306–315.
3. Maes, J.; Liquete, C.; Teller, A.; Erhard, M.; Paracchini, M.L.; Barredo, J.I.; Grizzetti, B.; Cardoso, A.; Somma, F.; Petersen, J.-E.; et al. An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. Ecosyst. Serv. 2016, 17, 14–23.
4. Huang, G.; London, J. Mapping cumulative environmental efects, social vulnerability, and health in the San Joaquin Valley, California. Am. J. Public Health 2012, 102, 830–832.
5. Qiu, B.; Li, H.; Zhou, M.; Zhang, L. Vulnerability of ecosystem services provisioning to urbanization: A case of China. Ecol. Indic. 2015, 57, 505–513.

6. Kehoe, L.; Romero-Muñoz, A.; Polaina, E.; Estes, L.; Kreft, H.; Kuemmerle, T. Biodiversity at risk under future cropland expansion and intensification. Nat. Ecol. Evol. 2017, 1, 1129–1135.
7. Grimm, N.B.; Foster, D.; Groffman, P.; Grove, J.M.; Hopkinson, C.S.; Nadelhoffer, K.J.; Pataki, D.E.; Peters, D.P. The changing landscape: Ecosystem responses to urbanization and pollution across climatic and societal gradients. Front. Ecol. Environ. 2008, 6, 264–272.
8. Eigenbrod, F.; Bell, V.A.; Davies, H.N.; Heinemeyer, A.; Armsworth, P.R.; Gaston, K.J. The impact of projected increases in urbanization on ecosystem services. Proc. R. Soc. B Biol. Sci. 2011, 278, 3201–3208.
9. Long, H.; Liu, Y.; Hou, X.; Li, T.; Li, Y. Effects of land use transitions due to rapid urbanization on ecosystem services: Implications for urban planning in the new developing area of China. Habitat Int. 2014, 44, 536–544.
10. Guo, Z.; Zhang, L.; Li, Y. Increased dependence of humans on ecosystem services and biodiversity. PLoS ONE 2010, 5, e13113.
11. Mcdonald, R.; Marcotullio, P. Global effects of urbanization on Ecosystem Services. In Urban Ecology: Patterns, Processes, and Applications; Niemelä, J., Ed.; Oxford University Press: Oxford, UK, 2011; pp. 89–239.
12. Li, Y.; Li, Y.; Zhou, Y.; Shi, Y.; Zhu, X. Investigation of a coupling model of coordination between urbanization and the environment. J. Environ. Manag. 2012, 98, 127–133.
13. Seto, K.C.; Güneralp, B.; Hutyra, L.R. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proc. Natl. Acad. Sci. USA 2012, 109, 16083–16088.
14. Dai, L.; Wang, Z.; Guo, T.; Hu, L.; Chen, Y.; Chen, C.; Yu, G.; Ma, L.Q.; Chen, J. Pollution characteristics and source analysis of microplastics in the Qiantang River in southeastern China. Chemosphere 2022, 293, 133576.
15. Su, C.-H.; Fu, B.-J.; He, C.-S.; Lü, Y.-H. Variation of ecosystem services and human activities: A case study in the Yanhe Watershed of China. Acta Oecologica 2012, 44, 46–57.
16. Estoque, R.C.; Murayama, Y. Landscape pattern and ecosystem service value changes: Implications for environmental sustainability planning for the rapidly urbanizing summer capital of the Philippines. Landsc. Urban Plan. 2013, 116, 60–72.
17. Das, M.; Das, A.; Pereira, P.; Mandal, A. Exploring the spatio-temporal dynamics of ecosystem health: A study on a rapidly urbanizing metropolitan area of Lower Gangetic Plain, India. Ecol. Indic. 2021, 125, 107584.
18. MEA, Millennium Ecosystem Assessment. Ecosystems and Human Well-Being: Synthesis; World Resources Institute: Washington, DC, USA; Island Press: Washington, DC, USA, 2005.

19. Elmqvist, T.; Fragkias, M.; Goodness, J.; Güneralp, B.; Marcotullio, P.J.; McDonald, R.I.; Parnell, S.; Schewenius, M.; Sendstad, M.; Seto, K.C.; et al. Stewardship of the biosphere in the urban era. In Urbanization, Biodiversity and Ecosystem Services; Elmqvist, T., Ed.; 2013; pp. 1–38.
20. TEEB. The Economics of Ecosystems and Biodiversity. Manual for Cities: Ecosystem Services in Urban Management. 2011. Available online: http//www.teebweb.org (accessed on 15 October 2018).
21. Ronchi, S. Ecosystem Services and Planning. In Ecosystem Services for Spatial Planning: Innovative Approaches and Challenges for Practical Applications; Green Energy and Technology; Springer: Cham, Switzerland, 2018; pp. 1–26.
22. Cortinovis, C.; Geneletti, D. A framework to explore the effects of urban planning decisions on regulating ecosystem services in cities. Ecosyst. Serv. 2019, 38, e100946.
23. Haines-Young, R.; Potschin, M. The links between biodiversity, ecosystem services and human well-being. In Ecosystem Ecology: A New Synthesis; Raffaelli, D., Frid, C., Eds.; BES Ecological Reviews Series; CUP: Cambridge, UK, 2010.
24. Maes, J.; Barbosa, A.; Baranzelli, C.; Zulian, G.; e Silva, F.B.; Vandecasteele, I.; Hiederer, R.; Liquete, C.; Paracchini, M.L.; Mubareka, S.; et al. More green infrastructure is required to maintain ecosystem services under current trends in land-use change in Europe. Landsc. Ecol. 2015, 30, 517–534.
25. Guan, Q.; Hao, J.; Ren, G.; Li, M.; Chen, A.; Duan, W.; Chen, H. Ecological indexes for the analysis of the spatial–temporal characteristics of ecosystem service supply and demand: A case study of the major grain-producing regions in Quzhou, China. Ecol. Indic. 2020, 108, e105748.
26. Owuor, M.A.; Icely, J.; Newton, A.; Nyunja, J.; Otieno, P.; Tuda, A.O.; Oduor, N. Mapping of ecosystem services flow in Mida Creek, Kenya. Ocean Coast. Manag. 2017, 140, 11–21.
27. Ferreira, M.L.; De Souza, L.C.; Conti, D.D.M.; Quaresma, C.C.; Tavares, A.R.; da Silva, K.G.; Kniess, C.T.; De Camargo, P.B. Soil Biodiversity in Urban forests as a consequence of litterfall management: Implications for São Paulo's ecosystem services. Sustainability 2018, 10, 684.
28. Grafius, D.R.; Corstanje, R.; Harris, J.A. Linking ecosystem services, urban form and green space configuration using multivariate landscape metric analysis. Landsc. Ecol. 2018, 33, 557–573.
29. Costanza, R. Nature: Ecosystems without commodifying them. Nature 2006, 443, 749.
30. Dendoncker, N.; Boeraeve, F.; Crouzat, E.; Dufrêne, M.; König, A.; Barnaud, C. How can integrated valuation of ecosystem services help understanding and steering agroecological transitions? Ecol. Soc. 2018, 23.
31. Gómez-Baggethun, E.; Martín-López, B. Ecological economics perspective in ecosystem services valuation. In Handbook of Ecological Economics; Martínez-Alier, J., Muradian, R., Eds.; Edward

Elgar: Cheltenham, UK, 2015; pp. 260–282.

32. Paetzold, A.; Warren, P.H.; Maltby, L.L. A framework for assessing ecological quality based on ecosystem services. Ecol. Complex. 2010, 7, 273–281.
33. Saarikoski, H.; Jax, K.; Harrison, P.A.; Primmer, E.; Barton, D.N.; Mononen, L.; Vihervaara, P.; Furman, E. Exploring operational ecosystem service definitions: The case of boreal forests. Ecosyst. Serv. 2015, 14, 144–157.
34. Sijtsma, F.J.; Van Der Bilt, W.G.; Van Hinsberg, A.; De Knegt, B.; Van Der Heide, M.; Leneman, H.; Verburg, R. Planning nature in urbanized countries. An analysis of monetary and non-monetary impacts of conservation policy scenarios in the Netherlands. Heliyon 2017, 3, e00280.
35. Zhang, W.; Yu, Y.; Wu, X.; Pereira, P.; Borja, M.E.L. Integrating preferences and social values for ecosystem services in local ecological management: A framework applied in Xiaojiang Basin Yunnan province, China. Land Use Policy 2020, 91, e104339.
36. Riegels, N.; Lynggaard-Jensen, A.; Jensen, J.K.; Gerner, N.V.; Anzaldua, G.; Mark, O.; Butts, M.; Birk, S. Making the ecosystem services approach operational: A case study application to the Aarhus River, Denmark. Sci. Total. Environ. 2019, 707, 135836.
37. Shi, Y.; Shi, D.; Zhou, L.; Fang, R. Identification of ecosystem services supply and demand areas and simulation of ecosystem service flows in Shanghai. Ecol. Indic. 2020, 115, 106418.
38. González-García, A.; Palomo, I.; González, J.A.; López, C.A.; Montes, C. Quantifying spatial supply-demand mismatches in ecosystem services provides insights for land-use planning. Land Use Policy 2020, 94, e104493.
39. Harrison, P.; Berry, P.; Simpson, G.; Haslett, J.; Blicharska, M.; Bucur, M.; Dunford, R.; Egoh, B.; Garcia-Llorente, M.; Geamănă, N.; et al. Linkages between biodiversity attributes and ecosystem services: A systematic review. Ecosyst. Serv. 2014, 9, 191–203.
40. Paruelo, J.M.; Texeira, M.; Staiano, L.; Mastrángelo, M.; Amdan, L.; Gallego, F. An integrative index of Ecosystem Services provision based on remotely sensed data. Ecol. Indic. 2016, 71, 145–154.
41. Yao, J.; He, X.; Chen, W.; Ye, Y.; Guo, R.; Yu, L. A local-scale spatial analysis of ecosystem services and ecosystem service bundles in the upper Hun River catchment, China. Ecosyst. Serv. 2016, 22, 104–110.