The role of socio-economic factors in planning and managing urban ecosystem services

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Abstract

How green spaces in cities benefit urban residents depends critically on the interaction between biophysical and socio-economic factors. Urban ecosystem services are affected by both ecosystem characteristics and the social and economic attributes of city dwellers. Yet, there remains little synthesis of the interactions between ecosystem services, urban green spaces, and socio-economic factors. Articulating these linkages is key to their incorporation into ecosystem service planning and management in cities and to ensuring equitable outcomes for city inhabitants. We present a conceptual model of these linkages, describe three major interaction pathways, and explore how to operationalize the model. First, socio-economic factors shape the quantity and quality of green spaces and their ability to supply services by influencing management and planning decisions. Second, variation in socio-economic factors across a city alters people's desires and needs and thus demands for different ecosystem services. Third, socio-economic factors alter the type and amount of benefit for human wellbeing that a service provides. Integrating these concepts into green space policy, planning, and management would be a considerable improvement on 'standards-based' urban green space planning. We highlight the implications of this for facilitating tailored planning solutions to improve ecosystem service benefits across the socio-economic spectrum in cities.

Keywords

Socio-economic factors; urban green spaces; urban ecosystem services; urban planning and management

1 Introduction

Green spaces in urban areas, such as gardens, parks, street trees, and other 'natural' features, provide vital ecosystem services that contribute to the wellbeing and health of city residents (Elmqvist et al 2013). This includes basic resources such as fresh water and food, as well as life-improving benefits such as opportunities for recreation, local climate regulation, and improvements in air quality (MA 2005; TEEB 2011). Given the projected dramatic increase in urbanization around the world (Seto et al. 2012), managing and optimizing urban ecosystem services is critical for social and ecological sustainability. Incorporating specific goals for managing and improving ecosystem services into urban planning and management has therefore been strongly endorsed (Bolund & Hunhammar 1999; Niemelä et al. 2010; Gómez-Baggethun & Barton 2013) and is increasingly explored in theory and practice (Tratalos et al. 2007; Cowling et al. 2008; TEEB 2011; Elmqvist et al. 2013; Lovell & Taylor 2013). However, empirical research on urban ecosystem services has generally neglected clear, contextual links between ecosystems and the benefits people derive from them (Luederitz et al. 2015).

In seeking to address this research gap, some scholars have highlighted the importance of the socio-economic circumstances of urban residents for determining benefits received from urban green space (e.g. Lin et al. 2014, Shanahan et al. 2014). However, why, when, and how socio-economic factors mediate ecosystem service has been poorly synthesized to date (Carpenter et al. 2009). The paucity of usable models and tools presents an even more immediate challenge for real-world application to guide the inclusion of these considerations into urban planning and management. In this paper, we use the ecosystem service supply chain framework to synthesize how socio-economic factors influence those services for people living in cities, crafting a conceptual model as a decision aid. We then identify how this can be used by planners and managers to improve the provision of ecosystem services in cities.

The supply of and demand for ecosystem services is not homogeneous across any individual city. Importantly, ecosystem service demand is determined by the needs and desires of people and is influenced by socio-economic factors such as income, wealth, education, and ethnicity (MEA 2005; Rounsevell et al. 2010; Ernston 2013). Socio-economic factors can also influence green space management and planning decisions, leading to uneven supply of green spaces across cities (Pham et al 2012). Thus, spatiotemporal variation in socio-economic factors within cities can lead to significant variability in the supply and demand of ecosystem services derived from green spaces (McDonald 2009; Escobedo et al. 2011). This means that the relationships between socio-economic factors and ecosystem services should be a key planning and management consideration (Cowling et al. 2008; Lyytimaki & Sipila 2009; Gómez-Baggethun & Barton 2013), despite rarely being addressed in urban planning policy or scholarship.

Three key insights about the role of socio-economics in urban ecosystem services are currently evident from the literature and all hinge on 'differences': (1) green spaces are perceived and used differently by different demographic groups (e.g., Madge 1997; Tinsley et al. 2010), (2) there are often inequalities in green space provision along socio-economic gradients (e.g., Pedlowski et al. 2002; Pickett et al. 2008), and (3) the types and importance of ecosystem services to urban residents can differ along socio-economic gradients (e.g., Tratalos et al. 2007; Lubbe et al. 2010; Cilliers et al. 2013). Importantly, recent research has started to reveal the potential mechanisms by which socio-economic factors can influence ecosystem service benefits. For example, Shanahan et al. (2015) showed that higher formal education levels and greater neighbourhood socio-economic advantage are associated with the use of local parks that incorporate native remnant ecosystems. Additionally, Peterson et al. (2008) showed that residents choosing to live in more natural areas were older, better educated, and more environmentally-oriented than those choosing residential areas with less green space.

With such evidence accumulating, there is an urgent need to bring these threads together to improve the conceptual understanding of how socio-economic factors influence ecosystem services in cities that can then be operationalized for urban planning. Such a model could then directly improve ecosystem service management by delineating and linking ecosystems service components such that urban policy-makers, planners, and managers can more clearly consider critical contextual factors in their focal areas (Cowling et al. 2008; Luederitz et al. 2015). Without this, there is the risk that planning initiatives to improve the quantity or quality of green space across cities will result in fewer or less equitable benefits for city inhabitants. We note here that, while some decision-making factors for private spaces differ from those for public spaces, planners and managers must influence both for equitable ecosystem service provision (Aronson et al. 2017). Many cities have simple prescriptive targets for green space quantity and spacing that are intended to provide equal access (Heynen et al. 2006), but these well-meaning targets may need to be reconsidered in the context of varying socio-economic contexts from city to city and within any given city.

Here, we first identify and conceptualize how socio-economic factors influence the supply, demand, and benefit of ecosystem services to people in cities. By framing this around the ecosystem service supply chain framework (also known as the 'ecosystem service cascade'), we distinguish between the biophysical supply of a service, the demand for it, and the benefit it gives people (Potschin & Haines-Young 2011). In turn, we focus on how socio-economic factors influence the links in the supply chain and illustrate this via three urban ecosystem service/disservice examples: moderation of temperature extremes, urban gardening, and fear and stress reactions. We then outline ways forward for planners and managers to apply this understanding by providing specific suggestions about how to use these concepts and the model to deliver better urban ecosystem service outcomes.

2 Linking socio-economic factors to ecosystem services

Our conceptual model distinguishes between the biophysical *supply* of an ecosystem service, the *demand* for it by people, and the *benefit* that people receive from a service that contributes to their well-being (Potschin & Haines-Young 2011; Tallis et al. 2012, TEEB 2010; Fig. 1). Urban ecosystems provide biodiversity and ecosystem processes that can potentially provide ecosystem services to people (i.e. ecosystem service supply). Socio-economic factors in cities affect ecosystem services through two distinct and interrelated direct pathways: (1) by influencing the management of urban green space and in turn ecosystem service supply, and (2) by altering human needs and activities and therefore people's demand for specific ecosystem services. For certain services, there is an (3) indirect pathway whereby a resident's socio-economic status can influence how the provision of an ecosystem service affects their wellbeing (i.e., their physical or psychological health). Along each of these pathways, ecosystem services can also feed-back to influence socio-economics (e.g., Wolch et al. 2014) although we do not focus on that bidirectionality here. Our model emphasizes the need to understand these multiple pathways through which socio-economic variables influence both the biophysical and social aspects of urban ecosystem service provision (Bagstad et al. 2013).

2.1 Socio-economic factors influence the supply of services

Changes to the amount and characteristics of urban green space affect the presence and abundance of species, the structure of vegetation, the ability of urban residents to access green space, and, subsequently, the ability of urban green spaces to actually supply ecosystem services (Gaston et al. 2013, Caynes et al. 2016). Socio-economic factors influence the ecosystem services supplied by green spaces by altering how much green space is present in cities and how it is managed (Figure 1). For example, city regulations, zoning laws, and management of both public and private green spaces often heavily influence the presence, composition, and structure of urban vegetation which can regulate temperature if managed toward that goal, and those policies and management approaches are often, in turn, influenced by socio-economics (Case Example 1).

Case Example 1: Supply of regulatory services and urban vegetation

The frequency of extreme temperature events has increased over time, a trend expected to increase in coming decades (Morak et al. 2013). Episodes of extreme temperatures are responsible for increased mortality in urban populations (Patz et al. 2005, Hondula and Barnett 2014) and are the second leading cause of climate-related deaths in the USA (Knowlton et al. 2011).

Urban green spaces and planted trees can ameliorate extreme temperatures as they reflect light, shade buildings, and lead to localized cooling through evapotranspiration (Loughner et al. 2012). For example, in the US coastal cities of Washington, D.C. and Baltimore, surface temperatures were 4°C cooler in streets in areas with vegetation while roads and buildings were 10-15°C cooler, and detailed climate modelling indicated that the presence of urban trees increased the velocity of cooling sea breezes into the cities (Loughner et al. 2012). In Phoenix, Arizona, high rates of fatalities were recorded among the homeless population within the central city area and industrial corridors where surface temperatures ran high, little vegetation cover existed, and air-conditioned shelters and medical services were less available (Jenerette et al. 2011, Harlan et al. 2013). Therefore, investment in high quality, heat-reducing green space for poorer neighborhoods is recommended as a means of reducing social inequity (Jenerette et al. 2011).

Policy initiatives can markedly influence the incentives and ability of a city and its planners and managers to address the needs of urban residents who have a strong need for a greater supply of temperature regulation from green vegetation (see Supplementary Materials). With programs that are context-specific and responsive to the different geographies of need in the city, city governments would be well positioned to increase that supply of regulatory services in areas where they are most needed.

Neighborhoods with greater socio-economic advantage commonly have more public parkland and even private lawn space than their disadvantaged counterparts (Boone et al. 2009; Dai 2011). Such differences often arise due to unequal power relationships between residents and local governments. More advantaged neighbourhoods often have greater leverage and can more effectively lobby city governments (Heynen et al. 2006; Pedlowski et al. 2002; Lovell & Taylor 2013). In Baltimore, Maryland, historic societal inequalities, such as segregation ordinances, are important determinants of current inequalities in access to green space (Boone et al. 2009). In turn, lower levels of accessibility and increased distances between people's homes and green spaces often mean lower levels of green space available for recreation (Coombes et al. 2010). However, tailored green space policies may shift this recurring pattern as seen in Bristol, England where public parkland is now equally or even over-provided in poorer neighborhoods (Jones et al. 2009).

The structure and function of urban green spaces, usually due to management decisions, can also vary according to the socio-economic conditions of the neighbourhood in which they are sited (Aronson et al. 2017). Those with greater socio-economic disadvantage often have lower vegetation cover (Iverson and Cook 2000; Pham et al. 2012; Talarchek 1990; Shanahan et al. 2014), fewer trees in public locations (Landry and Chakraborty 2009; Kuruneri-Chitepo & Shackleton 2011), and lower species richness (Clarke et al. 2013; van Heezik et al. 2013). A range of socio-economic reasons contribute to these patterns. For example, more advantaged populations can often afford larger properties in older neighbourhoods, which are associated with greater availability of space and time for vegetation establishment (Kirkpatrick et al. 2007; Lowry et al. 2012). Similarly, an individual's income and knowledge of the benefits that urban green space provides may influence the extent to which they create or maintain green space within their yard or communal space (Heynen et al. 2006; Andersson et al. 2007; Kirkpatrick et al. 2007).

Ethnicity and the subsequent norms thereof can also play a large part in modulating the characteristics of urban green spaces. In South Africa, residents of Botswanan descent clear their yards of all vegetation because of group norms about tidiness (Lubbe et al. 2010). Additionally, a number of studies have found that culture, demographics, housing type, and ownership can influence private or community-land land management (e.g., Talarchek 1990; Troy et al. 2007). How urban space is managed, e.g., the type of plants chosen or the hours spent on maintenance, can result in striking differences in grass versus tree cover and in amount of greenery overall.

2.2 Socio-economic factors influence demand for services

The link between socio-economic factors and demand for services has, to date, received little attention (Burkhard et al. 2012). People have numerous needs, including basic material for a good quality of life, access to clean air and water, security from disasters, and good social relations (MA 2005). Maslow (1943) proposed a hierarchy of needs to define universal human needs and this framework has been widely adopted in psychology, sociology and management (Figure 2). It categorizes need according to five levels, physiological, safety, love/belong, esteem, and self-actualization, where those at the bottom (e.g., physiological, safety) are more 'fundamental' than those at higher levels (e.g., esteem, self-actualization). While the ranking of human needs in this way has been criticized (Wahba & Bridwell 1976), we argue that such categorization, although not necessarily a strict hierarchy *per se*, is useful when considering how socioeconomic factors influence these different types of needs and, subsequently, how this might change demands for different ecosystem services. For example, as people increase in socio-economic advantage (e.g., increased income or higher levels of education), their demand for ecosystem services related to esteem and self-actualization (e.g., recreational or cultural services) may increase relative to those for services related to physiological health (i.e., food supply) that can be provided by remote locations outside the city or those services related to safety (e.g., flood or climate regulation) that can readily be met by technological means. This shift is exemplified in South Africa, where poor urban residents use their garden space for supplementary food production, whereas wealthier residents use gardens for relaxation and aesthetic services (Cilliers et al. 2013).

Socio-economic factors influence human behaviors that alter access to ecosystem services (Figure 1). Public parks are regularly cited as critical green space in urban landscapes; however, people must visit parks in order to receive certain ecosystem service benefits. Urban green space visitation rates are strongly influenced by crime rates, perceptions of safety, age, gender, cultural background, and socio-economic status (McCormack et al. 2010, Cohen et al. 2013, Reis et al. 2012, Peschardt et al. 2012, Lin et al. 2014, Shanahan et al. 2015). Visitation rates often reflect the outcome of supply, demand, and provision of ecosystem services but may directly indicate demand if supply and provision are controlled for or held constant. For example, Jones et al. (2009) found that over 40% of people in the most advantaged socio-economic group visited parks in Bristol, UK, compared to only 27% in the least advantaged group despite greater accessibility for this latter group. This disparity between socio-economic groups was driven by differing perceptions of reduced accessibility and compromised safety (Jones et al. 2009). Similarly, in an Australian city, Leslie et al. (2010) found that perceptions of safety and opportunities for socialization in green spaces resulted in more frequent park visitation and greater participation in walking activities for higher-status individuals. Perceptions that parks are unsafe are consistently more pronounced in disadvantaged areas and for specific ethnic groups (e.g., Lyytimaki & Sipila 2009, McCormack et al. 2010) and could substantially diminish ecosystem service demand and thus any eventual benefits (further explored in Case Example 2).

In the USA and parts of Europe, ethnicity explains some major differences in the use and preferences for outdoor recreation of non-white immigrants or non-white established populations compared to established white populations (Madge 1997; Johnson & Bowker 1999; Gobster 2002; Tinsley et al. 2010; Gentin 2011). These ethnic differences can also play out at a country-wide level. Özgüner (2011) highlights that Turkish visitors use parks more for passive recreation (e.g., picnicking) than visitors from Western countries, perhaps as a reflection of the more collective Turkish lifestyle.

Even across a city where parks are managed in similar ways and their distribution is equitable, they may provide very different benefits if demand for their services varies with socio-economic conditions.

Case Example 2: Disservices that diminish park visitation demand

While maximizing trees and shrubs in urban parks can appear to be a good idea, benefiting climate regulation, air purification, noise reduction, recreation, and aesthetics (Escobedo et al. 2011; Dobbs et al. 2014), for some urban residents that type of park design can have significant trade-off's (see Supplementary Materials). In fact, higher levels of woody vegetation may lead to heightened fear and stress as well as other disservices such as increased allergens and potential for infrastructure damage (Lyytimaki & Sipila 2009; Escobedo et al. 2011; Dobbs et al. 2014). In Leicester, Britain, Madge (1997) found that fear was a strong deterrent against park usage and demand for parks by women, the elderly, and Asian and African-Caribbean demographic groups, stemming from concerns about sexual violence, theft, and racial discrimination respectively. Vegetation cover can contribute to a perception that vegetation can conceal criminals and limit the vision of potential victims and surveillance (Kaplan et al. 1998; Reis et al. 2012).

Responsive city and neighborhood policies and management practices can alter these disservices, which may be especially important for vulnerable demographics. In Zimbabwe, lighting was more important than vegetation in determining crime in poorer neighborhoods (Nyabvedzi & Chirisa 2012). Obviously well-maintained vegetation can deter criminal activity due to the indication of higher levels of authority and surveillance (Wolfe & Mennis 2012). Thus, demand for green space services can be enhanced through top-down regulation that aims to increase the perception of safety in neighborhoods with higher crime rates. This could take the form of outreach programs as well as specific park design considerations that alter the look and feel of parks in areas where perceptions or realities linked to socio-economic conditions might diminish apparent demand for green areas.

Increased community involvement in parks and greater 'informal surveillance' along with the presence of authority figures may also alleviate perceptions of fear and stress disservices (Madge 1997).

Maslow's categories of human needs also vary with social factors in their potential to be met via technology and built infrastructure instead of from ecosystem services provided by urban greenspace and natural features. Those related to physical wellbeing and safety can be most easily substituted with increases in material wealth. Water and waste treatment needs can be met through water supply and sewer systems; flood regulation by the construction of dams, canals, and levees; climate regulation from air-conditioned buildings, and food through the import of agricultural products from more distant locations. Wealthier or more educated cities and countries may be better able to substitute or use technological solutions for water provision or flood mitigation (Luck et al 2009), reducing demand for these services from natural ecosystems. Poorer inhabitants of cities may rely more upon the cooling effect of nearby vegetation during heatwaves, while wealthier residents rely on more expensive air conditioning (Cavan et al. 2014). The MillionTreesNYC campaign recognizes that socio-economic status influences demand for temperature regulation from trees and places substantial focus on planning in "low-income and poor-health" neighborhoods (McPherson et al. 2011). Thus, substitution may reduce the demand for urban green space to provide certain ecosystem services but only if socio-economic conditions allow for adequate substitution. In contrast, substitution of services related to self-actualization or esteem (e.g., cultural services) may be more difficult. Therefore, demand for ecosystem services related to these particular needs may be insensitive to changes in socioeconomic factors. The impact of socio-economic factors on demand for ecosystem services may be especially complex if there is a negative relationship between true need and apparent demand. As described above, those who may benefit most from green space may not necessarily express (or have the power to express) demand for that space or associated services. This potential tension and its effect on ecosystem services should be explicitly considered in green space planning and management.

2.3 Socio-economic factors moderate benefits of services

Socio-economic factors can also influence the actual benefit that people receive from the use of an ecosystem service, even as the level of service supply or demand stay constant between groups of people (Figure 1). A service can be fully supplied and there can be demand for it, but the benefit it provides (e.g., how it contributes to human wellbeing) can vary depending on socio-economic factors (de Groot et al. 2010; Potschin & Haines-Young 2011). For example, urban gardens can be equitably distributed and even similarly structured (supplied) and equally used (demanded) by differing groups of people but the benefit they derive from them may differ depending on whether they gain primarily a provisional service benefit, such as food, or primarily a cultural service benefit, such as sense of place (Case Example 3). Those differences in how the same urban green space can benefit an individual or community can be driven by socio-economic status. Of all the connections between ecosystem services and socio-economic factors, the link between socio-economics and benefits is the least studied and most poorly understood or appreciated.

<u>Case Example 3: Benefits of provisioning & cultural services and urban gardens</u>

Urban gardens are often associated with the cultural values and liveability of cities, providing a range of ecosystem services (Barthel and Isendahl 2013). In South Africa, the importance of food provision from gardens relates to socio-economic gradients in that species that are useful as food are more frequent in the gardens of poorer residents who use gardens as a source of additional income or supplemental food (Lubbe et al. 2010; Cilliers et al. 2013). The same gardens that provide food may also form a crucial part of a community's sense of place and control, services that marginalized populations may find especially difficult to procure (Anguelovski 2013). Thus, the realization of different ecosystem service benefits may vary along with changes in socio-economic status (see Supplementary Materials).

When focusing on enhancing benefits from ecosystem services, city planners and managers would likely adjust policies and management schemes, rather than generating new ones. Urban managers could influence the strength and type of benefits through outreach efforts focused on increasing awareness around different functions of urban gardens, including holding gardening classes, and also by offering incentives that encourage and enable disparate urban dwellers to participate in gardening that is tailored to their needs (e.g., food versus aesthetics). Alternatively, planners and managers could focus their efforts in direct response to the existing type and level of demand and develop garden-friendly incentives and programs in areas of highest demand where those efforts would have the most rapid uptake and impact.

Perhaps the best example of this link between socio-economics and ecosystem service benefits relates to food security, which depends on food availability, access, utilization, and stability (FAO 2006). In South Africa, urban residents make socioeconomically-dependent planting choices in their urban gardens with implications for eventual food security benefits (Lubbe et al. 2010; Cilliers et al. 2013). Lubbe et al. (2010) found that South Africans with lower socio-economic status planted more utilitarian plants such as fruit trees despite their higher expense and long-term commitment needed for their culture because of job and market insecurities. However, while urbanites may not be barred economically or culturally from investing in natural resources such as fruit trees (i.e. increasing the supply to match demand), their ability to actually benefit from such investments can be hindered by other socio-political limitations like tenure security (e.g., Otsuka et al. 2001). Thus, despite investments in supply of certain ecosystem services and apparent demand, we speculate that the end benefit of the service may not be realized due to socio-economic factors. There may also be different levels of benefit that differing demographics may receive from ecosystem service provision. For example, the health and wellbeing benefits that can be gained from recreation in green space could be much higher for disadvantaged communities simply because their base-line wellbeing is lower and ultimately these people can have more to gain. There is support for this concept in that the health benefits of neighborhood green space tend to be much more evident for lower income communities (Mitchell & Popham 2008). The link between service provision and actual benefit is a nuanced one. Many of the same strategies that managers or city government officials can take to enable or incentivize benefits of ecosystem services will be closely related to, or even the same as, those used to alter people's demand. Yet consideration of the transformation of service provision to actual benefit will improve the chances that ecosystem services will benefit target audiences and thus feedback to influence the demand for such services.

3 Implications for city planners & land managers

We detailed the conceptual model to demonstrate its utility in organizing thinking and examined case examples to demonstrate its ability to operationalize current frameworks and corresponding theory and evidence. Practical implications of the use of this model are detailed below along with complementary methods and tools.

3.1 Improvement in 'standards-based' urban green space planning

Urban green space planning is commonly based on targets that describe a minimum area of green space per person or household and proximity to residential areas (Heynen et al. 2006). For example, accessibility standards for the United Kingdom are based on targets for the area of green space that should be within certain distances of people's homes (Natural England 2010), and the UN Habitat State of the World's Cities report suggests that a minimum of 8 m^2 of green space per person is required (UN-Habitat 2013). These approaches provide important guidelines that, if implemented, can assist in creating equity in the amount of green space available across socio-economic gradients (Shanahan et al. 2014). Yet, even if supply is uniform across a city, demand almost certainly will not be due to the different ways socio-economic factors influence supply versus demand versus benefits (Fig 1). The implications are that targeted green space provision, based on the spatial distribution of demand and potential benefits relative to socio-economic factors, can result in more equitable distribution of ecosystem service benefits. As such, a one-size-fits all approach to green space planning and management will not ensure that ecosystem service benefits are equally realized (Escobedo et al. 2011).

3.2 Understanding relationships between socio-economic factors and ecosystem services

3.2.1 Local assessment of ecosystem service supply and demand

Simply identifying where socio-economically advantaged and disadvantaged groups live within cities will likely provide some information to guide efforts directed at enhancing green space supply and demand. However, the most useful information will come from community surveys, focus groups and interviews that examine residents' perceptions and usage and experience of green spaces. This will be particularly useful for developing strategies tailored to the specific concerns or barriers associated with any one community. Community surveys can help managers gauge high and low demand so that they can prioritize management of particular ecosystem services relevant to the neighborhoods of that area (TEEB 2010). For example, in communities where personal safety is considered an important barrier to green space use, social strategies that include increased policing (Wilbur et al. 2002) or planning strategies that enhance the design of green spaces to increase visibility and perceptions of safety (Schroeder and Anderson 1984) may be appropriate. These strategies speak to the interplay between management of green space and human needs and activities as mediated by considerations such as access, incentives and outreach, as well as policy goals (Figure 1).

Understanding community values will complement current understanding of perceptions and usage of urban green spaces. Management of green spaces, particularly around ecosystem services, is a process of articulating values, both of management and of stakeholders, and responding to those values (Ernston & Sorlin 2013; Ives & Kendal 2014). Various mapping tools can be used to elicit the values of stakeholders spatially, such as Public Participation GIS, which may be particularly useful to green space managers (Ives et al. 2017). Using data from community surveys or methods like Public Participation GIS, managers can map out and qualitatively model the flow of prioritized services (e.g., Brown et al. 2014). To enhance green space planning and policy, the available information on community-specific socio-economic factors that prevent the use of green space could be used to identify particular areas or groups of need.

3.2.2 Quantitative analysis to understand drivers of green space benefits

The above methods will allow a basic characterization of our conceptual model's components whereas quantitatively-based modeling approaches are one suite of tools that could provide understanding of the interactions between supply and demand and predict ecosystem service outcomes. Knowledge of the strength and form of these interactions should better enable planners and managers to anticipate how altering characteristics of one component of the model may affect ecosystem service provision (Fig 1). The dynamics of socio-ecological systems often also have strong feedbacks between the social and ecological components (*en sensu* McPhearson et al. 2016). In particular, these feedbacks can drive the land management decisions made by municipalities and individuals in urban areas that may either negatively or positively influence urban ecosystems (Alberti et al. 2003). This more predictive understanding would be helpful in cases when new management strategies are being tested or where the demographics or wealth of a neighborhood around or containing green spaces are changing. Qualitative, participatory methods that include economic valuation are likely to be more appropriate if the objective is to explore the deeper meanings, values and interactions urban residents have with their local environment.

There is a need to develop more effective modeling techniques to enable landscape practitioners to apply evidence of the links between ecosystem service components and socio-economics in real-world contexts. Whichever modeling approach is used, there are three key components of the process: (1) gather data on critical or likely socio-economic factors that influence supply, demand, and benefits of ecosystem services (e.g., common factors detailed above as influential to services), (2) relate these to the physical/environmental variables that influence them (e.g., green space provision, condition, arrangement), and (3) model the impact of specific planning or management interventions that can affect outcomes (e.g., management actions, behavioral incentives, access improvement) (see Cowling et al. 2008). One of the biggest challenges of such quantitative modeling is the integration of social and environmental factors, which are measured using different techniques, scales, and units. In particular, many socio-economic variables are non-spatial, while the green spaces being managed are spatially located. In recent years, much work has been done on spatially mapping ecosystem service flow, supply and demand (van Jaarsveld et al. 2005; Burkhard et al. 2012, Garcio-Nieto et al. 2013, Dobbs et al. 2014). Yet future work must move past spatial representation of existing, static relationships to prediction and extrapolation across space and time. Examples of emerging approaches that can help in this strategy include applying techniques developed for species distribution modeling to associations between social values and environmental conditions (e.g. the Social Values for Ecosystem Services tool; Sherrouse et al., 2011) and spatially-referenced agent-based modeling (e.g., Matthews et al. 2007).

3.3 Implementation changes in planning, policy, and practice to enable ecosystem service benefits

A variety of innovative solutions for planners and managers can enable greater realization of ecosystem service benefits to a broader range of socio-economic groups. We note that a few success stories exist where policy makers and urban planners and managers successfully incorporated socioeconomic factors into ecosystem service work, such as the Milwaukee River Greenway run by a private and public community coalition (Aronson et al. 2017) and the Corridors of Freedom initiative in South Africa which is intended to connect socio-economically segregated communities via green infrastructure (The Guardian 2015). A few more posited interventions have already been mentioned here regarding specific services, such as planting more shade trees in neighborhoods that have less access to air-conditioning (Case Example 1).

For ecosystem service benefits such as recreation or food-provision, planners and managers can enact strategies to alter the supply of services and help enable positive behavioral or perception changes (see dashed lines between 'Management of Green Space' and 'Human Needs and Activities' in Figure 1). For example, when planning for new green spaces, underutilized urban areas can be incorporated such as vacant lots which may already be more prevalent in underserved communities. These types of new green spaces and others, like community gardens, can be co-managed with informal managers, dedicated citizens who can help foster community buy-in and build social capital (Andersson et al. 2007). Programs that lower the knowledge and resource barrier to private space gardening and greening (e.g., free tree seedlings or classes) might encourage community-level behavior shifts, though messaging must be carefully tailored to ensure equitable community buy-in (see Locke & Grove 2014 and dashed lines in Fig 1). Community engagement programs and activities in parks as well as government commitment to increase safety and a sense of belonging can also help overcome socio-economic barriers to park use (Cohen et al. 2013). In order to work with demographic differences, park managers might do well to provide an array of facilities to attract a more diverse array of visitors (Burgess et al. 1988; Gobster 2002) and design public spaces that satisfy public preferences for cleanliness and order, even in more natural settings (Burgess et al. 1988; Gobster & Westphal 2004, Ives & Kelly 2016). Managers can also use different marketing strategies, including social marketing strategies, about specific park amenities to attract underrepresented sectors of society (Johnson & Bowker 1999; Lovell & Taylor 2013; Ives & Kendal 2014).

4 Conclusions

A number of ecosystem service frameworks have been put forward that consider socio-economic variables or influences (e.g., Carpenter et al. 2009; Daily et al. 2009; de Groot et al. 2010). However, the specific links between socio-economic variables and ecosystem service provision have rarely, if ever, been explicitly conceptualised for urban planning (Carpenter et al. 2009). Our conceptual model explicitly embeds these links within the ecosystem service supply chain framework. By doing so, it emphasizes the importance of socio-economic factors in managing urban ecosystem services and identifies potential pathways through which land managers and policy-makers might intervene to alter ecosystem service provision.

Socio-economic factors can have a profound influence on the demand and supply of urban ecosystem services, and they heavily mediate the benefits that city residents can receive from green spaces. Consequently, urban planning that incorporates these factors into the provision and design of green spaces has the potential to markedly enhance health and wellbeing through more effective delivery of ecosystem services. Our model allows the identification of specific socio-economic barriers to ecosystem service delivery and will potentially reveal what types of interventions are necessary and where. Ultimately, this approach could shift planning strategies towards ecosystem service provision that better meets the needs and desires of diverse urban residents.

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Box 1: Glossary

Ecosystem services: the biophysical and social conditions and processes by which people, directly or indirectly, obtain benefits from ecosystems that sustain and fulfill human life (MA 2005).

Ecosystem service supply: the full potential of ecological functions or biophysical elements in an ecosystem to provide a given ecosystem service, without consideration of whether human recognize, use, or value that function or element (Tallis et al 2012, Villamagna et al 2013).

Ecosystem service benefit

Ecosystem service demand: the level of service benefit desired or required by people. Demand is influenced by human needs, values, institutions, built capital, and technology (Villamagna et al 2013).

Ecosystem service provision: the realisation or delivery of an ecosystem service resulting in actual benefit to people. Provision depends on both the supply of and demand for a service (Tallis et al 2012, Villamagna et al 2013).

Urban green space: all the natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales (Tzoulas et al. 2007). This includes both public and private green space, including parks, private yards and gardens, street trees, green roofs, etc.

Socio-economic factors: the combination or interaction of social or economic characteristics related to an individual or group, including occupation, education, income, and place of residence.

TABLES

Table 1. Ecosystem services considered to be especially relevant to urban residents, list adapted from Chapter 11: Urban Ecosystem Services in Elmqvist et al. 2014 using the service categories from the Millenium Ecosystem Assessment 2005.

Categories	Services
Provisioning	Food supply
	Water supply
Regulating	Urban temperature regulation
	Noise reduction
	Air purification
	Moderation of climate extremes
	Runoff mitigation
	Waste treatment
	Pollination, pest regulation & seed dispersal
	Global climate regulation
Cultural	Recreation
	Aesthetic benefits
	Cognitive development
	Place values & social cohestion
Supporting	Habitat for biodiversity
Disservices	View blockage
	Allergies
	Accidents
	Fear & stress
	Damages on infrastructure
	Habitat competition with humans

FIGURES

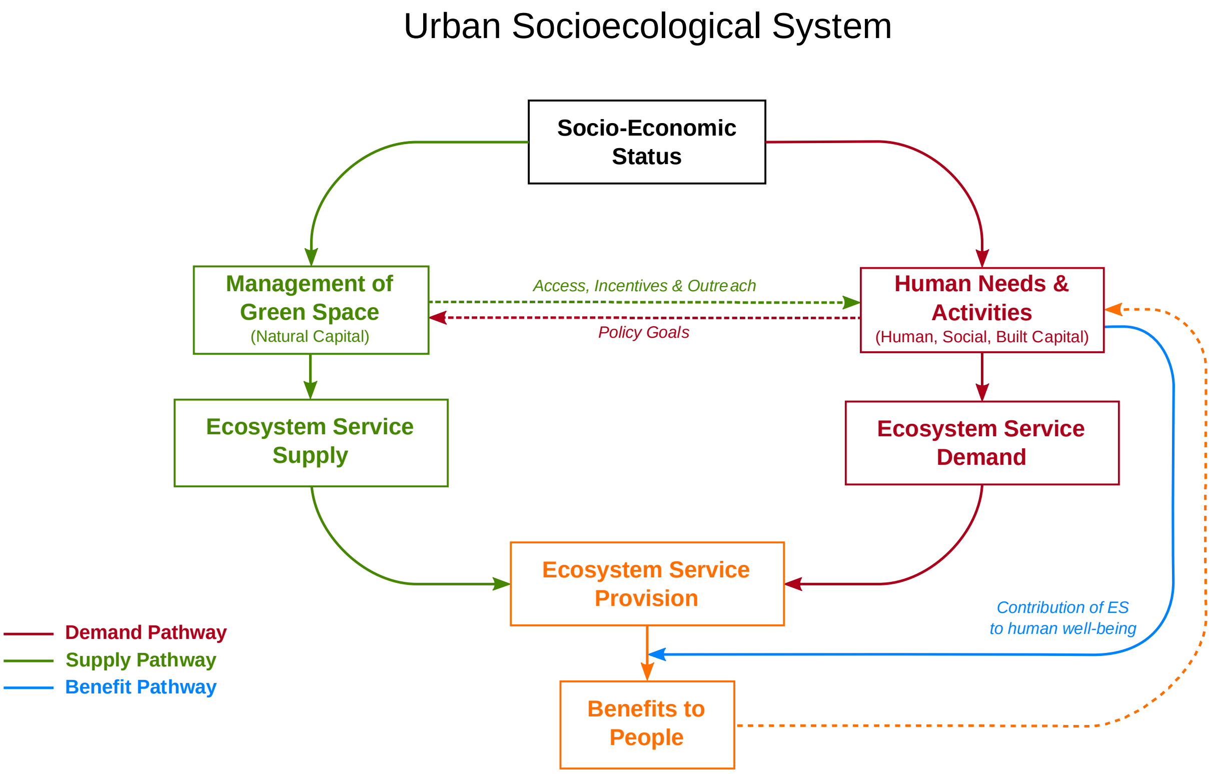

Figure 1. How socio-economic status affects the flow of ecosystem services in an urban socioecological system. The differently colored components refer to the three main pathways by which socio-economics can impact ecosystem service supply (1), demand (2), and benefit (3).

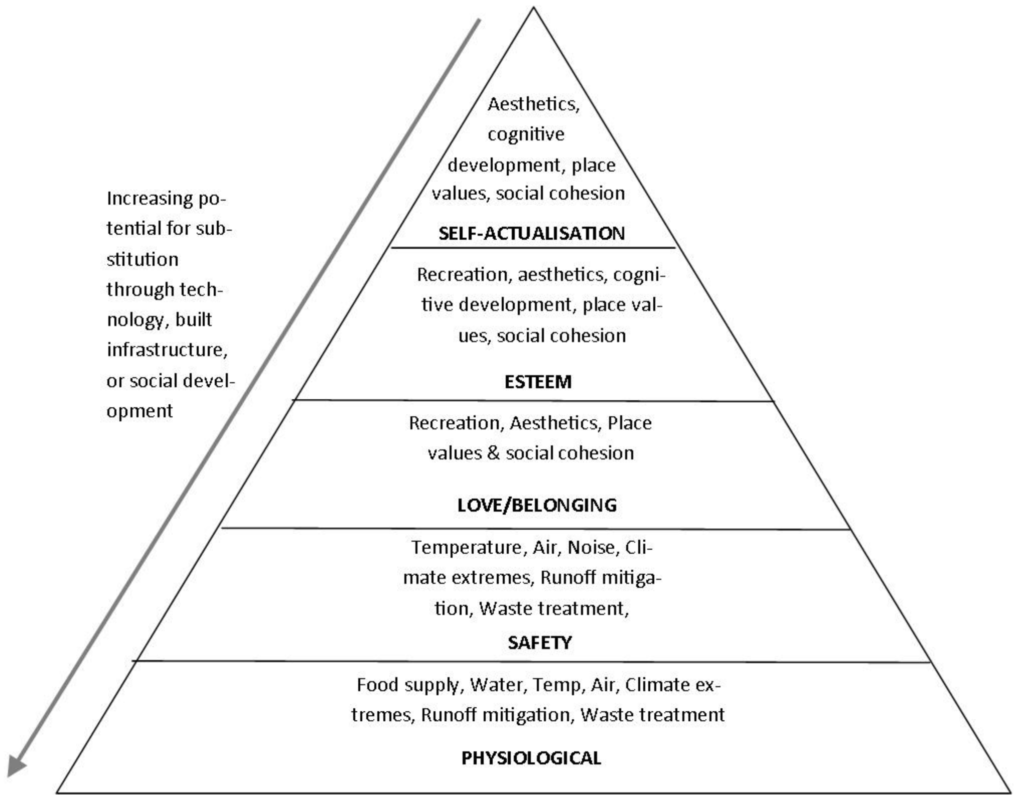

Figure 2. Urban-relevant ecosystem services can be parsed out according to Maslow's hierarchy of needs and the importance of ecosystems for delivering specific services may differ between differing socio-economic sectors of a population. As the type of needs become more survival-related (more base-level in the pyramid), there is increasing potential for substitution of ecosystem services for the same type of services derived from technology, built infrastructure or social development.