EcoPlan

Delivering Green Infrastructure

Literature Review

Delivering ecosystems services via spatial planning – reviewing the possibilities and implications of a green infrastructure approach

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Abstract

Ecosystem services have been researched and promoted widely as a tool to address biodiversity conservation and as an approach to tackle climate change mitigation/adaptation. This paper explores the potential for delivering ecosystem services through spatial planning, proposing an ecological turn in planning theory and practice. Specifically, we examine the emerging literature surrounding green infrastructure to: (1) identify ecological principles to inform planning policies and processes; (2) propose a re-scoping of spatial planning practices to place ecology, ecosystem services and environmental risks as central concerns of planning practice; and (3) examine effective procedures to ensure more ecologically sound outcomes in the planning process.

Introduction

Threats to biodiversity and climate change mitigation and adaptation pose some of the most complex and pressing challenges facing societies and policy-makers across the globe, requiring integrated and innovative policy-making to build resilient social-ecological systems and sustainable urban and rural areas. In summary, the challenge at the urban scale is to operationalise ecologically sustainable urban regions as a means to reconcile urban development with the biosphere (Wilkinson et al., 2013). However, devising means to ensure the integrity and longevity of the natural processes and ecosystems underpinning society has often been fraught with confusion on how to act and where to focus attention (Carter, 2007; Dryzek, 2005; Owens and Cowell, 2011). Such issues are ever more pressing as the impacts of demographic growth and rising consumption patterns increasingly undermine naturally occurring processes and erode biodiversity (Baker, 2006).

One response to the interlocking challenge of biodiversity and climate change risks has been to advocate the concept of 'ecosystems services'. In the last twenty years the *ecosystem approach* (EA) has been researched and promoted widely as a tool to address biodiversity conservation, and more recently, as an approach to tackle both climate change mitigation and adaptation, for example in relation to carbon storage, flood alleviation and cooling urban heat islands (O'Neill and Scott, 2011). The ecosystem approach is now seen as a major theoretical approach underpinning planning for complex systems (Smith and Maltby, 2003), at both the landscape scale (Potvin et al., 2011) and within urban areas (Gómez-Baggethun and Barton, 2013), providing a framework for looking at whole ecosystems in decision-making, and for valuing the ecosystem services they provide (DEFRA, 2005). The concept seeks to convey that nature needs 'to be protected not only for itself, but because it is essential for human life and society' (Granjou et al., 2013, 10). Although this concept originally emerged in the midtwentieth century, it has become so influential over the past decade that it now possesses 'many of the features of a 'Kuhnian paradigm' (Potschin and Haines-Young, 2011, 575), in its current domination of sustainability debates and prominence in directing research agendas (Braat and de Groot, 2012). Considered by some as 'the last best hope for making conservation mainstream – attractive and commonplace' (Daily et al., 2009, 21), operationalising the concept in day-to-day decision making has nevertheless proved a challenge, perhaps nowhere more so than in spatial planning (de Groot et al., 2010a; Geneletti, 2012).

Over the last decade, an extensive literature emerged charting the shift from *land-use* planning, characterised by regulatory approaches, towards *spatial* planning, whereby the role of planners and planning was re-cast to one of coordinator, integrator and mediator of the spatial dimensions of wider policy streams through negotiated governance, partnership working, and horizontal as well as multi-scalar actions (Nadin and Cullingworth, 2006; Tewdwr-Jones, 2012). While 'sustainability' has been central to these debates, the emergence of spatial planning has been largely driven by the competitiveness agenda, which seeks to position regions in a European and global economic space (Allmendinger and Haughton, 2009). However, faced with growing environmental risks, uncertainties and dilemmas, in this paper we argue for the need to fully embed ecosystem approaches into spatial planning theory and practice, proposing the notion of an *ecological turn in planning*. We suggest that planning has the potential to contribute towards a transition to more resilient places to better cope with complex environmental risks and disturbances. To address this, we emphasise the need to reflect on the interactions between the 'principles' guiding spatial planning activity, the 'practice' that both informs and is informed by these principles, and the 'procedures' employed to operationalise such principles and practice-informed knowledge in land use governance.

In this review paper, we seek to examine potential avenues for planning to deliver ecologically sound outcomes through examining the intersection between ecosystem approaches and spatial planning frameworks. In particular, we examine the emerging literature surrounding the 'green infrastructure' (GI) approach. This approach seeks to 'understand, leverage, and value the different ecological, social, and economic functions provided by natural systems in order to guide more efficient and sustainable land use and development patterns as well as protect ecosystems' (PCSD, 1999, 64). Seen to furnish 'the ecological framework needed for environmental, social and economic sustainability' (Benedict and McMahon, 2002, 12), the theory and application of GI has flourished in recent years and is now advocated by many as a means to enhance ecosystems services provision via spatial planning (EC, 2012; Gómez-Baggethun and Barton, 2013; Lucius et al., 2011; Rouse and Bunster-Ossa, 2013; TCPA and WT, 2012). However, a comprehensive review of literature linking the potential for GI to guide ecosystems services planning is lacking. Similarly, while a few recent commendable efforts have been made to expound what a GI planning approach may entail (Kilbane, 2013; Mell, 2013; Roe and Mell, 2013; Wright, 2011), an appraisal of the implications of this for the organisation and activity of spatial planning is conspicuous by its absence. We address these lacunae in this paper.

Accordingly, the remainder of this paper is structured in four sections. The next section briefly traces the emergence of the ecosystems services concept and examines contemporary debates regarding its theorisation. Particular attention is given to how ecosystems services thinking may parallel the objectives of spatial planning. The subsequent section reviews the potential for a GI planning approach to respond to the challenges of operationalising the ecosystems services concept in spatial planning. This discussion is structured using Hebbert's (2009) 'Three-Ps' framework of 'principles', 'practice' and 'procedures'. Following an account of this framework, an array of academic and practitioner literature is reviewed to identify the core 'principles' of the GI approach. Also identified are the broader guiding principles informing GI planning activity and the range of ecosystems services that GI is believed to enhance. The paper then identifies and discusses a number of themes common to GI 'practice'. Subsequently considered are the implications of a GI approach for the 'procedures' of spatial planning. Specific attention is devoted to the demands for transformation that a GI approach places on existing institutional arrangements and professional cultures. The final section of the paper concludes by reflecting on where the future may lie for a GI approach to spatial planning and offers some ideas on how the concept should be allowed to evolve.

The Concept of Ecosystems Services

Modern thinking on ecosystems services stems from the 1970s and a developing belief that 'by weighing the benefits to society of nature in the undeveloped state against the benefits of resource development, an objective basis for decision-making will be achieved' (Westman, 1977, 960). This increasing desire to stimulate public interest in conservation initiatives by a utilitarian framing continued through the 1980s (Ehrlich and Ehrlich, 1983; WCED, 1987). However, it was not until the 1990s that the 'mainstreaming of ecosystems services' truly emerged (Gómez-Baggethun, et al., 2010, 1209), with a growing number of academics from diverse backgrounds advocating the ecosystems services perspective as a means to facilitate better decision making (Costanza et al., 1997; Daily, 1997; Pearce and Moran, 1994). In 2005, the Millennium Ecosystems Assessment (MA, 2005) significantly raised the profile of the ecosystems services approach and securely placed it on the global policy agenda (Gómez-Baggethun et al., 2010). This heightened profile was subsequently reflected by the establishment in 2010 of a United Nations sponsored Intergovernmental Panel on Biodiversity and Ecosystems Services (IPBES) in a desire to repeat the awareness raising successes of Intergovernmental Panel on Climate Change (Larigauderie and Mooney, 2010). Buttressing such efforts was the publication of a report endorsed by the United Nations on 'The Economics of Ecosystems and Biodiversity' (TEEB, 2010) and subsequent studies exploring the usefulness of this perspective to decision making (Ring et al., 2010; Wittmer and Gundimeda, 2012). Today, the ecosystems services concept is resolutely situated within academic and practice debates on how to more accurately consider the value of environmental resources in decision making (Apitz, 2013; Gilvear et al., 2013; Peh et al., 2013; Tobias, 2013; van Wensem and Maltby, 2013).

Broadly conceived as 'the benefits people obtain from ecosystems' (MA, 2005, v), thinking on ecosystems services most frequently follows the categorisation of services advanced by the Millennium Ecosystems Assessment. These are namely (MA, 2005, 40):

- *Supporting Services*: services 'necessary for the production of all other ecosystem services' (e.g. nutrient cycling, water cycling, soil formation).
- *Regulating Services*: services 'necessary for the production of all other ecosystem services' (e.g. air quality regulation, climate regulation, water purification and waste treatment).
- *Provisioning Services*: the provision of 'products obtained from ecosystems' (e.g. food, fibre, fuel, pharmaceuticals, fresh water).
- *Cultural Services*: the 'nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences' (e.g. recreation and tourism, aesthetic values, sense of place, cultural heritage values).

These ecosystems services are then related to human well-being by their role in underpinning security, the provision of basic materials, health and social relations. All of these are conceived to facilitate freedom of choice and action. However, such delineations have not been immune from criticism with some authors questioning the appropriateness of the different categories advanced by the Millennium Ecosystems Assessment (Costanza, 2008; Wallace, 2007) and how they may be applied in practice (Lamarque et al., 2011). Of particular concern is the potential to confuse 'structures' and 'functions' with 'services' and 'benefits'.

Boyd and Banzhaf (2007) offer some clarification here by proposing that ecosystems services are not 'the benefits people obtain from ecosystems' (MA, 2005, v), but rather are the 'components of nature, directly enjoyed, consumed, or used to yield human well-being' (Boyd and Banzhaf, 2007, 619). In this more nuanced approach, services and benefits do not equate as 'ecosystems services are the aspects of ecosystems utilized (actively or passively) to produce human well-being' such that they 'become services if there are humans to benefit from them. Without human beneficiaries they are not services' (Fisher et al, 2006, 645). For example, recreation is cited by the Millennium Ecosystems Assessment as a 'cultural service', however, it is the enjoyment derived from recreation that provides a human benefit through a particular form of interaction with the environment, not the service per se.

Haines-Young and Potschin (2010) build upon this insight by proposing a 'services cascade'. This model distinguishes 'between ecological structures and processes created or generated by living organisms and the benefits that people eventually derive' (Haines-Young and Potschin, 2010, 115). These authors illustrate the clarity provided by their model via reference to how the presence of ecological structures like woodlands may function in slowing the passage of surface water. This capacity to reduce the intensity of river flow and potentially diminish the likelihood of flooding may be something that people then find useful. However, this perception of 'usefulness' is not a fundamental property of the ecosystem itself. Rather, the decision as to whether this function is regarded as a 'service' or not depends upon whether flood control is regarded as a 'benefit'. Society will consider or disregard this function as a 'benefit' in different places at different times. 'Therefore in defining what the 'significant' functions of an ecosystem are and what constitutes an 'ecosystem service', an understanding of spatial context (geographical location), societal choices and values (both monetary and non-monetary) is as important, as knowledge about the structure and dynamics of ecological systems themselves' (Haines-Young and Potschin, 2010, 116). This acknowledgement of the complex interactions between space and society resonates strongly with the underlying assumptions and purposes of spatial planning to facilitate mutually beneficial relations between humanity and the environment (Davoudi, 2012; Spirn, 1984; Wilkinson, 2012).

While primarily commending this model, Braat and de Groot (2012) question its 'unidirectional downward flow', and suggest that it 'is often interpreted to imply that ecosystem services flow effortlessly from ecosystems to human well-being' (Braat and de Groot, 2012, 8). Noting the assertion by Haines-Young and Potschin that a focus on the interpretation of 'benefits' (e.g. the service of flood control) can facilitate the formulation of policies to limit the pressure on 'structures' (e.g. woodlands), Braat and de Groot suggest that such mitigating policies account for just one aspect of how society may employ the ecosystems services paradigm as a means to facilitate more informed decision making. Hence, complementing the approach advocated by De Groot et al (2010b), these authors advance the view that careful attention to feedbacks via 'institutions, judgements, management and restoration' (Braat and de Groot, 2012, 8) may provide ways to 'enhance' the structures and functions that provide the services considered as benefits, rather than simply 'mitigate' the pressures upon such services. Thus, in keeping with the example furnished above, increasing the size of a woodland (structure) may amplify its capacity to slow the flow of water (function), reduce flooding (service) and thereby aid flood control (benefit).

From a policy perspective, analytical frameworks and policy instruments to promote ecosystem services have often been rooted in environmental economics, such as ecosystem valuation methodologies and payment for ecosystem services market-based policy tools (CNT and AR., 2010; DEFRA, 2007; DoEHLG, 2008; EC, 2012). However, there is currently a dearth of literature that addresses the ecosystem services approach from the perspective of spatial planning and how this may be translated into planning practice through the procedures employed in the formulation and implementation of policies designed to stimulate practical interventions.

Ecosystems Services, Spatial Planning and Green Infrastructure

As spatial planning is inherently concerned with socio-ecological interactions (Plieninger and Bieling, 2012; Selman, 2006; Wilkinson, 2012), this 'shift in the view of an ecosystem to one where people are considered part of an interactive holistic system' (Raffaelli and Frid, 2010, 4), acknowledges the role that informed planning can play in enhancing the beneficial functioning of ecosystems. Consequently, a number of recent studies promote use of the ecosystems services paradigm as a means to encourage better planning practice (Gómez-Baggethun and Barton, 2013; Niemelä et al., 2011; Schäffler and Swilling, 2013; Wilkinson et al., 2013). Within this emerging literature, however, limited attention has been given to addressing the principles of spatial planning and how these may be translated into practice through the procedures employed in the formulation and implementation of policies designed to stimulate practical interventions. One way to address this deficit is through the concept of 'green infrastructure' (GI). This concept 'emphasizes the importance of ensuring the provision of ecosystem goods and services for society and the value of functionally and spatially connected, healthy ecosystems' (Karhu, 2011, 7). In this sense, the GI concept both accommodates and transcends a focus on mitigation by proposing theoretical and applied reflection concerning how a proactive approach to planning for ecosystems services can enhance the shared benefits derived by positive socio-ecological interactions.

Hebbert's (2009) 'Three Ps' framework of *principles*, *practice* and *procedures* supplies a helpful structure for considering the potential offered by the GI concept to deliver ecosystems services via spatial planning. Under this typology, the 'principles' informing planning activity concern issues of high-order reflection on what planning should seek to achieve and how this may be accomplished. They are informed by theory and debate grounded in an appraisal of past endeavours, understandings of the present and predictions of the future. Thus, planning principles represent broad perspectives on ways to better the present, negotiate the future and learn from the past. 'Practice' differs from principles in that it relates to the analysis of particular situations that offer 'a means of learning from empirical experience of actually existing realities, typically through the vehicle of case studies' (Hebbert, 2009, 359). Finally, 'procedure' refers to planning processes, management techniques and skill sets. As such, procedure addresses issues concerning *how* to plan rather than *what* to plan. However, it is important to note that all 'Three Ps' are interrelated. Each interacts with and informs the other as 'principles lay the template, knowledge of practice demonstrates feasibility and sets benchmarks, procedures make the trajectory to implementation' (Hebbert, 2009, 359). These interrelationships are illustrated on Figure 1. Hebbert's typology is employed to identify and discuss the 'principles' of an ecologically-informed planning approach. With reference to existing 'practices', an endeavour is then made to assess the 'procedural' implications of operationalising this approach in spatial planning. From this it is shown that a GI approach supplies a feasible and effective means to operationalise the ecosystems services concept in spatial planning.

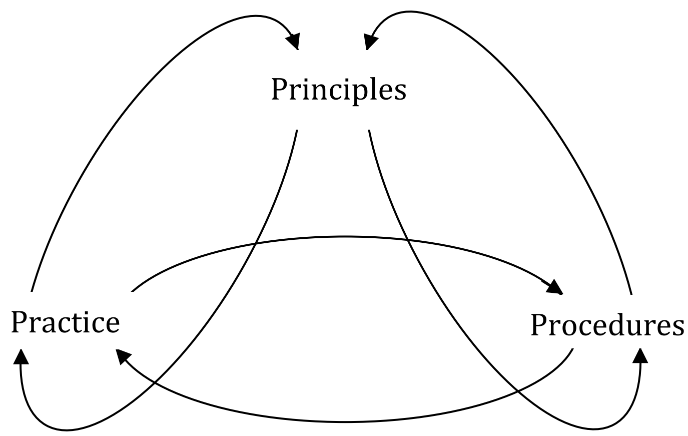

Figure 1:
Interrelationships between the *Principles*, *Practices* and *Procedures* of spatial planning

Principles of Green Infrastructure Planning

The primary focus of Anglophone planning systems has traditionally been the regulation of land-use to provide a framework for economic development while minimising externalities associated with competing land-uses through narrow land-use zoning and development control instruments. While land-use planning has always acknowledged care for the environment, meanings, representations and status of environmental issues as compared to development priorities have fluctuated over time (Davoudi et al., 1996). Within this context, landscape preservation has been an enduring and longstanding feature of land-use planning regimes. As Davoudi et al. argue (in relation to the UK system), planning practice has been underpinned by a 'moral and aesthetic notion of the environment as backcloth and setting' (1996, 429), as advocated by early planning pioneers. This perspective has resulted in what Selman (2010) refers to as an agenda of protection, amenity and ornament, reducing landscape concerns to a 'cosmetic exercise – something to do with prettification' (2010, 381). Alongside this concern with landscape as ornament, conservation policy has been underpinned by reactive, site-based approaches involving the designation of site-specific areas for the conservation of flora and fauna. These designated sites, alongside traditional planning preservation tools (greenbelts, areas of outstanding natural beauty, national parks) led to an approach characterised by 'islands of protection' (Owens and Cowell, 2011); in effect a collection of environmental assets.

With the much documented 'spatial turn' in planning debates in the 1990s/2000s, planning systems shifted beyond narrow land-use concerns to embrace a role of spatial coordination, characterised by flexible policy approaches and multi-scalar interventions (Albrechts et al., 2003). While 'sustainable development' became commonly cited as the ultimate goal within spatial strategies (Briassoulis, 1999), much literature charted the primacy given to the competitiveness agenda (particularly at the city-region scale) – see for example, Counsell and Haughton (Counsell and Haughton, 2003). In this context, environmental assets were perceived as 'development assets', performing a key role in place identity and packaged as quality of life capital (Owens and Cowell, 2011). Discourses surrounding sustainable urban environments were dominated by narrow debates surrounding compact urban forms, viewed as delivering both central city urban renewal and addressing the emerging climate change agenda through reducing the spatial separation of daily activities and therefore mitigating greenhouse gas emissions through reduced car dependency (McEldowney et al., 2005).

While sustainable development provided a flexible discourse for formulating spatial strategies, the growing focus on climate change and the heightened sense of risk from anticipated climate change impacts has provided an important emerging context for spatial planning (Campbell, 2006; Wilson, 2007). While there has been limited progress in developing international agreements designed to mitigate climate change and reduce greenhouse gas emissions, increasingly this climate change leadership deficit is being addressed at a city and regional scale. Whereas reducing greenhouse gas emissions has been a central concern for planners for over two decades through promoting compact urban forms, climate change adaptation is moving centre-stage as a key policy concern, for while climate change is occurring globally, its impacts are experienced locally, where people live and work (Donaghy, 2007). Spatial planning therefore has a crucial role to play in terms of reducing vulnerability and transforming the footprint of the places people live and work in to become more resilient to climate-related hazards so that they can cope with and recover more quickly from extreme disturbances such as flooding or heat stress (O'Neill and Scott, 2011). Through influencing the location, layout and design of development, spatial planning has the capacity to adapt the built environment to climate change by delivering a more multifunctional built environment that is safe and resilient to climatic extremes.

Addressing challenges emerging from climate change and biodiversity loss requires a sea-change in planning processes and practices to fully integrate the ecological dimension alongside traditional planning concerns. We outline the principles that inform this ecological turn in Table 1. In this context, 'green infrastructure' has emerged as a potential concept that may be employed to operationalise an ecosystem services based approach within spatial planning policies and practices. The green infrastructure approach moves beyond traditional site-based approaches of 'protect and preserve' towards a more holistic ecosystems approach, which includes not only protection but also enhancing, restoring, creating and designing new ecological networks characterised by multifunctionality and connectivity.

Table 1: Evolving planning principles and the ecological turn

Defining Attributes	Land use planning	Spatial planning	An ecological turn in spatial planning
Purpose	Planning for the 'public interest'	Planning for 'sustainable development'	Planning for 'resilient' places
Aims	Providing a land use framework to facilitate economic development	Ensuring the competitiveness of city regions within a globalised economy	Working with natural processes to enhance ecosystems services provision
Approach	Land use regulation	Spatial coordination	Social-ecological integration
Scope	Narrow and defined spatial and functional boundaries	Broad and 'fuzzy' spatial and functional boundaries	Inclusive and overlapping spatial and functional boundaries with particular attention to biogeographical delineations
Logic	Static	Flexible	Reflexive, adaptive and transformative
Administration	Functional silos	Increased communication and cooperation	Full integration
Urban Perspectives	Defined land uses	The compact city and urban renaissance	Landscape urbanism and ecological urbanism
Rural Perspectives	Separation of 'town and country'. Rural as inherently different.	Rural as supporting element to city region.	Rural as equal element in social-ecological continuum.
Landscape Perspectives	*"Islands" of protection*: landscape as ornament and site-based approach to protecting habitats and species	'Landscape as marketable asset': natural heritage as development assets	'Multifunctional landscapes': Protecting, enhancing, restoring and creating new ecological networks – *"connectivity"*
Emblematic policy approaches	Areas of Outstanding Natural Beauty; Green Belts; Land Use Zoning	Quality of life capital; landscape character assessments	*Green infrastructure* hubs, parcels, individual elements, corridors and land-use buffers
Design Concepts	Domination of nature. Intensive civil and mechanical engineering of solutions.	Management and manipulation of nature. Engineering solutions predominate, but less intensive methods accepted.	Biomimicry and less intensive methods favoured. Working with nature.

The theory and application of the GI planning concept has significantly increased over the past decade (Amati and Taylor, 2010; Barnhill and Smardon, 2012; Comhar, 2010; Davies et al., 2006; Dunn, 2010; Foster et al., 2011; Horwood, 2011; Hostetler et al., 2011; Kilbane, 2013; La Rosa and Privitera, 2013; Lerner and Allen, 2012; Llausàs and Roe, 2012; Mayer et al., 2012; Mell, 2013; Sandström, 2008; Thomas and Littlewood, 2010; Williams et al., 2010; Wright, 2011). While the origin of the term remains debatable (Allen, 2012; Pankhurst, 2012; Roe and Mell, 2013; Rouse and Bunster-Ossa, 2013), and there are a variety of interpretations as to what it entails (Cameron et al., 2012; Casperson and Olafsson, 2010; EC, 2012; Ellis, 2012; Madureira et al., 2011; Sylwester, 2009), virtually all understandings resonate with the frequently referenced definition advanced by Benedict and McMahon (2006, 1) as: 'an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions…and provides a wide array of benefits for people and wildlife'. Paralleling the concepts of 'structures' and 'functions' in ecosystems services theory (De Groot et al., 2010b; Potschin and Haines-Young, 2011), those advocating a GI planning approach focus on how 'assets' and 'functions' can furnish the ecosystems services deemed beneficial to society, underpinned by the core planning principles discussed below.

Firstly, to the fore among green infrastructure principles is the requirement to respect the context in which GI planning operates and to which a GI plan addresses (Eisenman, 2013; TCPA and WT, 2012; William, 2012). Here, GI planning is seen to entail 'a design vision that translates [a] planning strategy into physical reality while heeding the ecological and cultural characteristics of a particular locale – whether a region or an individual building' (Rouse and Bunster-Ossa, 2013, 5). Informed by the works of McHarg (1969), Spirn (1984) and Hough (1989), GI planning is seen as an 'evidence-based approach' (Gill et al., 2009; Weber et al., 2006) that seeks to understand, emulate and enhance local ecological and cultural distinctiveness so that it becomes 'both "effective" as an agent of environmental quality and "affective" as an expression of local conditions' (Rouse and Bunster-Ossa, 2013, 6). To advance such context sensitivity, a GI planning approach stresses the principle of collaboration (Barnhill and Smardon, 2012; Davies et al., 2006; Mayer et al., 2012; SG, 2012). Such a collaborative approach applies to the conception, design, implementation and maintenance phases of a GI planning initiative (Williamson, 2003). Indeed, those advocating this approach assert that 'successful green infrastructure initiatives build on the foundation of many disciplines and engage experts from various fields in network design and review' (Benedict and McMahon, 2006, 40). Moreover, promoters of the GI approach stress the need for collaboration to extend beyond the walls of expert institutions to involve non-specialist citizens whose 'subjective human needs, preferences, and perceptions are often decisive' in the formulation and implementation of successful GI initiatives (Erickson, 2006, 280).

Secondly, advocates of a GI approach also contend that planning for the protection and enhancement of GI assets and functions should precede the allocation of lands for development (LI, 2013; TCPA and WT, 2012). In this sense, GI planning should be seen to 'provide a framework for future growth while also ensuring that significant natural resources will be preserved for future generations' (Benedict and McMahon, 2006, 41). In emphasising the merit of protecting GI assets and functions prior to other forms of development activity, GI is thereby regarded as 'fundamental infrastructure' (Roe and Mell, 2013, 653) necessary for the delivery of a better environment for human and non-humans alike (Beatley, 2010; Gill et al., 2009; Grant, 2012).

Thirdly, GI approaches emphasise '*connectivity'* as central to promoting holistic planning approaches for ecosystem services. A review of GI practice in the UK lead Kambites and Owen (2006, 490) to conclude that connectivity is 'a pervasive and desirable characteristic of both green infrastructure itself and the process of green infrastructure planning'. In the context of GI planning, connectivity is used to refer to spatial integration (Andrés-Orive and Dios-Lema, 2012; Selman, 2012; Silva et al., 2010), scalar integration (McDonald et al., 2005; William, 2012) and institutional integration (Erickson, 2006; TCPA and WT, 2012). Accordingly, the review below discusses these various dimensions of connectivity as 'spatial connectivity', 'scalar connectivity' and 'institutional connectivity'.

Spatial connectivity refers to 'a physically connected system across the landscape' (Rouse and Bunster-Ossa, 2013, 19), and accounts for 'the degree to which a landscape facilitates or impedes the flow of energy, materials, nutrients, species, and people' (Ahern, 2007, 270). In this sense, a GI planning approach seeks to integrate the spatial concept of ecological networks originating in landscape ecology (Forman, 1995; Forman and Godron, 1986; Wiens, 2007) with the greenways concept stemming from a more anthropocentric spatial planning tradition (Flink et al., 1993; Hellmund and Smith, 2006; Little, 1990). An ecological network is 'a framework of ecological components, e.g. core areas, corridors and buffer zones, which provides the physical conditions necessary for ecosystems and species populations to survive in a human-dominated landscape' (Jongman and Pungetti, 2004, 3). Such networks render otherwise fragmented ecosystems biologically coherent by facilitating species movement and genetic exchange (Boitani et al., 2007; Opdam et al., 2006). This is achieved by connecting core areas (also called 'hubs') such as nature reserves via corridors (also called 'links') (Francis and Chadwick, 2013). Buffer zones surround these cores and corridor areas. They provide zones of transition to other land uses in which the network is embedded, such as an urban area or intensively farmed environment (Jongman et al., 2004). Therefore, the essence of ecological networks is ‘biopermeability and environmental continuity’ (Pungetti and Romano, 2004, 110). Greenways differ from ecological networks in their greater focus on human recreational access and mobility, as well as in their more linear format (Gobster and Westphal, 2004; Lindsey et al., 2001). Although cores and buffer zones may exist in greenways, they are not essential components (Fábos, 2004; Walmsley, 2006). Ahern (1995, 134) defines greenways as ‘networks of land containing linear elements that are planned, designed and managed for multiple purposes including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use.’ Therefore, a GI approach to planning promotes spatial connectivity along the form presented by ecological networks (cores, corridors, buffer zones) so as to assist biodiversity conservation while concurrently seeking to broaden the function of the network to facilitate anthropocentric utility (Pankhurst, 2012; Sandström, 2008; Williamson, 2003).

Scalar connectivity is intimately related to spatial connectivity but specifically refers to the integration of local planning initiatives with those at the regional, national and supranational levels (Allen, 2012; EEB, 2008; Steiner, 2002). In this sense, a GI approach parallels the longstanding objectives of spatial planning to encourage consistent and integrated policy hierarchies that both facilitate subsidiarity while concurrently ensuring a coherent approach across spatial and administrative scales (Adams et al., 2012; Hall and Tewdwr-Jones, 2010). Furthermore, Roe and Mell (2013, 653) suggest that ‘timescale as well as physical scale is important and embedded within both is hierarchical thinking’. In this respect, a GI planning approach is often advocated at the landscape scale in which localised site based initiatives are related to a strategic spatial strategy for the conservation of a larger area with shared topographical, ecological and land use characteristics (Forman, 2008; Green et al., 2013; Hamilton and Selman, 2005; Lerner and Allen, 2012; Matthews and Selman, 2006; Opdam et al., 2006; Selman, 2006). Such ‘strategic thinking’ (Ahern, 2007, 274) is frequently concerned with maintaining the assets and functions that distinguish landscapes while concurrently accommodating changes in land use over time (Brandt et al., 2003; Jaakkola, 2012; Primdhal et al., 2009; Selman, 2012). In this sense, it is considered that GI planning is ‘an adaptive process that, even with the best leadership, organizational structure, and appropriate goals, requires strategic approaches to assure evolutionary success’ (Erickson, 2006, 288).

Institutional connectivity relates to the multiplicity of ‘partnerships’ (Rouse and Bunster-Ossa, 2013, 75) necessary to enhance GI assets and functions for greater social and ecological benefit. As the movement of materials and species does not recognise administrative boundaries (Leitao et al., 2006), such institutional connectivity is generally a requirement for scalar integration as the spatial networking advanced by the GI planning approach spans localities, regions, nations and even continents (EEB, 2008; Mazza et al., 2011; Opdam et al., 2006; Silva et al., 2010). Consequently, those promoting a GI planning approach stress that 'it is essential that green infrastructure planning should involve operational connections between different administrative organizations' (Kambites and Owen, 2006, 490) as 'cross-jurisdictional cooperation is imperative' to the realisation of spatial connectivity (Erickson, 2006, 34). This emphasis on partnerships and cooperation across administrative boundaries and organisational structures harmonises with contemporary efforts in the theory and practice of spatial planning to promote 'joined-up thinking' and 'integrated governance' arrangements (Stead and Meijers, 2009; Thomas and Littlewood, 2010; Vigar, 2009).

The fourth core attribute of the GI planning approach is multifunctionality. It is this focus on the value in seeking to enhance multiple ecosystems services that Benedict and McMahon identify as differentiating GI planning 'from conventional approaches to land conservation and natural resources protection because it looks at conservation in concert with land development and man-made infrastructure planning' (2006, 2). Accordingly, those studying GI see multifunctionality as 'an integration and interaction between functions' (Roe and Mell, 2013, 655). Specifically referencing the environmental, economic and community 'ecosystems services' benefits provided by GI assets and functions, Rouse and Bunster-Ossa (2013, 19) assert that 'these benefits derive from the multiple and overlapping functions provided across different systems – hydrology, transportation, energy, economy, and so on – that can intersect in green infrastructure'.

Hence, in its focus on connectivity and multifunctionality, a GI approach reverses traditional planning practices wherein attention is directed at the provision of single functions (e.g. drainage, conservation, recreation) in specific locations with little interest shown to spatial, scalar and institutional integration. Figure 2 illustrates this polarity by representing the differences between traditional approaches to spatial planning and a GI planning approach. Using a bi-planar model structured along a *functional plane* (x-axis) and a *connectivity plane* (y-axis), Figure 2 portrays a GI approach as antipodal to the spatial, scalar and institutional disconnect that frequently characterises traditional modes of planning activity. Similarly, it depicts a GI approach as conversely positioned to the focus of traditional planning on the provision of just one function. In this sense, it shows how the GI concept seeks to steer spatial planning towards integrated land use governance wherein multifunctional ecosystems services potential are realised through enhancing positive synergies between abiotic, biotic and social systems.

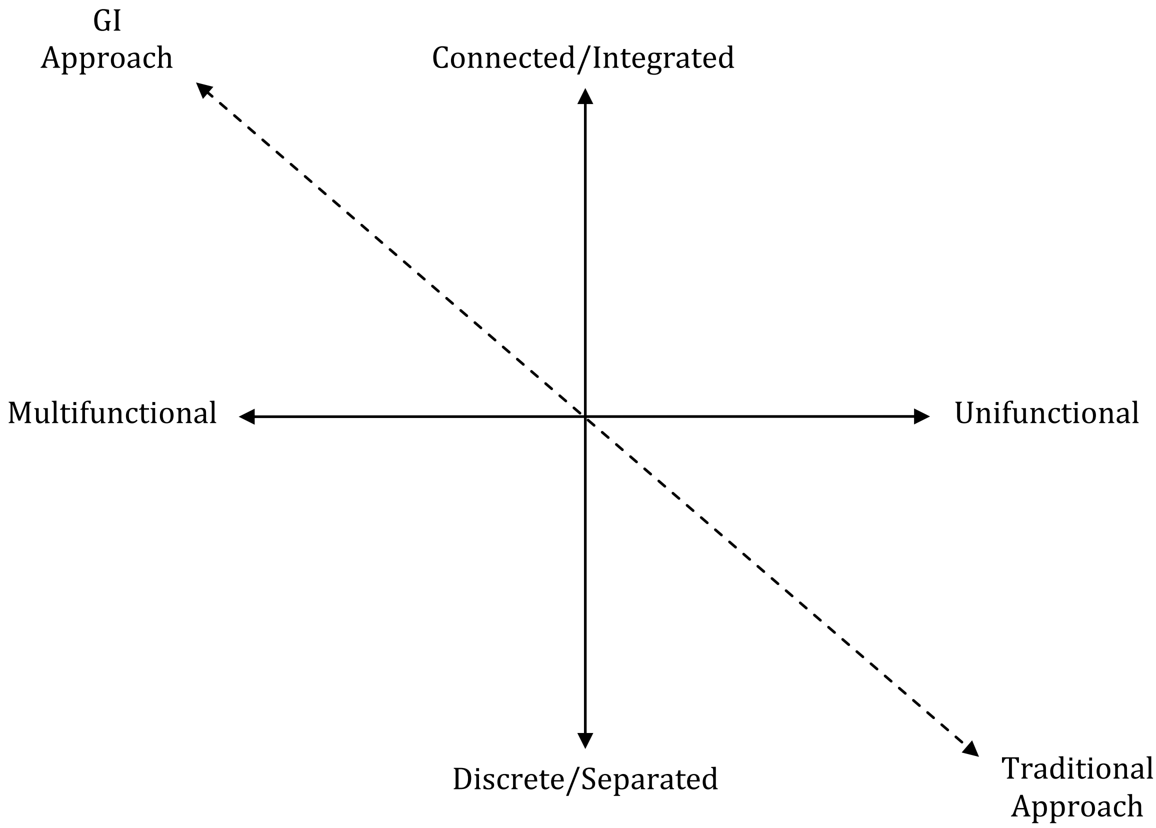

Figure 2:
Traditional versus GI planning approaches

Practices in Green Infrastructure Planning

In this section, we provide insights into GI planning practices from the literature as a means to identify the ‘scope’ and ‘content’ of a potential ecological turn in spatial planning. Practice examples offer orientation and may demonstrate the feasibility of delivering strategic planning principles. Such exemplars are generally supplied in the form of case studies which ‘are the staple of commissioned research and continuing professional development (CPD) training’ (Hebbert, 2009, 362).

Consequent of GI’s core principle of multifunctionality, such practice studies encompass a broad spectrum of ecosystems services benefits varying from habitat provision through to community development (see Table 2). Nevertheless, given the multitude of functions addressed by a GI planning approach, it is unsurprising to note that different researchers emphasise different functions in their case study work. In the USA for example, much GI related work has centred on urban storm water management (Brown and Caldwell et al., 2011; Chau, 2009; Novotny et al., 2010; NYC, 2010; USEPA, 2004). Here, practice examples illustrate the viability and cost effectiveness of a biomimicry approach to drainage design (EPA, 2010; Stenning, 2008). This work demonstrates the achievability of drainage management through the strategic use of planting to facilitate rainwater attenuation and thereby reduce the risk of inundation. However, such research is not confined to North America. Rather, it forms a recurring feature in GI case studies with an international array of authors seeking to advocate the benefits of a less intrusive engineering approach to drainage management (Fryd et al., 2012; Grant, 2012; Kruuse, 2011; WWT and RSPB, 2012). These practices most commonly focus on the planning and design of existing GI assets to enhance their ecosystems services functions and the provision of new assets to facilitate increased delivery of a range of functions surrounding drainage management. Moreover, this line of research frequently extends beyond the urban environment and is also evident in case studies concerning broader catchments (CF, 2007; Ellis, 2012; Weber et al., 2006). Often associated with such studies are novel assessment methods and advocacy work that promote a GI planning approach for climate change adaptation (Foster et al., 2011; Gill et al., 2009; Lerner and Allen, 2012). These studies support the strategic use of vegetation in the built environment as a means to mitigate the urban heat island effect (Gill et al., 2007) and counter flow surges during periods of heavy precipitation (Brown and Caldwell et al., 2011; Hoyer et al., 2011; Podolsky and MacDonald, 2008).

Another prominent theme in GI research is work focused on biodiversity conservation. This work has a strong spatial dimension and is thus predictably concerned with land use governance. As noted above with respect to *spatial connectivity*, much research in this area is rooted in the concept of ‘ecological networks’ (Hasse, 2010; Jongman and Pungetti, 2004b; Kilbane, 2013; Sandström, 2008). While evident across a range of jurisdictions, there is a notable focus on such ecologically focused practices within the European Union (EC, 2007; Karhu, 2011). A significant proportion of this literature regards the coordination of national and international initiatives to address ecosystems fragmentation (Bonnin et al., 2007; Silva et al., 2010), although recent years have witnessed a growing desire for a parallel focus on more localised ecological networks in urban environments (Francis and Chadwick, 2013; James et al., 2009; Niemelä et al., 2011; Pickett et al., 2004; Pickett et al., 2008). This work seeks to demonstrate the scientific procedures and planning practices required to deliver effective ecological connectivity (Jongman and Pungetti, 2004b). Although often facilitating an array of functions, a GI approach that prioritises biodiversity conservation risks generating institutional and political friction as GI’s core principle of multifunctionality is eclipsed and difficulties arise when attempting to balance anthropocentric utility with ecological protection (Roe and Mell, 2013).

Also notable with respect to many GI practice examples is a focus on human well-being. Such work often concerns the assessment and advocacy of recreational space provision and the creation of cycle/pedestrian networks (Bird, 2004; Butler, 2012; Erickson, 2006; Maas et al., 2009; NE, 2009; Takano et al., 2002; Tzoulas et al., 2007; van den Berg et al., 2010; Ward Thompson, 2011). These studies emphasise the physical health benefits that accrue from ease of access to natural or semi-natural spaces, with some contending that such access also provides psychological benefits (Coucher et al., 2007; Tsunetsugu et al., 2013). Furthermore, recent years have witnessed the emergence of studies the seek to evaluate the benefits of ecosystems services to local economic development and advocate a GI planning approach as a means to ensure sustained local and regional economic growth (LCRP, 2010; RICS, 2011). While such studies often have a quantitative emphasis (Ecotec, 2008; LPI, 2012; Vandermeulen et al., 2011), others also advance qualitatively focused arguments for adopting a GI planning approach (AGMA, 2011).

Procedures for Green Infrastructure Planning

Reference to practice can help set benchmarks and through frequent citation generate ‘common knowledge’ (Horwood, 2011) of progressive thinking. However, practice examples often represent isolated cases ‘privileged by combinations of ownership, location and subsidy’ (Hebbert, 2009, 363). Moving GI beyond such exemplary but exceptional instances of ‘common knowledge’ and institutionalising it as ‘common practice’ requires attention to how practitioners and the public engage with planning processes. Consequently, it is vital to consider what implications a GI approach holds for the *procedures* of spatial planning. Such implications are identified and discussed below as issues concerning the requirement for greater ‘integration’ and the need to conceive GI as a ‘proactive’ planning approach to enhancing ecosystems services.

Integration

The core GI principles of connectivity and multifunctionality call on planners to concurrently achieve seemingly disparate goals such as flood control, recreational space provision and habitat conservation (EC, 2012; Novotny et al., 2010). For this reason, GI planning necessitates a spectrum of experience drawn from an array of theories, practices and opinions (Benedict and McMahon, 2006, 40). Hence, a GI approach ‘requires a co-ordinated approach from a multi-disciplinary, cross-organisational, cross-boundary team of partners’ (TCPA, 2012, 10). It is in this sense that GI planning encourages a departure from traditional modes of organisational activity wherein multidisciplinary communication is hampered by rigid professional delineations buttressed by a legacy of inflexible bureaucratic structures. As noted by Kambites and Owen (2006, 490), 'The "silo mentality" whereby different departments of a local authority work separately from each other – and occasionally in conflict with each other – is inimical to the nature of green infrastructure planning'. Moving beyond this 'silo mentality' demands long term commitment and a willingness to listen to the opinions of others whose views may not always correspond with one's own (Forester, 1999). While the format of such collaboration will likely differ between organisations and be tailored to the local institutional, socio-economic and environmental landscape, such efforts are likely to yield greatest profit when a framework for inter-disciplinary engagement exists (Huitema et al., 2009). With reference to learning from 'practice', Rouse and Bunster-Ossa (2013) show how a structured approach to creating 'partnerships' between an array of professional actors with different disciplinary backgrounds was critical to the formulation and delivery of the 'GreenPlan' for Philadelphia. Similarly, Medearis and Daesking (2012) demonstrate how coordinating the efforts of a multidisciplinary team was key to the planning, design and development of the environmentally sensitive Rieselfeld area in Freiburg, Germany.

In addition to such horizontal integration, a GI approach advances vertical integration between different levels of the planning hierarchy and across spatial scales (Allen, 2012; McDonald et al., 2005). As materials, nutrients and species rarely respect administrative boundaries, it is incumbent that broad national, and where appropriate international, frameworks are formulated to facilitate the coordinated delivery of GI networks (Jongman et al., 2004). Of particular concern is the need to generate coherent frameworks that help avoid potential mismatches between objectives at different spatial or institutional scales (Roe and Mell, 2013). Such frameworks provide the strategic spatial and land use direction shaping the production of more localised GI initiatives at regional and local levels of the planning hierarchy (CABE, 2009). The benefit of cross-scale coordination is demonstrated in practice by Primdahl et al. (2009). In their analysis of varying administrative approaches to planning each of Copenhagen's five 'green wedges', these authors show how different levels of coordination resulted in different degrees of success in the delivery of multifunctional spaces that provide an array of benefits to local residents. In particular, they note how the lack of a harmonised approach between certain local authorities resulted in greater fragmentation and the provision of relatively limited recreational infrastructure in comparison to green wedges where a more strategic approach was adopted.

Table 2: Ecosystem services benefits of GI

Sample Ecosystems Services Benefits of GI	Summary Description	Sample References
Drainage Management	Managing the flow of surface and/or subsurface water through biomimicry that uses less energy intensive and expensive engineering solutions than those traditionally employed.	Brown and Caldwell et al., 2011; Chau, 2009; Ellis, 2012; EPA, 2010; Grant, 2012; Hoyer et al., 2011; Novotny et al., 2010; NYC, 2010; Podolsky and MacDonald, 2008; Stenning, 2008; USEPA, 2004
Habitat Provision	Establishing suitable areas and environmental conditions for individual organisms and ecological communities to thrive.	Andrés-Orive and Dios-Lema, 2012; Beatley, 2010; CGIF, 2011; Erickson, 2006; Hostetler et al., 2011; Mell, 2013; Naumann et al., 2011; NE, 2009; Pankhurst, 2012; Rouse and Bunster-Ossa, 2013; Sandström, 2008; Selman, 2012; TEP, 2011; Williamson, 2003
Ecological Connectivity	Creating functionally contiguous land and water habitats that facilitate multi-scalar connectedness of ecological processes (e.g. species dispersal, nutrient transfer, hydro-ecological flow).	Allen, 2012; Benedict and McMahon, 2006; CF, 2007; Comhar, 2010; Davies et al., 2006; Flink et al., 1993; Francis and Chadwick, 2013; Hamilton and Selman, 2005; Hasse, 2010; Hellmund and Smith, 2006; Jongman and Pungetti, 2004; Kambites and Owen, 2006; Leitao et al., 2006; Silva et al., 2010; Sylwester, 2009; Walmsley, 2006
Landscape Conservation	Managing ecological processes, land uses and social-ecological interactions that define and associate a mosaic of areas across a broad scale. It involves balancing habitat provision and ecological connectivity (see above), with sustainable social and economic patterns of use.	Allen, 2012; Boothby, 2000; de Groot et al., 2010; LI, 2013; Mell, 2010; Plieninger and Bieling, 2012; Rouse and Bunster-Ossa, 2013; Selman, 2006, 2012
Health, Well-Being & Community Development	Promoting positive individual and communal physical, psychological and social conditions. This entails fulfilling and enhancing a range of different needs, including: basic requirements, (food and energy); developmental necessities (outdoor education and community development opportunities); and growth facilitation (contact with nature).	CABE, 2009; Coucher et al., 2007; Dunn, 2010; EC, 2012; EKN, 2012; Entrix, 2010; Geller, 2003; LI, 2009; Maas et al., 2009; Ong and Peterson, 2011; SG, 2011, 2012; Shackell and Walker, 2012; Takano et al., 2002; Tzoulas et al., 2007; van den Berg et al., 2010; Ward Thompson, 2011

Recreational Space (Provision & Access)	Providing ease of access to a variety of different types of recreational space, including: formal public gardens; natural and semi-natural spaces (woodlands, meadows, remediated quarries); outdoor sports facilities (playing fields, walking tracks); and community gardens/allotments.	Byrne and Sipe, 2010; Casperson and Olafsson, 2010; Erickson, 2006; Fábos, 2004; Gobster and Westphal, 2004; Hellmund and Smith, 2006; Hine et al., 2008; Jaakkola, 2012; Lindsey et al., 2001; Little, 1990; NE, 2010; Primdhal et al., 2009; van der Valk and van Dijk, 2009
Sustainable Transport (Route Provision & Access)	Ensuring access for all to infrastructure that responds to current need and accommodates future demand, yet does not endanger public health or ecological integrity.	Ahern, 1995; Benedict and McMahon, 2006; Erickson, 2006; Fábos, 2004; Flink et al., 1993; Girling and Kellett, 2005; Jaakkola, 2012; Kambites and Owen, 2006; Little, 1990; Pankhurst, 2012; Rouse and Bunster-Ossa, 2013; Walmsley, 2006
Climate Change (Mitigation & Adaptation)	Facilitating forms of planning and designing that achieves a desired state by remaining responsive to both sort and longer term change in environmental conditions.	Foster et al., 2011; Fryd et al., 2011; Gill et al., 2007; Gill et al., 2009; Kazmierczak et al., 2010; Lerner and Allen, 2012; NWCCP, 2011
Economic Development	Supporting sustained and sustainable forms of growth that improves standards of living.	AGMA, 2011; CNT and AR., 2010; Ecotec, 2008; LCRP, 2010; LPI, 2012; Mell, 2009; RICS, 2011; Vandermeulen et al., 2011

This integrative approach also entails end-user participation in the formulation, implementation and maintenance of GI assets and functions. Various practice-based case studies have demonstrated that cross-sectional community involvement in the decisions affecting their locality is essential to the success of GI initiatives (CGIF, 2011; Mayer et al., 2012; SG, 2011; Williamson, 2003). For example, Erickson (2006) identifies the involvement of multiple community groups and non-governmental organisations in the development and instigation of GI initiatives as crucial to the realisation of the Chicago Wilderness project. Likewise, Rouse and Bunster-Ossa (2013) demonstrate how community involvement was key to the formulation of plans for a regional park in Birmingham, Alabama. Nevertheless, Kambites and Owen (2006, 492) caution against the twin 'dangers of consulting only the "usual suspects" and consulting in order to get acceptance of already formulated plans'. To counter these pitfalls, it is important that public participation be commenced at the inception stages of GI proposals (SG, 2011). Moreover, Erickson (2006) notes the importance of empowering local communities to take ownership of GI planning by facilitating them as leaders in the initiation and development of GI projects.

Proactivity

A GI approach is a proactive approach. Therefore, 'green infrastructure should be planned and protected before development' (Benedict and McMahon, 2006, 41). In this way, the provision of a strategy to improve the connectivity of GI assets and enhance GI functions should structure spatial planning activity. Informing such strategies should be 'robust scientific knowledge gained from a number of fields including landscape ecology, land use planning theory and practice, and landscape psychology' (Roe and Mell, 2013, 653). Using such 'sound evidence' (TCPA and WT, 2012, 10), efforts should be made to produce comprehensive maps of GI assets from which to formulate both holistic spatial planning frameworks and site-specific initiatives (Casperson and Olafsson, 2010; Comhar, 2010; Weber et al., 2006). Nevertheless, Kambites and Owen (2006, 488) advise that if such a cartographic exercise 'is not set within an effective planning process, the mapping of green infrastructure, albeit a vital component of the process, remains little more than a technical exercise'. Accordingly, mapping GI assets is a means to an end rather than an end in itself. In this sense, maps form tools which aid rather than replace critical engagement with a GI planning approach.

Ahern (1995; 2007) offers some assistance here by proposing a four-fold typology of spatial strategies that practitioners may employ when involved in GI planning activities (see Table 3). These strategies focus on 'protective', 'defensive', 'offensive' and 'opportunistic' approaches to spatial planning. Each requires close attention to multifaceted vertical and horizontal integration, land use zoning, the formulation of issue-specific policies and the designation of site-specific objectives. When taken in combination, these strategies can inform different types of planning interventions in different locations at different times. In reflecting the GI principle of 'context sensitivity', these alternate approaches can thus be deployed in accordance with their appropriateness to the social and environmental circumstances at hand. In confirming the assertions of Braat and de Groot (2012), sensitive application of these strategies may thereby provide ways to enhance the 'structures' (assets) and 'functions' that provide ecosystems services benefits, rather than simply mitigating the pressures upon such services. Consequently, the strategies can be employed to help translate the *principles* of a GI approach into planning *procedures* by learning from and informing *practice* on how ecosystems services may be enhanced via spatial planning.

Table 3: Typology of Spatial Strategies for GI Planning

<table>
<tr><th rowspan="2">Principles</th><th colspan="3">Procedures</th><th rowspan="2">Practice Examples</th></tr>
<tr><th>Background Requirements</th><th>Spatial Strategies</th><th>Summary of Spatial Strategy</th></tr>
<tr><td rowspan="4">Connectivity (spatial, scalar, institutional)

Multifunctionality

Context Sensitivity

Collaboration

Prioritize GI</td><td rowspan="4">Integration (functional, spatial, scalar, institutional)

Partnerships (inter-disciplinary working, end-user participation)

Proactivity</td><td>Protective</td><td>Taking preventative measures to preserve GI assets and functions before they are threatened by erosion or change by development.</td><td>• Creating national parks and nature conservation sites
• Flood plain designation
• Greenbelt, wedge, corridor designation</td></tr>
<tr><td>Defensive</td><td>Taking measures to defend GI assets and functions that are already suffering attrition from development pressure.</td><td>• Creating buffer zones
• Environmental impact mitigation
• Formulating green space access standards</td></tr>
<tr><td>Offensive</td><td>Taking remedial or restorative actions to repair or replace GI assets and functions.</td><td>• Creating new GI cores and corridors
• Ecological restoration
• ‘Daylighting’ culverted watercourses
• Environmental adaptation initiatives
• Enhancing and/or providing access to existing green spaces</td></tr>
<tr><td>Opportunistic</td><td>Recognizing the potential for comparatively non-contributing landscape elements to be managed or structured differently to enhance the assets and functions of a GI network.</td><td>• Biodiversity enhancement initiatives
• Sustainable drainage schemes
• Greenways projects
• Urban greening initiatives
• Initiating ‘GI plan’ production</td></tr>
<tr><td></td><td></td><td colspan="3">Adapted from Ahern (1995; 2007)</td></tr>
</table>

Conclusion

In essence, the GI approach represents ‘a philosophy or organizational strategy that provides a framework for planning conservation and development’ (Benedict and McMahon, 2006, 15). With a focus on improving the multifunctional potential of connected local and landscape scale environmental assets, it furnishes ‘the “umbrella” for disciplines to unite’ (Wright, 2011, 1011) and consequently promotes ‘increased dialogue between planners, developers, and policy-makers’ (Mell, 2010, 241). A GI approach focuses on positive synergies. It facilitates working on numerous schemes at various scales that reinforce each other’s spatial and functional attributes in a variety of ways. Establishing a holistic GI framework for connecting these initiatives provides the means through which such endeavours generate long term cumulate impacts that are mutually beneficial to both society and the environment. In doing so, it is contended that the GI approach offers an effective means to operationalise the ecosystems services paradigm in spatial planning. However, such a GI approach moves planning beyond a simple recalibration of contemporary modes of thinking and doing. Rather, it involves a ‘transformation’ in the ways spatial planning systems are structured and how practitioners conceive the world in which they act in and upon. To embrace these challenges we argue for an ecological turn in spatial planning theory and practice. This involves developing and refining ecological principles to inform planning policies and processes. It entails a re-scoping of spatial planning practice to place ecology, ecosystem services and environmental risks as central concerns of planning practice. Such an ecological turn also necessitates devising more effective procedures to ensure better ecologically sound outcomes in the planning process, which may require an institutional culture change and an expanding of core competencies of professional planners. In this regard, green infrastructure has potential to provide a key discursive storyline, acting as a powerful metaphor for an ecosystem services approach – in other words, it places ‘green infrastructure’ in a similar position to traditional physical ‘grey’ infrastructure in terms of requiring investment and provides a positive, proactive narrative rather than traditional ‘preserve and protect’ conservation approaches.

Although possessing deep roots in the history of landscape ecology, recreational planning and human ecology, GI planning is nevertheless a nascent approach. Consequently, experimentation and continuous learning characterise GI planning activity. In this sense, Erickson (2006, 290) advocates a ‘strategy of taking small steps, building support, demonstrating successes, and then tackling more’. Be it in the transfer of novel assessment techniques from Berlin to Malmö and Seattle (Kruuse, 2011), or the expanded application of lessons learned from previous strategies (GLA, 2012), a responsive and collaborative approach to new knowledge must continue to typify the GI approach. This review has attempted to demonstrate that there is a growing wealth of such knowledge regarding the theory and practice of GI planning. In collating and distilling the central messages from the forefront of GI thinking, this review contributes to an enhanced understanding of *principles*, *practice* and *procedures* of a GI approach. In doing so, it is hoped to buttress and advance the emerging ‘ecological turn’ in spatial planning.

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