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Integrating an urban green space typology into procedural 3D visualization for collaborative planning

N. Neuenschwander *, U. Wissen Hayek, A. Grêt-Regamey

Planning of Landscape and Urban Systems, Swiss Federal Institute of Technology, Switzerland

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ABSTRACT

Urban green spaces offer multiple ecosystem services (ES), which provide a variety of benefits to human well-being. Yet in urban planning they are not taken into account systematically. Recently new tools have been developed integrating ES into procedural modeling and visualization to raise stakeholder awareness for the explicit ES trade-offs that have to be made. These tools yet do not allow fast and comprehensive integration of ES provision in urban environments. In this paper we show how urban green space typologies can be linked to ES provision for facilitating collaboration between stakeholders of different backgrounds. Based on a generic typology green spaces were mapped and linked with information on potentially provided ES and their parameters. Further, pattern designs of the green space types were described with a form-based code. Both the map of green space types and the pattern designs were integrated into the parametric modeling and visualization chain of Esri CityEngine resulting in 3D visualizations of the green space patterns and correlating ES indicators. The green space typology allows for integrating different kinds of knowledge from both science and practice communities. The procedural model enables rapid interactive visualization of urban patterns and calculation of simple indicator values on the provision of ES. The simple approach for mapping green space types with low data requirements and the generic green space design patterns allow for transferability to other places and application to large areas. The developed approach is simple and fast yet comprehensive to communicate the vital importance of all green space types within the urban environment.

1. Introduction

Today, more than half of the world's population live in urban areas (UN-Habitat, 2011). A crucial challenge coming along with this increasing urbanization is how to secure the livability, that is the well-being of the inhabitants of cities and agglomerations (Pacione, 2003). One of the most pressing problems is the deterioration of environmental qualities in urban regions, which seriously affects human well-being (Grimm et al., 2008; Sevilla-Buitrago, 2013).

Indispensable parameters contributing to human well-being in urban areas are the ecosystem services (ES) offered by urban green spaces (Bolund & Hunhammar, 1999; MA, 2005; TEEB, 2012; Breuste, Haase, & Elmqvist, 2013). Urban green spaces are patches of land in the urban environment with predominantly vegetated surfaces including, e.g., street trees, private and public gardens, lawns and parks, garden plots, cultivated land, urban forests, and wetland (Swanwick, Dunnett, & Woolley, 2003; Breuste et al., 2013). If these green spaces are of suitable quality they can provide a wide variety of benefits for people (Kambites & Owen, 2006). For example, the vegetation of urban green spaces influences the urban microclimate and contribute to mitigating urban heat islands, which in turn increases amenity and attractiveness of the urban environment (Kleerekoper, van Esch, & Salcedo, 2012). Further, nearly all green spaces offer recreational facilities (Breuste et al., 2013) and have been proved to directly influence human physical activity, recreation and health (Kaplan, 1993; Kaplan, 2007; Nassauer, Wang, & Dayrell, 2009; Tzoulas et al., 2007). Public green spaces offer the opportunity for social cohesion as they are places to rest and to meet people (Maas, van Dillen, Verheij, & Groenewegen, 2009). They can also play an important role for social and cultural integration, especially for children and young people who like to play in urban green spaces (Seeland, Dübendorfer, & Hansmann, 2009; Kaźmierczak, 2013). Unsealed land contributes to flood prevention by stormwater absorption (Breuste et al., 2013). Moreover, urban green spaces can build diverse mosaics and resources for biodiversity (Marzluff &

* Corresponding author. Address: ETH Zurich, Stefano-Franscini-Platz 5, HIL H 52.1, 8093 Zurich, Switzerland. Tel.: +41 44 633 66 67.

E-mail addresses: neuenschwander@nsl.ethz.ch (N. Neuenschwander), wissen@nsl.ethz.ch (U. Wissen Hayek), gret@ethz.ch (A. Grêt-Regamey).

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Rodewald, 2008), which then increase quality of life for residents arising from interaction with urban nature (Yli-Pelkonen & Niemelä, 2005). Although the value of urban green space services and their potential key role in sustainable urban transformation is well known (Swanwick et al., 2003), current urban development in many areas is leading to a decrease in these services. Urban densification resulting in reduced open space and increasing landscape and habitat fragmentation is diminishing the quality of green spaces, particularly as habitats for plants and animals as well as for recreation (Boyko & Cooper, 2011, Di Giulio, Holderegger, and Tobias, 2009, Jaeger, Bertiller, Schwick, & Kienast, 2010).

Increasing efforts are made to integrate ES into environmental decision making in general (see, e.g., Bagstad, Semmens, Waage, & Winthrop, 2013 for an overview and assessment of tools) and urban decision making in particular. This can be done in form of spatially explicit mapping of stacked ES in order to raise the awareness of the benefits of biodiversity and ES for urban areas (McPhearson, Kremer, & Hamstead, 2013) or by synthesizing knowledge and methods for the classification and evaluation of ES as a guideline for urban planning (Gómez-Baggethun & Barton, 2013). Yet these approaches are not integrated into real-world decision making processes at municipality and regional levels, and more effort has to be put into making the support tools ready for practice (Gómez-Baggethun & Barton, 2013; Daily et al., 2009). More specifically, appropriate indicators and typologies of urban green spaces and their ES as well as mechanisms of governance of green spaces are missing for successful planning and design of urban green spaces across scales and facilitating collaborative planning processes (James et al., 2009).

That inter- and transdisciplinary collaboration is essential for more sustainable and socially acceptable urban transformation is widely accepted (Pacione, 2003; Healey, 2006; Scholz, 2011). Recently, integrated concepts and methods, which are evolving under the umbrella term "geodesign", seek to facilitate transdisciplinary spatial design processes by informing the creation of design proposals with GIS-based scientific knowledge to guide user-driven interventions (Goodchild, 2010; Steinitz, 2012; Batty, 2013). In particular, spatially explicit visualizations are known to facilitate such collaboration processes (Wissen, Schroth, Lange, & Schmid, 2008; Sheppard & Salter, 2004; Schroth, Wissen Hayek, Lange, Sheppard, & Schmid, 2011). Decision making regarding urban development options further requires an understanding of the interactions of different environmental factors and of how they affect the quality of the urban patterns (Niemelä, 2011). In this context, support tools for urban design have been developed which support nuanced value-based judgments and effective stakeholder negotiation by fostering the understanding of ES trade-offs evolving from higher demand of one service over the others (Grêt-Regamey, Celio, Klein, & Wissen Hayek, 2013). In the latter approach ES are integrated into procedural modeling with shape grammars and 3D visualization of design options. Relationships between landscape elements and environmental parameters for estimating the provision of the ES are encoded into shape grammars which specify spatial design options. Implementing the parametric shape grammars in the procedural modeling software Esri CityEngine (ESRI, 2013), 3D visualizations of design options can be generated along with a reporting of ES indicators. In an interface the end-user can interactively change the value of the ES and receive an alternative design option. This can be a powerful tool for developing alternative urban design patterns, where the stakeholders are aware of the explicit ES trade-offs that have to be made, opening the space for negotiation and solution finding. In general the modeling and visualization approach is straight forward. However, the tool does not yet allow fast and comprehensive integration of ES provision in urban environments (Grêt-Regamey et al., 2013).

Based on Grêt-Regamey et al. (2013), we show how urban green spaces can be linked to ES provision for easy integration into procedural GIS-based modeling and 3D visualization and facilitate collaboration between stakeholders with different backgrounds. The goal of this study is to provide an approach to linking urban green spaces to environmental parameters and landscape elements that relates to the quantity and quality of the provision of different ES. We illustrate the approach in an urban context, where we show in detail the development of a green space typology, which links green space types, ES parameters, and form-based codes of green space design. Further, we explain the implementation of the typology into GIS-based procedural modeling and visualization. Finally, we discuss the presented approach with regard to its potentials and limitations for implementation into practice.

2. Methods

2.1. Conceptual framework

Fig. 1 shows the overall workflow of the implementation of an urban green space typology with integrated ES parameters for procedural GIS-based modeling and 3D visualization comprising three major processing stages: (1) specification and mapping, (2) GIS-based procedural modeling, and (3) rendering and reporting.

2.2. Case study

We implemented and tested our workflow using a case study in Altstetten, a district of Zurich, Switzerland. On a regional scale, the district is situated in the Limmattal, the valley of the river Limmat (Fig. 2). In the valley, the riverbanks are an important and ecologically valuable linear belt of urban green spaces. The local and regional green space structure and quality is of supra-regional importance because it links the lake of Zurich with the European river system.

In the last decades, the urbanization process induced an impressive demographic growth and the originally rural region with small, scattered villages changed into an agglomeration landscape where the settlement area has almost merged into one linear city (Koch, Schröder, Schumacher, & Schubarth, 2003). Connectivity between the two forested hills, which frame the valley and the river, is severely disturbed and fragmented by railways, highways, and wide spread settlement areas (Grün Stadt Zürich, 2006a). Remaining green spaces have to satisfy demands for diverse land uses like local recreation, work and residential areas, agriculture, and industry within a tight space (Koch et al., 2003). Increasing demand for work and living space necessitates carefully made trade-off decisions between the provision of built-up area and green spaces (Grün Stadt Zürich, 2006a). However, the fine-grained political structure with 16 municipalities belonging to two different cantons, Zurich and Aargau, complicates comprehensive analyses and an integrated concept development (Koch et al., 2003). This makes enhancing ecological and social sustainability of the region a difficult task.

At the local scale, the district with an area of about 747 ha is characterized by a heterogeneous mix of densely built urban structures with residential, commercial, and industrial areas. Further, Altstetten covers a wide range of urban green space types from forest, agriculture, and wetland to a diverse and scattered mosaic of gardens, lawns, and parks. Valuable habitats for various species are provided by the extensive forest edges, grasslands, or wetland habitats at the riverbank (ZPL, 2003). The connectivity of habitats is good along the river but limited across the settlement area due to missing stepping stones and the railway tracks which cut through the area (Grün Stadt Zürich, 2006a).