

Towards a socio-ecological spatial morphology: integrating elements of urban morphology and landscape ecology

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Abstract. *The recent shift towards greater emphasis on biodiversity and urban ecosystems has increased the need for greater understanding of the green areas in cities as ecological environments. However, landscape ecology and urban morphology have yet to be integrated into a joint field. In this paper steps are taken towards developing an integrated socio-ecological urban morphology based on developments in each field. Such a morphology can inform professional practice in urban design. Comparisons of the different objects of description in the two fields are made and their different means of description – notably the patches, corridors and the matrix in landscape ecology, and the streets, plots and buildings in urban morphology. This provides a basis for a joint description in which these elements together form a configuration of patches.*

Keywords: urban morphology, landscape ecology, sustainability, socio-ecological urbanism, urban design

The last decade has produced extensive and convincing proof of environmental threats on a scale unprecedented in human history. Not least, the expectation that two-thirds of the world's population will live in cities by the year 2050 (United Nations, 2017) is focusing attention on the ability of urban and ecological systems to support human wellbeing.

It is increasingly agreed that, given the right strategies for their future development, cities

are part of the solution, rather than the root of the problem. This concerns both socio-economic issues and ecological ones, since species and ecosystems in urban landscapes are increasingly seen as vital for the urgent task of safeguarding the biosphere (Barthel *et al.*, 2018; Colding *et al.*, 2013). Cities are combinations of social and ecological systems (Berkes *et al.*, 1998) in which humans interact with ecosystems and are vital for their support. Seen in this way cities are socio-ecological

landscapes that need to be properly designed and managed (Andersson *et al.*, 2014).

This puts new demands on urban morphology as a vital basis for successful design and maintenance of urban landscapes. More precisely, it challenges urban morphology to expand and develop conceptions and descriptions of urban form that also include urban ecosystems and how such systems are structured and shaped by the spatial form of cities. An early example is the work of Conzen (1960) on the morphology of fringe belts – the development of spacious zones at the edge of cities that harbour large-scale land uses that later become embedded in the urban area. These have proved useful from the point of view of urban ecology, especially in relation to biodiversity (Hopkins, 2012, 2018). However, the study of natural elements in urban morphology generally remains limited. Among the exceptions are the Urban Structural Unit (USU), developed to include the structure of unbuilt as well as built space in cities, and the related ecologically significant criterion of surface sealing (Osmond, 2010). However, to be properly grounded, the way forward must include increased exchange with conceptions of spatial form in ecology, something highly developed in the sub-field of landscape ecology, which actually exhibits similarities to urban morphology. Hence, this paper addresses central theoretical and descriptive issues concerning the possibility of a joint spatial morphology for cities conceived as socio-ecological landscapes. Such a morphology would both support the further development of knowledge about cities as socio-ecological entities and inform and support an extended professional practice in urban design that includes urban ecosystems (Barthel *et al.*, 2013). In short, such a morphology would be an essential step if we are to respond to the urgent need to guide urban systems towards trajectories of greater environmental sustainability.

We aim to contribute to such a development. In this paper such a unified social-ecological spatial morphology is addressed in purely descriptive terms. Similarities and differences between basic elements of spatial form in both

landscape ecology, such as *patches*, *corridors* and *matrixes* (Alberti, 2008), and urban morphology, such as *streets*, *plots* and *buildings* (Conzen, 1960; Moudon, 1994; Whitehand, 2001) are identified and discussed. This is in line with the second of Batty's three themes in his proposal for a research programme for urban morphology, 'linking structure to process, establishing basic units of morphological description and deriving spatial relations consistent with the underlying geometry of cities' (Batty, 1999). In this way a basic unit of morphological description is identified that is meaningful from the points of view of both landscape ecology and urban morphology. Such a unit can be the basis for a unified spatial morphology with relevance to both ecology and the social sciences, including practices dependent on either or both. In a subsequent paper we aim to move beyond descriptions of landscape patterns in themselves, towards developing an understanding of how such patterns underpin the functioning of urban and ecological systems.

The development of urban ecology and landscape ecology

Essential for a unified spatial morphology, drawing on both landscape ecology and urban morphology, are means whereby the spatial form of cities can be described in a manner that comprises not only the built environment but also urban green (and blue) environments and their ecosystems. It is necessary here to consider landscape ecology (see, for example, Forman and Godron, 1986), which may be regarded as an equivalent in ecology to urban morphology in relation to urbanism. This field, which is of increasing importance in ecology generally, concerns the description and explanation of function and change in natural landscapes and has developed a set of formalized concepts and geometric definitions that describe the spatial patterns of landscapes.

Landscape ecology is a fairly recent field that developed in the 1970s (McDonnell, 2011, p. 5) in close relation to urban ecology, both fields being dependent on major theoretical

shifts within ecology. For a long time, cities were not seen as objects of useful study in ecology. This reflected what was later referred to as ‘the myth of the balance of nature’ (McDonnell, 2011, p. 6). In accordance with this belief, ecologists, in their aim to study nature in its true state, turned away from environments encroached on by humans with the effect that ‘for much of the twentieth century the discipline of ecology contributed relatively little information to our understanding of human settlements’ (McDonnell, 2011, p. 7).

This does not mean that there were no ecology-related problems in cities. On the contrary, these were widespread in the rapidly industrializing cities of the nineteenth century, and such problems as pollution and sanitation were high on the social and public health agendas. However, these problems were at the time approached by the emerging environmental sciences based in engineering rather than the ecological sciences. Importantly, this created a lasting connection of urban environmental problems to technological solutions rather than ecological ones. Moreover, it helps recognition of the deeper differences among current approaches to sustainable urban development. For instance, what is known as ‘sustainable urbanism’ typically has its roots in the environmental sciences, while the foundations of ‘landscape urbanism’ are to be found in ecology (Marcus *et al.*, 2013).

In recent decades, however, the field of urban ecology has grown rapidly from its origins in the early 1970s (McDonnell, 2011), not least owing to broad recognition that ecological systems are not static, but open, dynamic and regulated by external forces. Importantly, it is also generally acknowledged that such external forces have their origins not only in natural phenomena, such as fires and storms, but also in human activities, such as agriculture and urbanization. Hence, in this paradigm humans are understood as intrinsic parts of nature and its ecological processes and nowhere is this influence more apparent than in cities.

Significant for the rapid growth of urban ecology has been the parallel development of landscape ecology (Andersson, 2006). Alberti states in her synthesising work that ‘landscape

ecology is, perhaps, the first consistent effort to study how human action (that is, changing spatial patterns) influences ecological processes (for example, fluxes of organisms and materials) in urbanizing environments’ (Alberti, 2008, p. xii). This echoes the definition of the field by early pioneers such as Carl Troll, Ernst Neef and Josef Schmithüsen, even though such a conception of the environment as a holistic ecological system highly influenced by man was looked upon with suspicion when the dominant disciplinary ideal was scientific specialization (Leser and Rodd, 1991, p. 831). Forman and Godron (1986, p. 7) characterize landscape ecology by contrasting it to ecology in general, pointing out that the latter has focused on the *vertical* relationships among organisms within a relatively homogenous spatial unit, whereas landscape ecology has focused on the *horizontal* relationships between spatial units. Hence, one of the central assumptions in landscape ecology is that ecological processes can be inferred from spatial patterns (Andersson, 2006), an idea not unfamiliar in urban morphology.

Means of description

In any morphological description we can make a distinction between *means of description* and *objects of description*, where the first concerns the representation of entities in space and the second concerns the nature of these entities. In geography, which has influenced the development of both landscape ecology and urban morphology, one description is in terms of points, lines or polygons and the extent to which landscape ecology and urban morphology share these attributes will be examined here. Objects of description, however, can vary greatly in geographical content and clearly vary also between landscape ecology and urban morphology.

In landscape ecology there are three aspects of natural landscapes for which spatial description is essential: first, landscape *structure*, or the arrangement of landscape elements; secondly, landscape *functioning*, or the movement and flows of, for example, animals,

plants, water and wind through the landscape structure; thirdly, landscape *change*, or the dynamics of the structure and its functioning over time (Dramstad *et al.*, 1996, p. 14). There are similarities to certain aspects of urban morphology. For instance, in the consideration of townscape (or urban landscape) by Conzen (1960, pp. 4–5), we find the distinction between three broad aspects of urban landscapes dependent on morphological description: first, there is the *town plan*, or the arrangements of streets, plots and buildings (or more precisely their block-plans); secondly, there is the interdependence of town plan and *land use*, bridging between the elements of the plan and social and economic activity; thirdly, there is the *evolutionary approach*, describing the changes of both town plan and land use over time.

Essential for all of these aspects in both fields are means whereby one can describe the spatial patterns of natural or urban landscapes, that is a spatial morphology. The essential elements of such a morphology in landscape ecology are fixed (Forman and Godron, 1986, p. 23). These elements are *patches*, *corridors* and *matrixes*, which in combination form a characteristic mosaic for each individual landscape (Dramstad *et al.*, 1996). In landscape ecology these elements are geometric descriptions of spatial patterns in the natural landscape, with parallels in the urban landscape in urban morphology.

In general terms, in landscape ecology a 'patch' is defined as 'a non-linear surface area differing in appearance from its surroundings' (Forman and Godron, 1986, p. 83); 'corridors' are 'narrow strips of land which differ from the matrix on either side' (*ibid.*, p. 123); and 'matrix' is 'a surrounding area that has a different species structure and composition' (*idem*, p. 83). Importantly, such descriptions are most often done from the point of view of certain species or groups of species. They often imply a binary landscape with on the one hand 'patches' and 'corridors' that together constitute the habitat of a species or species group, and on the other hand a 'matrix' defined as the non-habitat surrounding the patches and corridors (Ricketts, 2001) (Figure

1). Importantly, what species group descriptions are made of determines the scale of the description with important consequences for its resolution. Such descriptions are intended to support different explanations of landscape dynamics, for instance the processes that give rise to spatial patterns or, conversely, how spatial patterns structure landscape dynamics (Dramstad *et al.*, 1996, p. 15).

In urban morphology, more specifically in Conzen's seminal work, the town plan comprises *streets*, *plots* and *building block-plans* (hereafter referred to simply as 'buildings') (Conzen, 1960, p. 5). 'Plots' (or parcels) here constitute the basic elements in patterns of land division, which geographically defines and differentiates property rights and land uses and hence works as an organizational framework. As such, it also provides the framework change over time (Conzen, 1960; Panerai *et al.*, 2004). This is naturally also influenced by the pattern of 'streets', which offer accessibility to 'plots' and thereby create specific relative locations in the urban landscape. 'Buildings', finally, are physical manifestations that support or enhance the particular land uses of different plots. The combination of streets, plots and buildings constitute the town plan in urban morphology, in a similar way that patches, corridors and the matrix constitute a landscape mosaic in landscape ecology. We can here identify similarities between the two sets of elements. Geometrically, the 'plot' in urban morphology resembles the 'patch' in landscape ecology, where both most often take the shape of some form of compact polygon. We also see a clear geometric likeness between 'streets' and 'corridors', where both, in contrast to patches and plots, take the shape of more elongated polygons. However, at closer scrutiny these similarities in means of description are not matched by similarities in object of description.

What is termed 'the matrix' in landscape ecology does not have an equivalent in urban morphology. The matrix is what surrounds patches and corridors and is typically constituted by a continuous element of similar ecological composition that contrasts with the content of patches and corridors. Therefore, patches and corridors constitute exceptions in

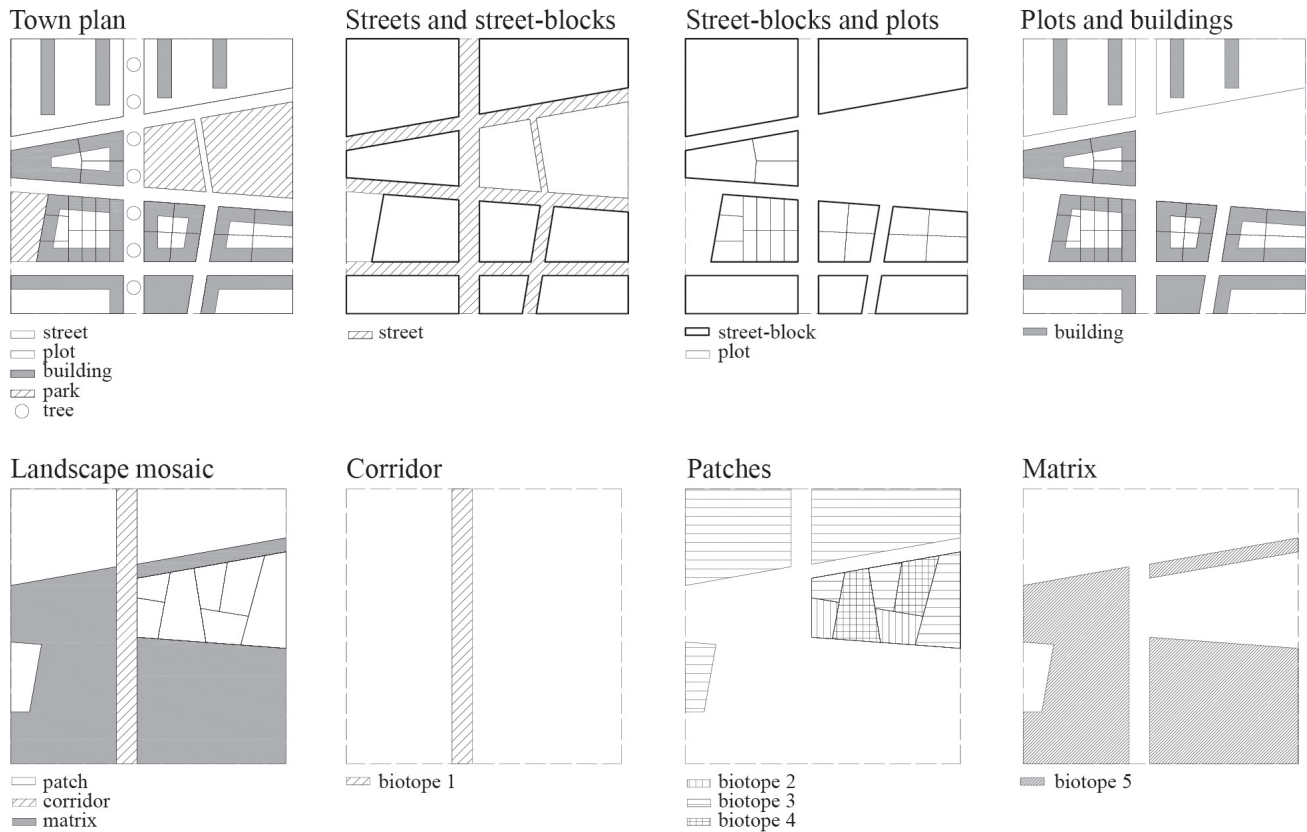


Figure 1. Morphological description of an urban area according to the concept of the town plan constituted by the elements: streets, street-blocks, plots and buildings (top), and morphological description of the landscape mosaic: corridors, patches and matrix (bottom). Descriptions in urban morphology and landscape ecology may on the surface exhibit similarity, but ontologically they are distinct.

the broader landscape and can be the effect of both natural causes and human interventions. For instance, both agricultural or windfall patches may occur within a continuous forest matrix. It is therefore not surprising that ecologists first considered patches as analogous to islands (Dramstad *et al.*, 1996), but soon abandoned this analogy and acknowledged the effects of the matrix on the distribution and population dynamics of organisms inhabiting patches and corridors (Ricketts, 2001). The matrix may have very many shapes and sizes and hence also dominates landscapes to varying degrees, but generally it ‘plays a dominant role in the functioning of the landscape (that is, the flows of energy, materials, and species)’ (Ricketts, 2001, p. 159). Even though there is no equivalent to ‘the matrix’ in urban morphology, we may see how a similar notion

could be useful in that field. Urban areas are also surrounded by something like a matrix, often in the form of natural landscapes, just as the built-up areas in cities often form the matrix for its green areas.

Finally, ‘buildings’ do not have an equivalent in landscape ecology. The closest we get is perhaps the geomorphology of natural landscapes, which in urban settings can be designed to varying degrees.

The commonalities in the elements in landscape ecology and urban morphology when it comes to the means of description in the two fields are also recognized in urban ecology. Alberti suggests that the horizontal structure of ecosystems ‘can be represented by patches (the ecological unit) and parcels [or plots] (the economic unit)’ (Alberti, 2008, p. 258). However, though the similarities between

these sets of elements are intriguing, there is reason for caution in interpretation, since each is part of a quite distinct landscape ontology – that is they differ when it comes to their object of description.

Objects of description

Notwithstanding the similarities in the means of description, there are important differences in what is represented by these means of description, that is the objects of description. The landscape element ‘corridors’, for instance, should not be understood as equivalent to the element ‘streets’ in urban morphology, despite the geometric similarity. While ‘corridors’ may be used for movement by different species and on different scales – just as streets may be used for movement by humans on different scales, depending on the transportation mode in cities – they do not share the primary function of spaces for movement that streets have in contrast to plots or street-blocks (Hillier, 1996). Rather ‘corridors’ are very similar to ‘patches’ in what they represent, in that they constitute an identifiable and distinct set of *biotopes* in the landscape, albeit with an elongated geometric shape. Hence, there is a weak *functional* distinction between ‘corridors’ and ‘patches’ and the difference is owing more to its characteristic form and relation to the surrounding matrix.

In pursuing this further it is necessary to acknowledge the fundamental differences between natural and urban landscapes as conceived in landscape ecology and urban morphology. *Ecosystems* are typically a conjunction of living (biotic) entities, that is animals and plants, and non-living (abiotic) entities, such as water and rock. Moreover, they are structurally made up of *biotopes*, that is areas of uniform environmental conditions, often classified by their plant compositions, and providing habitats, or parts of habitats, for particular sets of plants and animals: examples are wetlands, salt-water marshes and grasslands. Together biotopes build up particular configurations that are often easy to distinguish by the human eye. When we move through natural

landscapes, it is biotopes that make up the typical variations in land cover, plants and trees. In some countries ‘biotope’ is synonymous with the term habitat, but in this paper a distinction is made between the two. Habitats are defined from the point of view of a particular species or population and often comprise several biotopes, while biotopes describe broader biological communities including several species and populations in coexistence.

Viewed in relation to ecological concepts urban landscapes are constituted by, on the one hand, what may be called an ‘abiotic’ dimension, comprising physical artefacts, such as infrastructures and buildings, and on the other hand a ‘biotic’ dimension dominated by humans and their activities and land uses. It then becomes clear that landscape ecology is equally concerned with both the biotic and abiotic dimensions of landscapes, whereas there is primacy of the ‘abiotic’ dimension in urban morphology. This is so even though we often read land uses into urban forms, for instance when it comes to different building types. Moreover, urban morphology conceives of urban landscapes from a distinctly anthropocentric standpoint. This primacy of the human perspective in urban morphology, and the lack of it in landscape ecology, is a major reason for the differences in conception and terminology of spatial form in the two fields. This can be illustrated by the way in which certain types of green space and water in urban morphology are understood largely as spaces for human activity, while in landscape ecology they are understood as made-up of biotopes that form parts of ecosystems.

Hence, a divide is commonly recognized in both landscape ecology and urban morphology between ‘built land’ and ‘unbuilt land’, which often means that the one field emphasizes one and neglects the other. For instance, what in urban morphology are distinguished as different elements, such as streets, plots and buildings, can in landscape ecological descriptions often be summed up as simply ‘developed land’, or ‘grey infrastructure’. The biotope map for Stockholm, for instance, distinguishes three categories: ‘developed land with no/scattered vegetation’ (less than

10 per cent), 'developed land with scarce vegetation' (10–30 per cent) and 'developed land with dense vegetation' (30–50 per cent) (Lövfénhaft *et al.*, 2002). The whole area of concern in urban morphology is here clumped together as 'non-vegetation'.

Landscape ecology conceives of natural landscapes and urban landscapes as ecosystems made up of different biotopes forming a variety of natural habitats, including both biotic and abiotic dimensions. But typically, it excludes the specifically human habitat or describes this only as the negative of natural landscapes. Similarly, urban morphology conceives of urban landscapes, including their green areas, as exclusively human habitats (Moudon, 1997), typically disregarding their ecological dimensions. If we maintain the biotic-abiotic distinction it also means that in urban morphology urban spaces are often treated as 'abiotic' structures for human activity. Accordingly, it can be concluded that objects of description in landscape ecology – captured by its particular means of description (patch, corridor and the matrix) – are both the biotic and abiotic dimensions of natural habitats, while objects of description in urban morphology – captured by its means of description (streets, plots and buildings) – are the 'abiotic' dimensions of human habitats.

This discussion may seem to emphasize the differences between urban and natural landscapes. In fact, most natural landscapes are co-created by humans, most typically through agriculture, forestry and urbanization. So many biotopes in natural landscapes are not really 'natural' but highly artificial and actually maintained by humans, as in the case of agricultural parcels. Similarly, typical morphological elements in cities, such as plots and streets, are often heavily planted, at least in part, and have major importance for urban ecosystems. Moreover, in cities unplanned ecological activity often occurs in unintended locations, such as roadsides and train embankments, which are often of considerable ecological importance. In short, descriptions in landscape ecology and urban morphology are often concerned with the same urban element but conceive it differently.

A common level of geometric description in urban morphology and landscape ecology

Summarizing so far, the means of description in landscape ecology centre on three elements – patches, corridors and the matrix – and all are similar in their objects of description in that they concern biotopes, which together constitute ecosystems and natural habitats. Where they differ is in form, patches being compact, corridors elongated and the matrix encompassing. In an effort to generalize these elements in preparation for an integration of them with elements in urban morphology, one may downplay the importance of these differences in form, such as the elongated shape of corridors or the encompassing character of matrices, and argue that all of them at a general geometric level are polygons, which together make up spatial patterns, configurations or mosaics. At this general level they can actually all be regarded as patches doing the same thing, that is identifying and spatially defining sets of biotopes.

Similarly, spatial description in urban morphology from a town-plan perspective may be summarized by three elements – plots, streets and buildings – all three having the same object in that they all concern physical ('abiotic') structures that support human habitats. Where they differ, as do the elements in landscape ecology, are in form: plots are compact, streets elongated and building plans variably shaped. In accordance with the geometric abstraction of the descriptive elements in landscape ecology into polygons, an argument can be made for a similar abstraction of the elements in urban morphology. Clearly plots take the geometric form of polygons, and street-blocks are polygons in geometrical terms, albeit constituted by other polygons consisting of plots. Similarly, streets are represented as polygons too, albeit elongated, similar to the elongated polygons representing corridors in landscape ecology. Buildings too are polygons in their plans. Hence, we may also in the case of urban morphology argue that, at a purely geometric level, the elements in the Conzenian triad of streets, plots and buildings, are all polygons that together make

up particular patterns or configurations. They all identify and spatially define elements that together constitute the physical structure of human habitats in cities.

It may be concluded that more or less any landscape, whether natural or urban or any combination of the two, can be described by a configuration of polygons. Such configurations in natural landscapes are constituted by a set of polygons defining both biotic and abiotic dimensions of biotopes making up natural habitats. In urban landscapes they are constituted by a similar set of polygons defining the 'abiotic' aspect of human habitats.

Hence, what is needed to merge the two into a unified spatial morphology is a description that extends and generalizes the traditional Conzenian town-plan description. Different directions may be identified. On the one hand, there are attempts that extend the Conzenian idea. In these morphological units are defined in relation to other morphological units. An ambitious description of this kind has been put forth by Kropf (1993), and discussed by Osmond (2010). Kropf proposes a taxonomy of built form at nine levels, from building materials to combinations of urban types. Each level is logically tied to the others in a hierarchy. Useful for our current task is an intermediate level in this taxonomy

called *sertum* (Kropf uses Latin names for the taxonomic levels) that addresses streets and blocks. Kropf here divides streets into street segments and street intersections, which brings the geometric description of streets closer to the compact polygons describing plots and buildings, supporting our attempt to develop a basic descriptive unit. Also of importance to us is the extension of Kropf's taxonomy of built form to a similar hierarchy of unbuilt space, as proposed by Osmond (2010), thereby integrating green areas, such as parks and gardens, into this descriptive framework.

In line with Scheer's argument (2018), we want to avoid preconceived hierarchies and relations between urban elements. Scheer argues that such preconceptions may obscure cultural variety in urban morphology. While we agree with this, we are of the view that it may also aggravate the development of descriptions that aim to combine the morphology of natural and urban landscapes, since their different ontologies are not simply joined in the same hierarchies. While this may be possible in principle, and Osmond (2010) makes a good case for it, we follow Scheer's suggestion of treating urban elements simply as discrete data points. This simplifies description greatly and makes it possible to

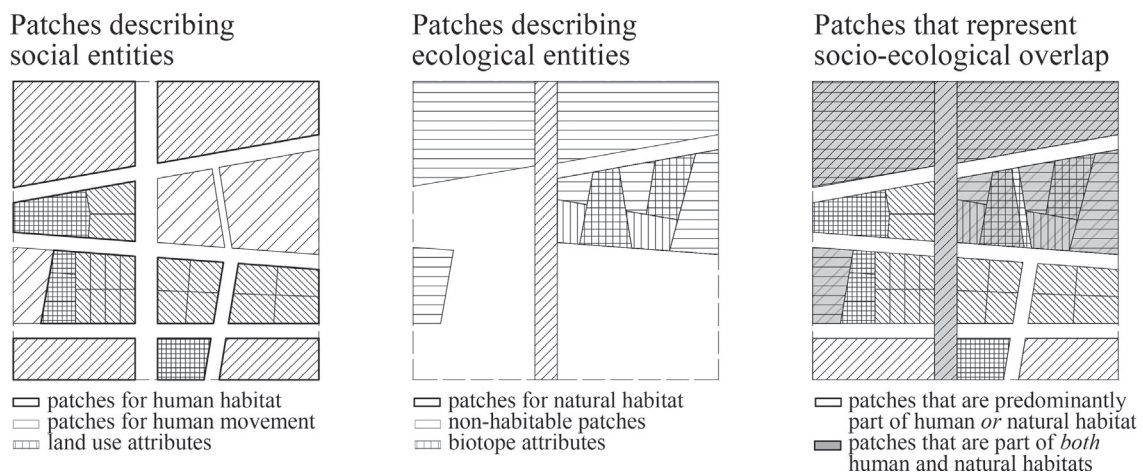


Figure 2. A combined socio-ecological morphology in which two types of geometrical representation are proposed: patches describing social entities (left), patches describing ecological entities (middle) and combined socio-ecological entities, such as elements that form part of both natural and human habitats (right).

define these morphological elements as nodes in a network description.

In this light urban and peri-urban areas can be treated as landscape mosaics that can be described by configurations of polygons. These polygons describe either natural or human habitats. They often overlap and thereby define new polygons that combine elements of natural and human habitats. For instance, a polygon that defines a street segment aligned with a row of oaks, at the same time describes an element in both a natural and human habitat. Hence, in descriptions of urban areas we can recognize polygons that distinctly describe social or ecological entities but also those that represent socio-ecological overlap. All of them could be given a common term. In accord with the argument of Scheer (2018), we borrow terminology from landscape ecology and suggest the rather neutral term ‘patch’. Hence, in the kind of combined socio-ecological morphology we aim for here, what is mapped are patches in the form of polygons of varying size and shape. These either describe social entities, such as ‘abiotic’ elements of human habitats, or ecological entities, such as biotic and abiotic elements of natural habitats, or combined social-ecological entities, such as elements that form part of both natural and human habitats (Figure 2).

Conclusion

The aim of this paper has been to develop a unified spatial morphology of cities as socio-ecological systems that can support both research about cities and the practices involved in urban development. Critical is an understanding of spatial form as defined by buildings and landscaping in cities, since this constitutes the central medium whereby urban processes can be structured and directed by these practices. The means of description for the kind of spatial morphology proposed may be termed *configurations of patches*. These constitute a geometric abstraction of plots, streets and buildings, as well as patches, corridors and matrices – central elements in urban morphology and landscape ecology

respectively. Objects of description for such a joint spatial morphology are elements of both natural and human habitats.

Such a configuration of patches can be studied simply as a pattern in the landscape, but it may also be conceived as a dynamic set of relations that structure some kinds of flow or exchange processes between its constituent patches. The latter is what is found in real urban and natural landscapes. A critical issue is how to describe not only the patterns but also the particular dynamic processes conditioned by the connections that these patterns harbour. Such connections differ depending on what is defined as the moving agent. In urban landscapes, we tend to define that agent as humans and therefore identify the street system as facilitator of such connections. In extension of this we envisage a rather distinct spatial separation between flows and locations in urban landscapes. In natural landscapes, in contrast, the agents are manifold and take the form of all kinds of species. It is where flows do not give rise to a particular spatial system and consequently we do not expect the same spatial separation between flows and locations that we find in cities. Instead, flows between patches take place by crossing other patches. The effectiveness of such connections in the natural landscape is dependent on how permeable patches are and the geographical distance between them (Verbeylen *et al.*, 2003). This poses new challenges for description. It is clear that to investigate the dynamic potential of such interconnected configurations of patches in both natural and urban landscapes demands a systems perspective.

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