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The Provision of Urban Ecosystem Services Throughout the Private-Social-Public Domain: A Conceptual Framework

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As cities are largely private systems, recent investigations have assessed the provision of ecosystem services from the private realm. However, these assessments are largely based on the concept of ownership and fail to capture the complexity of service provision mediated by interactions between people and ecological structures. In fact, people interact with ecological structures in their role of land tenants and stewards, further modulating the provision of ecosystem services. We devise a theoretical framework based on the concepts of ownership, tenancy, and stewardship, in which people, as mediators of ecosystem services, regulate the provision of services throughout the private-social-public domain. We survey relevant literature describing these dimensions and propose a comprehensive framework focused on the private-social-public domain. Our framework can advance ecosystem service research and enhance the provision of ecosystems services. The inclusion of people's individual, social and public roles in the mediation of ecosystem services could improve how benefits are planned for, prioritized, and optimized across cities.

Keywords

co-generation, co-benefits, multifunctionality, socio-ecological systems, adaptation

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Investigations of urban ecosystem services have flourished in the last two decades (e.g., Bolund and Hunhammar 1999, Gómez-Baggethun et al. 2013, Luederitz et al. 2015). Though a universal definition of urban ecosystem services is yet to be achieved, these can be generally referred to as "*services that are […] produced by ecological structures within urban areas*" (Luederitz et al. 2015, p. 99). Urban ecosystem service assessments to date have been largely based on land use typology that assumes ecological structures (e.g., vegetation, unsealed soil, etc.) to be homogenous within the same land use type (e.g., Breuste et al. 2013, Haase et al. 2014, Grafius et al. 2016). However, much of ecosystem service provision is mediated by more complex interactions between people and urban ecological structures that change under human management at multiple spatial and temporal scales (Borgström et al. 2006, Ernstson 2013).

People have varied personal values, attitudes, and preferences toward the urban environment (Cook et al. 2012, Lovell and Taylor 2013), which are reflected in the different capacity, breadth, and timing of their environmental activity. For example, individuals might moderate ecosystem services provided by urban trees at multiple levels, from planting or removing trees within the residential land they own and manage (Ossola and Hopton 2018a), but also participating in community tree planting efforts within their neighborhood, and even encouraging their local government to implement larger urban forest strategies. In this way, the interactions between people and urban ecological structures can affect not only the extent of ecosystem service provision, but also their spatial heterogeneity, temporal variability, and historical legacies as we observe to date (Nassauer and Raskin 2014, Dallimer et al. 2015).

People in democratic societies are organized through hierarchical non-exclusives spheres - *individuals, communities,* and *government* (Hanna and Jentoft 1996). These, however, represent more than simple spheres of individual or communal activity, including shared knowledge capital and reciprocal influence – namely a *domain*. As such, in their role of ecosystem service mediators, people can assume one or multiple roles in modulating ecosystem service provision throughout what we define as *private-social-public domain*. This integrated domain is particularly relevant in modern cities and towns where people are closely related to each other and where most of the global human population lives (United Nations 2015).

In this contribution, we describe a comprehensive framework based concurrently on the concepts of ownership, tenancy, and stewardship, as conceptual *dimensions* in which people, in their role of ecosystem service mediators, regulate service provision throughout the *private-social-public domain*. At the outset, we describe these dimensions by analyzing relevant investigations of urban ecosystem services. Then, we discuss how a framework based on the *private-social-public domain* can be used to advance ecosystem service assessments and leverage provision of ecosystem services under urban socio-environmental change.

Ownership, tenancy, and stewardship as conceptual foundations

Private, collective, and public ownership

Asset ownership is perhaps the most evident trait of all urban areas (Svendsen and Campbell 2008), yet the product of the biophysical, historical, socio-economic, and cultural context characterizing each urban area. Private ownership of urban greenspace, urban land covered by

vegetation and with little impervious surface, is the most widespread tenure regime (Goddard et al. 2010, Gaston et al. 2013, Andersson et al. 2014), though collective ownership of yards, green commons, community gardens, and green roofs is increasingly popular (Robertson 2012, Colding et al. 2013). As such, most urban ecological structures globally are situated within various forms of privately or collectively-owned land. In the US, for instance, about 20,000 public urban greenspaces cover an area of 6070 km^2 (The Trust for Public Land 2011), whereas the yard area of the 90 million households exceeds 81,000 km^2 (Borman et al. 2001). In the UK, 87% of households (22.2 million) have yards that span across 4430 km^2 of urban land (Davies et al. 2009), whereas the nearly 16,000 public greenspaces cover 1065 km^2 (Davies et al. 2011). Similarly, 6.7 million Australian households that have a yard outnumber the country's 52,000 public greenspaces (ABS 1997, 2007). Because privately and collectively-owned areas make up most of urban landscapes, it is therefore not surprising that recent ecosystem service investigations have shifted focus from public urban greenspace (Bolund and Hunhammar 1999, Chiesura 2004, Young 2010) to include land owned by individuals and groups of people (Cameron et al. 2012, Cook et al. 2012, Gaston et al. 2013, Larson et al. 2016, Daniel et al. 2016, Lin et al. 2017, Niemiec et al. 2017).

A general aspect related to ownership is that ecosystem services are often generated via socio-environmental processes that transcend both physical and intangible boundaries set by asset ownership, such as fences or administrative borders (Lockie 2013). For example, residential yards and gardens can provide suitable habitat for numerous species of animals and plants, and as such, can act as transboundary habitat patches or ecological corridors for urban biodiversity (Goddard et al. 2010). Similarly, unsealed soil within residential properties can cumulatively decrease stormwater runoff while generating larger hydrological services for urban communities (Green et al. 2012). In fact, private and collective ownership can i) increase the number of potential mediators of urban ecosystem services in urban areas (Gaston et al. 2013); ii) promote the decentralization of service provision (Dennis et al. 2016); and iii) reduce overall risks and individual costs related to service provision (Green et al. 2016b). The presence of a large number of relatively small mediators of ecosystem services can allow for the management of resilience of urban systems (Colding and Barthel 2013, McPhearson et al. 2015), because the loss of some mediators can be theoretically offset by the large number of them remaining across the urban landscape.

Property rights associated with ownership, however, set both entitlements and obligations (Lockie 2013), that can indirectly lead to the generation of some disservices. For example, the excessive use of chemicals during yard maintenance can have deleterious effects on local biodiversity and increase environmental pollution (Amweg et al. 2006, Raciti et al. 2011). Similarly, impervious paving within residential yards can increase stormwater runoff within neighborhoods (Perry and Nawaz 2008). Some private and collective ownership entitlements, such as *the exclusion of non-owners* (Andersson et al. 2014), can hinder the generation of non-transboundary ecosystem services, such as those related to greenspace access, public health, and socio-environmental justice (Wolch et al. 2014, Hand et al. 2016). Further, the higher number of small private and collective mediators can increase temporal variability and spatial heterogeneity of provision of ecosystem services as compared to public mediators, and even generate conflicting outcomes for provision (Gaston et al. 2013). However, some evidence suggests that owners might influence each other, for example by sharing their horticultural knowledge, or

management practices and preferences (Harris et al. 2013, Niemiec et al. 2016). This can limit heterogeneity and variability of ecosystem service provision (Sisser et al. 2016), but also reinforce practices leading to some ecosystem disservices, such as those related to the misuse of water and fertilizer.

Occasionally, private and collective owners can voluntarily limit some of their entitlements and increase their obligations for greater non-personal benefits. For example, about 20% of the US population (>60 million people) lives in more than 300,000 neighborhoods regulated by homeowner associations that require standard asset management practices, such as those related to maintenance and landscaping (Lerman et al. 2012). Thus, the delivery of environmentally-sensitive and standardized practices through these associations could enhance ecosystem service provision while limiting its temporal variability and spatial heterogeneity, as reported for urban biodiversity conservation (Martin et al. 2003, Lerman et al. 2012).

Ultimately, owners can also entirely renounce their property rights when abandoning urban land and built structures as in shrinking cities (Green et al. 2016a). Globally, more than 370 cities have shrunk by at least 10% in the last 50 years (Blanco et al. 2009), thus representing a widespread phenomenon despite the rampant urbanization trend. In a *post-ownership* regime, urban vacant land might well represent a *non-property* when not claimed or purchased by a new owner (Colding et al. 2013). However, property rights and the contextual *duty of care* (Lockie 2013) are more often transferred to other owners, such as other individuals, governments, trusts, NGOs, or land banks (Alexander 2015, Green et al. 2016a). Although urban vacant land is more frequently associated with ecosystem disservices rather than services (Nassauer and Raskin 2014), it can still provide important emerging or lost benefits, through appropriate environmental restoration and management (Burkholder 2012, Gardiner et al. 2013, Herrmann et al. 2016).

Private, common, and public tenancy

Tenancy is a form of tenure by which a tenant receives limited and temporary ownership rights and duties over an asset, usually through a monetary exchange regulated by a contract (e.g., rent under a lease agreement) (Wehrwein and Woodbury 1930). In the last century, tenancy has generally decreased in favor of ownership; however, the former still represents a significant percentage of the urban tenurial system in many cities and countries. For example, in 1890 residential units rented across the US exceeded 60% of total households (Wehrwein and Woodbury 1930), but they have progressively decreased to 30% to date (Callis and Kresin 2016). Similarly, 36% of residential units in the UK are currently rented (UK Department for Communities and Local Government 2015). Based on real estate dynamics, urban assets are frequently under a transient lack of tenancy (i.e., vacancy), as reported in the US where the average year-round vacancy in 2015-2016 approached 10% nationwide (Callis and Kresin 2016).

As opposed to ownership, significantly higher turnover rates also characterize tenancy. The current average length of tenancy for a household in the UK is about 3.5 years (UK Department for Communities and Local Government 2015). Likewise, about 40% of the Australian population (7.8 million people) moved within a 5-year period (2006-2011) (Ossola and Livesley, 2016). Similar to asset ownership, tenancy also modifies how people interact with urban greenspace and the ecological structures therein, particularly in residential landscapes.

This is quite stark when considering that apartment tenants with little access to private yards are more likely to exercise in public greenspace, with lower average obesity compared to house owners living in the same neighborhood (Björk et al. 2008).

Much of the published research on ecosystem services in urban systems has likened ownership to tenancy (Dobbs et al. 2013, Gaston et al. 2013, Snep et al. 2016). At parity of ownership, however, a significant amount of urban greenspace and ecological structures can be subjected to disparate and variable tenancy-driven management practices (Fig. 1). These differences in management practices can cause complex cascading effects on service provision and more research is warranted. As potential mediators of ecosystem services, tenants might not be allowed or have interest to invest resources in practices aimed to enhance service provision (e.g., installation of rain gardens and green roofs, tree plantings, etc.) or even basic asset upkeep (Stern 2011). Where environmental management is delegated to professional services or contractors, this is also likely to be different from that of residents (Cook et al. 2012). Further, high tenancy turnover rates might reduce community involvement in environmental issues (Andreasen 1996, El-Zein et al. 2006), the efficacy of community educational efforts and social learning (van Heezik et al. 2012, Beumer and Martens 2015), or effects like neighbor mimicry and social contagion (Zmyslony and Gagnon 1998, Hunter and Brown 2012, Minor et al. 2016). Although more spatially limited than residential tenancy, tenancy of public land, such as urban green commons and community gardens, represents a further form of tenure when actioned through the payment of rent or fees (Colding et al. 2013).

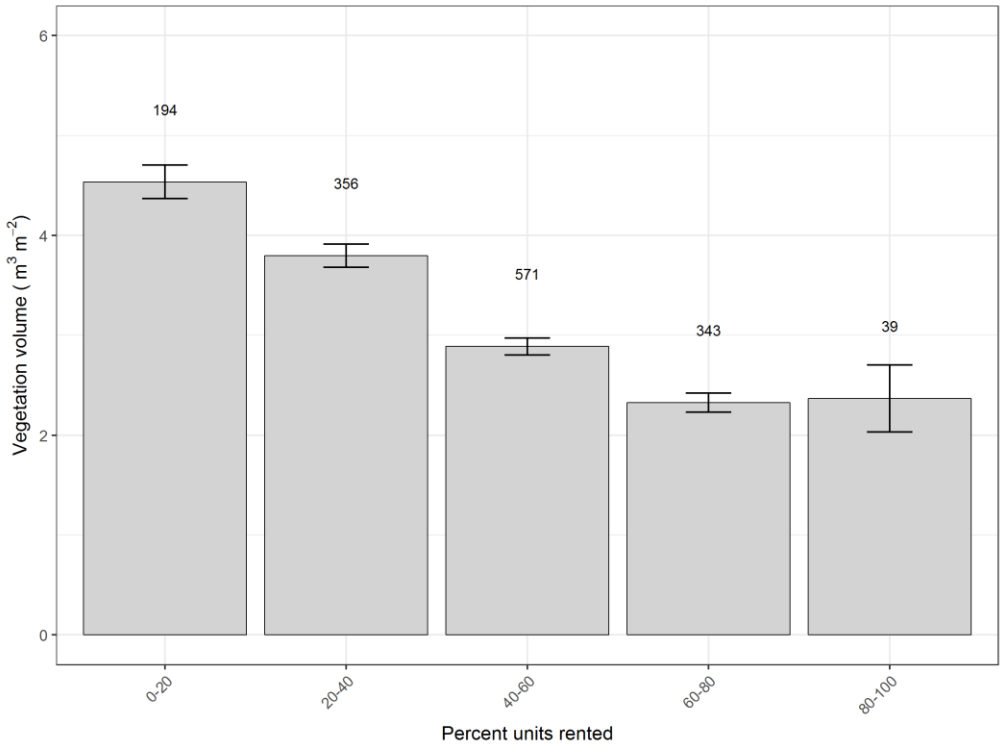

Figure 1. Mean vegetation volume in ~1.4 million residential parcels across 9 US cities and 1503 neighborhoods in relation to tenancy (i.e., percentage of housing units rented). Figures above bars represent the number of census tracts considered, errors bars are standard errors of the mean (drawn from data in Ossola and Hopton (2018b)).

Individual, civic, and public stewardship

Stewardship is a further type of environmental management (Chapin III et al. 2010) through which people can mediate the provision of ecosystem services (Barthel et al. 2005, Krasny and Tidball 2012, Andersson et al. 2014, Connolly et al. 2014). These cover the entire spectrum of ecosystem services ranging from biodiversity conservation (Asah and Blahna 2013) and stormwater management (Shandas 2015), to food production and environmental restoration (Krasny et al. 2014). Stewardship is mostly actioned through formal and informal civic groups of volunteers and community-based networks, which operate at multiple scales and across sectors (Fisher et al. 2012, Connolly et al. 2013, Romolini et al. 2016b). These civic stewardship networks can be large and structured, reaching hundreds of organizations as observed in Seattle, WA and Baltimore, MD, where more than 500 groups operate across each city (Romolini et al. 2013). However, stewardship groups are not evenly distributed across urban landscapes, because their activity is usually targeted towards specific local environmental issues or socio-ecological functions (Romolini et al. 2013, Connolly et al. 2014). Participation in stewardship groups is often related to education and economic status (Shandas 2015), thereby further complicating the spatial patterns of how stewardship mediators manage for ecosystem services across urban landscapes. Civic stewardship often lacks official mandates and largely relies on community-driven initiatives, whereas public stewardship is generally framed through formal statutes, regulations, and laws. Individual stewardship can also take place when people implement environmental actions outside a formal affiliation to stewardship groups or networks (Hunter and Brown 2012, Moskell and Allred 2013, Cerra 2017). This type of stewardship can occur on both public and private land, as recently reported for homeowners' control of animal and plant invasive species across residential landscapes in Hawaii and New Zealand (Niemiec et al. 2016, Niemiec et al. 2017).

Whereas stewardship is frequently confused with ownership (Romolini et al. 2012), the former rarely takes place on land directly owned by groups or associations (Svendsen and Campbell 2008). More often, stewardship actions take place on public and vacant land, and to a lesser extent on land privately owned by individuals or organizations (Fisher et al. 2012). Further, compared to private ownership and tenancy, where individuals manage assets to obtain personal gains, stewardship arises from an altruistic drive directed to benefit others, the entire community, or the environment (Romolini et al. 2012, Fisher et al. 2015). Civic stewardship also extends beyond simple environmental management and maintenance including activities such as monitoring, education, community engagement, and fundraising (Svendsen and Campbell 2008). Civic stewardship is an effective mechanism to preserve urban *social-ecological memory* and the knowledge capital necessary to sustain ecosystem service provision over time, and thus resilience and adaptive capacity (Barthel et al. 2010, Andersson and Barthel 2016, Romolini et al. 2016a). Civic stewards, such as non-profit organizations are, however, generally smaller, more numerous, and less centralized compared to public stewards (i.e., municipal, county, state, or federal governments) (Svendsen and Campbell 2008). Also, the size of a stewardship group can dictate breadth and impact of its environmental actions. For instance, large community groups tending public trees can achieve higher tree survival and growth compared to smaller stewardship groups (Jack-Scott et al. 2013). Stewardship likely varies based on people's origin and place history. For example, people living in exurban, tourism-centric, or retirement communities can have vastly different perceptions of environmental values

compared to highly urban communities (Allen and Moore 2016, Vercoe et al. 2014), which in turn can affect their capacity to mediate for ecosystems services. As previously described for collective and private ownership, the high number of civic and individual stewards can increase the breadth of ecosystem service provision. In turn, this can have detrimental effects on spatial heterogeneity and temporal variability of service provision, particularly when considering stewardship mediators change rapidly over time (Fisher et al. 2012).

Provision of urban ecosystem services throughout the *private-social-public domain*

The *private-social-public domain* represents the space where the three conceptual foundations – *ownership*, *tenancy*, and *stewardship* – can intersect and mediate the provision of ecosystem services in urban systems. We envisioned this framework through a network model where conceptual foundations are depicted as triangles whose vertices represent private, social, and public mediators (Figs. 2, 3). Vertices are linked through vectors representing the relationships and interactions among mediators that lead to the generation of urban ecosystem services. For instance, a private residential yard might provide different ecosystem services based on different tenancy and stewardship mediators (Fig. 2). A tenant maintaining the yard could in fact mediate lower biodiversity or stormwater benefits compared to the owner engaged in individual stewardship actions, such as the installation of a pollinator garden or a water-sensitive urban design (Fig. 2A, B). In this scenario, the private tenant could mediate significant personal benefits (e.g., psychological wellbeing, enjoyment), whereas the action of the private owner would be geared towards the provision of personal and public ecosystem services. Exemplifying further, civic stewardship groups could intervene to remove impervious surfaces or install a vegetable garden in the same private yard (Fig. 2C). This scenario would enhance the provision of individual, social, and public ecosystem services from the private realm, such as those related to food production, public health, or stormwater control. Multiple ecosystem service mediators, acting on the same urban land, can in this way enhance urban landscape multifunctionality (Lovell and Taylor 2013, Hansen and Pauleit 2014, Holt et al. 2015) because they initiate and sustain additional ecosystem services through their novel interactions with urban ecological structures. This is a pivotal issue in urban areas, where the amount of available land and ecological structures able to sustain ecosystem services are generally more limited compared to non-developed or rural ecosystems.

While synergistic urban ecosystem service mediation might be less common than individualistic mediation, various instances could include several mediators and more complex relationships among them (cf. Figs. 2, 3). A city government might in fact provide standard maintenance of public streetscapes (e.g., tree pruning, irrigation) using city employees or a private contractor (Fig. 3A), but these green spaces could be further tended by civic and individual stewards mediating additional ecosystem services (e.g., pollination through flower planting, education, etc.) (Fig. 3B). Similarly, a public community garden might have vegetable beds individually rented and managed by private citizens, but comprehensively cared for by a civic stewardship group (Fig. 3C). This would provide a wider range of private, social, and public ecosystem services (e.g., food, community learning, and stormwater runoff mitigation). A framework that theorizes service provision throughout the *private-social-public domain* across ownership, tenancy, and stewardship dimensions can in this way improve the resolution and

accuracy of current assessments of urban ecosystem service co-generation, as promoted by different human mediators. This can advance research efforts aimed to measure the distribution of ecosystem services among private, social, and public beneficiaries, and as such, socio-environmental equity studies (Ernstson 2013, Wolch et al. 2014).

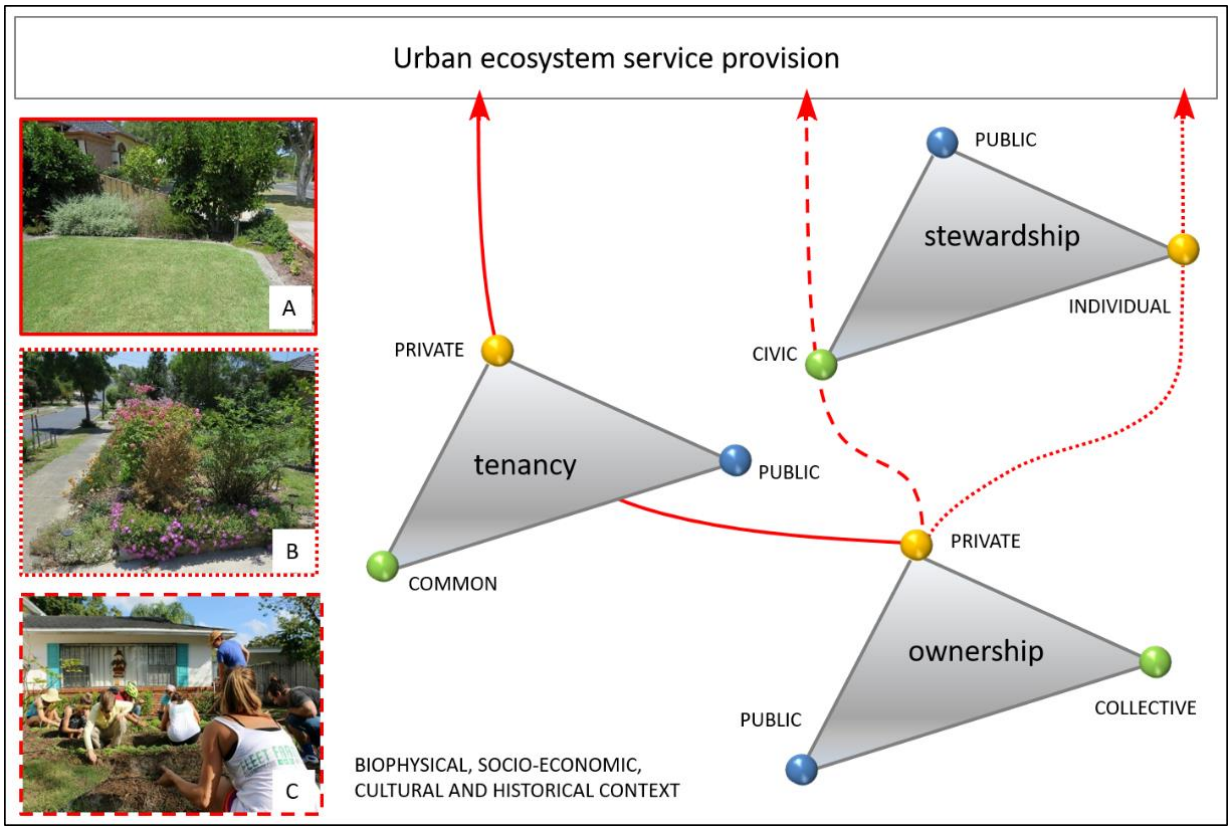

Figure 2. Hypothetical relationships among ecosystem service mediators throughout the *private-social-public domain* in relation to ownership, tenancy, and stewardship in A) a rented property where tenants oversee yard maintenance (solid line), B) a residential yard fitted with a water-sensitive urban design and a pollinator garden by the owner (dotted line), and C) a private yard transformed into a vegetable garden by a civic stewardship group (dashed line). Photo courtesy: Jessica Kurylo (A, B) and *Fleet Farming*, Orlando, FL (C).

Further, a critical aspect of all urban socio-ecological systems is that these invariably change with time following complex dynamics dictated by forces such as urbanization, development, de-urbanization, exurbanization, or re-development (Seto et al. 2011, Vercoe et al. 2014). However, dynamic assessments of ecosystem services are underrepresented in the scientific literature, despite their importance to understand past and future drivers and effects of socio-ecological change (Wagner & Gobster 2007). Urban socio-ecological systems usually change at multiple temporal and spatial scales following patchwork rather than homogenous dynamics. For instance, a residential parcel might have been owned by the same individual over several decades, during which the adjacent parcel might have changed numerous owners or dozens of tenants. Similarly, a vacant lot abandoned decades earlier could have been promptly cleared by a city government following a blight control ordinance, before being handed over to a civic stewardship group interested in establishing a community garden. Ownership and tenancy dynamics parallel those of housing markets which usually follow *boom and bust cycles* related to

economic and social development. As such, it is reasonable to expect that the mediation of ecosystems services from owners and tenants throughout the *private-social-public domain* would be reflective of these trends over time.

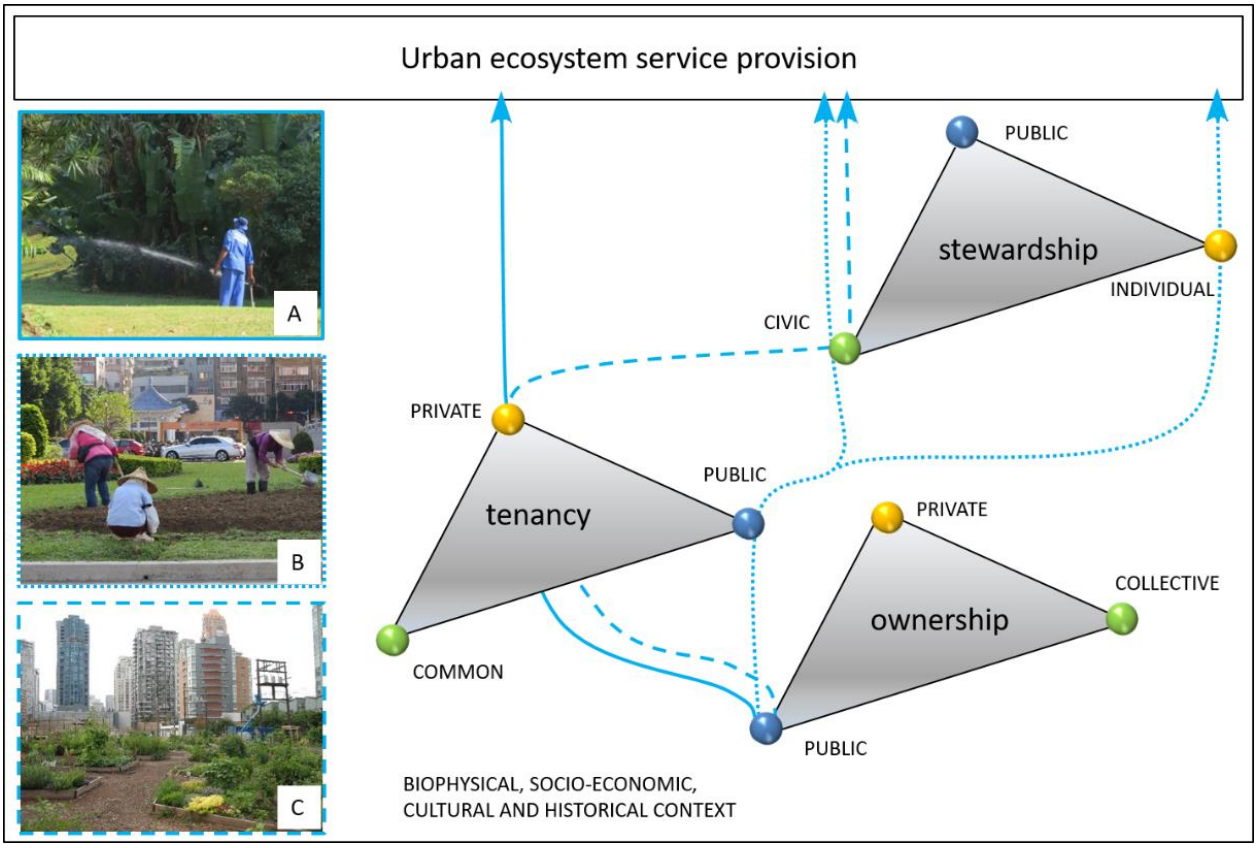

Figure 3. Hypothetical relationships among ecosystem service mediators throughout the *private-social-public domain* in relation to ownership, tenancy, and stewardship (triangles) in A) a public streetscape managed by a private contractor (solid line), B) a streetscape tended by civic and individual stewards (dotted line), and C) a community garden on public land managed by a civic stewardship group and vegetable beds rented by private citizens (dashed line).

In the same way, stewardship networks have been shown to continuously change and adapt over time (Connolly et al. 2013). For instance, a civic stewardship group might cease to operate due to the lack of volunteers and participation, but its mission could be continued by a different group having greater resources. Thus, former stewards could either decide to change stewardship group, continue their activity as individual stewards outside a formal group, or completely discontinue their activity. More comprehensive evaluations of stewardship dynamics could inform how people mediate urban ecosystem services provision throughout the *private-social-public domain* over time. This is particularly important when considering that informal environmental management, such as that promoted by individual stewards, can help urban systems to adapt during periods of socio-environmental change and instability (Andersson et al. 2007, Cerra 2017). When sufficiently guided and fostered by public or social actors, private stewardship could also increase people's attitudes towards social norms and community

reciprocity, the expectation that other individuals will similarly engage in positive environmental actions (Niemiec et al. 2016).

Limitations and ways forward

It is important to note that not all the possible relationships between owners, tenants, and stewards would exist within a particular *private-social-public domain* (Figs. 2, 3). Urban socio-ecological systems are unique local phenomena. Consequently, relationships arising among ecosystem service mediators throughout the private-social-public domain are likely to depend upon the environmental, socio-economic, cultural, and historical context intrinsic of each city. This is apparent when analyzing stewardship networks across different cities, which differ based on urban form and sociological and historical settings (Romolini et al. 2013). As such, the operationalization of our framework requires an initial definition of context-specific points of reference to benchmark how and to which extent ecosystem services will be provided by multiple mediators.

It is also true that people continuously find new ways to foster environmental actions and change (Connolly et al. 2013, Dennis et al. 2016), particularly within the civic sphere, which may be more innovative and responsive compared to private and public ones. For instance, stewardship groups such as *Depave* in Portland, OR and *Fleet Farming* in Orlando, FL, recently promoted the removal of impervious surfaces and the installation of community gardens within private realms; environmental actions unimagined only a few years ago. Novel relationships among mediators in urban ecosystems can arise under the stimulus of socio-environmental change and socio-ecological innovation (Dennis et al. 2016). Thus, attempts to apply this conceptual framework should aim at detecting all private, social, and collective mediators involved in the provision of particular ecosystems services, while mapping the connections among these mediators. In this way, the application of this framework could initially target selected systems over small spatial and temporal scales (e.g., community gardens, adjacent neighborhoods) where mediators and their connections can be more easily mapped and monitored (Egerer et al. 2018).

The translation of ecosystem service research into urban planning is recognized as a fundamental element to improve urban sustainability (Gómez-Baggethun and Barton 2013, Luederitz et al. 2015). However, the awareness of ecosystem services among urban planners and managers, as well as their translation into practice, are limited (Andersson et al. 2014, Rall et al. 2015). The proposed framework, building upon two theoretical dimensions – ownership and tenancy – already regulated and operationalized through urban planning, could facilitate bridging the gap between ecosystem service research and practice. This could also assist the continued collection of data related to private, social, and public service mediators, their changes over time, and the creation of historical datasets useful to evaluate dynamics of urban ecosystem service provision. Approaches based on citizen science and emerging technologies, such as big data and Internet of Things, could further benefit the operationalization of the proposed framework and future ecosystem service assessments.

A holistic approach that considers private, social, and public mediators will provide useful insights to how ecosystem services could be prioritized and optimized based on mediators' values, capacity for action, and resources available. *Who does own, occupy, and take*

care of urban land? What connections and dynamics operate within and among private-social-private domains? What role do people have as ecosystem service beneficiaries, and more importantly as ecosystem service mediators? These are a few questions that could be answered through the lens of the proposed framework to help resolve how ecosystems services arise, develop, and change across urban landscapes. Nowadays, scientists are investigating and envisioning how cities should be grown and greened to enhance and sustain urban ecosystem services (Lin and Fuller 2013, Wolch et al. 2014). People in their multiple roles, and how these change over time, need to be part of this exploration.

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