

ORIGINAL RESEARCH PAPER

Explanation of Green infrastructure principles of landscape in order to sustainability^{1,2}

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ABSTRACT: Green infrastructure provides a contemporary approach to the conceptualization and management of landscape resources. The attention given to growth in green infrastructure has been backed up by the evolution of a number of overarching principles that provide green infrastructure research with a multi-layered understanding of the shifting nature of landscape resources. The object of research outlines the complex nature of green infrastructure development, its meanings, its perception in the landscape and use as an approach to landscape planning. Three central topics are distinguished. Firstly, by exploring variations in the imports of green infrastructure, the second explores the role of perceptions in the value and the role of green infrastructure resources and last one discusses the current green infrastructure use by practitioners. The varied shades of green infrastructure are outlined and an assessment is made of how the principles of green infrastructure have been translated into appropriate landscape management. In this study identify a number of conceptual and execution principles for green infrastructure. Founded on these discussions, this study suggests that a green infrastructure approach to planning can be practiced to take on the complex challenges of current landscape planning. With continued growth of green infrastructure, some of the most pressing topics in preparation, such as green space planning or sustainable urban development, can be discussed and These issues are discussed throughout the inquiry and clear links are drawn between this exploratory green infrastructure research and planning exercise.

Keywords: Green infrastructure, landscape resources, perception, landscape planning, sustainable urban development

RUNNING TITLE: Green infrastructure principles of landscape

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INTRODUCTION

Today, many historical centers of cities suffer from social, cultural, economic, and environmental depression and they are degenerating (Hwang, 2014). In the course

of this movement, the old centers with their historical and ethnic factors which are emblematic of the city's ethnic heritage and cultural heritage richness. Referable to the economic position of the occupiers and the lack of appropriate programs, these grains have no ability to deploy in the urban development cycle. As a consequence, many

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of the physical, social, and cultural assets existing in this old centers are degenerating today. These substances are gradually faced with economic and social problems, such as the rise of inactive areas and the recession of social capital. While in line with the necessity of debating the inclusion of culture in urban plans and policies, many scholars have acknowledged that with the advent of post-industrial change and the emergence of urban competition topics, profound changes have been taking place in the ways in which social and economic values were created which culture makes for a new and important role (Scott, 2000). As culture has been capable to provide the appropriate choices to bring out of the inspirational elements, including the introduction of appropriate concepts and scales for interventions from the position of urban politics (Landry, 2006). As in point of views of some scholars (Seifert & Stern, 2007; Bianchini & Ghilardi, 1997), cultural preparation is one of the most commonly used responses to developments in post-industrial urban centers. However, today, most urban managers and planners don't have a deeply perception about the seat of culture, history and cultural resources as a creator and valuable factor in the planning and execution of urban projects. Also, in most of the documents of urban evolution and at the phase of making the landscape of designs, cultural components don't have a special place; Therefore, in that respect is no paying attention to the development impact of culture on the character of life and performance of the place is not perceptible. Culture has still been ignored as a missing link in these plans and there is no program for easing of cultural and historical capital to create the elastic, multi-functional and competitive spaces. Instead of protecting historical-cultural identity, these programs focus more on land development and don't use of the historical function and cultural potential in advancing the competitive ability of the urban centers. Many of the implemented plans of attacks are unable to entrance of historic edifices and structures to the conception of capital; So far, most tasks have focused on agile and immediate revenues and away from cultural and social capacities; As a consequence, more stress was placed

on economic value creation than on creating capital. The cause for this is the ambiguity of how the civilization is linked to economics, income, and social capital. In fact, there is still no perception that culture is an urban capital and regeneration can't succeed without regard to this gene and can't be a loyalty to historical and cultural issues (Lotfi, 2011). That is why local residents have usually pushed away during the most of renovation projects; This process is destroying social networks and cultural assets which have collected over the years in the area (Lee, 2012).

The research questions themselves are split into three sections and link up to the rubric of the dissertation. These parts are green infrastructure, environmental perceptions and spatial planning, each of which is discussed firstly as independent areas of research and then collectively to show the relationship between these. However, although empirical data relating to each specific area has been developed, the overarching questions outlined in this part are debated across each green infrastructure theme. Although the whole thesis reviews green infrastructure development, the first area of research specifically examines the comparable and contrasting definitions, meaning and values placed upon it. Thus, the research questions outlined below explore the diverse and sometimes contradictory interpretations of green infrastructure to assess where there are parallels and differences between academic, practitioner and policy research.

MATERIALS AND METHODS

Green infrastructure

Although there has been a relatively rapid development in green infrastructure research, there are still questions as to what 'green infrastructure' is as a concept and as a landscape delivery mechanism. Some authors have even queried the validity of a green infrastructure approach to landscape planning as simply 'old wine in new bottles' (Davies et al., 2006:6). Moreover, a number of authors debating green infrastructure has considered it as a redevelopment of existing concepts relating to

green space planning (i.e. MacFarlane, Davies and Roe, 2005). However, there is an important semantic element to this debate that questions the validity of the term ‘green infrastructure’ as the correct terminology for the elements it is said to represent. Both the term ‘green’ and ‘infrastructure’ have been discussed and presented elsewhere as offering a range of contrasting and sometimes contradictory meanings (CABE Space, 2005). As such, the concept is still fraught with contradictions.

Examples of the disparity between the proposed definitions of green infrastructure can be seen in the research of TEP (2005:1), Benedict and McMahon (2002:12), TCPA (2004:6) and Williamson (2003:4).¹² Each of these offers a definition that emphasizes a diverse range of components that constitute green infrastructure and delve into what Davies et al. (2006:6) call a semantic pick-and-mix of theories and terminology. Consequently, the Green Infrastructure North West website proposes that green infrastructure ‘...differs from conventional approaches to open space planning because it considers multiple functions and benefits of green space in concert with land development, growth management and built infrastructure planning’ (Green Infrastructure North West, 2006, <http://www.greeninfrastructurenw.org.uk>).

These contrasting definitions raise important questions, such as what constitutes green infrastructure and in which theoretical discipline should it be located? The term ‘green’ can be used to reflect the environment, environmentalism, nature or recycling, but can also be viewed as a Marxist or Feminist concept (Dobson, 1995; Benedict and McMahon, 2006; Dapolito Dunn and Stoner, 2007). ‘Green’ has strong connotations with the environment, but Professor Mark Shucksmith questioned the green value or emphasis of green infrastructure. In answer to Shucksmith, the work of Williamson (2003) and Ahern (2007) can be presented to support the use of the term ‘green’ in green infrastructure, emphasizing the ecological functions associated with the concept. The work of Benedict and McMahon (2002, 2006), TEP (2005) and the Town and Country Planning Association (TCPA,

2004) could also be used as they propose an ecological viewpoint of what ‘green’ infrastructure presents, but note that different landscape elements at different spatial scales also constitute green infrastructure. These authors highlight that ecological elements and the role of natural resources as integral to what ‘green’ infrastructure is. Furthermore, ODPM (2005) noted that ‘green’ infrastructure can also play a role in promoting sustainability.

Definition of Green Infrastructure

There are currently as many definitions of green infrastructure as there are authors working on the concept.¹⁴ As in most academic and practitioner research, the definitions used by an organization or an author relate directly to the focus of their own green infrastructure research. Conservationist authors (i.e. Benedict and McMahon, 2006) strongly emphasize the ecological and biodiversity components, planners may review the concept in terms of policy implementation (i.e. Ahern, 1995; Fábos, 1995), while recreational Greenways and green infrastructure specialists may focus on the benefits gained through development (i.e. CABE Space, 2005a; Kleiber, Hutchinson and Williams, 2002).¹⁵ However, although there is an almost ever-increasing diversity in the definitions developed for green infrastructure, there are common themes which underlie each of them. Below, the Countryside

The broad scope offered by the Countryside Agency’s¹⁶ definition may, however, be a representation of the organization’s broad remit rather than a lack of focus in their green infrastructure thinking of both a policy and a delivery level. The definition also highlights the complexity of defining what green infrastructure is. By noting the role of different ecological and social systems, the Countryside Agency promotes the view that green infrastructure can be an all-encompassing approach to planning that can be used by a diverse range of practitioners. A further comparison of the complex nature of the green infrastructure concept can be made by examining a selection of other definitions (Table 1).

TEP (2005)	Green Infrastructure: the physical environment within and between cities, towns, and villages. The network of open spaces, waterways, gardens, woodlands, green corridors, street trees and open countryside that brings many social, economic and environmental benefits to local people and communities.
TCPA (2004)	Green Infrastructure is a sub-regional network of protected sites, nature reserves, green spaces and greenway linkages. Green Infrastructure should provide for multi-functional use...it should operate at all spatial scales from urban centers through to open countryside.
Benedict and McMahon (2002)	Green Infrastructure is an interconnected network of green spaces that conserve natural ecosystems values and functions and provides associated benefits to human populations. Green Infrastructure is the ecological framework needed for environmental, social and economic sustainability.
Williamson (2003)	Our nations natural life support system – an interconnected network of protected land and water that supports native species, maintains natural ecological processes, sustains air and water resources and contributes to the health and quality of life for America’s communities and people

Tab 1: Green infrastructure definitions and principles

From the definitions presented above, the following elements are seen as being frequently reported as constituting green infrastructure: access, spatial variance, multi-functionality, natural and human benefits, biodiversity, sustainability, and connectivity. Each of the four definitions above notes that green infrastructure is, or should be, part of a wider ecological network linking different ecological features. These features range from the specific landscape elements noted by TEP and the TCPA to more general uses of the term ‘green spaces’ as noted by Benedict and McMahon and Williamson. Therefore, it can be suggested that one idea consistently found in definitions of green infrastructure is the role of connectivity and the development or maintenance of wider green infrastructure networks.

Secondly, each of the four definitions specifically mentions the wide-ranging benefits green infrastructure hold. Benedict and McMahon note the benefits humans can gain from green infrastructure, whilst TEP present three proposed spheres of benefits, namely social, economic and environmental. TEP thus note that green infrastructure should not be thought about as providing benefits for only one sphere of influence but for a number concurrently.

In the wider debates relating to green infrastructure, this point may be central to promoting the concept as a practical approach for delivering multiple and diverse benefits. The proposed benefits noted by TEP show similarities with the sustainability agenda of ODPM highlighting the need to discuss economic development, social justice and environmental protection in a collective context with green infrastructure (TEP, 2005; Campbell, 1996; ODPM, 2003). The role of multiple benefits is further highlighted by the role sustainability plays in the definitions of TCPA and Williamson. Both note that the uses of landscape designation or protected landscape status are important components of green infrastructure, placing the broader targets of conservation policy at the center of the concept. Benedict and McMahon go further than TCPA and state that green infrastructure should provide a high level of environmental, social and economic sustainability. The role of sustainability in defining green infrastructure has also been noted by ODPM, who stated that functional green infrastructure is needed to create a positive sense of place, provide environmental protection and enhance the quality of life for those who live and work there (ODPM, 2005).

ODPM, therefore, propose that they believe

green infrastructure has a role to play in developing sustainable places by outlining the need to develop quality landscapes and protect human and ecological components of the natural and built environment. The need to develop better places to live through the creation of multi-functional and connected

environments has also been noted in the work of [Davies et al. \(2006\)](#). In their research, multi-functionality is viewed as a process of delivering multiple benefits on the same site, aiding social inclusion, health, education and improving a sense of place. (Table 2)

	Benedict and McMahon (2002)	Countryside	Countryside Agency and	Davies et al. (2006)	Gallent et al. (2004)	Gobster and Westphal (2004)	Lindsey et al.	ODPM (2003)	TCPA (2004)	TEP (2005)	Weber, Sloan, and Wolf (2006)	Williamson (2003)
Accessibility			X		X	X						
Concept and a resource	X	X		X								
Connectivity and networks		X							X	X	X	
Integration of different cross-boundary ideas (people places and policy)												
Multi-functionality	X	X	X	X		X		X		X		
Multiple benefits	X	X					X	X		X		
Planning	X	X	X	X				X	X	X	X	
Scale		X						X				
Sustainability	X	X						X				X

Tab 2: Actor interpretations of what constitute principles of green infrastructure

The discussion of several different definitions of green infrastructure above highlights that the concept holds a panoply of meanings. However, as noted previously in this study, there are a number of principles that underpin the concept. Firstly, green infrastructure provides connectivity between different places ([Williamson, 2003](#); [Weber, Sloan and Wolf, 2006](#); [TEP, 2005](#); [Benedict and McMahon, 2002](#)).

secondly, they provide multiple benefits for a number of diverse user groups ([Lindsey et al., 2001](#); [ODPM, 2005](#); [Gobster and Westphal, 2004](#)); thirdly, green infrastructure has the potential to act as natural resources, whether a sink or reservoir, for large-scale environmental

systems; and, fourthly, green infrastructure should be used to develop interconnected networks of accessible and functional open spaces ([Gallent et al., 2004](#); [Hidding and Teunissen, 2002](#)). Each of the areas noted above in [Table 2.2](#) is proposed as being central to the construction of green infrastructure as a practical delivery mechanism and support the development of a new working definition of green infrastructure that will be used throughout this research

Green Infrastructure typologies

Within discussions of any green space planning practice, an examination must be made of how the spaces are composed. [Davies](#)

et al. (2006) developed a typology that they felt could constitute green infrastructure. This typology, developed using stakeholder participation, outlined that green infrastructure is made up of a number of diverse landscape features and components¹⁸ and presented a number of classifications proposed to hold a ‘green’ value. The Davies et al. typology system mirrors work developed by Ahern in his classifications of Greenways. Ahern based his typology classifications on issues of scale, goals, landscape context and planning strategy rather than on elements or issues discussed in reference to the development of the green infrastructure concept (Ahern, 1995).

Using Ahern’s typology to assess green infrastructure provides an opportunity to explore the

difficulties in categorizing green spaces. Different landscape elements, for example, cemetery, may be managed to provide a site for reflection and spiritual respite but could be located in an ecologically important landscape. It may, therefore, be imperative

in the development of green infrastructure to acknowledge the variance in land use and actual land classifications. The Royal Commission for Environmental Pollution (RCEP) have also attempted to develop a typology for green infrastructure (RCEP, 2007). The RCEP outlined the categories as formal, informal, green space corridors, strategic green spaces, sports grounds and public-private spaces as their broad classifications of what constitutes green infrastructure. When compared to the stakeholder analysis of Davies et al., this system compares favorably. It also highlights similarities to the use of the National Land Use

Database (NLUD) classifications system (Figure 1) These classifications can be assessed alongside Ahern’s typologies of landscape context and scale as the differences in size and function of each element allows it to be classified according to a number of conceptual ideas into specific classifications. Consequently, the classifications of specific elements (developed through context, scale, and goals) provide a framework through which green infrastructure elements can be defined.

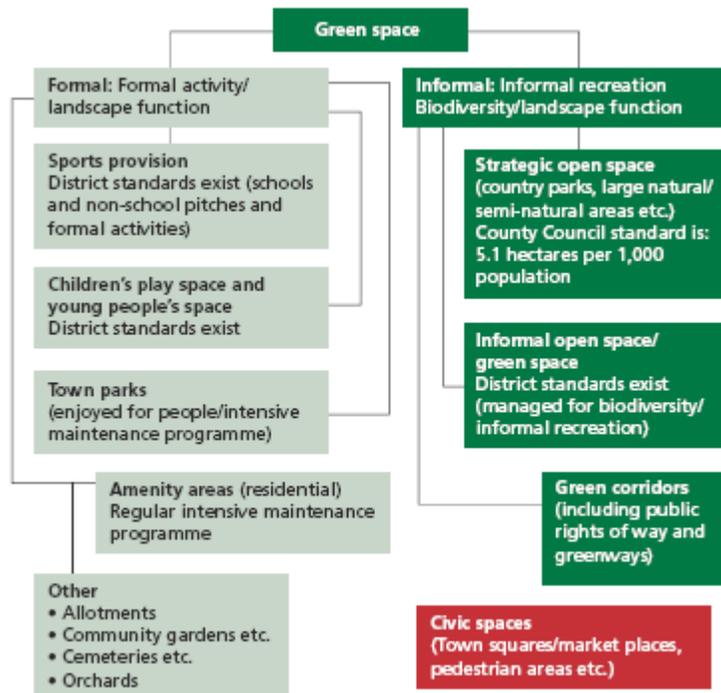


Fig 1: NLUD (a) and RCEP (b) land use and green space classifications

NLUD Land use classification

Order	Group
Agriculture and fishers	Agriculture 1-1
	Fisheries 1-2
Forestry	Managed forest 2-1
	Un-managed forest 2-2
Minerals	Mineral working 3-1
Recreation and leisure	Outdoor amenity and open spaces 4-1
	Amusement and show places 4-2
	Libraries, Museums and galleries 4-3

It is, however, important to state that, without a clear idea of what green infrastructure is made up of, it is difficult to debate the different semantic and disciplinary values of the concept. A green infrastructure typology, therefore, needs to be

discussed in conjunction with the literature, assessing both its conceptual basis and its value to landscape management practices. Furthermore, the complex, ecological, political and social influences of its development can also be reviewed. An assessment of this kind, therefore, allows an examination of the underlying principles (e.g. connectivity, multi-functionality, and access) to be reviewed.

Finally, Ahern also noted that green infrastructure is currently at a point in its development where its future success lies with its supporters. Ahern suggests that, as the world is in a state of constant change, the big opportunity is due to the necessary reconstruction of existing infrastructure and the possibility to build infrastructure in a ‘green’ way (Ahern, 2007 personal communications; Nelson, 2004). Ahern himself updated his research on Greenways and applied a similar typology to that proposed for green infrastructure. (Table 3)

Typology classification	Element or function
FORM	<i>Ecological</i> (physical space, connectivity, elements) <i>Economic</i> (costs of space, design) <i>Social and cultural norms</i> (users of a space, aesthetics of a space, motivations)
FUNCTION	<i>Ecological</i> (biodiversity, conservation) <i>Economic</i> (industry, business, regeneration) <i>Social</i> (education, recreation, health)

Tab 3: Proposed typology classifications

The role of green infrastructure as a diverse set of landscape elements thus provides it with an inherent ability to adapt to a wide range of research and planning scenarios. The level of adaptability also enables the concept to be discussed by a range of users who can incorporate elements of the concept into their own work. Consequently, a range of landscape elements can be considered green infrastructure due to the diversity in form, function, and location, plus it can also be viewed as multifaceted or scaled.

Sustainable Communities

The migration of people towards urban areas in the United Kingdom, like many other urbanized

nations, has placed increasing pressures on the development of the landscape (Hiding and Teunissen, 2002; Burdett and Sudjic, 2008). The pressure being witnessed in urban centers is also now being felt at the urban-fringe, where sprawl and the development of polycentric networks of residential and industrial land have lowered the availability of land for development (Sir Peter Hall, 07/04/2006; Davis, 2006). The rate of global urban sprawl has been compounded by developments in transport and communication infrastructures that have allowed people to commute over greater distances. In turn, this has led to a greater demand for housing, transport, communication developments and other

essential services. Thus, the cycle of increased development and demand has placed increased pressures upon green and brownfield sites to serve the changing nature of the population (Peet and Watts, 1996; Barnes, 2005).

The continued growth of urban areas has led ODPM (2003) and DTLR (2002) to suggest that the nation's population is now 80-90% urban based. This figure was reported by ODPM (2003) as placing disproportional pressures onto both service and green infrastructure in areas of growth, i.e. in South- East England, and has moved traditional urban-rural problems into the urban-fringe (Countryside Agency, 2006). Migration into urban centers to access employment, education, housing, and health care has long been associated with economic growth and has been seen in the UK since the Industrial Revolution (ODPM, 2003; Dennis, Henriques and Slaughter, 1969). However, there has been a counter-movement of people away from urban centers to escape the pollution, population densities and stresses of urban life (Fábos, 2004). Migratory trends, firstly towards and subsequently away from urban centers, has raised questions concerning the quality and fragmentation of urban and urban fringe landscapes (Hidding and Teunissen, 2002; ODPM, 2003). As a positive move in attempting to ameliorate these problems, a growing research literature reviewing sustainable communities has developed. This literature reviews how migration into and away

from urban cores has affected both the physical and social landscape of the UK (Melbourne, 2004; Power and Wilson, 2000). Moreover, this research has investigated those factors that influence community development in order to make sustainable places. In response to this research, ODPM has championed research and policy aimed at creating better places to live, work and recreate, culminating in the Sustainable Communities Plan (ODPM, 2003).

Sustainable Communities, although a relatively new term in the UK, is not a new idea in North America where Smart Growth has been extensively promoted. The Smart Growth agenda proposes reinvestment in existing landscapes to develop more efficient mixed-use communities as the main element of developing sustainable places. In a UK context, the Sustainable Communities remit includes the development of communities around integrated housing, commercial and essential infrastructure serving a variety of different income groups (Geller, 2003). In Figures 2.5 and 2.6, the main elements of both agendas can be seen. This figure shows that the integration of community economic and environmental agendas can promote livability, environmental equity and sustainable development (Shafter *et al.*, 2000). Consequently, Sustainable Communities, like sustainable development, are being proposed as an amalgamation of a number of complex relationships between multi-scale actors and influences. (Figure 3,4)

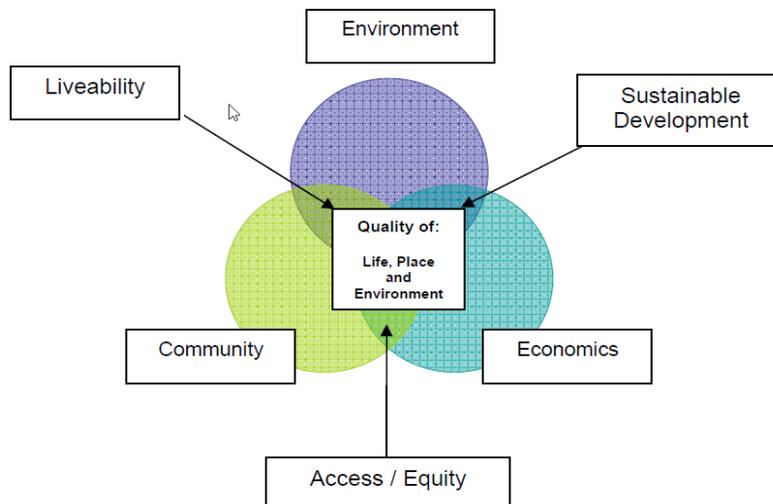


Fig 3: Components of what makes a quality of place system (based on Shafter *et al.*, 2000)

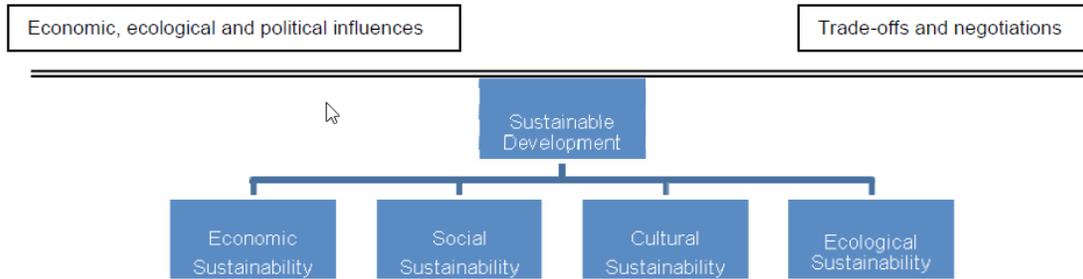


Fig 4: Elements of sustainable development: adapted from Rannikko (1999)

RESULTS AND DISCUSSION

The principles of green infrastructure

Ecological networks and green infrastructure

Ecological networks are those elements within the landscape that have the functional role of connecting different ecological features to form wider networks (Liu and Taylor, 2002). Although every environment functions differently, there are overarching themes that link ecological networks and the benefits they hold for green infrastructure thinking. One of the core principles of ecological networks is the formation of connective networks that allow migration and movement (ecological, economic or social) by connecting a number of supporting systems within a polycentric matrix (Farina, 1998). Thus, in a comparable way to how grey infrastructure has been used to link people, places, and the environment, ecological networks can be used to link different ecological elements. Within the literature reviewing ecological networks, a series of benefits examining this process has been discussed aiding the sustainable development of landscape resources. These include the provision of opportunities for ecological and human mobility, species diversification, maintaining or increasing biodiversity, and the ability to aid the stabilization of ecological systems by making additional resources available (Forman, 1995; Liu and Taylor, 2002). Each of these factors is assisting what Jongman and Pungetti (2004:4) call an ecological support system within human orientated landscapes. The literature also proposes a number of ideas that support the green infrastructure concept and include how networks can reduce landscape fragmentation

by connecting smaller networks, aiding the connective nature of larger networks, e.g. Patch-Corridor Matrixes (Forman, 1995).

Fragmentation

Landscape fragmentation and isolation has been discussed within landscape ecology as one of the main principles supporting network theory (Forman, 1995). Both Forman and Almo Farina (1998) have discussed how landscape fragmentation is a continuous phenomenon in the relationship between ecological and human influences. This is a dynamic relationship, especially since humans started to develop wider tracts of land for industry, commerce, and housing. With the process of land development, ecological patches have become increasingly fragmented, which has resulted in the development of fragile (or balanced), isolated and homogeneous elements (Peters et al., 2006; Dramstad, Olson and Forman, 1996). Consequently, each landscape element in a fragmented system becomes progressively more isolated as it develops independently of other systems. Laurence (1999), however, suggest that the creation of network systems is a process that can reduce the fragmentation of a landscape and reduce the stresses of development by allowing alternative capitals to be brought into a system. The roles of isolation and homogeneity are also noted by Peltonen and Hanski (1991) as holding both a positive and negative effects on ecological networks. They highlight how isolation enables stable and secure populations to emerge that may be threatened by higher order species if linked to wider networks. Beier and Noss (1998) also suggest a theory questioning the beneficial role of larger network systems as a positive

factor for smaller populations. Alternatively, Cook (2002) and Henein and Merriam (1990) presented the positive role that connecting landscape fragments have for ecological and human populations. The role of connecting landscape elements has also been derived from the theory of Island Biogeography (MacArthur and Wilson, 1967). Island Biogeography states that within a given landscape there is a causal relationship between the current species or biodiversity level and that of colonizing species. This theory proposes that colonization and extinction are fundamental components of isolated systems that can lead to a state of equilibrium between ecological resources and the population residing there. In terms of landscape fragmentation, Island Biogeography reviews isolation as the main conceptual idea supporting the processes of a given space. However, Huggett (1995) questioned whether true island isolation is possible with the progressive integration of patches following the development of new landscape networks. Island Biogeography, therefore, outlines the relationship between the landscape and its supported populations within a proposed isolated state. However, as Huggett states, whether it is possible to truly describe a space as isolated from the surrounding systems is contested, as it is difficult to be spatially isolated because of the numerous ways in which energies, capitals and populations can move across landscape boundaries. Landscape isolation and fragmentation are therefore important principles of a systems approach to landscape connectivity. The role fragmentation has played in the development of landscape ecology and ecological networks can be shown through the Patch-Corridor Matrix Model described by Forman (1995). In this system, (see Figure 2.7 and Figure 2.8) a number of links, hubs and nodes combine to support the ecological populations of a system. The matrix itself is the wider location or landscape in which hubs, nodes and corridors are found that provides further resources that can be used in other hubs or corridors. Cook (2002) suggests that this enables a wider range of benefits to be developed within a given system.

The system is simple in terms of its use of

natural landscape features, e.g. woodland or fields (nodes) and uses features such as riparian corridors (links) to connect them. Moreover, ecological networks aid the assimilation of smaller systems with larger systems. The Patch-Corridor Matrix Model, therefore, stresses the importance of natural processes in developing the spatial configuration of the landscape. The maintenance of this system is crucial if the ecological integrity of the landscape is to be preserved. Anna Stanton supports this view, highlighting that ‘each element can itself be a system; and each system can be an element in a larger system’ (Stranton, 2006:404). Fragmentation is, therefore, an important issue in ecological networks debates and, through the development of networks, landscape isolation can be lowered and larger systems can be connected. Green infrastructure may also have a role to play in this debate due to its ability to take many different shapes, sizes, and forms. These infrastructures may, therefore, fulfill the numerous roles of hubs or corridors (Benedict and McMahon, 2006).

Mobility

Almo Farina states that the ‘spatial arrangement of patches, their different quality, the juxtaposition and the proportion of different habitat types are elements that influence and modify the behavior of species, populations, and communities’ (Farina, 1998:12). Farina notes that within discussions of ecological networks there is a fundamental relationship between ecological networks and human populations which impact directly on each other. Farina also discusses the role mobility holds in discussions of ecological networks. If linking fragmented landscapes is one element, then a second is the ability of both ecological and human populations to move freely through these systems. Peltonen and Hanski (1991) also add that, although some authors (e.g. Cook, 2002) may question the sustainability behind increased access, they believe that larger networks offer potentially larger benefits because of the spatial diversity of accessible landscape features that offer more choice. Botequilha Leitão and Ahern (2002) present similar findings, noting that environmental sustainability relies heavily on the relationships

between landscape elements, biodiversity, and human interactions. Therefore, the development of networks within a landscape provides a greater number of potential areas for inputs that allow capital to flow freely between them. Thus the role of movement for ecological (E) and social (S) capitals is heavily linked to the physical availability of links and their social use.²⁴ Laurence and Laurence (1999) use this theory to assess the movement of arboreal animals, stating that allowing different species to colonize and migrate may actually lower environmental stresses. Although their work offers a very specific ecological example, it highlights how colonization and dispersal can potentially provide additional resources to mitigate against the stresses of development or environmental change.

Landscape Connections

The third proposed principle of ecological networks is the role of connecting landscapes. Although this area was addressed in the assessments of lowering fragmentation and mobility, landscape connectivity is seen as a vital element of network theory (Laurence and Laurence, 1999). Henein and Merriam (1999) support this view, stating that landscape connectivity is integral to effectively allowing populations to disperse. Jongman, Kulvik, and Bristiansen (2004) have also suggested that one of the main functions of a landscape is connectivity and connectedness. However, Beier and Noss (1998) present a note of caution by questioning whether the modifications made by humans to the environment generate further benefits or whether they actually hinder the process of connectivity. Herein lies a fundamental issue within green infrastructure: should ecological processes be viewed as independent ecological systems, or is green infrastructure a confluence of human behavior working with or using ecological networks?

Forman and Gordon (1986) state that there should be an ecological emphasis placed upon connectivity. However, Benedict and McMahon (2006) have suggested that human influences are now crucial in these interpretations.

Landscape connectivity in terms of the work of Benedict and McMahon, therefore, implies connecting both ecological and human populations across different boundaries. To focus this argument within a planning context, Botequilha Leitão and Ahern (2002) note that connectivity is fundamental to the spatial concepts that support land-use planning and conservation. The integration of ecological networks, human influences and spatial distribution developed in landscape ecology has, therefore, also become a key element in the development of green infrastructure.

The role of multi-functionality in the development of green infrastructure

In the previous two sections, ecological networks and connectivity were discussed as two of the main conceptual ideas underpinning green infrastructure. This third section reviews the role of multi functionality as a key idea in developing green infrastructure. Multi-functionality has been used most frequently in terms of green infrastructure as a way of ensuring that landscapes create a better quality of life, place, and environment. This has been, to some extent, achieved through a process of integration and interacting within current governance and planning structures (Selman, 2002). The interaction of practitioners, planners, and decision-makers has led to a number of areas being highlighted in the discussions concerning multi-functionality. These issues include the integration of different development agendas with planning policy frameworks; the need to understand landscape diversification when dealing with the development of multi-functional spaces; and an awareness of the ecological, economic, and social influences that promote multi-functionality (Kambites and Owen, 2007). An acknowledgment that multi-functional spaces may also lead to access to multiple economic, ecological and social benefits also needs to be made (Blackman and Thackray, 2007). Planners and policy-makers may also need to discuss the role multi-functionality can play in promoting cultural and economic links between people and the landscape.

The need to develop landscapes that provide

functions for a number of demographic groups has been promoted widely. Through the development of Greenways, urban forestry, and urban greening, multi-functionality has become broadly accepted as one of the main tenets of green infrastructure planning (Little, 1990; Ahern, 1995; Beatley, 2000; Konijnendijk, 2003). Each of these authors suggests that the ability of a multi-functionality approach to landscape planning to be integrative at a number of different scales enables the delivery of what Konijnendijk et al. suggests are green elements fulfilling the many functions of physical infrastructures (2006:99). Matthews and Selman (2006) also theories on the benefits of multi-functionality, stating that it has aided the move away from single-use spaces in order to provide a broader range of benefits for a wider target.

Diversification

The role of integrating different policy agendas holds a critical role in discussions of multi-functionality. However, several authors have noted the role diversification plays in developing landscapes as a practical way of managing change in the environment (Countryside Agency, 2003). Davies and Scurlock (2004), for example, suggest that perceptions of the landscape and their subsequent use are influenced by the changes seen in cultural, ecological and economic influences. They see multi-functionality as a method of mitigating these changes by providing additional opportunities for landscape use. Matthews and Selman (2006) also suggest that the flexible nature of multi-functional planning allows a physical landscape to develop its ecological, economic and social capitals and consequently raise its capacity to cope with change. Selman (2002) supports this view, presenting the idea that an understanding of the ecological, economic and social capacity of an environment allows planners to develop spaces that value each element of the landscape as a singular system but also as part of the whole.

Accessibility to resources

Access to a wider resource base is one of the

proposed primary functions of multi-functional spaces. The CIAT mandate is one of the best examples, showing how different organizations describe landscape access and its functions simultaneously. A more in-depth discussion of CIAT will be presented in section 2.8; however, it promotes the diversification of landscape functions providing better access to activities or opportunities for the populations who use these sites. These benefits can be ecological, economic or social, but are proposed as a method of creating interactive spaces that aid the quality of a place and consequently the quality of human well-being. The accessibility and availability of resources are at the center of the CIAT agenda as it proposes that the utility of the landscape is fundamental to its sustainable use. Consequently, the roles of multi-functionality, location, landscape form and connectivity are important elements in this discussion (Gallent et al., 2004; CABE Space, 2003).

The three areas outlined above have all promoted multi-functionality as a method of integrating and providing a broad range of benefits to a wide target population. Konijnendijk (2003) and Konijnendijk et al. (2006) examined the role multi-functional spaces provide in linking places and summaries that the broad range of benefits and opportunities green infrastructure provides actively encourages people to use them. Spaces can, therefore, link people across spatial boundaries because of the actual location of a resource, which may increase the capacity of the landscape to cope with this need. Konijnendijk (2003) has also stated that multi-functional planning, as outlined previously, allows different organizations to work across physical and administrative boundaries. Finally, the Countryside Agency (2003) states that landscape multi-functionality also aids the movement of people across physical spaces by providing a range of opportunities and benefits for the user. This, they state, allows people access to urban and rural landscape networks with the knowledge that they will benefit from their movement. Overall, multi-functionality has been described in the research literature as the ability to provide a wider range of opportunities and benefits (demographic, financial or ecological) at different scales, and

has been highlighted as one of the primary elements of green infrastructure.

CONCLUSION

In conclusion, the progress made in developing an evidence base for future green infrastructure development means that the green light does appear to be on. Progress has been made in the development of a number of overarching green infrastructure principles that can be translated into planning policy at a number of scales. However, for progress to continue, political and financial support needs to increase at a local, regional and national level. The available evidence base also needs to be promoted if the green infrastructure is to be embedded in current and new planning policy. Furthermore, the inclusion of green infrastructure references and principles in current policy and strategic thinking highlights the progression already made and a review of the current research debates suggest this process will continue. Green infrastructure planning may, therefore, be seen as an approach, bringing together a range of ideas and practices and promoting a set of best practice landscape management techniques. Consequently, as a way of meeting the challenges of development, green infrastructure offers a dynamic or fluid process for shaping the landscape and meeting the future needs and opportunities of different urban and urban-fringe landscapes. Finally, by proposing that green infrastructure is the resilient landscapes that support ecological, economic, and human interests that maintain the integrity of the landscape, promotes landscape connectivity and enhances quality of life, place and the environment, green infrastructure can meet the complex needs of our ever-changing landscapes and promote a more holistic approach to landscape management.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this

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