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Green Infrastructure Design from a Social-Ecological Systems Approach

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Abstract: This paper is based on a critical analysis of the state of the art of green infrastructure design from a social-ecological perspective and it develops a conceptual framework focusing on brownfields as highly complex spaces. An understanding of social-ecological relationships is key to emerging new urban landscapes of green infrastructure however, research on green infrastructure planning from a social-ecological systems approach is limited. Green infrastructure can benefit from a landscape approach providing a systems view. The social-ecological systems perspective can reinforce the design of green infrastructure to integrate social and ecological aspects that influence on its behaviour and generate emergent, open-ended landscapes. This perspective offers a better understanding of the interactions in a green infrastructure system. Therefore, social-ecological systems approach to design green infrastructure can be beneficial to the development of emergent new urban landscapes on brownfields. The next step is the mapping of social-ecological system parameters within a green infrastructure that will enable the comparison with existing green infrastructure design.

Keywords: Green infrastructure, Social-ecological systems, Complex adaptive systems, Landscape, Brownfields

1. Introduction

Many cities with a dense urban fabric are looking into brownfield sites to further develop their green infrastructure. Many of these sites have become key elements within the local green infrastructure system due to the ecological diversity that has developed over time while they have been neglected. The disturbance of the original site conditions has led in some cases to the development of unique ecosystems and the neglect has resulted in the expansion of ecosystems that have been left to grow and not managed. These "wild" green areas are different from the designed urban green spaces and their reclamation for human recreation is a complex task because past industrial activities have disturbed the soil layers, vegetation, topography, and hydrology of many brownfield sites. The social and ecological complexity of reclaiming these spaces for green infrastructure needs to be approached holistically including the processes and relationships between the different social and ecological actors inside and outside their physical boundaries.

2. Brownfield reclamation and green infrastructure design

2.1 Brownfield Reclamation and Remediation Approaches

Brownfields are a consequence of economic and industrial activities that have taken place on land previously undeveloped. These activities have exploited existing material and energy resources, they have modified the original topography, and disturbed the vegetation and soils layers, having an impact on the overall natural processes. They have left a toxic legacy of degradation and contamination that constrains the remediation and future uses of these sites. Moreover, the impact of this legacy extends beyond the physical boundaries of the site as the energy and matter flow throughout the site and reach adjacent areas posing environmental and health hazards that can spread over the vicinity. The remediation strategies to remove hazards and reduce risks often involve infrastructure based on engineering (Genske 2003).

The standardised engineering practices that create urban infrastructure are based on reductionist, mechanistic and monofunctional approaches (Bélanger 2013). They generate structures that partially hide the natural processes that take place in cities, becoming only partially visible and blurring the human understanding of these processes and the landscape (Bélanger 2013). These structures are fragmented (Lokman 2017 Cyborg artikulua), single purpose, and they are designed exclusively based on efficiency and cost savings (Bélanger 2013, Pellegrino et al 2015). The search for efficiency has contributed to their rigidity and lack of flexibility (Bélanger 2013, Pellegrino et al 2015). They are designed to withstand known levels of stress (García García 2017) but once they reach a threshold, they may collapse causing devastating consequences. Hence, the infrastructure solutions applied to environmental remediation can be rigid to disturbances, inflexible to change and vulnerable to accidents and disasters.

2.2 Social Values of Brownfields

The reclamation of urban brownfields is associated with social values. The values attributed to brownfield sites relate to the values attributed to the environment by the social system in which they are embedded. Brownfields can be places valued for their ecological diversity and because they represent a "wild" urban alternative to homogeneous "cosmetic" green environments. However, at the same time they are feared because they are places of uncertainty and risk that generate anxiety and discomfort (Tzoulas, Korpela et al. 2007, Meyer 2007, Jorgensen, Keenan 2011). The disparate objects and vegetation that result from the process of neglect contribute to a sense of disorder and indeterminacy that is seen as a fundamental part of the attraction of these sites (Heatherington 2017). This disparity of objects and vegetation generates a landscape that is the opposite of the pastoral landscape that is considered of great value.

The reclamation of urban brownfields has social values and therefore, an exclusively ecological and technological approach to remediation is reductionist and ignores the desires and aspirations of the social environment where they are embedded. The ecological and social aspects of reclamation need to be linked to include the phenomenological aspects of brownfields and the interrelationships between social and ecological actors to prevent sites disconnected from their environment.

2.3 Green Infrastructure Principles

The principles of green infrastructure planning (Hansen, Pauleit 2014, Pauleit, Hansen et al. 2017) are generic and can be applied to a wide range of different contexts (Ahern 2007). The concept of green infrastructure includes spaces of different size, shape, and qualities. The generic nature of the principles makes easier a limited and biased application enabling individual spaces of high environmental quality that contribute weakly to a particular green infrastructure to be included within. Conversely, highly degraded spaces of very low ecological quality may be included as key parts of a particular green infrastructure (Davies, Macfarlane et al. 2006).

Furthermore, the generic character of the principles gives an instrumental approach to the planning of green infrastructure (Körner 2001 citado por Prominski, 2004) through which generic, context-independent solutions are sought to be implemented. This prevents from attributing social meanings to the elements of green infrastructure and from developing universal, generally applicable strategies (Prominski, Martin 2004) at the expense of losing the contextual diversity that gives uniqueness to each element.

2.4 Systems View of Green Infrastructure

The lack of a clear and distinctive definition of green infrastructure and the insufficient development of its theoretical basis generates multiple interpretations of the term. Some of these interpretations are reductionist, in that respect they can refer to certain elements such as green roofs or drainage systems separately. This interpretation breaks green infrastructure into elements ignoring the relationships between them and the dynamics that give rise to its behaviour.

However, designing infrastructure involves designing relationships because it is about designing a system that moves people, organisms, and materials from one location to another (Herrington 2017). When the different aspects of a system are analysed using a reductionist approach, the interactions between them and with their environment are ignored. Yet, it is important to analyse these interactions because when they change, they often intensify or neutralise other factors that influence the environment (Heiland 2009). A systems view of green infrastructure provides an understanding of social, cultural, and economic relationships, as well as ecological ones, offering a more holistic view, although this view is challenging due to its complexity (Haber, Schröder 2009).

Nevertheless, a deterministic approach to green infrastructure planning does not pay enough attention to the relationships between its elements, actors, and environment. Development of green infrastructure entails changes at the individual and collective level in urban areas (Phillips de Lucas 2020). Although green infrastructure is presented as a solution to increase the quality of life of cities, at neighbourhood level it can lead to changes such as gentrification and the displacement of the most deprived residents. A deterministic approach that seeks to improve the ecological function in cities only through the spatial and physical configuration of ecosystem elements can ignore new relationships that may arise as a result. Although there is a causality between green infrastructure and quality of life, the physical environment is not the only factor responsible for improving the quality of life (Næss 2016).

Similarly, the reclamation of brownfields for green infrastructure is put forward as a solution to environmental problems in areas of low green space provision. However, this environmental determinism ignores the often-negative values associated with these spaces and the negative attitudes towards them. The causes of the environmental damage that has led to their neglect and degradation are the result of complex intertwined social, economic, ecological, and political relationships that perpetuate this damage (Phillips de Lucas 2020).

2.5 Design of landscape processes and relationships

Brownfields are landscapes that are distant from the pastoral ideal based on the pre-industrial cultural landscape. This landscape ideal is deeply rooted in Western culture. Usually, landscape planners and designers seek to define the actions needed to guide landscapes towards a static, fixed, pastoral state.

However, the pastoral ideal has some problems. It is reductionist (Prominski, Martin 2004) because it reduces the complexity of the landscape to make it predictable and static as opposed to the intrinsic dynamism of landscapes. It is also deterministic since pastoral landscapes are designed considering only the aesthetic component and ignoring other aspects that can contribute to the development of an attractive landscape such as the ecological function of the landscape.

Additionally, planning and designing a pastoral landscape in brownfields involves the development of a strategy to conceal and camouflage the natural and material processes. This strategy ignores the context and hides the histories and processes of the place, blurring interactions and erasing connections that make these spaces more meaningful to the public (Engler 1995, Meyer 2007).

Nevertheless, the uncovering of these processes in landscapes does not fit with the pastoral aesthetics. Faced with the impossibility of reverting brownfields to their original state and with the risk of creating meaningless "camouflaged" landscapes, brownfields need new ways of seeing through the design of processes and relationships that contribute to the creation of healthy environments and generate positive perceptions and interactions (Schröder 2001 cited by, Prominski, Martin 2004).

Landscape urbanism advocates the design of processes in disturbed areas that foster the emergence of relationships and interconnections that provide an aesthetic experience (Corner 2014). However, projects based on landscape urbanism theory have attempted to design processes and relationships have had mixed results (Kuitert 2013, Wall, Dring 2014).

One of the aspects that influences the design of processes is the physical boundary of the site. Designing with processes involves designing with material flows and time-related dynamics that exceed the physical boundaries of the site. In this respect, the concept of connectivity enables considering both the processes and flows within and outside the project site boundaries.

Therefore, green infrastructure as a tool for landscape development can contribute to a new way of seeing landscapes by designing processes and relationships through a systems approach that considers these relationships. It is especially in brownfields where such design of complex processes and relationships are needed to make easier the vision of a neglected space as a starting point for a landscape that is still unknown.

3. Green infrastructure and social-ecological systems

The design and management of green infrastructure requires a view that encompasses the multiple social and ecological actors interacting with each other and with their environment, their relationships, and the processes. A better understanding of social-ecological relationships is essential to emerge new multifunctional, connected, and adaptive urban landscapes of green infrastructure (Pickett, Steward TA, Burch, Dalton, Foresman, Grove, and Rowntree 1997, Tzoulas, Korpela et al. 2007) since landscape is the framework where these relationships occur as well as the outcome (Mell, Ian 2009).

The social-ecological systems theoretical framework can provide hints on how to integrate human agency and urban ecological processes and a better understanding of their interrelationships (Andersson 2018, Preiser, Biggs et al. 2018). Social-ecological systems are complex adaptive systems, and their attributes can be useful to understand the adaptive behaviour of green infrastructure.

Landscape urbanism has developed a similar vocabulary to complex adaptive systems for the design of large green spaces (Wohl 2018). However, the design of green infrastructure from a complex adaptive systems perspective has had a relatively limited development and there is little research on green infrastructure planning and design from a social-ecological systems approach (Mell, Ian 2009, Hansen, Pauleit 2014).

This research work seeks a better understanding of social-ecological dynamics in green infrastructure from a complex adaptive systems perspective by focusing on brownfields as highly complex spaces. This will enable the development of strategies of design of relationships and processes from a social-ecological perspective for emergent landscapes. The work aims to test the hypothesis that brownfields are designed for green infrastructure as emergent complex landscapes through the processes and relationships that arise between social and ecological agents and with their environment. If brownfields are green infrastructure, if green infrastructure is landscape, if landscape is a social-ecological system, if landscape is an adaptive complex system, then green infrastructure is designed as an adaptive complex landscape system.

4. Methodology

This research falls within the category of research for design and it provides the foundation to generate knowledge on new green infrastructure design possibilities. A literature review forms the basis to develop a critical analysis of the state of the art and create a conceptual framework for green infrastructure design from a social-ecological systems approach. The conceptual framework elaborates on the links between brownfields, green infrastructure, and social-ecological systems. Through this analysis a map of the green infrastructure system as a social-ecological system can be developed. This map can be done by establishing the boundaries of the system and identifying the parts and relationships that make up a social-ecological system and then analysing how these are expressed in a green infrastructure system. The parameters developed are then compared with existing green infrastructure designs that claim complex adaptive systems approaches to test the hypothesis that green infrastructure can be designed as complex adaptive systems.

5. From a landscape approach to a social-ecological systems approach

The design of green infrastructure as landscape incorporates social values and meanings to the urban environment that an exclusively technological and instrumental approach lacks. Landscape is a social-ecological system and therefore, the design of green infrastructure involves the design of a social-ecological system. This is an exercise of mapping a social-ecological system and an analysis of how the attributes of a social-ecological system are shown in a green infrastructure system. Furthermore, to better understand how relationships are expressed in a green infrastructure from a social-ecological systems approach, the influence of system variables and interrelationships between agents on system dynamics and the identification of leverage points for intervention are analysed.

The concepts green infrastructure and landscape are related. In that sense, they refer to natural and green areas that are relationally structured, linking scales and spaces. In addition, landscape is the setting on which green infrastructure lies, and it is built upon. Green infrastructure shapes places, it creates landscapes and therefore, it can be designed as a landscape. However, the design of green infrastructure often follows reductionist and deterministic approaches that ignore the relationships and processes that are key to provide ecosystem services. The design of green infrastructure can benefit from a landscape approach to provide a holistic (Rouse, Bunster-Ossa 2013) and a phenomenological perspective.

The mosaic model used in landscape ecology is one of the approaches to the design of green infrastructure as landscape. Landscape ecology is one of the disciplines on which green infrastructure is based (Mell, Ian C. 2008). It provides a theoretical perspective and analytical tools to understand how complex and diverse landscapes operate in relation to ecological processes (Pickett, S. T. A., Cadenasso et al. 2004, Ahern 2007) and a vocabulary for these processes (Hill 2009).

The mosaic model can describe the spatial configuration of landscapes (Ahern 2007) as a structure formed by patches, corridors, and matrices (Forman 1986). Through this model, the spatial configuration of green infrastructure can be described by establishing a correlation between its spatial elements and the structural elements of landscape according to the mosaic model. Thereby, green infrastructure can be positioned within a framework of ecological processes and relationships.

However, the configuration of green infrastructure based only on patches, corridors and matrices is generic and context independent. The spatial elements of green infrastructure are diverse, and its design needs to be contextual as the ecosystem functions are context specific.

Equally, the term landscape refers to the environment in which humans live, give meaning to, and interpret. These interpretations include the view of landscape as a system and as a place. Both interpretations share that the meaning of landscape does not arise from the individual elements of the landscape, but from the relationships between them (Motloch 2001).

Therefore, by approaching the design of green infrastructure strategically as a landscape and by focusing on relationships and processes, green infrastructure can relate to a place unlike reductionist approaches that concentrate on individual elements or generic technological solutions. A landscape approach is context-responsive and site-specific because it can incorporate meanings and ecological site processes. This way, green infrastructure becomes an instrument of landscape creation and urban greening through design that responds holistically to place and landscape character (Sala, Puigbert et al. 2014).

A landscape strategy for green infrastructure that incorporates the design of processes and relationships can be approximated using spatial patterns that can accommodate relationships that contribute to ecosystem services. The patterns of a landscape are the physical expression of social-ecological relationships and processes (Rouse, Bunster-Ossa 2013) and they are linked to human perception (M'Closkey 2017), for that reason, they are useful to understand and design ecological relationships and processes.

The ecological relationships and processes supported by a landscape can vary according to the type, size, and design of the spatial configuration of landscape patterns. Certain ecosystem functions and services can be encouraged through the design of landscape patterns. However, even if there are causal relationships between pattern, process, and scale (Novotny, Ahern et al. 2010), spatial configuration alone does not ensure ecosystem functions and services. If processes do not always have a deterministic influence on spatial patterns (Hill 2001), then the spatial configuration of landscape patterns also has no deterministic influence on processes, and thus on the performance of green infrastructure in the provision of ecosystem services. Therefore, the design of the spatial configuration of the landscape is not enough to support the processes and interactions that give rise to ecosystem functions and services.

The understanding of relationships and processes and consequently, viewing the landscape as a dynamic and relational system (Nijhuis 2013), opens opportunities to manipulate landscape processes (Nijhuis 2013) that provide ecosystem functions and services. This can be done through strategies that guide a landscape towards an optimal dynamic configuration (Hill BDLA, 2009). This is an open-ended, emergent, and nonlinear landscape configuration as opposed to the controlled final fixed design of landscapes.

Green infrastructure is a network of physical and biophysical elements that provides services (Herrington, 2017) and encompasses different scales and complexities of the social-ecological processes it supports (Hansen, Pauleit 2014, Pauleit, Hansen et al. 2017, Lennon, Scott et al. 2016). Therefore, the design of green infrastructure can be approached from a dynamic and relational landscape system perspective.

Moreover, green infrastructure is usually developed on urban areas, and therefore, it is in close contact with people. For that reason, an intertwining of multiple social and ecological processes and relationships occurs across different scales of green infrastructure. Traditional landscape design has ignored the social dimension and it has conceptualised landscape as a scene or framework. Contributions from philosophical approaches such as phenomenology have changed the traditional scenic view of landscape to incorporate human experience and perception into the landscape (Swailes 2016). This perspective places humans as active participants that interact with the landscape and allows the consideration of social-ecological relationships and processes in the design of green infrastructure.

A social-ecological system approach can reinforce and expand the landscape perspective to include the social system along with the ecological system to understand how the different pieces that make up a green infrastructure system fit together and interact with each other to provide ecosystem services (Herrington 2017).

6. Conclusions

The reclamation of urban brownfields for green infrastructure needs a holistic approach that encompasses the processes and relationships between social and ecological agents within and beyond the physical boundaries of the sites that make up a green infrastructure.

A social-ecological systems approach to the design of green infrastructure provides a better understanding of the relationships between the agents and their environment as well as the processes that influence the behaviour of a green infrastructure. This understanding can enable the development of strategies of design of relationships and processes for emergent, open-ended, uncertain landscapes and opens opportunities to manipulate landscape processes through the identification of leverage points of intervention.

Although some green infrastructure projects claim the adoption of social-ecological systems attributes, their implementation is still limited. The identification of social-ecological system parameters within a green infrastructure system is needed for comparison with existing designs and be able to claim a social-ecological performance.

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