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DESIGN CRITERIA FOR REGENERATIVE SYSTEMS LANDSCAPES

DANIEL BERGQUIST AND PER HEDFORS

Abstract

In this paper we explore General Systems Theory (GST) as a conceptual support in landscape architecture (LA). The point of departure is the complexities and embeddedness of landscapes in multiple scales of society and environment – systems landscapes – a conceptualisation to which we add *regenerative*, to stress the need for design that restores and enhances environmental and human resources and their capacity to regenerate over time. Through the lens of regenerative systems landscapes, we engaged in an interdisciplinary method we call landscape dialography; the combination of reflective discussion, visual representation, sketching and systems diagramming of systems landscapes throughout and across multiple temporal and spatial scales. This allowed us to highlight significant systemic relations and make them concrete as visionary hypotheses in a physical context. Through this iterative learning process, specific representations were selected out of the sequence to illustrate emergent criteria for design. The paper is concluded by proposing a set of design criteria for regenerative systems landscapes, to be incorporated in landscape architecture and applied in management, planning and design.

Keywords:
General Systems Theory (GST),
Landscape Architecture (LA),
urban design, spatial planning,
sustainability, regenerative.

Introduction

Landscape architects have dealt with human-nature interactions at least since the beginning of industrialisation (e.g. Olmsted, 1870; 1885; Geddes, 1949; Geddes and Stalley, 1972; Spirn, 2000; Rogers, 2001; Martin, 2012). Examples include mitigating environmental impacts of human settlements through designs that draw benefit from ecosystems in various ways. While such approaches are today referred to with new concepts; e.g. ecosystem services, the idea is thus not new in the planning and design professions. It is however not clear to what extent the designed landscapes indeed become sustainable in a wider time-space perspective. This may partly be explained by difficulties associated with any attempt to define, empirically analyse or measure sustainability (Bell and Morse, 2008). The cultural systems in which landscape architects work also involve a multitude of competing views and continuous negotiations about what constitutes sustainability. Perhaps even more important is that many urban design projects address only a few aspects of sustainability at a time (e.g. Brun, 2015), potentially resulting in fragmentation and isolation of functions and elements, as well as externalising impacts to other landscapes (e.g. Hornborg, 2001; Wackernagel, 1994; Rees and Wackernagel, 1996; Bauman and Tillman, 2004).

More specifically within Landscape Architecture (LA), externalities can be mitigated through what is sometimes referred to as mass balancing; moving as little (ground) material as possible the shortest distance in the terrain, still creating multi-effectiveness and aesthetically appealing design adapted to the topography and indigenous vegetation of the habitat (Booth, 1983). However, such exclusive focus on the local and small scale may in reality not solve problems at aggregate scale levels, but simply pass them on to landscapes at other locations (c.f. Lyle, 1994; Murphy, 2016; Booth, 1983).

Whereas externalities are one possible outcome of too narrow system boundaries, so is failure to realise the full potential of landscapes. Rather than claiming that LA needs simplicity to be successful, there is great potential in design concepts in which interconnectivity and complexity play central roles (Gustavsson, 2004; Lyle, 1994; Motloch, 2016). In this paper we explore concepts for developing such an approach, especially targeting landscape architects primarily active in practice and with the need and interest to formulate deeper questions and consequently achieve more informed and reflective design decisions, i.e. to consider more of the totality in specific sites. It is our concern that this is seldom the case in contemporary LA practice. Programmes are often premiered regardless of their practical implications or longitudinal outcome. Dreyfus and Dreyfus (1980) attribute such shortcomings to the limitations of human intellect, i.e. that no individual can know everything and apply all knowledge in every instance. This is why we believe that LA would benefit from a broader and theoretically grounded design process, and that this may be achieved by a closer look into the patterns of natural ecosystems.

Specifically, the systems perspective in this paper is represented by General Systems Theory (GST), as conceived by among others systems ecologist H.T. Odum (1971; 1996; 2007). GST conceptualises the world as one open system, global in scope, and within which all processes in nature and society are nested sub-systems that interact by exchanging resources, building storages and dissipating energy, matter and information across time and space. In this view, systems relations enable resources to flow between systems at different scales, thus forming a web of exchange where certain organisational patterns have been identified as universal (Hall, 1995).

The reason for targeting LA in this paper is the latent capacity within the field to think and act holistically. *Design with nature* (McHarg, 1969) is already the pervading world-view of a landscape architect much as gardeners or foresters take the natural processes and dynamics for granted in their accomplishments (Hedfors and Florgård, 2012). This indicates an understanding of e.g. biological and social conditions simultaneously. Therefore, we hold many landscape architects as possible ambassadors of a systems approach in the practical design professions. Thinking of landscapes in terms of their systemic relations brings to the forefront their inherent complexity; and may remind designers of more aspects than initially perceived or communicated by clients, as well as the need for exploratory width and humility in design; qualities otherwise often overlooked in the smaller scale and time-constrained specific project. Thus, we call for more curiosity and reflection in design, both in terms of systemic complexity, and the moral responsibilities that come with the formative role of landscape architects engaged in the creation of new human settlements and their relations to nature and society as a whole.

Dimensions of urban design and landscapes

In urban design, there is a tendency to focus on spatial organisation of artefacts – purely man-made objects. All involved parties of interest might not be skilled at analysing systemic relations out of the merely visual media used to depict objects, without taking part of oral or written descriptions of a certain project. Original ideas may be lost due to the difficulty to communicate invisible phenomena in visual media. Particularly elusive dimensions of landscapes include indirect and cascading relations, complex causalities and externalities across scales. Detecting, understanding and planning to appropriately handle such phenomena is a major challenge for designers. It is in this context that giving priority to visual representation of elements and objects implies a risk that physical dimensions in the concrete human scale are overemphasised at the expense of intangible or non-visible, though crucial relations. This calls for approaches that support simultaneous consideration of the visible-invisible, concrete-abstract, direct-indirect, local-global etc. The systems approach we propose essentially concentrates on such relations between elements, to shift focus from the idea of artefacts to the spatial organisation of both structure (landscape morphology), and non-visible relations, i.e. functions and the dynamic processes, activities, flows and connections that together shape landscapes.

Designing for effective integration of diverse aspects requires basic understanding of systems dynamics (Murphy, 2016). Whereas there are examples of a systemic view in spatial planning and design (e.g. Alexander, et al., 1977; Motloch and Woodfin, 1993; Partanen, 2015; Murphy, 2016) it has also been largely ignored periodically. In other disciplines such as landscape ecology (e.g. Forman and Godron, 1986; Naveh and Lieberman, 1994) and social-ecological urbanism (e.g. Barthel, et al., 2013) similar approaches are also explored, but they seldom reach broader application and practical implementation in the planning and design professions. This paper may therefore be thought of as a bridge between theoretical systems thinking and LA practice. Having said this, we acknowledge the diverse body of knowledge represented by the multitude of systems perspectives in other fields, which indeed would merit a broad discussion of its own. However, we have chosen to delimitate this paper by only introducing a selection of key points from systems thinking, which we identify as particularly useful to operationalise in the practical design disciplines. Furthermore, the paper draws primarily on systems theories put forward by the ecologist H.T. Odum (e.g. 1987; 1996; 2007). As will be shown, this represents a different school of thought than landscape ecology or social-ecological urbanism. In brief, the difference may be seen as resulting from Odum´s most central principles of self-organising systems and maximum empower. These principles are not commonly the theoretical starting point in contemporary urban design and LA practice.

Objectives

The objective of this paper is twofold: (1) to develop an approach to urban design based on GST; operationalised as a set of guiding criteria, and (2) to tie more closely together the life sciences – here represented by GST – with LA and urban design. In so doing, we focus on the management of landscapes and the creative and critical thinking and design processes involved, to develop and propose criteria that may be used for structuring, guiding and evaluating design in its different stages.

Delimitations

Much as Lawson (2006) speaks of designers as acting on preconceived individual principles, GST may contribute important insights to be internalised in designers´ philosophies, hence strengthening the critical and creative thinking processes within the field (c.f. Murphy, 2016). Still, designers act freely and it is not in our interest to affect the stylistic expression of specific designs. Rather, we aim to support designers with conceptual tools for thinking about complex relations, zooming and moving across scales, to identify and explore potential synergetic connections in landscapes. Consequently, the paper is more exploratory than explanatory, in that we develop hypothetical visions of how LA could be executed as a profession, as opposed to empirically evaluating any actual landscape. Inspired by Deming and Swaffield (2011), we draw on an exploratory strategy of inquiry that combines inductive theory building and deductive theory testing in an iterative process, limited only by the overall objective of finding ways to articulate systems theory in the practical design professions. Hence the intentional absence of conventional research questions, an important factor that enabled us to remain truly exploratory and open-minded throughout the research process.

Furthermore, the paper should be considered in contrast to the more common use of GST in environmental evaluation (c.f. Ulgiati, Odum and Bastianoni, 1994; Federici, et. al., 2003; Beck, Quigley and Martin, 2001; Zhang, et. al., 2011; Russo, Buonocore and Franzese, 2014). GST is seldom used proactively in planning and environmental decision making, despite its potential (Odum, 1996). Therefore, we utilise LA as a vehicle for positioning GST more clearly in design practice, and conversely, GST for grounding LA in systems theory. Ideally, application of the criteria should be prior to project implementation, or to follow up the success of specific designs by post-evaluation, though with the explicit aim to make sure that sustainability goals are incorporated in designs and hence have a better chance to be met and maintained in practice.

Moving beyond sustainability

Without knowing it, we have designed our cities to create unhealthy citizens and ecosystems (Murphy, 2005). The organisation of contemporary urban landscapes is therefore difficult to define as "good design". However, there is fortunately no shortage of concepts for synthesising human and environmental goals. Before the wide-spread dissemination of the concept *sustainable development* (United Nations, 1987), sustainability aspects were obviously not new but very central to the undertakings in spatial planning, though conceptualised in different ways, such as long-term and comprehensive planning concerning all spatial scales (e.g. Cornell, 1968). Sustainability as understood in this paper may however be better described as the simultaneous consideration of multiple qualities as identified in the PEBOSCA framework (Berg, 2010). These include: Physical, Economical, Biological, Organisational, Social, Cultural, and Aesthetical resources. We also incorporate the term *resilience*, which refers to the ability of systems to cope with shocks and disturbance while maintaining their organisational structure (Holling, 1973). While we are aware of the many more nuances of sustainability and resilience, for the sake of brevity and alignment with our objective, suffice it to say that they have both contributed to the advancement of the life sciences and design disciplines alike.

From a more critical stance, however, sustainability and resilience, when applied in practice, often translate into finding ways only to maintain status quo (O'Hare and White, 2013). In the context of planning research and design practice, therefore, we primarily see these concepts as important milestones, or transitory towards planning, design and management based on deeper understanding of social-ecological phenomena. To this aim, regeneration, or *regenerative*, may be more adequate, since merely sustaining civilisation is not enough. Rather, we must design regenerative communities and landscapes (McHarg, 1998). Here, regenerative implies a shift towards conscious re-design of human-environment interactions that heal and amplify ecosystems (Zari, 2015).

Methods

This work is the result of "landscape dialography", which we define as a process of reflective discussion supported by visually representing landscapes throughout and across multiple temporal and spatial scales. Dialogue [dia- (through), -logos (words/knowledge), Greek (converse with each other)] is the mutual exchange of ideas between parties, in our case the participants in our research, through words and verbal communication. Sketching and visual representation were additional factors of progression, here represented by "-graphy", (drawing, represent) – the process by which concepts and design criteria were visually represented as visions of concrete landscapes.

Landscape dialography as a feedback and design evolution tool

In this work, landscape dialography was primarily used as a vehicle for theorisation, i.e. as a method applied in an iterative and exploratory, though essentially hypothetical context, as opposed to empirical inquiries or design in practice. Consequently, the process lacks conventional design stages and real-life cases. However, the city of Uppsala, Sweden, with its ridge, river and lake, and other memories from physical sites of the participants' repertoires and preconceptions, were used to concretise the theoretical discussions. The approach was also tested with planners from Uppsala municipality, landscape architects and other practitioners in urban planning and design, to expose our thinking and collect additional insights.[1]

In practice, this entailed a series of recurring discussions in which a number of different participants met, to jointly envision and discuss ideal scenarios of regenerative landscape functions and processes, followed by putting the visions on paper in an iterative learning process. The images were simple drawings to grasp the complex concepts evolving in dialogue, and as presented in the following sections, they are basic data and thus of course not polished and might look rather naïve. More importantly, they indicate important phases that were used as stepping stones in our intellectual process. As such, the visual illustrations presented

1 These activities were part of SYSLAB – a collaboration project funded by Vinnova, in which a range of actors gathered on a recurring basis to jointly develop tools for systems thinking in urban planning.

throughout the paper simultaneously constitute our empirical material on which we base our analysis and discussion, and method used to articulate problem formulations and conclusions. This approach resembles some methods for collaborative planning and design, such as charrettes (e.g. Condon, 2008), and other methodologies used by practitioners of LA and related professions (c.f. Turner, 1996) to encourage shared thinking. In comparison, what primarily distinguished our method of landscape dialography was that the purpose was not the modelling of a specific physical form, but to develop and select emergent criteria for design.

System diagramming

To further support our attention to non-visible relations, dialography also included depicting system organisation in two-dimensional flow charts called systems diagrams (Odum, 1995). A range of standardised symbols are deployed, representing the main types of system components (e.g. producer, consumer, storage) and interactions; e.g. input and output flows, transformation and feedback; roles and processes that have been found in a range of different systems (Odum, 1996). The method offers a visual language to describe invisible yet crucial flows of e.g. energy and materials, internal and external interactions and interdependencies, while simultaneously considering theories that govern system organisation (Brown, 2003).

While following this path, we turned to emphasise *activities* performed by humans in the envisioned systems landscapes, instead of merely visible artefacts. The activities in the images represented relations, connections, and flows, i.e. non-visible phenomena that would otherwise be difficult to discern. The visual representations generated had two different functions: (1) *Conceptual Progression*, the sequential evolvement of representations indicating the critical moments and nodes during our research project in linear time; (2) *Representation of Criteria*, specific representations selected out of the sequence to formulate and illustrate our results in the form of criteria for design.

Landscapes: LA and related fields of knowledge

Landscape architects operate in planning, design and management at different scale levels from garden art to regional planning. The landscapes they consider are the result of numerous processes. Bell (1999) describes landscapes as something that people experience everywhere with all their senses, from the city to the remote wilderness. They use the patterns of the landscape that they comprehend to find their way, and they find pleasure or displeasure in it. Those patterns and the landscape they comprise are dynamic and changing. Geological, ecological and cultural processes operate over varying time intervals. Thus, landscape is a synthetic concept addressing an amalgam of patterns, perceptions and the processes and activities that change both patterns and perceptions

(Bell, 1999). This inclusive way of describing landscapes integrates and dissolves traditional dichotomies like nature-culture, human-natural, and artificial-natural.

LA should not be confused with other professions in urban design like (building) architecture, which is based on a profoundly different technical paradigm and as such falls outside of the scope of this paper. LA, on the other hand, manages the interaction of two fundamental principles of space formation: tropism and tectonics (Hedfors, 2014). Tropism is the regenerative principle nested in trees, shrubs and other living photo-synthesising organisms forming space with their masses. Tectonics, the non-biological static framework of a building where the column carries the beam. However, this conceptual pair is not to be understood as a dichotomy, where one opposes the other. They are not contradictory or always interdependent. Tropism may exist without tectonics, i.e. regardless of the capacity of humankind to erect tectonic structures. In opposition, tectonics does not arise without tropism, since human beings are dependent on the living environment for their existence. It is therefore important to distinguish between integration versus interaction, i.e. whereas tropism and tectonics may never be integrated, they may interact in terms of relating to each other in various ways.

Biological understanding of the dynamism of the living and non-living lays the ground for managing landscapes and adopting regenerative design principles. Here, particularly central concepts in the shaping of landscapes are ecosystems and ecotones; the borderland where different habitats overlap and combine their respective qualities in the same location (Kahn, 2005). Much as Kahn (2005) speaks of ecotones as a metaphor for creative interdisciplinary work, thinking of certain landscapes as ecotones may inspire designers to move beyond compartmentalisation and separation of elements, to refined interaction of tropism and tectonics where diversity and connectivity are at the core.

Landscape ecology is another field of knowledge aiming to improve landscapes (c.f. Ahern, 2002; Forman and Godron, 1986; Ndubisi, 2002) though as pointed out by Murphy (2016), primarily emphasises key areas such as conservation, biodiversity, ecosystem health and productivity. Arguably this is a limited version of ecology applied to a smaller scale. An expanded systems view is important, not least to keep in mind the global challenges relevant to urban design. Furthermore, while landscape ecology is primarily a descriptive discipline, LA adapts certain results as a prescriptive vocation in need of criteria for implementation. Lyle (1999) suggests the making of predictions and talks about an emerging era of predictive adaptation to learn to design landscapes in a responsible way. This era of prediction uses the skills developed in earlier phases in history in the shaping of the physical environment to serve the users´ wishes, needs and purposes well. Form-making is a phase, according to

Lyle, in which the completed design is envisioned and represented visually before being built. At their best, the outcomes are formally logical and symbolically meaningful, but seldom aligned with local ecology and landscapes at larger scales.

The emerging era of predictive design, according to Lyle (1999), increases our abilities for storing information, technology etc., for considering the behaviour of an imagined form in relation to its environment, and for shaping it on that basis. Predicting is not deterministic but a way of exploring the infinite. However, landscapes are also the result of a series of considerations and decisions made by e.g. designers – a process seldom made explicit and seen as a 'black box'. The design process is described as being partly based on tacit knowledge of which some is considered impossible to make explicit (Schön, 1983; Lawson, 2006; Collins, 2010). In the following, we contribute to the demystification of the black box by exploring the concept of systems landscapes and its potential for grounding the design process more explicitly in GST.

Systems landscapes

Human settlements are landscapes where a range of human and environmental resources converge. By constantly cycling energy, materials and information, internally and in relation to external environments (Zhifeng, et al., 2014), resource support areas are geographically vast and potentially far reaching, impacting society and environment in both positive and negative ways (Zari, 2015; Zhifeng, et al., 2014). Whereas all landscapes are site specific and unique geographical entities, urban landscapes in particular may also be seen as complex nested systems, combining tropism and tectonics in a multitude of ways, and always drawing resources from the larger scale systems in which they are embedded, e.g. the larger region or city, its infrastructure, green-blue structures and people. Hence, we conceptualise landscapes as system(s) landscapes (c.f. Granvik and Hedfors, 2015). To this conceptualisation we add *regenerative*, to underscore the need to move beyond sustainability. Consequently, we define *regenerative systems landscapes* as site specific, context dependent, though globally nested, social-ecological systems, operating at multiple scales of society and environment, while strengthening the capacity of ecosystems.

Systems thinking: learning from patterns in nature

In formulating his ideas on land use, Lyle (1999), a landscape architect, found inspiration in the work of ecologist Howard T. Odum. Conversely, H.T. Odum´s work reflects a clear progression towards application of his ideas in planning and design (Odum, 1996; Odum and Odum, 2001; Odum, 2007). Another example of this mutual interest is Motloch and Woodfin (1993), who claimed that since many different kinds of systems appear to share many properties, the general systems approach is highly relevant for landscape planning, design and management, since it essentially entails the practical integration of a multitude of aspects ranging from health to productivity and regeneration. Adding to this the potential in interacting tropism and tectonics, it is clear that an understanding of shared system behaviours is central for design as vocation to correlate well with systemic order. According to Motloch (2001) this can most easily be achieved by responding to context in ways that embrace interdependencies and integrate interdisciplinary knowledge. Cross fertilisation of systems theory and design has thus already been pioneered by many, but as noted e.g. by Lyle (1994), represents a scholarly work that has become increasingly silent in later years, as many of the original thinkers have retired or passed. Building on this legacy of interdisciplinary exchange, in the following we briefly introduce GST to explore its potential as a unifying theoretical basis for LA.

GST: concepts of particular relevance for LA

While sketching hypothetical sites and reflecting on the visualisations through the application of GST, dialography enabled us to identify a selection of patterns and concepts that are particularly central when envisioning regenerative systems landscapes. One such pattern is the capacity of systems to combine structural stability and a fluctuating access to resources (Odum, 1996; 2007). However, this does not imply striving for equilibrium, or any other static system state. Rather, stability and change are combined domains in systems, and as such represent a universal pattern that offers guidance in human design. The theoretical underpinnings of these arguments derive from a range of thermodynamic principles and concepts, of which the following were identified as the most relevant for forming a useful theoretical basis for LA.

Second law of thermodynamics

Dialography brought our attention to a range of materials and forms of energy required to transform physical landscapes and enable the activities we depicted. Consequently, we ended up in the second law of thermodynamics (2nd law), which states that “available energy is degraded in any energy transformation process” (Odum, 1996, p.16). The 2nd law thus stipulates that it is impossible to transform any resource, be it energy, material, or information, without losing a part of its initial potential. When a resource (e.g. landscape) is transformed, essentially it is divided into two parts. Firstly, the intended result, e.g. product or service, or landscape form and function. Secondly, a fraction of lost potential that is dissipated i.e. leaves the system in the form of disorganised output. In thermodynamics this is referred to as entropy, and in systems diagrams it is represented using the symbol for heat sink (figure 1).

The 2nd law is perhaps the most fundamental of the natural laws, since it essentially states that in any activity energy is inevitably degraded. When sketching alternative land uses, the 2nd law made us realise that every design decision is associated with lost potential of physical energy.

However, another central tendency of self-organising systems is to develop towards higher levels of complexity (Motloch, 2016) by prioritising processes that increase access to and use resources efficiently. Keeping these patterns in mind during the dialography sessions hence made us reflect on what elements and processes could be added to the design to compensate for losses according to the 2nd law and amplify the capacity to efficiently regenerate and build resources.

Self-organisation and feedback

All systems organise in relation to the 2nd law. Relations emerge that make efficient use of resources and build storages for future use, a process called feedback. Feedback that restricts a system, e.g. a species to overshoot its resource base, is labelled control, or negative feedback. Positive feedbacks are relations that strengthen a system´s capacity to access resources i.e. that reinforce the system. It applies where relatively smaller amounts of resources of high quality (e.g. crucial information with high legitimacy) are fed back from a system higher in hierarchy, to amplify productivity of processes at lower levels. Sub-systems then, in turn, make use of the feedback to produce and deliver output flows that are either used or recirculated internally, or contribute to the larger scale system(s) from where resources were initially fed back. Whereas specific actors may have different functions and positions in such processes (c.f. Abel, 2013), the functions are equally important since they are all needed to maintain overall stability of the system as a whole (Bergquist, 2008).

This relational pattern by which systems organise is referred to as autocatalytic system design, autopoiesis or self-organisation (Odum, 1987; Şorman, 2015). It is particularly apparent in tropism; the inherent force of living plants to organise and form space with their masses – an emergent property only realised with access to solar energy, rainfall, soil etc. as feedbacks provided by the larger scale ecosystems of which plants are part.

The concept of self-organisation draws attention to the tendency of systems to develop dialectical relations in terms of flows (both physical and relational) in different directions. In systems diagramming such interactions are expressed as flows of renewable (R) and non-renewable (N) inputs and outputs – including yield (Y) – moving from left to right, and feedback (F) flows moving from right to left, as in figure 1.

Self-organisation maximises the performance of systems in the long run while coping with the 2ndlaw, and can be found in all systems operating far from thermodynamic equilibrium. It has therefore been put forward as a general system principle (Odum, 1987). Acknowledging its relevance, Partanen (2015) shows how it can also be applied to the organisation of complex socio-political systems, such as planning processes. Still, as pointed out by Zhang, de Roo and van Dijk (2015), self-organisation

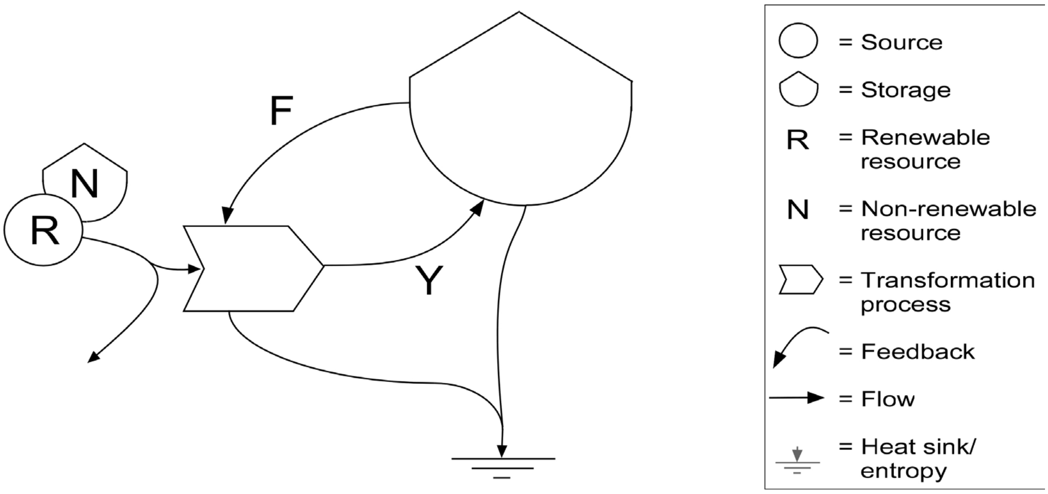


Figure 1
System diagram illustrating feedback in self-organising systems. This way to depict systems facilitates the consideration of non-visible relations and functions, e.g. while shaping individual objects or landscapes as a whole.

remains relatively underexplored in research on landscape change, urban planning and development. This is unfortunate, since urban systems in particular are characterised by high degrees of uncertainty, unpredictability and non-linearity, phenomena at the core of theories on self-organisation.

Maximum power and maximum empower

GST stresses the need to focus on relations between systems at multiple scales, even though the aim may be to understand relatively isolated and small-scale phenomena. This is because systems self-organise to develop structures and processes that enable access to resources and optimise their use in competition with other systems. In early 20th century, Lotka (1922, cited in Hall, 1995) defined this as the maximum power principle. It was proposed as the fourth law of thermodynamics (4th law) and later reformulated by Odum (1999) as maximum empower, to add the tendency of systems not only to compete with others, but also to contribute to the larger whole in which they are embedded (c.f. Bergquist and Rydberg, 2009).

Maximum empower offers some interesting implications for LA, since it brings attention to processes that are beneficial at multiple scales and for several individual parts simultaneously. During the dialography sessions, this gave rise to intensive debate, since it implies that in design it is not enough to solve problems at singular scale levels. Equally important is the contribution to larger scales. This implies a normative yet theoretically grounded reasoning that legitimises processes, and indeed, designs, that do not allow for parts to maximise their potential at the expense of others. This is why maximum empower may be useful for landscape design in a regenerative context. Maximum empower would then apply if processes at all system scales work together to improve available resources and efficiency of the system as a whole, i.e. contribute to the regenerative process of systems landscapes. In practice, this implies facilitating exchange of resources in several directions within and across different parts of systems, by establishing connections, flows and feedbacks where all parts of a system are mutually stimulating and reinforcing (Odum, 1987; Bergquist and Rydberg, 2009).

Applying GST in LA

According to Gustavsson (2004) we are rooted in an age that seeks instant landscape effects, but from an environmental viewpoint, instant effects are not really wanted (negative feedback). Instead, a regenerative approach is required that involves greater richness and complexity evolving over time (self-organisation), directed in a knowledgeable way (positive feedback). Healthy cities need effective green-space networks; not just to promote healthy living for city dwellers (maximum empower), but also to sustain wider biodiversity, to promote water and air quality, food and energy security and to regulate climatic extremes (Zari, 2015). These are dynamic processes where the regenerative capacity may be less apparent in a short time perspective but may increase substantially over time as e.g. green-blue systems, as tropism-driven spaces, evolve. All this is well known but is rarely reflected in urban design. Rather than trying to freeze parks and gardens and making them static (tectonic) features, they would be enhanced if their long-time dynamic and structural changes are treated from a deep and active understanding (Gustavsson, 2004).

Whereas similar ideas have been explored in e.g. landscape ecology (c.f. Forman and Godron, 1986; Ahern, 2002), they seldom achieve more than marginal implementation and practical application in the planning and design professions. For example, Lang (1987) notes that designers appear to find many issues difficult to consider explicitly. While the design professions have much in the way of normative theory – prescriptions for action – they are weak in positive or explanatory theory; description of the phenomena and processes with which they deal. Lang (1987) therefore attempts to sketch the nature and scope of a theoretical base for the design fields akin to those of other applied fields such as medicine. More recently, similar ideas based on the appreciation of ecological system complexity have been proposed by e.g. Motloch (2017), who promotes transition from anthropocentric to complexity-centric co-design. Similarly, in this paper we propose GST as a theoretical framework for LA to move towards design methods underpinned by the understanding and respect for ecological processes.

Design criteria for regenerative systems landscapes

Murphy (2005) has defined a number of design criteria, categorised as quality-of-life and quality-of-environment. However, Murphy continues, LA has not yet matured as a design discipline to the extent that it is capable of guiding this type of dynamic development of the human landscape. Thus, there is a need to begin to plan and design systems landscapes in ways that embrace rather than obstruct continuing change. To facilitate such focus, we now turn to articulate our set of criteria. Simultaneously, we visually represent potential results from application of the criteria in design. To delimit our scope in this process of dialography, we did not assess the entire spectrum of LA practice, but selected those aspects identified as especially relevant for the application of GST. Compared to what landscape architects actually face in practice, the visions are therefore intentionally simplistic, to select and isolate general patterns for design. The criteria we formulated in this way are:

- Design for self-organisation
- Create ecotones
- Internalise resource use
- Facilitate regenerative processes
- Create internal feedback
- Enable diversity and multi-functionality

Design for self-organisation

The principle of self-organisation implies that solutions that work in the long run emerge from a balance of positive and negative feedback. During the dialography sessions this translated into finding possible ways for conscious planning and building of structures and functions in the locale that allow actors and elements to develop their own interrelationships, e.g. by combining tropism and tectonics in different ways. One classical example is the use of green-blue infrastructure (tropism) to treat storm water runoff from tectonic structures, as a source for growing biomass in parks and gardens. Most contemporary urban designs lack such interaction of tropism and tectonics, resulting in compensation by external and often non-renewable resources (cf. Beck, Quigley and Martin, 2001; Martin, et al., 2006). A possible explanation raised by one of the dialography participants is that potential feedback relations have not been identified and are hence being under-utilised. Here, urban agriculture was mentioned as an alternative approach that would enable more beneficial connections. Especially in urban community gardens, conditions offer both physical structure and a social arena for citizens to share and cycle local resources, thus establishing connections that minimise the need for non-renewable resources (Bergquist, 2012), i.e. to self-organise in ways that reinforce tropism through tectonics.

Turning to the prospects of establishing such beneficial connections between tropism, tectonics, and people, the design criterion emerged; design for self-organisation. It may be operationalised as broad inventories of resources, processes, actors and potential connections in situ. By doing selective inventories, a deliberate process may evolve, in which designers consider when and if the physical space would obstruct or support self-organisation.

Create ecotones

Connectivity between elements refines structures, functions, and processes (Forman and Godron, 1986). In the urban context, building blocks are surrounded by streets and roads to be accessible. Greenery forms a third infrastructure. The connectivity patterns between these structures compete, and site-specific prioritising is usually the approach to solve the predicaments. However, in drawing on the concepts of tropism and tectonics, dialography allowed us to envision an alternative approach that entangles static (built) and dynamic (living) elements and processes so as to support one another. Thus, we introduced the concept of ecotones as inspiration when formulating this criterion; as the intentional creation of patchy transitions that connect traditional dichotomies such as static-dynamic, urban-rural, human-natural etc. The need for such solutions is especially apparent considering the sharp edges between the built environment (the grey) and the green-blue matrix of wedges of different scales, green corridors, streams and lakes (Berg, et al., 2013), the latter often missing totally in city maps. The criterion of ecotone thinking may help urban planners and designers to overcome such barriers and hence realise the potential of specific systems landscapes.

Internalise resource use

Disconnected grey-green-blue structures are thus commonplace in urban contexts. When criticising this organisational structure during the dialography sessions, we identified an important though often overlooked lack of relations between structures and elements. This undermines the potential for making use of locally available resources seen as ecosystem services. Which, in turn, made us conclude that urban systems may be improved by internalising resource use to a larger extent, e.g. by optimising connectivity and the proportions of tropism and tectonics. Where local conditions allow regeneration on site this may be a more resource efficient approach than imports. In figure 2 this reasoning is exemplified by an ecotone comprising the simultaneous production of recreational experience, climate regulation, habitat, and timber for use in housing constructions.

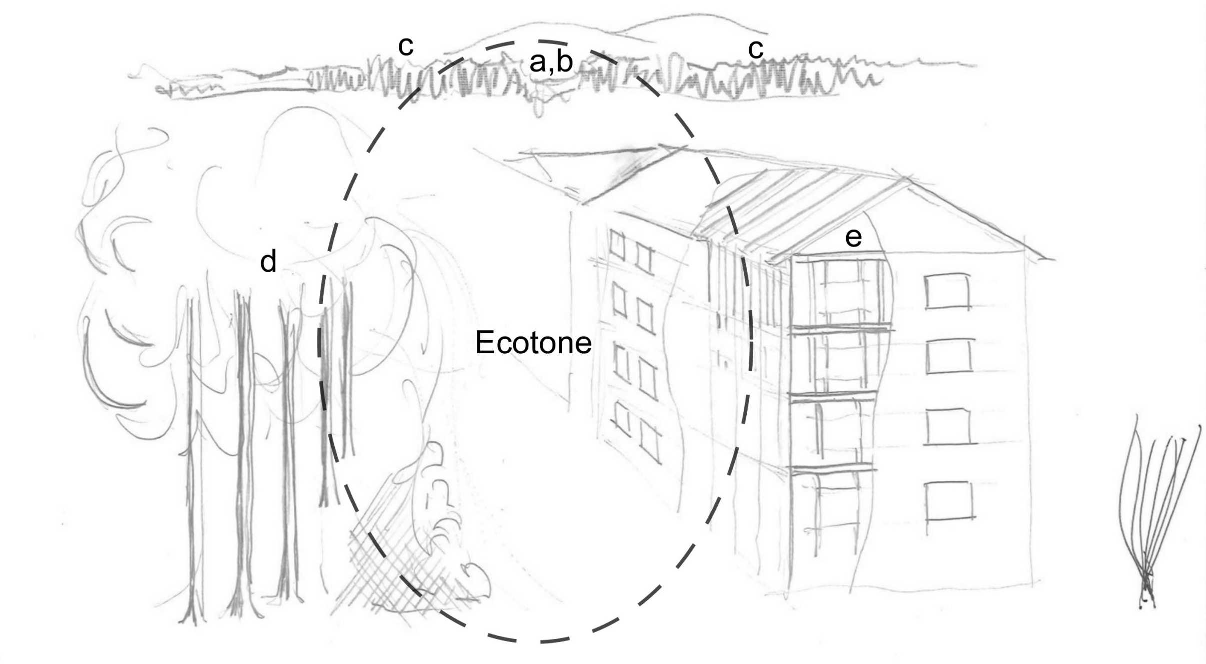


Figure 2
Ecotone: an early image from the dialography sessions used to facilitate our interdisciplinary dialogue. An ecotone is here exemplified by depicting timber sourced from the adjacent city park or forest (a). To compensate for the loss resulting from deforestation (b), new trees are planted in the forest (c), and in a park added at the site (d), serving as construction material in future construction projects. In this design conceptualisation, the exploded view of the building (e) shows the tectonic structure of wood as a renewable resource thus regenerated in situ.

This alternative way of designing systems landscapes enables the built environment to meet some of its resource needs through internal sources and regeneration, thereby self-providing its own ecosystem products and services. The criterion serves to make this ambition more explicit, i.e. to internalise resource use by building local self-sufficiency, hence mitigating externalisation and displacement effects. However, the use of local resources is always limited by, and should be in proportion to, the rate that resources are being regenerated in the specific site.

Facilitate regenerative processes

Re-localisation of bioenergy systems is one example where regenerative processes are facilitated (c.f. Bergquist, Cavalett and Rydberg, 2012). Energy crops, e.g. Salix sp. and Alnus sp. can be cultivated in distributed stands following the urban topography, as illustrated in figure 3, another sketch developed through dialography. Here, biomass for district heating is produced on-site by making use of the access to water on a flood plain or river bank. The plantations offer additional ecosystem services particularly relevant for climate change adaptation; filtration of storm water runoff from adjacent buildings, i.e. tectonic structures, buffer zone for river flood protection, as well as wetland biodiversity. The location in the ecotone between urban and rural areas implies recreational opportunities are also created. This way to reconsider the proportion of tropism and tectonics would generate multi-functional systems landscapes where regenerative processes are at the centre. Another way to put it is to prioritise tropism in urban landscapes, as it represents a fundamental principle for space formation where regenerative processes are particularly obvious.

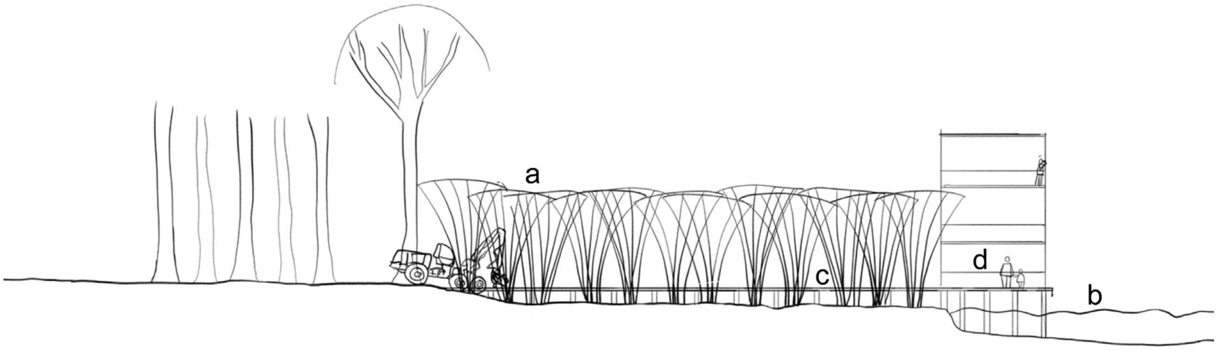


Figure 3
Regenerative systems landscape with integration of bioenergy production (a), storm water management (b), wetland biodiversity (c) and recreation (d) in the urban-rural ecotone.

Contribute feedback

At a local level, designing for self-organisation implies a need to enable feedback at multiple scales. One way to achieve this is to integrate an array of human needs and ecosystem functions. Again, urban agriculture provides a concrete example, here in terms of conditions being created that enable feedback to be harnessed locally, in the form of sunlight and rainfall, waste for compost (Bergquist, 2012) and ecological knowledge (Barthel, Folke and Colding, 2010). However, the principle of maximum empower suggests that appropriate designs are those that also contribute to larger scales of society and environment. This may be identified by performing inventories of connections and impacts that reinforce regenerative processes, and by determining at which levels these occur. In figure 4 we illustrate this reasoning in an urban setting, developed during dialography and supplemented with the systems diagram in the upper part.

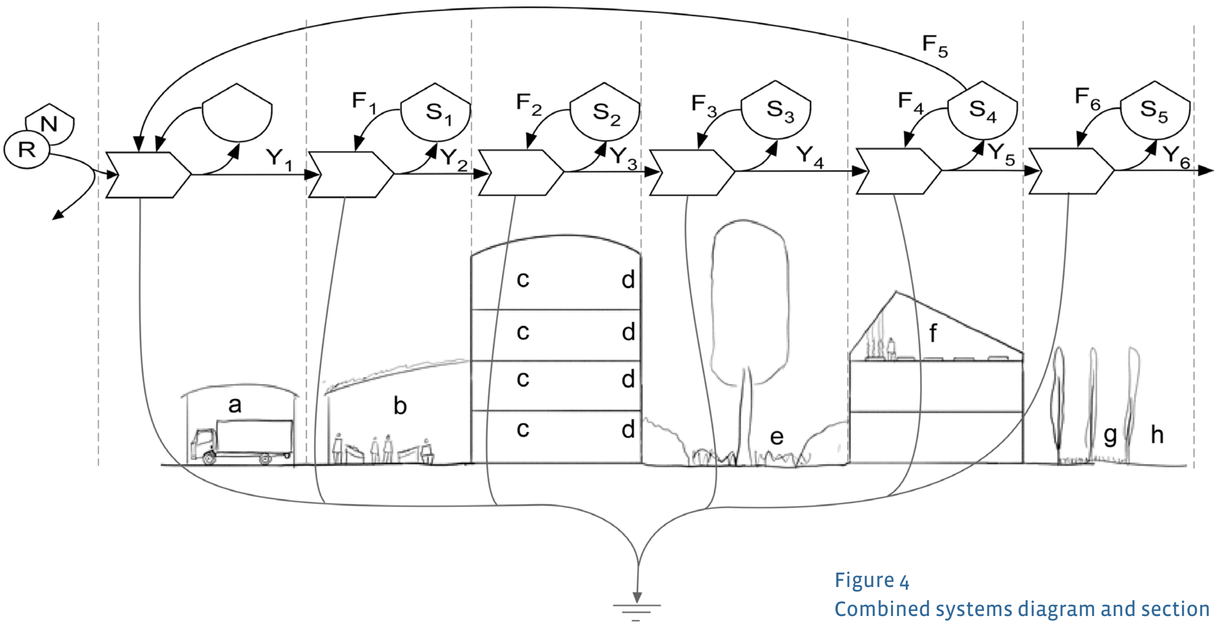


Figure 4
Combined systems diagram and section highlighting feedback loops at multiple scales, and that enable the systems landscape to utilise its potential for regenerative processes.

From left to right, in this illustration a truck (a) delivers produce from nearby agriculture running on renewable (R) and non-renewable (N) resources. The yield (Y_1) is provided as input to an urban farmers market (b, storage, S_1). The produce is paid for by urban residents – a feedback to farmers both in the form of monetary payments and signalled preferences (F_1). Produce is consumed by residents (Y_2) and while storing (S_2) and preparing the food in their homes (c), organic waste is generated (Y_3). This in turn is used as fertiliser (F_2, F_3, F_4) for urban agriculture in window farms (d), community gardens (e, S_3) and rooftop greenhouses (f, S_4), yielding additional food products to residents (Y_4) and enabling them to contribute work (Y_5) in the garden (g, S_5) which in turn generates ecosystem services (Y_6) to nearby green-blue structures (h), and hence the systems landscape as a whole. Surplus compost is likewise fed back to rural farmers and used as fertiliser (F_5) by making use of the truck going back to the rural area.

Enable diversity and multi-functionality

The principle of maximum empower suggests that design should enable processes to run on multiple sources and regenerate a diversity of outputs and multi-functionality at various scales. In the dialography sessions it became clear that particularly blue-green structures represent elements of city building with major significance, e.g. for alleviating negative externalities through on-site regeneration of resources instead of imports. In figure 5 we explored this reasoning in a sketch of a hypothetical urban block that shows how to turn every single building in a city towards the sun. This becomes more crucial the further away from the equator the city is located.

Primarily used to facilitate our shared thinking, figure 5 conceptualises a certain cluster of relations between tropism and tectonics that would strengthen conditions for multiple beneficial effects. By using the tectonic building structures to expose a larger area to sunlight, tropism is invited on green roofs (a), and walls (b), in addition to the yard (c). Opportunities to harness wind and solar energy are also improved, e.g. for renewable electricity and heating.

While the idea of opening blocks towards the sun is not new, it is seldom adopted in dense districts. Today, we find many projects that overlook this possibility, which is clearly not guiding urban development to the extent that it could. We therefore have included this example in order to restate the obvious. Conscious design and maintenance of diverse and multi-functional systems landscapes thus imply maximising the extent of biologically living ground to refine the green and grey spaces alike.

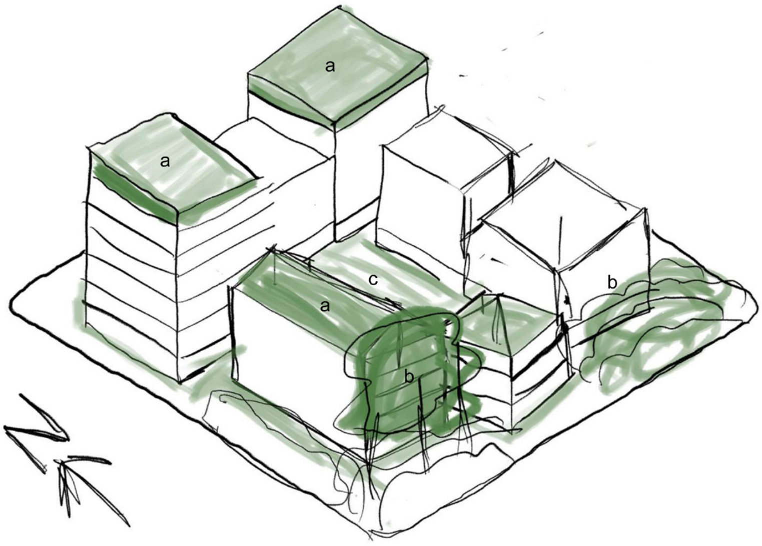


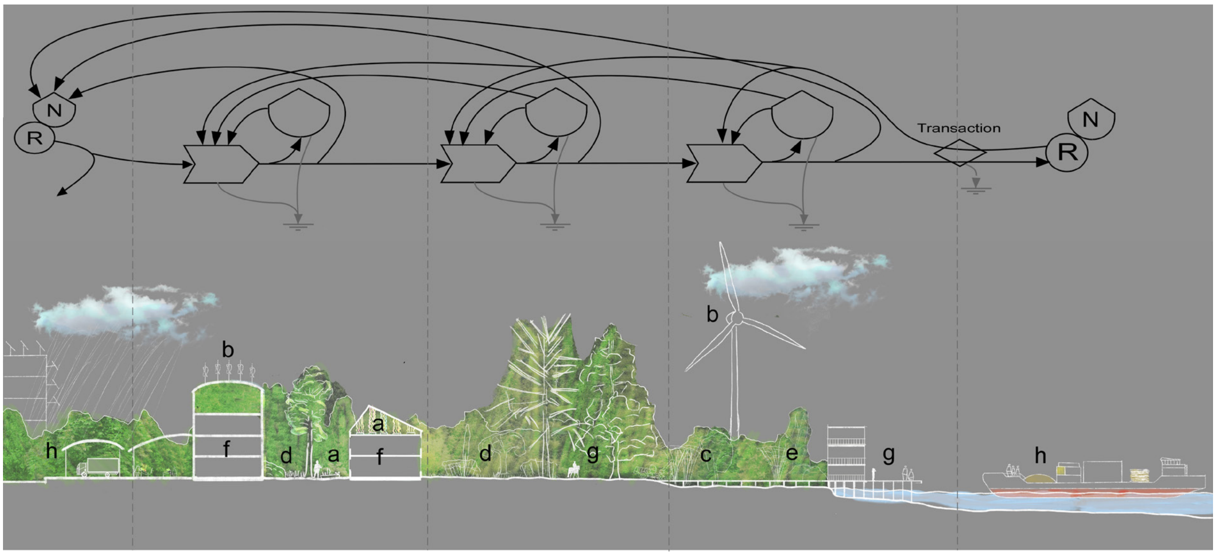
Figure 5
A city block turned towards the sun enables diversity and multi-functionality, here exemplified by having green roofs (a), walls (b), and yards (c) and designed in a way that makes it possible to maximise surfaces exposed to sunlight, as an input to regenerative processes on site.

Synthesis – from objects to regenerative relations

In figure 6 we offer a source for reflection by tying together the criteria, conceptual images and illustrations used hitherto, in an aggregated vision of a regenerative systems landscape considered as a coherent whole. Instead of focussing on specific objects and artefacts in this hypothetical systems landscape, we emphasise an array of activities, processes and functions.

Figure 6 is not to be interpreted as a finished blueprint of any specific landscape, but rather as a snapshot of the final stage of the research process, thus highlighting and synthesising the issues raised through dialography. Examples directly visible in the locale range from the production of food (a), wind power (b) and biomass energy (c), to waste and water

Figure 6
Components and sub-systems in a regenerative systems landscape. Note the feedback loops moving from right to left, which indicate resources that are distributed across scales to facilitate local regenerative processes of various kinds. The barge on the far right here represents connections to other systems landscapes through imports and exports.



management in gardens (d) and wetlands (e). The layout in direct connection to housing (f) enables access to labour by residents to manage landscape functions, as well as benefitting from increased biodiversity and recreational values (g). Meanwhile, invisible though crucial connections to supportive rural and distant systems landscapes are represented by transport systems, imports and exports (h). This vision thus represents an ideal, yet purely hypothetical scenario, in which a systems landscape has been designed through self-organisation and hence is managed as a coherent whole. To facilitate regenerative processes, the design explicitly strives towards finding the best possible alignment with local ecology and people, in cycling and building storages of resources in situ.

Concretely, the results from the dialography process depicted in figure 6 imply a call to avoid excessive sealing of land and maintaining green multi-layered structures as a regenerative resource. By prioritising green structures (tropism) in such patchy ecotones, interaction increases with tectonic structures, which creates new opportunities for making use of resources that are regenerated locally to compensate for losses due to the 2nd law of thermodynamics, as well as alleviating negative externalities. Through application of our criteria for regenerative systems landscapes, diversity and multi-functionality have taken the form of reinforcing feedback and multiple connections across scales. Individual parts work together to strengthen the capacity of the systems landscape to simultaneously generate useful materials, reduce energy and resource use, offer experiences and recreational values, while (re)building the capacity of ecosystems to regenerate over time.

Discussion and conclusions – contextualisation of the design criteria

Obviously, figure 6 conveys only a fraction of the complexity of real systems landscapes. This is evident considering particularly dense agglomerations, e.g. towns, cities and mega-cities. Regardless of the scale, such systems landscapes, through the lens of GST, may be conceived as places of transformation; where urban sub-systems draw on many types of input resources that are transformed into multiple outputs. In the process, a share of energy potential is always lost according to the 2nd law. Urban systems landscapes (of transformation) may thus have great potential for diversity, since they represent sites where resources and people converge in a limited geographical area. However, they can likewise result in high maintenance areas, i.e. sites that require continuous resource throughput to be sustained. It is therefore possible to conclude that smart designs are those that build capacity of local regenerative processes, to avoid negative externalities and displacement effects in the long term. One way to achieve this is to prioritise the establishment of multi-functional systems landscapes that may exist and regenerate indefinitely by self-providing resources to a higher extent, as opposed to excessive resource throughput and imports.

The concept of self-organisation provides important insights into how systems develop solutions that work in the long run. Our process of dialography supported us in exploring how this reasoning may be applied in urban design. The results indicate an opportunity for landscape architects to mimic organisational patterns found in natural ecosystems. This approach may assist in solving design predicaments by using more explicitly the built environment to amplify green-blue structures, and vice versa. As such, the approach offers an ontological model that strengthens design-with-nature in the era of predictive adaptation. In other words, to learn to design landscapes in a way that is based on patterns that have been found to be general for all kinds of living systems. In accepting regeneration as a fundamental principle for moving beyond sustainability, our design criteria offer a systematised approach in this endeavour. While in this paper we have only tested this approach by exploring hypothetical examples of systems landscapes, it serves to draw attention to a way in which LA may be more closely linked to GST, and hence take a significant step towards maturing as a discipline more explicitly rooted in theory and the basic understanding of living systems.

Conversely, our set of design criteria may be used to position systems thinking more clearly in the practical design professions. The illustrations presented represent our first attempt to propose both concrete visions of regenerative systems landscapes, and more importantly, a means to develop theoretical thinking to the benefit of future human settlements and Earth as a whole. One central conclusion is the need to give more priority to tropism, as it represents a fundamental principle for space formation where regenerative processes are particularly active. Another is to avoid excessive sealing of land and maintaining green multi-layered structures as a regenerative resource. Though such prioritisation is not new in urban design – what we propose is essentially to transition from a design process based on site-specific prioritising, to systems thinking and synthesis, i.e. to join human design and environmental self-design in mutually symbiotic ways. We believe that such an integrated approach may trigger the emergence of new solutions and synergies in planning and design.

Crucial resources here are human and environmental resources and their interdependence that are made concrete in time and space at each specific site. A conclusion is therefore that mind-sets need to merge as the modifying and management of landscapes have to be based on an integrated theory of ecological systems thinking and future-oriented design theory with a widened time-space perspective. Thinking of sites as systems landscapes gives guidance in design conceptualisation, problem formulation and solutions, by demonstrating emergent relations to be considered in all scales. While this approach remains to be tested empirically, as a hypothesis it serves to illuminate the need and potential of abandoning compartmentalisation of landscapes as rural, urban, institutional, natural or cultural, and instead to zoom out to see coherent wholes of complex nested systems. We believe that landscape architects – guided by our design criteria – may thereby have a greater chance to move beyond sustainability. Future case study research is needed to show examples of apparently new ideas and design solutions evolving from the use of this approach to regenerative systems landscape design.

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References

Abel, T., 2013. Emergy evaluation of DNA and culture in “information cycles”. *Ecological Modelling*, 251(February), pp.85–98.

Ahern, J., 2002. *Greenways as strategic landscape planning: theory and application*. Doctoral thesis Wageningen university.

Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fisksdahl-King, I. and Angel, S., 1977. *A pattern language*. Oxford: Oxford University Press.

Barthel, S., Folke, C. and Colding, J., 2010. Social-ecological memory in urban gardens – retaining the capacity for management of ecosystem services. *Global Environmental Change*, 20(2), pp.255–265.

Barthel, S., Colding, J., Ernstson, H., Erixon, H., Grahn, S., Kärsten, C., Marcus, L. and Torsvall, J., 2013. *Principles of social-ecological urbanism – Case study: Albano Campus, Stockholm*. Stockholm: TRITA-ARK Forskningspublikationer.

Baumann, H. and Tillman, A.M., 2004. *The hitch hiker’s guide to LCA*. Lund: Studentlitteratur.

Beck, T.B., Quigley, M.F. and Martin, J.F., 2001. Emergy evaluation of food production in urban residential landscapes. *Urban Ecosystems*, 5(3), pp.187–207.

Bell, S., 1999. *Landscape: patterns, perception, process*. London: Routledge.

Bell, S. and Morse, S., 2008. *Sustainability indicators. Measuring the immeasurable?* London: Earthscan.

Berg, P.G., 2010. Timeless cityland – an interdisciplinary approach to finding the sustainable human habitat. Uppsala: Baltic University Press and Department of Urban and Rural Development, SLU University.

Berg, P.G., Ignatieva, M., Granvik, M. and Hedfors, P. 2013. Green-blue infrastructure in urban-rural landscapes: Introducing resilient citylands. *Nordic Journal of Architectural Research*, 25(2), pp.11–42.

Bergquist, D.A. 2008. *Colonised coasts. Aquaculture and emergy flows in the world system: cases from Sri Lanka and the Philippines*. Doctoral thesis Uppsala University.

Bergquist, D.A. 2012. Emergy synthesis of urban agriculture in Rio de Janeiro, Brazil. *Emergy Synthesis 6, Theory and Applications of the Emergy Methodology*. *Proceedings of the 6th Biennial Emergy Research Conference*. USA: University of Florida, Gainesville. pp.253–264.

Bergquist, D.A. and Rydberg, T., 2009. Towards a transdisciplinary understanding of emergy accumulation. *Emergy Synthesis 5, Theory and Applications of the Emergy Methodology. Proceedings of the 5th Biennial Emergy Research Conference*. USA: University of Florida, Gainesville. pp.15–22.

Bergquist, D.A., Cavalett, O. and Rydberg, T., 2012. Participatory emergy synthesis of integrated food and biofuel production: a case study from Brazil. *Environment, Development and Sustainability*, 14(2), pp.167–182.

Booth, N.K., 1983. *Basic elements of landscape architectural design*. New York: Elsevier.

Brown, M., 2003. Resource imperialism: Emergy perspectives on sustainability, international trade, and balancing the welfare of nations. In: S. Ulgiati, M. Brown, M. Giampietro, R. Herendeen and K. Mayumi, eds. 2003. *Advances in energy studies. Reconsidering the importance of energy. 3rd biennial international workshop*. Padova: SGE Publisher. pp.135–149.

Brun, M., 2015. Tanketradisjoner i startfasen – tilbakeblikk: Landskapsarkitektur for femti år siden. In: P. Hedfors and C. Dahl, eds. 2015. *Urkunder och husgudar. Pionjärernas litteratur och andra källor till landskapsarkitektur*. Uppsala: FUSE and Movium, Swedish University of Agricultural Sciences.

Capra, F., 1996. *The web of life. A new scientific understanding of living systems.* New York: Anchor Books.

Collins, H.M., 2010. *Tacit and explicit knowledge*. Chicago: The University of Chicago Press.

Condon, P.M., 2008. *Design charrettes for sustainable communities*. Washington D.C.: Island Press.

Cornell, E., 1968. *Arkitekturhistoria*. Stockholm: Almqvist and Wiksell.

Deming, E.M. and Swaffield, S.R., 2011. *Landscape architectural research: Inquiry, strategy, design*. Hoboken, N.J.: John Wiley & Sons.

Dreyfus, S.E. and Dreyfus, H.L., 1980. *A five-stage model of the mental activities involved in directed skill acquisition*. Washington, DC: Storming Media.

Federici, M., Ulgiati, S., Verdesca, D. and Basosi, R., 2003. Efficiency and sustainability indicators for passenger and commodities transportation systems. The case of Siena, Italy. *Ecological Indicators*, 3(3), pp.155–169.

Forman, R.T.T. and Godron, M., 1986. *Landscape ecology*. New York: Wiley.
Geddes, P., 1949. *Cities in evolution*. London: William and Norgate.

Geddes, P. and Stalley, M., eds., 1972. *Patrick Geddes: Spokesman for man and the environment; a selection*. New Brunswick, N.J.: Rutgers University Press.

Granvik, M. and Hedfors, P., 2015. Evergreen issues of planning? Learning from history for sustainable urban-rural systems landscapes. *European Journal of Spatial Development*, 5(December), pp.1–21.

Gustavsson, R., 2004. Exploring woodland design: Designing with complexity and dynamics – woodland types, their dynamic architecture and establishment. In: N. Dunnett and J. Hitchmough, eds. 2004. *The dynamic landscape: Design, ecology and management of naturalistic urban planting*. London: Spon Press. pp.246–293.

Hall, C., 1995. What is maximum power? In: C. Hall, ed. 1995. *Maximum power. The ideas and applications of H.T. Odum*. Louisville, CO: University Press of Colorado.

Hedfors, P., 2014. Tropism and tectonics: Fundamental principles of space formation. *Journal of Landscape Architecture*, 9(2), pp.64–71.

Hedfors, P. and Florgård, C., 2012. Design with nature: The gardener's view. In: M. Luccarelli and P.G. Røe, P.G., eds. 2012. *Green Oslo: Visions, planning and discourse*. London: Ashgate. pp.198–211.

Holling, C.S., 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4(November), pp.1–23.

Hornborg, A., 2001. *The power of the machine. Global inequalities of economy, technology and environment*. New York: Altamira Press.

Kahn, A., 2005. Defining urban sites. In: C. Burns and A. Kahn, eds. 2005. *Site matters: Design concepts, histories and strategies*. London: Routledge. pp.281–296.

Lang, J., 1987. *Creating architectural theory: The role of the behavioral sciences in environmental design*. New York: Van Nostrand Reinhold.

Lawson, B., 2006. *How designers think: The design process demystified*. Oxford: Architectural Press.

Lyle, J.T., 1994. *Regenerative design for sustainable development*. New York: Wiley.

Lyle, J.T., 1999. *Design for human ecosystems: landscape, land use and natural resources*. Washington D.C.: Island Press.

Martin, J., 2012. *Genius of place: The life of Frederick Law Olmsted*. Cambridge, MA: Da Capo Press.

Martin, J.F., Diemont, S.A.W., Powell, E., Stanton, M. and Levy-Tacher, S., 2006. Emergy evaluation of the performance and sustainability of three agricultural systems with different scales and management. *Agriculture, Ecosystems & Environment*, 115(1–4), pp.128–140.

McHarg, I.L., 1969. *Design with nature. Garden City*. New York: Natural History Press for the American Museum of Natural History.

McHarg, I.L., 1998. *To heal the earth: selected writings of Ian L. McHarg*. Washington, D.C.: Island Press.

Motloch, J., 2001. *Introduction to landscape design*. New York: John Wiley.

Motloch, J. and Woodfin T.M., 1993. General systems theory, cultural change, and a human science foundation for planning and design. *Journal of Systems Research*, 10(2), pp.1–26.

Motloch, J., 2016. Unlocking complexity: Big science project and research agenda. *International Journal of Design & Nature and Ecodynamics*, 11(4), pp.563–572.

Motloch, J., 2017. Complex system co-design: Pathway to becoming an appreciative system. *Proceedings of the 8th International Multiconference on Complexity, Informatics and Cybernetics (IMCIC 2017)*, pp.49–56.

Murphy, M.D., 2005. *LA theory: an evolving body of thought*. Long Grove: Waveland Press.

Murphy, M.D., 2016. *LA theory. An ecological approach*. USA: Island press.

Murphy, M. and Hedfors, P., 2011. Systems theory and LA. In: R. Berney, ed. 2011. *Urban nature*, CELA. Los Angeles, USA. 30 March–2 April 2011.

Naveh, Z. and Lieberman, A.S., 1994. *Landscape ecology: Theory and application*. 2nd ed. New York: Springer-Verlag.

Ndubisi, F., 2002. *Ecological planning: a historical and comparative synthesis*. Baltimore: Johns Hopkins University Press.

Odum, H.T., 1971. *Environment, power and society*. New York: John Wiley.
Odum, H.T., 1987. *Living with complexity*. The Crafoord prize in the bioscience. Crafoord lectures. Stock-

holm: The royal Swedish academy of science.

Odum, H.T., 1995. Self-organisation and maximum power. In: C. Hall, ed. 1995. *Maximum power. The ideas and applications of H.T. Odum*. Louisville, CO: University Press of Colorado.

Odum, H.T., 1996. *Environmental accounting: EMERGY and environmental decision making*. New York: John Wiley & Sons.

Odum, H.T., 1999. Limits of information and biodiversity. In: H. Löffler and E.W. Streissler, eds. 1999. *Sozialpolitik und* Ökologie*probleme der Zukunft*. Vienna: Österreichischen Akademie der Wissenschaften. pp.229–269.

Odum. H., 2007. *Environment, power, and society for the twenty-first century; The hierarchy of energy*. New York: Columbia University Press.

Odum, H. and Odum, E., 2001. *A prosperous way down: Principles and policies*. Louisville, CO: University Press of Colorado.

Olmsted, F.L., 1870. Public parks and the enlargements of towns. In: R. Twombly, ed. 2010. *Frederick Law Olmsted: Essential texts*. New York: WW Norton & Company.

Olmsted, F.L., 1895. Parks, parkways and pleasure grounds. In: R. Twombly, ed. 2010. *Frederick Law Olmsted: Essential texts*. New York: WW Norton & Company.

O'Hare, P. and White, I., 2013. Deconstructing resilience: lessons from planning practice. *Planning Practice & Research*, 28(3), pp.275–279.

Partanen, J., 2015. Indicators for self-organisation potential in urban context. *Environment and Planning B: Planning and Design*, 42(5), pp.951–971.

Rees, W. and Wackernagel, M., 1996. Urban ecological footprints: Why cities cannot be sustainable – and why they are a key to sustainability. *Environmental impact assessment review*, 16(4–6), pp.223–248.

Rogers, E.B., 2001. *Landscape design: a cultural and architectural history*. New York: Harry N. Abrams.

Russo, T., Buonocore, E. and Franzese, P.P., 2014. The urban metabolism of the city of Uppsala (Sweden). *Journal of Environmental Accounting and Management*, 2(1), pp.1–12.

Schön, D.A., 1983. *The reflective practitioner: How professionals think in action*. Aldershot: Arena.

Şorman, A., 2015. Metabolism, societal. In: G. D'Alisa, G.Demaria and G. Kallis, eds. 2015. *Degrowth: A vocabulary for a new era*. London: Routledge.

Spirn, A.W., 2000. Ian McHarg, LA, and environmentalism: Ideas and methods in context. In: M. Conan, ed. 2000. *Environmentalism in LA*. Washington D.C.: Dumbarton Oaks Research Library and Collection. pp.97–114.

Turner, T., 1996. *City as landscape: a post-postmodern view of design and planning*. London: Spon.

Ulgiati, S., Odum, H.T. and Bastianoni, S., 1994. Emergy use, environmental loading and sustainability. An emergy analysis of Italy. *Ecological Modelling*, 73(3–4), pp.215–268.

United Nations, 1987. *Our common future*. World commission on environment and development. Oxford: Oxford university press.

Wackernagel, M., 1994. *Ecological footprint and appropriated carrying capacity: A tool for planning toward sustainability*. Ph.D. School of Community and Regional Planning, The University of British Columbia.

Zaitzevsky, C., 1982. *Frederick Law Olmsted and the Boston park system*. Cambridge, Mass.: Belknap P.

Zari, M.P., 2015. Ecosystem services analysis: Mimicking ecosystem services for regenerative urban design. *International Journal of Sustainable Built Environment*, 4(1), pp.145–157.

Zhang, S., de Roo, G. and van Dijk, T., 2015. Urban land changes as the interaction between self-organisation and institutions. *Planning Practice and Research*, 30(2), pp.160–178.

Zhang, Y., Yang, Z., Liu, G. and Yu, X., 2011. Emergy analysis of the urban metabolism of Beijing. *Ecological Modelling*, 222(14), pp.2377–84.

Zhifeng, Y., Yan, Z., Shengsheng, L., Hong, L., Hongmei, Z., Jinyun, Z., Meirong, S. and Gengyuan, L., 2014. Characterizing urban metabolic systems with an ecological hierarchy method, Beijing, China. *Landscape and Urban Planning*, 121(January), pp.19–33.

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