G Model
RECYCL-3347; No. of Pages 10
ARTICLE IN PRESS
Resources, Conservation and Recycling xxx (2016) xxx–xxx
Contents lists available at ScienceDirect
Resources, Conservation and Recycling
journal homepage: www.elsevier.com/locate/resconrec

Full length article

Space-time information analysis for resource-conscious urban planning and design: A stakeholder based identification of urban metabolism data gaps

Ilse M. Voskamp[a,b,*], Marc Spiller[a], Sven Stremke[b,c], Arnold K. Bregt[c,d], Corné Vreugdenhil[c,d], Huub H.M. Rijnaarts[a]

[a] Sub-Department of Environmental Technology, Wageningen University & Research, P.O. Box 17, 6700 AA Wageningen, The Netherlands
[b] Landscape Architecture Group, Wageningen University & Research, P.O. Box 47, 6700 AA Wageningen, The Netherlands
[c] AMS, Amsterdam Institute for Advanced Metropolitan Solutions, Mauritskade 62, 1092 AD Amsterdam, The Netherlands
[d] Laboratory of Geo-Information Science and Remote Sensing, Wageningen University & Research, P.O. Box 47, 6700 AA Wageningen, The Netherlands

ARTICLE INFO

Article history:
Received 31 March 2016
Received in revised form 2 August 2016
Accepted 25 August 2016
Available online xxx

Keywords:
Urban metabolism
Sustainable resource management
Urban infrastructure
Urban planning
Spatiotemporal analysis

ABSTRACT

The research presented here examined at which spatial and temporal resolution urban metabolism should be analysed to generate results that are useful for implementation of urban planning and design interventions aiming at optimization of resource flows. Moreover, it was researched whether a lack of data currently hampers analysing resource flows at this desired level of detail. To facilitate a stakeholder based research approach, the SIRUP tool – *"Space-time Information analysis for Resource-conscious Urban Planning"* – was developed. The tool was applied in a case study of Amsterdam, focused on the investigation of energy and water flows. Results show that most urban planning and design interventions envisioned in Amsterdam require information on a higher spatiotemporal resolution than the resolution of current urban metabolism analyses, i.e., more detailed than the city level and at time steps smaller than a year. Energy-related interventions generally require information on a higher resolution than water-related interventions. Moreover, for the majority of interventions information is needed on a higher resolution than currently available. For energy, the temporal resolution of existing data proved inadequate, for water, data with both a higher spatial and temporal resolution is required. Modelling and monitoring techniques are advancing for both water and energy and these advancements are likely to contribute to closing these data gaps in the future. These advancements can also prove useful in developing new sorts of urban metabolism analyses that can provide a systemic understanding of urban resource flows and that are tailored to urban planning and design.

1. Introduction

The notion of urban metabolism (UM) has inspired new ideas about how cities can be made sustainable and it has fostered quantitative approaches to the analysis of urban resource flows (Agudelo-Vera et al., 2012; Castán Broto et al., 2012; Zhang, 2013). UM refers to the processes whereby cities transform raw materials, energy, and water into the built environment, human biomass, and waste (Decker et al., 2000). UM can be traced back to Marx in 1883, who used the term metabolism to describe the exchange of materials and energy between society and its natural environment (Pincetl et al., 2012; Zhang, 2013). In 1965 Wolman re-launched the term as he presented the city as an ecosystem, and later others also used the term UM in representing a city as an organism (Barles, 2010 Castán Broto et al., 2012; Pincetl et al., 2012; Zhang, 2013). Since Wolman's early study of urban metabolic processes, two distinct quantitative UM approaches have developed that aim to describe and analyse the material and energy flows within cities. One describes the UM in terms of solar energy equivalents ('emergy'). Related school of scholars emphasizes the earth's dependence on the sun as an energy source and the qualitative difference of mass or energy flows. The second and most widely used approach, is associated with the fields of industrial ecology and engineering (Barles, 2010; Castán Broto et al., 2012; Pincetl et al., 2012). Related research largely consist of empirical studies that account for the energy and

* Corresponding author at: Sub-Department of Environmental Technology, Wageningen University & Research, P.O. Box 17, 6700 AA Wageningen, The Netherlands.
E-mail address: ilse.voskamp@wur.nl (I.M. Voskamp).

http://dx.doi.org/10.1016/j.resconrec.2016.08.026

material/mass flows of a city, using methods such as material flow analysis (MFA), mass balancing, life cycle analysis (LCA) and ecological footprint analysis (Castán Broto et al., 2012; Kennedy et al., 2011; Pincetl et al., 2012; Zhang, 2013).

Multiple scholars have argued that the latter type of UM analyses, the flow quantifications associated with the mainstream UM approach, are useful for urban planning and design (Castán Broto et al., 2012; Chrysoulakis et al., 2013; Kennedy et al., 2011; Moffatt and Kohler, 2008; Pincetl et al., 2012). However, these authors also argue that major efforts are still needed to make UM analyses useful for informing urban planning and design aiming at optimization of urban resource flows (Kennedy et al., 2011). Indeed, only three examples of application of UM for designing more sustainable urban infrastructures are referred to in literature (Codoban and Kennedy, 2008; Oswald and Baccini, 2003; Quinn, 2008), of which just one is a peer-reviewed article.[1] The only recent scientific contributions on this topic all discuss the planning support system developed in the BRIDGE project (Blecic et al., 2014; Chrysoulakis et al., 2013; Mitraka et al., 2014). In professional literature, some other recent examples can be found. In the Netherlands, research on the resource flows of Rotterdam was conducted and used as a basis for urban design strategies, in the context of the International Architectural Biennale 2014 *Urban by Nature* (Tillie et al., 2014). In the *Circular Buiksloterham* project in Amsterdam an 'Urban Metabolism Scan' was performed and used as foundation for a vision for the Buiksloterham area, including site-specific technical interventions and a design concept (Gladek et al., 2015). So, although the theoretical potential of UM analysis for urban planning and design is increasingly addressed in the scientific literature, scientific reports that illustrate how this potential can be realised with practical implementation remain limited thus far.

Possibly, UM analyses are still of limited use for urban planning and design because they are performed on a scale level that does not match urban planning and design practice (Moffatt and Kohler, 2008; Pincetl et al., 2012; Spiller and Agudelo-Vera, 2011). The UM is usually analysed for a period of a year on city or regional scale (Kennedy et al., 2011; Niza et al., 2009); analyses on a more detailed level are said to be hampered by lack of data (Codoban and Kennedy, 2008; Pincetl et al., 2012; Shahrokni et al., 2015). Such large-scale analyses, however, do not reveal which metabolic processes and functions are operating at various spatial and temporal scales. Yet, planners and designers need such information to decide upon the appropriate interventions to realize a resource-conscious strategy. In other words, they need this information to inform their planning and design decision-making regarding interventions aimed at urban climate adaptation, climate mitigation and/or resource efficiency. To be useful for urban planners and designers, UM analyses should thus provide detailed and spatial and temporal explicit data on the scale at which these practitioners work (Chrysoulakis et al., 2013; Golubiewski, 2012; Moffatt and Kohler, 2008; Pincetl et al., 2012; Vandevyvere and Stremke, 2012).

Therefore, the study presented here aims to answer the following questions: (a) "at which spatial and temporal resolution should resource flows be analysed to generate results that are useful for implementation of urban planning and design interventions?" and (b) "is UM analysis at this desired level of detail currently hampered by a lack of data?". To answer these questions the *"Space-time Information analysis for Resource-conscious Urban Planning"* (SIRUP) tool was developed and applied in a case study of the city of Amsterdam, the Netherlands. The SIRUP tool enables an analysis on two levels: I) assessing on which level of detail in space and time stakeholders need information on resource flows to inform urban planning and design decision-making aimed at developing resource-conscious strategies, and II) evaluating whether existing data can provide the information needed or that there is a data gap. The qualitative tool facilitates information and knowledge sharing and discussion between stakeholders. Stakeholder involvement in UM research is essential to leverage availability of and access to urban resource data and it allows identifying the information needs of urban planning and design practitioners (Voskamp et al., 2016; Zhang et al., 2015).

2. Methods and materials[2]

2.1. Development of the SIRUP tool

The *"Space-time Information analysis for Resource-conscious Urban Planning"* (SIRUP) tool is based on the work of Vervoort et al. (2014), who developed the tool *Scale Perspectives* to elicit societal perspectives and generate dialogue on governance issues. Their tool consists of a frame with pre-defined spatial and temporal scales in which stakeholders can outline the relevant scales for a particular governance issue. For the SIRUP tool, this frame is adapted for the purpose of identifying on which spatiotemporal resolution stakeholders need information on resource flows and for assessing whether existing data can provide this information on the resolution needed (Supplementary material, Fig. S1). The SIRUP tool is applied in four steps (Fig. 1). These steps aim to (I) generate an inventory of UM interventions, (II) determine the information needed for implementing each of these interventions, (III) describe the spatiotemporal resolution of existing data relevant for the intervention and (IV) identify whether the resolution of identified data can satisfy the stakeholders' intervention information needs.

2.2. Application of the SIRUP tool

The SIRUP tool was applied in a case study of Amsterdam. As part of this case study, stakeholders were involved that are engaged with urban planning and design decision-making aimed at developing resource-conscious strategies for the city of Amsterdam. The stakeholders comprised researchers, environmental managers from utilities, landscape architects and urban planning & design practitioners. Eleven of these stakeholders were interviewed, using semi-structured interviews, and thirteen stakeholders participated in a workshop.

Step I and II of the SIRUP tool were used to identify on which spatiotemporal resolution stakeholders need information on resource flows. In step I, the stakeholders were asked to describe a resource-conscious intervention that they envision to be implemented in Amsterdam. Participants were also asked to specify in the SIRUP frame (Supplementary material, Fig. S1) at which spatial scale level the intervention would take places and which time frame they envisioned for implementation. In step II, participants were asked to specify the information needed for implementing the intervention mentioned and to indicate the required spatial and temporal resolution of this information in the SIRUP frame (Fig. 1). The interviewer or workshop facilitator had to ensure that participants described the information on resource flows that is necessary to enable the intervention. Pen-and-paper format was used because this allows for greater flexibility than a digital setting (Vervoort et al., 2014). After the workshop, all contributions were digitalized and labelled to enable the selection of interventions that are within the scope of the research. The interventions were labelled according

[1] Although Codoban and Kennedy (2008) were the first to refer to Oswald and Baccini (2003) in this light, Kennedy et al. (2011) were the first to mention all three examples.

[2] A more elaborate description of the method is provided as Supplementary material (S1. Elaborate description of methodology).