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Social-Ecological Connectivity to Understand Ecosystem Service Provision across Networks in Urban Landscapes

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Abstract: Landscape connectivity is a critical component of dynamic processes that link the structure and function of networks at the landscape scale. In the Anthropocene, connectivity across a landscape-scale network is influenced not only by biophysical land use features, but also by characteristics and patterns of the social landscape. This is particularly apparent in urban landscapes, which are highly dynamic in land use and often in social composition. Thus, landscape connectivity, especially in cities, must be thought of in a social-ecological framework. This is relevant when considering ecosystem services—the benefits that people derive from ecological processes and properties. As relevant actors move through a connected landscape-scale network, particular services may "flow" better across space and time. For this special issue on dynamic landscape connectivity, we discuss the concept of social-ecological networks using urban landscapes as a focal system to highlight the importance of social-ecological connectivity to understand dynamic urban landscapes, particularly in regards to the provision of urban ecosystem services.

Keywords: social-ecological systems; landscape connectivity; social-ecological networks; urban; coupled human-natural systems

1. Introduction

Movement of ecological actors across a landscape is a prerequisite for many ecological processes and functions [1]. This movement can be supported, redirected, or hindered by landscape features, resulting in dynamic networks of habitat nodes across space that are used according to the needs and capacities of various ecological actors [2]. The form, distribution, and function of a network embedded across a landscape determines patterns of connectivity [3]. Connectivity is one of many intrinsic properties of a network, describing the degree to which the landscape facilitates or impedes movement of ecological actors between nodes [4]. From a network perspective, connectivity is typically quantified as either structural connectivity (i.e., the pattern of the network in space) or functional connectivity (i.e., how a network is actually used) [5,6]. This distinction between network form and connectivity utility highlights a critical need for a deeper understanding of the interactions between landscape pattern and ecological process to understand movement patterns of diverse ecological communities in dynamic landscapes [2,7,8]—landscapes that consistently change in structure, composition, and function over time.

A robust understanding of network form and resulting changes in connectivity in dynamic landscapes is critically important in the Anthropocene as humans rapidly modify land [2,3,9,10]. Dynamic landscapes experience a high degree of land turnover [11], ultimately resulting in changing patch size and structure, resource abundance, and habitat quality through time. These dynamics manifest in myriad forms and can range from pulsatile changes (e.g., between seasons) to systemic regime shifts (e.g., extreme climate change), which are not mutually exclusive [8]. In these contexts, human movement and the ecological processes that are affected are also critical components [12,13]. Important work has laid the theoretical foundation for dynamic ecological network structural and functional properties, and how spatial ecological network and connectivity within the network influence ecosystem function [2]. The importance of human activities in local and global ecosystems suggests that it is worthwhile to consider social-ecological networks from an ecosystem services perspective. Ecosystem service provision can be predicated on the magnitude and pattern of movement (i.e., the connectivity) of organisms and people across a network. This intervention can help bolster our theoretical and applicable understanding of how relevant actors (human and non-human) are affected by changes in landscape form and ecological function [14]. Here, we use the term "network" to refer to the relevant links and nodes of a system and the term "connectivity" as a landscape-level metric that describes the potential for and patterns of movement through a network. While who or what is moving, in what way, and for what purpose is study- and taxon-specific [15], connectivity analyses can bridge the concepts of landscape structure and ecological function through time and over space [16].

To integrate the concepts of networks, connectivity, dynamic landscapes, and movement into an ecosystem services framework, we must consider the landscape from a social-ecological perspective because both social and biophysical landscape characteristics influence who experiences which ecosystem services and to what extent through time [17,18]. Additionally, considering the social-ecological connectivity of ecosystem services throughout a network can inform how landscape-scale networks can support human wellbeing and ecological resilience (e.g., resistance to regime shifts). Ecosystem services such as pollination and pest control from mobile insects, allergen reduction by pollen competition, and water flow paths/uptake are largely linked to the network structure and connectivity of green spaces [19], but are also characterized by intra-annual dynamics and directional changes through time. Similarly, barriers and promoters to human movement likely influence the ways in which people receive recreational, aesthetic, and cultural ecosystem services. While not all ecosystem services apply to all spaces, scales, or situations, many ecosystem services require movement, and therefore can be better understood when considering the interacting dynamics of providers and recipients through a network (Figure 1). An understanding of the functional connectivity of social and ecological networks in concert with one another can then guide the selection and application of relevant ecosystem services in a given context [20,21].

Urban landscapes are a compelling study system to understand the interplay between social and ecological networks because they are especially heterogeneous in land use/land cover and social demographics [22]. These fine-scale patterns affect movement of people and wildlife across cities [23,24], suggesting that understanding urban connectivity (e.g., the movement of people, organisms, and ideas) is predicated on understanding both the biophysical and social networks together. Moreover, urban areas are dynamic and both physical and social turnover can be quite high [25]. Social processes like gentrification, zoning, and community investment/divestment alter the ways in which diverse communities of people and organisms are distributed across the landscape. These social dynamics likely associate with environmental dynamics (e.g., changes in land use), producing unique spatial patterns in urban areas through time [26–29]. Social-ecological networks have been the subject of research in, for example, movement ecology and social cohesion to independently made strides to understand the connectivity of urban biodiversity and ecosystem functions [14,30], and the social relations and connectivity within urban communities [31]. When considered from an interdisciplinary standpoint, movement phenomena have the potential to synergize to affect ecosystem functions and human wellbeing across a city [32]. In short, connectivity is an important interdisciplinary metric of networks embedded in urban environments at various scales [19,33], and should continue to be integrated into spatially explicit conversations of ecosystem services provisioning [34].

In this paper, we discuss the importance of social-ecological connectivity as a metric and tool to better understand and assess social-ecological networks distributed across dynamic systems. We begin by describing social-ecological connectivity from a network perspective integrating work across disciplines. We then discuss the importance of this concept in the context of urban ecosystem services and offer practical considerations for examining and applying this concept drawing from published work. We support that considering connectivity within a social-ecological network can better assess the hybrid nature of human activities and ecological functions in urban landscapes. Though we focus on urban landscapes in this exploration, such frameworks can be applied to other systems including agricultural and (semi-)natural landscapes.

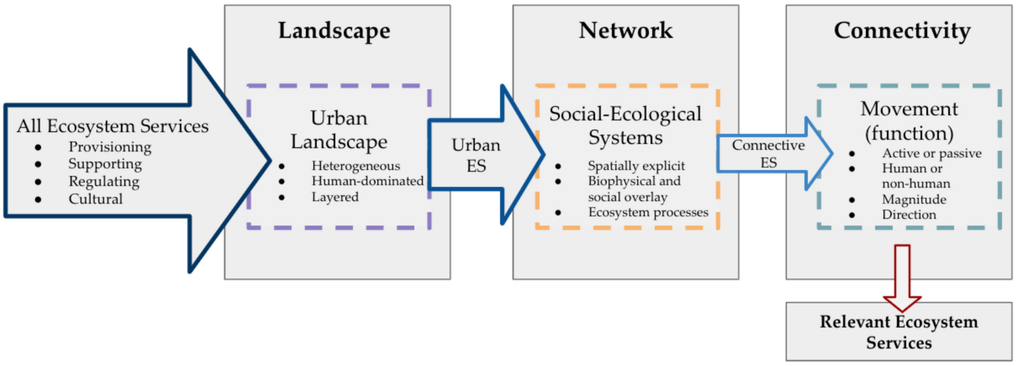

Figure 1. Conceptualization to identify ecosystem services that are well-suited to social-ecological connectivity analyses. Ecosystem services, outlined in the Millennium Ecosystem Assessment [35], consist broadly of the provisioning, supporting, regulating, and cultural benefits that nature and also green spaces in cities provide to support human well-being. Social-ecological connectivity can support the movement of ecologically-relevant actors across a network, thus supporting ecosystem services. When considering the function and utility of an ecosystem services framework to support an understanding of social-ecological connectivity in cities, we must hone our selection of relevant ecosystem services by considering the nuances of the urban landscape, the requisite movement implied by connectivity studies, and the overall application in a SES.

2. Networks in Dynamic Urban Landscapes

In urban areas, connectivity is typically addressed from either an ecological or a social perspective, and the methods, constraints, and applications of these studies are often confined to disciplinary pursuits. In this section, we outline the disciplinary definitions of connectivity, emphasize the importance of examining connectivity from a social-ecological perspective, and apply this concept to understand social-ecological networks in urban landscapes. We acknowledge that the body of work on connectivity and networks is large, and there is a long history of research in this field [2,12,14,36,37]. Thus, while we are unable to cover all definitions and concepts, here, we aim to review, situate and elevate the work on socio-ecological connectivity for this Special Issue on dynamic landscape connectivity.

2.1. Connectivity

Connectivity is a metric that quantifies the capacity for movement within a network across a landscape [15]. Ecological connectivity is the degree to which a landscape facilitates or impedes movement of organisms within a network, and can be measured as "the probability of movement between all points or resource patches in a landscape" [1]. While the ecological and biological relevance for individual-species studies and conservation is clear, incorporating movement patterns of an entire community is challenging [38,39]. Furthermore, while connectivity is a widely used concept in ecology, it is defined and measured quite differently across the literature generating some confusion around a unified concept [5,14,40]. Bolliger and Silbernagel [41] argue that connectivity studies should be situated within an explicit framework to provide knowledge of movement of organisms across a landscape.

Social connectivity can measure how actors within a social network are connected [42,43]. Connections and linkages among human actors occur through communication, collaboration, and knowledge exchange, and while social connectivity has digital components, it is arguably best facilitated in-person [44,45]. For example, meeting and recreation spaces in cities such as public parks or community gardens are sites for emerging ideas, knowledge production, and innovation [46]. Social connectivity is also a component of sustainability and resilience as connections between people decreases social isolation and fragmentation, which may contribute to communities' resilience to change [46–50] and promotes positive environmental transformations [48,51,52]. Much like ecological connectivity, increasing social connectivity requires balancing tensions with diversity and limiting trade-offs [42], and can be explicitly linked to the physical environmental structure, which determines how people move and interact across a landscape [53]. Thus, from a resilience theory perspective, it is important to consider that intermediate levels of connectivity promote network resilience by balancing trade-offs between the benefits and dangers of connectivity [54]. As Gonzalez and colleagues argue [2], co-designing networks with actors and stakeholders may best reduce potential trade-offs. Further inclusion of social factors in dynamic connectivity can improve our understanding of the costs and benefits of connectivity in urban social-ecological systems.

Social-ecological connectivity is a scalable lens through which to understand urban network links [55]. Resource patches or nodes (e.g., habitat, shared social spaces) can be classified at highly localized or diffuse landscape scales, depending on research questions. Individual patches (as small as distinct pixels in a dataset) retain characteristics that contribute to or hinder movement. In highly complex systems such as cities, this has the benefit of reducing biases from strict a priori definitions of network nodes and linear links. It also allows for an analysis of network modularity, identifying clusters that are highly connected and highlighting potential for targeted planning to increase weak between-cluster connections. Additionally, connectivity analyses are flexible enough to evaluate differences between structure and function [4,56]. Details about unique patches, connections (links), and corridors, and the capacity to layer the specific ecologies of various species across the same physical landscapes can be included in connectivity analyses and comparisons.

The integration of social and ecological perspectives of connectivity can provide a robust, scalable, and actionable approach to urban environmental functions [21]. Independent foci on social and ecological connectivity underscore the importance of movement of people, goods, wildlife etc. in the modern city, yet research and applications remain siloed. Ecological or biophysical connectivity research in urban areas reasonably focuses on the physical landscape [33,57], while social and urban planning research considers measures of social features of a given city region when assessing connectivity. For example, connectivity metrics are often leveraged in planning and executing independent social or environmental development in fields such as urban parks and recreation, transportation engineering, and urban design [58–60]. But studies look at relatively static sociodemographic characteristics of a neighborhood such as land ownership (public vs. private) or the presence of certain social amenities [33]. A clearer understanding of relevant mechanisms and consequences of movement requires an integration of ecological and social connectivity theories as ecologically-relevant movement across a landscape is not specific to ecological or social systems. Social-ecological models and network frameworks can provide an opportunity to focus on interactions between the social and ecological [14], to bolster the often-siloed concept of connectivity, and to address separate application of connectivity in urban areas (Figure 2).

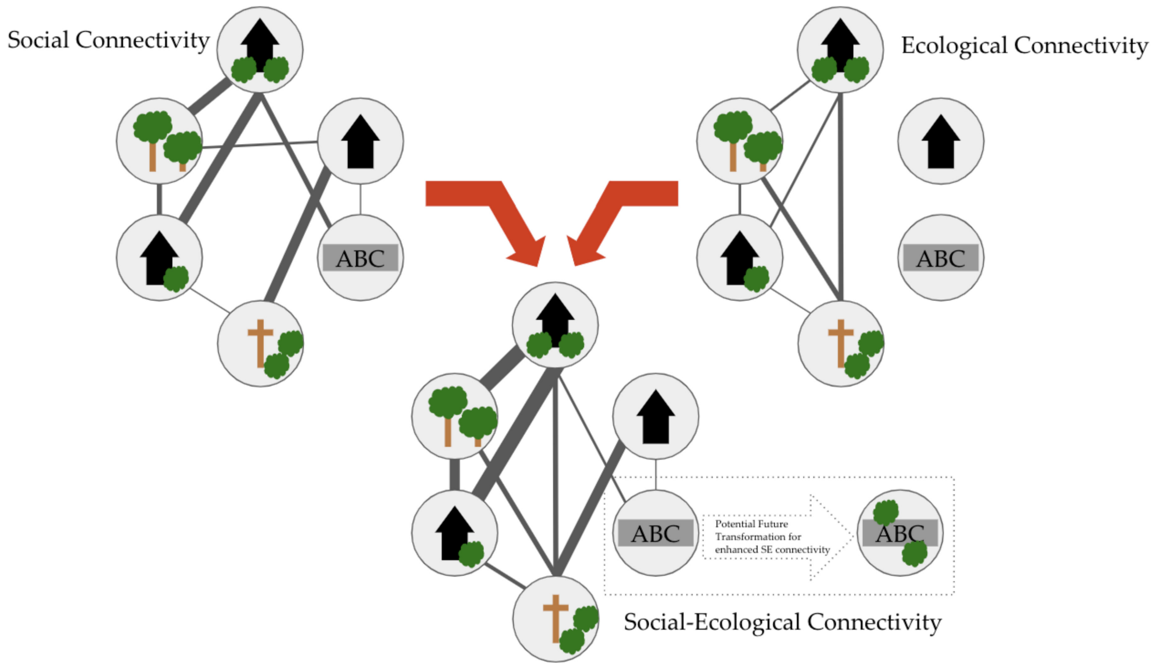

Figure 2. Illustration of the network possibilities when considering movement across different land types from a social (top left), ecological (top right), and social-ecological (bottom) perspective. In each instance, grey circles represent different parcels of land use considered nodes in the network: residential (house icon), park (tree icons), school (depicted by "ABC"), and church (cross)) with varying degrees of green cover. Lines represent movement (links) between sites (nodes) by ecologically-relevant actors (thicker lines indicate stronger connections), although the context for this understanding depends on the specific disciplinary or interdisciplinary paradigm. In a social scenario, people move between parcels and interact with others accordingly. In an ecological scenario, organisms such as pollinators utilize available and accessible habitats. In a social-ecological scenario, ecosystem services from pollination (e.g., flowers or gardens) are experienced by people based on how both pollinators and humans move throughout the landscape. Stronger connections between sites indicate that pollinators and people are connecting those spaces, resulting in stronger ecosystem services provisioning and receipt between those parcels. Furthermore, ideas surrounding pollinator conservation and/or ecosystem services have the potential to permeate parcels currently devoid of habitat as people in a system learn about these topics. This capacity for education and connectivity of ideas can contribute to future land transformations, resulting in changed environmental quality and connectivity. Within the broader landscape-scale network, we may also have modularity patterns of connectivity (either social, ecological, or social-ecological), where high connectivity is clustered within a sub-section of nodes. This may have implications for ecosystem services provision across the whole landscape network. Here we represent stronger connectivity by thicker lines, and in producing social-ecological connectivity we illustrate a simple additive approach or model (social + ecological) for simplicity, while acknowledging that aspects of the landscape may influence combined social-ecological magnitude.

In sum, an interdisciplinary framework of social-ecological connectivity that acknowledges and approaches networks from a unified perspective of ecological and social connectivity can better explain and support human and wildlife patterns and wellbeing in dynamic urban landscapes [61]. Here, the movement of people is also an equal player in the equation for ecosystem services provisioning. Thus, nodes within the network are not only defined as habitat spaces for wildlife, but also as social spaces; links between nodes must be then explicitly considered as a social-ecological process. We posit that social-ecological connectivity is a valuable landscape-level concept to explain the inherent interdependence and feedbacks between the movement of people and the movement of ecologically-relevant actors in a network across space and through time. The modularity of these networks also matters, where sub-networks form dense connections, while the between-cluster connectivity is sparse. Modularity can help balance the trade-offs in benefits and disadvantages of social-ecological connectivity.

2.2. Urban Social-Ecological Networks and Connectivity

Urban social-ecological systems (SES) are the contemporary paradigm of modern cities [62], and have been effectively theorized and applied to support conservation and sustainability objectives (e.g., [63,64]). As such, SES are a good starting point to apply and understand social-ecological connectivity at the urban landscape scale [65]. Bridging this gap between the disciplinary definitions, methods, foci, and applications of social and ecological connectivity has the potential to help explain and predict interactions between social and ecological systems [66].

Urban SES can be examined through the lens of social-ecological networks by thinking about pathways, interactions, and connections between social and ecological systems [67]. Social-ecological networks exhibit diverse typologies, but all seek to deliberately examine and explain complex systems in which human activities shape ecological patterns and functions in terms of nodes and linear links [36]. These networks are particularly important in urban and urbanizing areas and represent intersections between human residents and livelihoods and the biophysical environment [68]. In these human-dominated landscapes, the movement of organisms, genetic material, pathogens, etc. cannot be accurately understood or predicted without simultaneously understanding the underlying social connections [69]. For example, the severity of early outbreaks of SARS-CoV-2 and resulting COVID-19 illness in cities globally can be attributed in part to population density, income levels, and inequitable access to social services, but also to the availability, size, and distribution of urban green spaces that provide people access to fresh air and recreation space while maintaining social distance [70].

Social-ecological networks exhibit unique, quantifiable properties that can be leveraged to support conservation and sustainability goals. For instance, instability and increasing variance in networks can foreshadow ecological disruptions [71], and alignment between social and ecological network realms can reduce ecological disturbances [72]. While it is a useful undertaking, constructing and analyzing useful social-ecological networks is difficult in cities due to disciplinary discrepancies in definitions, colonial legacies of ideal urban form, and urban landscape heterogeneity [69]. Unsurprisingly, examining large, complex landscapes in terms of nodes and linear links can be challenging. Thus, emphasizing an understanding of landscape social-ecological connectivity based on the theoretical foundation of social-ecological networks is a useful and focused metric that can similarly support conservation and sustainability goals in urban areas.

2.3. Dynamics of Urban SES

Urban SES often change rapidly, as land use turnover and fine-scale land cover are driven by environmental disturbances, decision-making, governance changes, and market economics [25,73]. These dynamics result in different network structures and different patterns of connectivity, and overall oscillations or trajectories of change are likely to affect groups of ecologically-relevant actors differently [25]. Networks with high social-ecological connectivity should theoretically have a high degree of ecological and social resilience. As these dynamic landscapes experience disturbance (e.g., tree loss, urban development), functional redundancies at various spatial scales can "pick up the slack" in maintaining processes such as pollination, recreation and climate mitigation to provide ecosystem services for local communities [2,74] (further discussed in Section 3). Consider the following hypothetical example: major construction blocks a large, tree-lined road for many commuters. Here, a network with high social-ecological connectivity would compensate for this dynamism by having existing alternative routes that provide similarly safe, beautiful, and timely commutes. The needs for and patterns by which people move across this urban landscape facilitates the establishment of street trees along these routes, which provide a connected aesthetic and functional system. Alternatively, the same disturbance in a network with low social-ecological connectivity would result in commuters needing to take unsafe or long commutes along routes with little greenery, reducing overall wellbeing and energy use efficiency. To date, we are unaware of any work in urban ecological or social-ecological connectivity that includes dynamic ecological variables combined with dynamic social variables (e.g., how people move through landscapes during hot vs. cold weather; or how changes in canopy cover across multiple well connected parks change animal movement behavior and social connections of common park visitors). A few recent studies have evaluated how a change in social variables in parallel with changes in ecological variables over time affects social-ecological system outcomes [75,76], but more work needs to be done to fully examine these complexities in relation to social-ecological connectivity of networks.

3. Linking Social-Ecological Connectivity and Urban Ecosystem Service Provision

A useful intervention in SES research, particularly in urban areas, is the ecosystem services concept, outlined in the Millennium Ecosystem Assessment [77]. Ecosystem services provide a platform to discuss relationships between nature and the human experience, highlighting the importance of regulating, supporting, provisioning, and cultural services provided by diverse biota. Social-ecological connectivity can contribute to a deeper understanding and application of ecosystem services by incorporating spatial and temporal dynamics that better reflect the actual services provided to individuals and communities across a social-ecological network [78]. In this section, we explore how social-ecological connectivity conceptually relates to ecosystem service provision in cities and emphasize the importance of linking these two concepts.

3.1. Connectivity and Ecosystem Services

Several studies have linked theoretical and applied dimensions of connectivity and urban ecosystem services [19,79], contributing to understanding patterns of ecosystem service provisioning across urban landscapes. Here, studies examine connectivity from the perspective of networks of habitats which support ecosystem services across a landscape [36,80,81]. While at least one study considers connectivity itself as an ecosystem service or benefit [34], we see social-ecological connectivity as a foundational network metric that helps explain and operationalize ecosystem service provisioning and the dynamics thereof. Some ecosystem services certainly have an intrinsic element of movement (see below). Other services, however, are also predicated on the movement of the ecosystem service-providing organism (e.g., pollinators) or the human(s) receiving the service (e.g., recreators at a city park). Considering social-ecological connectivity as a metric of how ecosystem services can and do flow via relevant actors within a network can focus our understanding of ecological and social processes and their consequences across a landscape [82].

Connectivity in urban areas is not inherently without social-ecological costs—often considered ecosystem service trade-offs or ecosystem disservices [19,83,84]. For example, improving ecological, species-specific connectivity for pest species, pathogens, or high-dispersing neobiota may result in economic and health losses to society [19]. Similar disservices are also possible from the perspective of social-ecological connectivity. For example, improving transportation access for people to visit high-quality urban green spaces for recreation without simultaneously increasing environmental education (e.g., on "Leave No Trace" principles) and habitat quality monitoring could produce unintended consequences of invasive species spread or habitat degradation from human overuse. The consideration of social-ecological connectivity as a foundational layer for the distribution of ecosystem services can provide a more nuanced and powerful analytical lens for understanding movement in dynamic social-ecological landscapes.

3.2. Ecosystem Services via Social-Ecological Connectivity in a Network

Ecosystem services suited to a social-ecological connectivity concept involve some element of movement across space [82]. These movements may be active or passive and may occur by humans or other biota within a system or may occur through abiotic transfer such as wind-dispersal or flowing water. For example, the movement of wild bees that provide crop and flower pollination services across a landscape requires a connected habitat with sufficient floral resources and safe passages. Kremen et al. [85] refers to these services, which depend on the movement of organisms as "mobile-agent-based ecosystem services (MABES)". Alternatively, the movement of people may affect the received ecosystem services provided by a system. For example, large trees isolated on private property may not provide the same cultural or aesthetic ecosystem services as trees of equal size in public lands. In a public scenario, local residents can travel to a site to participate in relevant recreational, relaxation, or educational experiences that relate to urban trees, even though the tree itself is immobile [86,87]. However, these same ecosystem services are subject to pulsatile and regime-shift dynamics. For example, cultural services from the aforementioned park trees may not be as accessible during winter months when deciduous trees are dormant and weather is cold. As part of these annual patterns in ecosystem services provisioning, local trees along a roadside may provide disproportionate cultural ecosystem services for residents, regardless of tree size or species.

Connectivity-based ecosystem services should be viewed in light of their application to the system writ large. Particularly in urban areas, but really within any SES, the application and contribution to human wellbeing are paramount. Johnson et al. [88] make the case for evaluating ecosystem services via service path attribution networks (SPANs), emphasizing and quantifying the actualized trajectory from the biotic element (ecosystem service provider) to the human recipient. We suggest that it is critical to further our investigation of dynamic processes that define these actualized ecosystem services. Ecosystem services providers, ecosystem service recipients, and the landscapes they interact in are all subject to different social and ecological dynamics. These dynamics all interact to determine the extent and magnitude of a given ecosystem service. Consider the following example, which illustrates the potential for understanding social-ecological connectivity of relevant ecosystem services in a given location based on the functions of specific actors and recipients. Pest control by invertebrate or vertebrate predators involves the dynamics of three groups of ecologically-relevant actors: the pests, the predators, and the humans who not only experience the pests as a problem but also provide food and other resources to pest populations. All of these actors experience and move through the landscape differently, resulting in a pattern of connectivity specific to the exact social-ecological system or problem at hand. However, it is also notable that in this scenario, the ecosystem service of natural pest control is most relevant in locations where the greatest net benefits will be received by the most people, and this is likely to change through time. This can be quantified through an evaluation of the interplay between the movement of people and the movement of ecologically-relevant actors in relation to the landscape.

4. Practical Considerations: Limitations and Application

In this theoretical discussion, the question emerges of how theory translates into application in urban regions. In this section, we provide an example of how we have applied this concept in modeling connectivity of ecosystem services across urban social-ecological networks (community gardens). We then address limitations of this approach.

4.1. Application of Socio-Ecological Connectivity in a Model Dynamic System

Urban social-ecological systems that form a network are complex, but are also ideal to assess and analyze connectivity from a social-ecological perspective. Our previous work used urban community garden networks across three US cities (Chicago, Baltimore, and New York City) to measure social-ecological connectivity across networks in urban landscapes [65]. Specifically, we used networks of urban community gardens managed by common stakeholder groups as a landscape-scale social-ecological network to model the magnitude and direction of social-ecological connectivity across cities. The biophysical features of the city landscape (e.g., density of buildings, canopy cover, number and size of green spaces) in combination with the social features (e.g., crime rates, community centers) informed the resistance surfaces across which ecosystem service-providing actors might reasonably move through different urban landscapes at a given time point. Through this work, we identified heterogeneity in the capacity for each garden network to support the movement of ecologically-relevant actors across the different city landscapes. For example, the availability and distribution of green spaces in Baltimore, MD, created a theoretically more balanced flow of ecosystem service-providing actors across the garden networks, while the high clustering of gardens in combination with social amenities in neighborhoods in New York, NY, produced higher overall connectivity but rather unequal spatial flows of ecosystem service-providing actors. While our landscape features were taken at a given time point, we see opportunity for repeated analyses over time with updated data to better assess how changing variables influence patterns of social-ecological connectivity, and thereby incorporate dynamic properties. Other studies in urban areas are using private backyards to model and predict ecological connectivity, and offering ideas on how to apply this from a social-ecological perspective [89]. Such work combining social and ecological concepts in connectivity is in its infancy, and future work will require finer-scale social data and the integration of social and temporal dynamics in these landscapes to adequately measure dynamic connectivity and service provision.

4.2. Considering Limitations

To inform recommendations for moving such work forward, we must consider the limitations in the translation from theory to practice [33]. One consideration that may limit social-ecological connectivity research is the technical or computational demands of current connectivity methodologies including analysis. Depending on the given question at hand and model system, the data collection, data processing, and subsequent analysis of social-ecological connectivity requires both skills and knowledge from researchers and often entails resources to do the computational analysis. For example, in the work discussed above, the open-access data sets used in the analysis to both create the social-ecological network (urban gardens) in which to model social-ecological connectivity were very large (approximately 1.2 GB of data for all three cities, focused on one-time measurements) and demanded high computational power, namely a university supercomputer. The necessity of highly technical computing requires that social and natural scientists collaborate closely with computer scientists and engineers while simultaneously navigating the interdisciplinary challenges of working in complex systems. However, the capacity for the integration of high-resolution social and ecological data across a broad spatial extent and through time, and comparisons of cities is a valuable endeavor as we strive to develop generalizable theories of social-ecological systems and research-informed best practices for urban design and ecosystem-services planning of dynamic landscapes.

5. Conclusions

In this paper, we discuss an interdisciplinary understanding of connectivity in social-ecological networks—an important concept in relation to ecosystem service provision. We focus on urban landscapes to highlight the importance of social-ecological connectivity to understand dynamic urban landscapes, and the provision of urban ecosystem services. This work supports and deepens thinking and concepts in socio-ecological networks, urban ecosystem services, and urban resilience [2,36,90,91]. Urban landscapes as an excellent example due to high land use heterogeneity at small spatial and temporal scales and human dominance in the urban environment. Thus, landscape-level connectivity of social-ecological networks must be considered and assessed as both a biophysical and a social process. As urban populations grow, and city demographics and physical structures change over time and space, it is a ripe time to assess how green spaces and people are connected across these dynamic landscapes, and how this relates to ecosystem service provision. It is important to emphasize that this concept of dynamic social-ecological connectivity can be applied across different land use types, including for example agricultural, coastal and semi-natural landscapes. Research in different landscape contexts can combine the physical attributes of landscapes with both social and ecological patterns of movement that represent ecosystem service flows to fully understand dynamic landscape processes.

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