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No perfect tools: Trade-offs of sustainability principles and user requirements in designing support tools for land-use decisions between greenfields and brownfields

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No perfect tools: Trade-offs of sustainability principles and user requirements in designing tools supporting land-use decisions between greenfields and brownfields

Abstract

The EU Soil Thematic Strategy calls for the application of sustainability concepts and methods as part of an integrated policy to prevent soil degradation and to increase the re-use of brownfields. Although certain general principles have been proposed for the evaluation of sustainable development, the practical application of sustainability assessment tools (SATs) is contingent on the actual requirements of tool users, e.g. planners or investors, to pick up such instruments in actual decision making. We examine the normative sustainability principles that need to be taken into account in order to make sound land-use decisions between new development on greenfield sites and the regeneration of brownfields – and relate these principles to empirically observed user requirements and the properties of available SATs. In this way we provide an overview of approaches to sustainability assessment. Three stylized approaches, represented in each case by a typical tool selected from the literature, are presented and contrasted with (1) the norm-oriented Bellagio sustainability principles and (2) the requirements of three different stakeholder groups: decision makers, scientists/experts and representatives of the general public. The paper disentangles some of the inevitable trade-offs involved in seeking to implement sustainable land-use planning, i.e. between norm orientation and holism, broad participation and effective communication. It concludes with the controversial assessment that there are no perfect tools and that to be meaningful the user requirements of decision makers must take precedence over those of other interest groups in the design of SATs.

Keywords

Sustainability principles; User requirements; Decision support tools; Land-use decisions; Brownfield redevelopment; Planning

1. Introduction

Soils support a range of fundamental ecosystem and societal services (Gardi et al., online first; Robinson et al., 2014). Their holistic management is essential for sustainable development because of their multifunctional role in preserving biodiversity, achieving food security, enabling climate change adaptation or, last but not least, providing a foundation for buildings and infrastructure developments. Anthropogenic land-use has progressively compromised the quality and availability of land. Urbanisation and growing global demand for biofuels, food and feed are causing conflicts over land use to occur at the expense of healthy soils and the ecosystem services deriving from them (cf. Bringezu et al., 2012; UNEP, 2014). Often taking place on the most fertile and productive land, urbanisation is a particularly disruptive form of land transformation (Imhoff et al., 2004). Land take on intact natural or arable areas (often referred to as *greenfields*) that involves sealing these areas for residential or commercial developments is in stark contrast to sustainable land management practice. As key instrument of sustainable environmental management, the aim of land-use planning must be to assess the diverse benefits and costs of the different land-use requirements and achieve a balance between them.

Soil sealing has been increasingly seen as a major cause of soil degradation (cf. EC, 2012b; Kovalick and Montgomery, 2014; Pediaditi et al., 2010). A growing awareness of the problem is evident at high political levels, as exemplified by the 68th United Nations General Assembly having declared *2015 the International Year of Soils* (UN, 2013) and by the efforts undertaken to introduce a European *Soil Thematic Strategy* (EC, 2012a). The *Roadmap to a Resource Efficient Europe* (EC 2011) calls member states' national policies to account for their impacts on land use, the goal being to achieve zero net land take by 2050. The European Commission has defined "soil sealing [as] the permanent covering of an area and its soil by impermeable artificial material […]" (EC, 2012b, 39) and reports that in the European Union alone about 1,000 km² of soil were lost annually during the 1990s (ibid). At the same time, so-called *brownfields* exist – land that in many cases has been densely sealed for production, infrastructure or military purposes but no longer serves these purposes and has become underutilized. There are different definitions of *brownfields* (cf. Alker et al., 2000; Schädler et al., 2011). Put simply, they can be characterised as derelict and underused sites that are often contaminated. These sites regularly contain remains of buildings and other facilities reflecting their previous uses and offer no immediate prospect of re-development. Revitalisation normally requires coordinated intervention by stakeholders (cf. EC, 2012b). Brownfields' revitalization is considered to offer a sustainable alternative to soil sealing (Bartke, 2013). This article discusses the potentials of designing assessment tools to support decisions between greenfields and brownfields in the urban development context.

At the local planning level, where there is pressure to attract new developers with the aim of generating tax revenues and creating jobs, *greenfields* are often perceived as being more attractive to investors and are therefore willingly earmarked for development. Indirect impacts on local people's health or on the ability of future generations to utilise limited soil resources are often neglected in the course of practical decision making based on simple business accountancy rules. Ensuring that there is an adequate appreciation at high levels of the need for soil protection and of the general desirability to revitalise even potentially contaminated sites hinges on whether the full benefits and costs of land-use decisions – including their negative impacts on society through the overexploitation of nature – are communicated in a way that influences local

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land-use planning and investment decisions. Several sustainability assessment tools (SATs) and approaches have been elaborated in an effort to inform and foster brownfield regeneration and sustainable land management (Bartke et al., 2013; Morio et al., 2013; Pediaditi et al., 2010; Stezar et al., 2013). Following on the recent attempt to better understand decision-making approaches including experts and stakeholders (Árvai et al., 2014), the potential limits of SATs' design and application are analysed in this paper.

2. Aim and scope

The aim in this paper is to understand the potential of SATs to support sustainable land-use decisions relating to *greenfields* and *brownfields* by proposing a structured approach for assessing the quality of SATs – and to demonstrate how this approach can inform future SAT design. By '*quality*' we mean the property of a SAT to account for both normative sustainability principles and practical user requirements; in other words, a SAT is of high quality if it is accepted and embraced by relevant end-users and, at the same time, if it contributes toward reaching well-founded decisions that support sustainable development.

To accomplish this aim, this article will first provide information about the sustainability challenges posed by land-use management, introducing an integrated normative and user driven approach to SAT design (Section 3). Second, the materials and methods are described to conceptualize the top-down normative approach to distil constitutive elements of sustainable development into principles suited to determine the potential of SATs to contribute to sustainability (Section 4). Section 5 introduces background information on the key user groups of SATs identified in empirical research and on their bottom-up recognized requirements regarding proper SAT design. Some interim results regarding the specific trade-offs involved in sustainable urban land-use management are discussed in Section 6. Following this, three conventional approaches are introduced, represented in each case by a typical assessment tool selected from the literature, and their performance with regard to addressing the trade-offs identified is judged (Section 7). Section 8 presents a discussion of the results relating to SAT design vis-à-vis user requirements. The final section concludes with a number of controversial recommendations for designing land-use management decision support tools.

The novelty of this work consists in conceptualizing the connections between sustainability principles and different SAT user groups and their distinct tool requirements. These connections are related to three typical SAT approaches. This makes it possible to formulate recommendations to SAT designers and specific stakeholder groups – in particular scientists and experts – for how to express their needs. The intention of this paper is not to judge the absolute quality of selected SATs but to identify and illustrate the inevitable trade-offs involved in designing SATs. By thus informing the general design of SATs, it is possible to establish a basis for making better informed decisions that facilitate the efficient management of land and safeguard the limited resource of soil.

3. Sustainability Assessment Tools: The case of land-use decisions about brownfields and greenfields

Although there cannot be a fixed rule that *brownfield* regeneration is to be preferred per se over *greenfield* sealing and development, there is some common ground that allows us to take this order of preference as a valid assumption from a sustainable land-use perspective. This has to do partly with the range of people who advocate *brownfield* regeneration instead of urbanisation and soil sealing (e.g., Bagaeen, 2006; Bartke, 2013; EC, 2012b; Pediaditi et al., 2010; Schädler et al., 2013; Thornton et al., 2007a, b) and partly with the distinct attributes of *greenfield* and *brownfield* development.

Greenfield sealing jeopardizes different types of sustainable soil functions which satisfy various needs and yet are not reflected in real estate prices; such functions are often ignored in decision making processes. For example, natural unsealed areas generally contribute to the stability of the socio-ecological system by (1) performing vital services such as providing groundwater and drinking water, producing oxygen and regulating the climate, (2) acting as a natural supplier of raw materials, including unique plants, types of wood and animals, (3) functioning as the basis of genetic information, analyses of which can be used to optimise crops or develop new medicines, and (4) being used for human recreation thanks to their cultural or aesthetic value (Baumgärtner, 2006). When they are sealed, the ability of such areas to perform these functions is diminished.

Brownfield regeneration has been defined as sustainable if it involves the "management, rehabilitation and return to beneficial use of brownfields in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations in environmentally sensitive, economically viable, institutionally robust and socially acceptable ways within the particular regional context" (Dixon, 2007, 91). Based on the Brundtland report's definition "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, 43), Thornton et al. (2007a, 118) ask "does the competent public authority, when enacting new incentives, consider the needs of the present and the future when using methods to redevelop brownfields?" – to which we would add "when deciding about *brownfield* regeneration and the alternative of *greenfield* sealing?"

For real estate developers, the main obstacle to deciding to reuse *brownfield* sites – and hence the reason for resorting to *greenfield* development – is a combination of the high costs they fear it would involve to prepare derelict sites (including clean-up of any actual or potential contamination, cf. Bartke, 2011) and the fact that the benefit to society of *not* building on yet more undeveloped land is not reflected in the decision-making process – partly due to inadequate assessment tools, which could otherwise inform land management. Of course, decisions about land development are institutionally embedded in land-use policies, and regulations differ between countries depending on their different traditions regarding property rights and their different perceptions of the importance of preserving natural resources (cf. Tan et al., 2014; Thornton et al., 2007a). Ultimately, however, sustainability issues become relevant in decision making only when they are made visible and it becomes apparent that indirect costs have to be borne by someone. As long as the negative social effects of development do not affect the planning or investment strategies of the actors involved (e.g. the considerations of urban planners or the decisions of politicians), they will be ignored in everyday land-use decisions. Different methods for incorporating these dimensions into land-use decisions and even monetising ecosystem services have been established in economic theory (Batemann et al., 2013; Nuissl and Schröter-Schlaack, 2009; Robinson et al., 2014). Whether they are expressed in monetary or non-monetary terms, however, the overall effects of sealing need to be aggregated in a meaningful way and made "visible" to decision makers by means of SATs in order to have an influence on their decision calculus. While quantification methods are by no means a panacea for incorporating sustainability into land-use management, they are highly important in practical and political decision making. They measure factors relevant to decisions which would otherwise remain undetermined. They explicitly attribute significance to these factors as elements of influence which would otherwise be neglected. SAT approaches designed to support sustainable land-use decisions take this as their starting point, either revealing different value-laden factors explicitly or including the value judgements of relevant stakeholders in decision-making processes.

Although extensive literature exists on models and indicator systems for sustainability assessment (cf. Bond and Pope, 2012; Bossel, 1999; Diefenbacher et al., 2001; Singh et al., 2009), there seems to be little literature on assessing the sustainability of brownfield redevelopment (cf. Bleicher and Gross, 2010; De Sousa, 2008; Pediaditi et al., 2010; Schädler et al., 2013, 2011). Rather than elaborating an additional or parallel taxonomy of SAT for land-use decisions involving the brownfield redevelopment option, instead we have reworked the analytic framework devised by Pediaditi et al. (2010) and have substantiated it through Hartmuth et al. (2008)'s general approach, establishing an integrative concept of SAT design that connects top-down (↓) norm-based constitutive sustainable development elements with bottom-up (↑) end-user requirements, as illustrated in Figure 1.

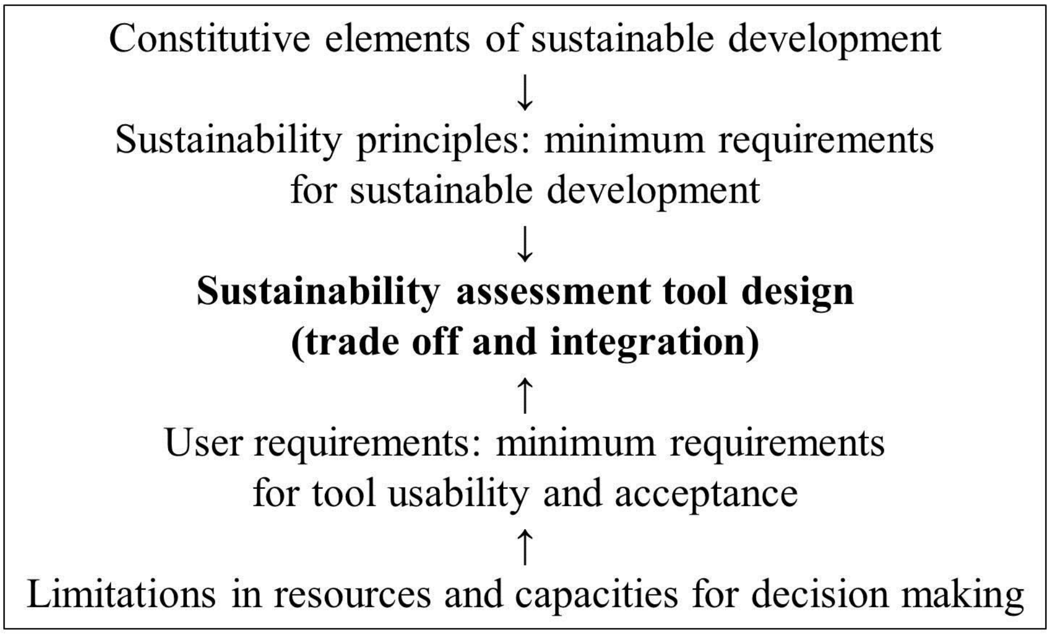

Fig. 1. Integrative concept of sustainability assessment tool design – adapted from Hartmuth et al. (2008, 263) and reflecting the analytic framework devised by Pediaditi et al. (2010).

Hartmuth et al. (2008) developed a local sustainability indicator system that contextualizes the fuzziness of sustainable development concepts in order to render them useful as a yardstick, or benchmark. Their approach connects the bottom-up identification of local problems with a set of sustainability principles that reflect certain minimum requirements for sustainable development. Pediaditi et al. (2010) were among the first to establish the degree to which so-called *brownfield greenspace indicator tools* satisfy both user requirements and sustainability principles. We take up their approach in a modified way in as much as this paper is focussing not on the specific question of greening (or restoring) *brownfield* sites but on the policy option of re-developing *brownfields* in the sense of "recycling" them for reuse by society as opposed to sealing the soil and developing a pristine or arable *greenfield* site. In doing so, the focus is on a different set of assessment tools and user requirements. Moreover, our interest lies less in discussing specific SATs and more in elucidating the trade-offs triggered by the distinctions between sustainability principles, user requirements and tool characteristics. Moreover, we allow in our analysis for different types of users groups with potentially distinct interests.

We classify SAT design as a two-tier approach, merging a normative perspective and deductive demand for specific tool components embodied in sustainability principles (top-down) with an inductive approach based on users' requirements (bottom-up). Our design approach in seeking to develop ideal SATs involves taking account of both holistic norm-oriented deductive principles as well as inductive elements based on user requirements – background information on both will be provided in Sections 4 and 5 below.

4. Sustainability requirements

To be meaningfully supporting land-use management, SATs must adhere to the overarching normative objective of sustainable development. The tools must embody an understanding that justifies calling them "sustainability" assessment tools. This request is challenged by demanding a clear definition of sustainable development, e.g. following WCED (1987). While we do not intend to discuss in any further detail the contradictory nature of different approaches to the operationalization of sustainability, we will argue that, generally speaking, policies, regulations and decisions should be based on the most appropriate information available; in other words, SATs should make available reliable information suitable for evidence based decision making.

Referring first to the top-down approach, the main elements of sustainable development that ought to be embodied in SATs can be found in sustainability norms that reflect the key constitutive elements of sustainable development. For this we refer to the well-established Bellagio STAMP – SusTainability Assessment and Measurement Principles (Pintér et al., 2012). These principles have been developed in a multi-stakeholder procedure supervised by the Organisation for Economic Co-operation and Development (OECD) and the International Institute for Sustainable Development (IISD) in response to wide-spread demands for greater agreement with the natural environment and for instruments to protect the well-being of present and future generations. Different measures to assess SATs have been proposed (e.g. Chanchitpricha and Bond, 2013; Wittmer et al., 2006) and these could also have been applied in this study. However, the Bellagio Principles are selected on account of their seemingly wider dissemination and acceptance. Pediaditi et al. (2010, 23) point out that the "discipline of sustainability indicator development has matured, establishing the Bellagio Principles which sustainability monitoring and evaluation schemes should follow" and provide a list of references for "[r]eviews of the complexities of indicator development and barriers to their use hav[ing] underlined the need for greater consideration of the Bellagio Principles and user's needs within sustainability indicator tools/framework".

The Bellagio STAMP are a set of guiding norms used to evaluate improvements in the measures adopted to achieve sustainable development (Pintér et al., 2012). According to Pintér and colleagues, the norms were designed to support any stakeholder engaged in measuring societal development, considering various policy options or promoting change. Table 1 summarizes the eight principles contained in STAMP. In a nutshell, Principles 1 and 2 call for an overarching understanding of what sustainable development is and what its determinants are; Principles 3 and 4 nest this understanding within a temporal and spatial context for which specific frameworks and indicators describe the essential constituents; Principles 5, 6 and 7 define how the sustainability assessments should take place; and finally, Principle 8 calls for the institutionalization of the procedures.

Each Bellagio Principle demands respect also in the case of land-use management (as exemplary references in Table S1 in the supplementary material illustrate). However, looking at the different Principles, we need to recognize that potential trade-offs likely are to arise when they are transferred from the normative to the practical context of tool design. We will address them in Section 6 below after discussing users' requirements.

Table 1

Overview on Bellagio SusTainability Assessment and Measurement Principles (modified from Pintér et al., 2012).

Bellagio STAM-Principles (in brief)	Requirements for assessments (in brief – see Table S1 in supplementary material for further details and links to land-use management)
1 Guiding vision and 2 Essential considerations	Assessment of sustainable development is guided by the goal of delivering well-being within the capacity of the biosphere to sustain it for future generations. Assessment considers: the underlying social, economic and environmental system and the interactions among its components; dynamics and interactions; risks and uncertainties; implications for decision making, including trade-offs.
3 Adequate scope and 4 Framework and indicators	Assessment adopts: an appropriate time horizon to capture both short- and long-term effects; an appropriate geographical scope. A conceptual framework identifies domains within which core indicators are identified.
5 Transparency, 6 Effective communications and 7 Broad participation	Development and use of indicators will: disclose data sources and methods; disclose potential conflicts of interest; use clear and plain language; use visual tools and graphics to aid interpretation; make data available in as much detail as is reliable and practicable; find appropriate ways to reflect the views of the public, while providing active leadership; engage early on with users.
8 Continuity and capacity	Assessment requires: repeated measurement; responsiveness to change; investment to develop/ maintain adequate capacity; continuous learning.

5. User requirements

Each SAT employs a specific understanding of sustainable development and each is its own advocate, why it is effective in assessing progress toward sustainable development. Still, many decision support tools that have been developed in research contexts to support decision making in brownfield regeneration processes are not utilized in practical decision contexts (Bartke et al., 2013). Decision making by developers, investors, regulators and planners rarely relies on such assessments –SATs have not been embraced by their assumed end users, as originally anticipated by their designers. Clearly, SATs do not meet the acceptance requirements of these users. In order to resolve this situation, the top-down perspective must be paired with a positive analysis asking stakeholders to specify their views as potential users on how SATs should be designed.

Such a bottom-up approach is needed in the SAT design not only in order to enable the general set of norm-oriented principles to be adjusted to the different spatial, temporal and social settings. As Schädler et al. (2013) state, the assorted measures, by which sustainability can be ascertained and assessed, are themselves contingent on the necessarily subjective views of stakeholders. The authors refer to debates about different approaches deriving indicators for measuring and monitoring the attainment of sustainable development goals in such contexts. Hartmuth et al. (2008, 261) explain "if the basic concept of sustainability is to be used as a yardstick for political and administrative action, the players involved will be forced to particularize the global concept of sustainability and place it into their national or local context respectively". More than this, a bottom-up approach, as indicated in Section 3, is also necessary in order to learn about the – so far from our point of view – under recognized role and requirements of distinct end-user groups regarding properties of SATs. These groups are not unitary, either in their preferences or their demands. Nevertheless, in previous evaluations of assessment tools, either particular interests have often been merged into a single (consensual) stakeholder view (e.g. Wittmer et al., 2006) or else they have been limited to considering a single stakeholder group (e.g. Pediaditi et al., 2010). Instead of such approaches or more general ones, in the following a positivist approach is applied.

Actors use or do not use a SAT – actually, it can be assumed they scan available SATs and select one that satisfies their needs for application in a specific context. This must not be the 'best' tool, but one that at least satisfies individual threshold needs. By using some and refusing other tools, they more or less directly inform tool designers about their preferred tool properties, i.e. they inform designers from the bottom up about their requirements regarding SATs' characteristics. Contrary to the norm-oriented approach described in Section 4, we take a positivistic approach: instead of trying to work out how a tool should be designed to make it the "best", we ask which relevant user groups of SATs are, what their distinct needs are and, in the next Section, whether these requirements are met.

At a workshop on "Sustainability assessment of urban brownfield potential – Presentation and discussion of procedures for municipal practice" (vhw, 2009), different approaches and tools (described in Section 7 below) were presented in a neutral manner to a mixed and self-selected audience of 21 participants (excluding observers). In an open debate and in focus group-like stakeholder group specific sessions, the requirements and quality characteristics needed in a 'good' sustainability assessment were determined from the point of view of SAT target users – in other words, the critical requirements that need to be met.

The workshop participants were from diverse backgrounds, e.g. representatives of local and state authorities, property holders and developers, representatives of the general public (municipal actors) as well as technical experts and academics. To understand user and stakeholder specific requirements that SATs need to fulfil, the participants needed to be classified into meaningful groups. Different approaches to such a classification are possible. In order to divide the participants into distinct user groups, the normative objective of Bellagio Principle 7 "Broad participation" is employed. This principle emphasizes the need to understand that sustainable development cannot be defined or assessed by a single actor but that several groups of key actors exist and have to be identified and recognized. The principle calls for assessments that "find appropriate ways to reflect the views of the public, while providing active leadership" (Pintér et al., 2012, 24). Based on this principle, the following user groups of SATs are defined: the *decision-makers* who use SATs to make decisions regarding property development and investment, the (*representatives of the general*) *public* who are affected by or wish to influence the relevant planning processes in the interests of citizens, and the *expert consultants* and *scientists* who provide technical advice and norm-oriented guidance to both the public and the decision makers, e.g. through SAT design. The workshop assembled together roughly equal numbers of representatives of all three groups. Table 2 reports briefly on the backgrounds of the user groups' members. Background however is just one predictor of actual expertise in an area, which develops over time and context (Alexandrescu et al., 2014). The grouping reflects the expertise and interest of the workshop's individuals as perceived by the authors as observers (e.g., the representatives of urban development departments were interested in but no specialists in regeneration, therefore classified to the public representatives group and not the experts).

Table 2

Three key user groups of SATs supporting decisions about brownfield and greenfield development.

Number	Brief description of participants' backgrounds	User group
6	Several representatives of municipal urban development departments; local urban design department; federal state ministry of social affairs, women, diversity; regional administrative authority	Public (representative)
7	Federal state and several private property holders and developers; real estate investor; municipal planning authority approving developments	Decision maker
8	Consultants on urban planning and communication; federal state officer for environmental protection; consultant and academic specialized in ecology and sustainability; academics specialized in sociology and sustainability assessment, economics, and landscape planning, environment, urban planning	Expert consultant / scientist

As part of the general discussion at the workshop, a total of six dimensions of quality issues were identified by the stakeholders, which in our opinion can be used as general assessment criteria for the SAT properties required by users. Table 3 describes the criteria using statements made by the workshop participants and links them back to the Bellagio Principles – something to be more closely revisited further below.

Table 3
User requirements and related Bellagio STAMPs.

Criteria	Example questions users have regarding SATs	Link to Bellagio Principles
Objectivity	Is it possible for the methods to be manipulated by users or others involved in the assessment? Are the findings free of external influences? Are they science-based? Are the evaluation aspects sustainability-orientated?	Principle 1: Guiding vision Principle 2: Essential considerations Principle 4: Indicators
Transparency	How transparent are the assessment methods and the calculation algorithms? Are there clearly defined time frames and goals? Are the evaluation methods comprehensible and traceable? Do they indicate risks and uncertainty?	Principle 4: Framework and indicators Principle 5: Transparency
Practicability	How quickly and straightforwardly can the method be applied? Does understanding the method involve training or reading lengthy manuals? What costs are entailed by conducting the method – and how much time is required? How much data is needed? Do the methods provide decision support? Are the results easy to assess and are they comprehensible?	Principle 3: Adequate scope Principle 6: Effective communications (clear and plain language; make data available in as much detail as is reliable and practicable)
Participation	To what extent can interest groups have their concerns included? Are conflicts made transparent and subject to debate among stakeholders?	Principle 7: Broad participation
Flexibility	Is the method tied to local circumstances or does it work only for certain categories of land or use? To what extent can the methods' modalities (such as criteria) be adapted to local conditions? Is reversibility addressed?	Principle 3: Adequate scope
Institutional embedding	Can sustainability assessment methods be embedded in formal legal planning procedures such as regional planning and municipal zoning? Can they be subject to legal or jurisdictional review for binding decisions?	Principle 8: Continuity and capacity

These six criteria were further discussed in the group sessions and ranked by the different groups in order of importance. The groups weighted some of the quality criteria more strongly than others. Table 4 and Figure 2 show the relative importance of the individual criteria, i.e. a ranking of importance, for each user group identified.

Table 4
Requirements for Sustainability Assessment Tools' quality criteria expressed by three key user groups in rank-order from least (1) to most important (6).

	Decision makers	Scientists/ Experts	General public
Objectivity	1	6	2
Transparency	2	5	5
Participation	3	4	6
Practicability	6	3	4
Flexibility	5	1	1
Institutional	4	2	3

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embedding

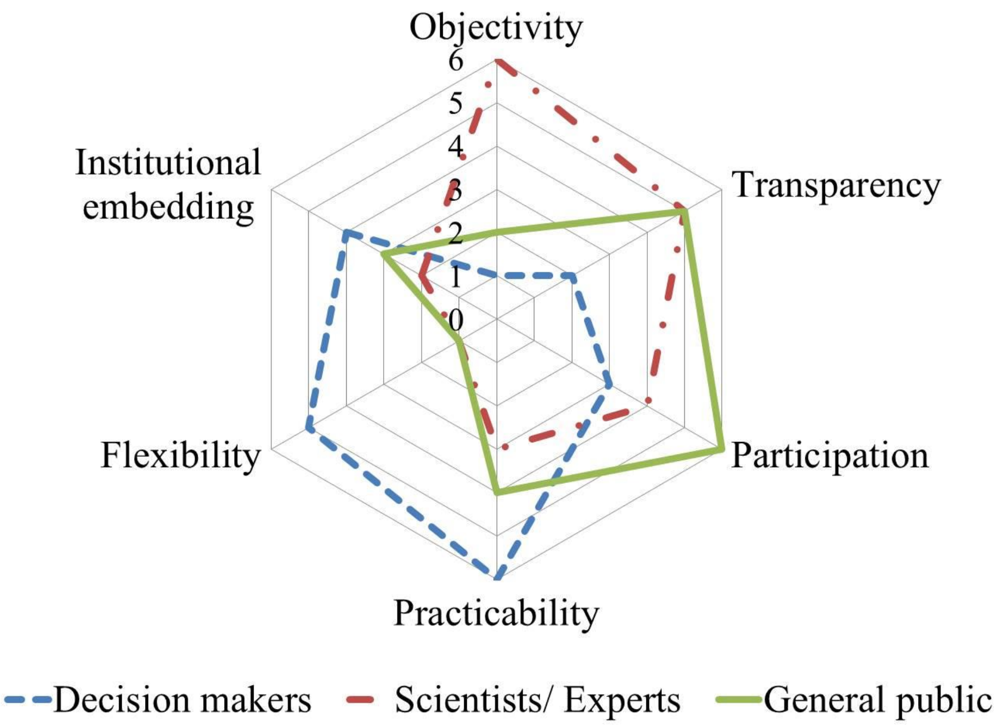

Fig. 2. Requirements for Sustainability Assessment Tools' quality criteria expressed by three key user groups in rank-order from least (1) to most important (6).

Figure 2 shows the different requirements of the groups identified. The criteria demonstrate similarities and differences. Certain criteria are clearly valued highly by distinct groups, e.g. representatives of the general public stress the importance of participation and decision makers need practicable and flexible tools, while experts consider objectivity to be the most crucial criterion. Furthermore, Fig. 2 shows that academics and experts attach less importance (measured by ranking points) to the flexibility and practicability of decision support tools than do decision makers and the general public. Instead, they set great store by impartiality, objectivity, and the close link between the method and the normative demands of sustainability. Decision makers, by contrast, state practicability to be most important. Moreover, they accord relatively high importance to flexibility while at the same time emphasizing the need for institutional embedding. In sum, it seems that each group favours specific criteria on the bases of its respective requirement profile.

6. Trade-offs between sustainability principles and user requirements

The discussions contained in Sections 4 and 5 give cause to conclude that there is a threefold trade-off at work: first, within the normative principles, second, within the user groups based on their requirements and, third, between the top-down principles and the bottom-up requirements.

Revisiting the normative level, claims are found to adhering to a set of rules when assessing progress towards sustainable development. Each Bellagio Principle must be respected also in the case of land-use management (as the references in Tab. S1 illustrate). Often, such principles are justified one-by-one, yet the contradictions that arise when they are to be adhered to and applied holistically are rarely discussed. When examining the different principles, however, we need to recognize that potential trade-offs are likely to arise when they are to be applied in tool design. By way of an example: Principle 2 calls for a deep understanding of the determinants of sustainable development, which requires knowledge of underlying social, economic and environmental systems and their components, relations as well as dynamics and uncertainties. It also requires an understanding of the trade-offs and synergies. Undoubtedly, such comprehensive considerations can only be derived on the basis of a sound knowledge of the complex systems involved, which in itself demands thorough investigation, data collection, monitoring and assessment. Elaborating this knowledge is at the heart of science. – To take a contrasting view, Principle 7 calls for a participatory approach that includes a broad public early on. This can (and even must for certain systems) significantly inform the research process, but it might also contradict the normative aim and compromise objectivity, e.g. when weighting different system components. As Sterling (2012) states, discourse between scientists, policy makers and members of the public is often conducted for contrasting reasons, at times with the intention of organizing, as much as respecting, competing public interests. “Prominent experts have questioned whether ordinary people have the right or even the ability to engage on complex technical issues” (ibid.). Whether or not one favours or is sceptical about transdisciplinarity, both these principles involve complex trade-offs, not only against one another but also against Principle 6, which requires effective communication and practicability in data presentation. When discussing sustainability there is just as much a need for complexity (Sterling, 2010) as there is for participation (Hartmuth et al., 2008) – yet both principles require a considerable investment in time and effort for the purpose of information gathering and processing. Diefenbacher et al. (2001) and Meyer et al. (2007) stress that having a system of indicators to assess sustainable development always involves a trade-off between a less than manageable flow of data on the one hand and overly compact information which can no longer be interpreted because it is too abstract. The demand for comprehensiveness would require that the evaluation set is comprehensive and depicts the problem in the best-possible way, entailing a very large number of criteria. For the purpose of applicability, conversely, it would be sensible to limit the set of criteria; hence, a pragmatic compromise is needed instead of spending years of theoretical work trying to find a perfect solution to the problem. The resources for such a high investment in terms of budget, time, skills and capabilities are limited in practice. Hence, demands for practicability and visualization are not easy to reconcile with a desire for perfect holistic tools that represent complex systems. Thus it is clear that not all the Bellagio principles can be satisfied in the same fully encompassing way.

Moreover, at first sight Figure 2 also suggests that three user groups differ significantly in their weighting of desired SAT properties. In order to test this hypothesis, we compared the pair-wise distances between the groups based on the different quality requirements. We apply Kendalls tau correlation test (Kendall, 1975), i.e. the calculation of the proportion of concordant pairs minus the proportion of discordant requirement pairs. Conventional correlation tests are not appropriate in such situations due to the dependencies between the items in each matrix such as for groups in Fig. 2. Dietz (1983) revisted a wide class of permutation tests for association between matrices and found Kendall's tau and Spearman's rho to have appropriate power and invariance properties. This resulted in a correlation coefficent of -0.733 ($p<0.05$) for the decision makers vs experts/scientists (the less straight forwardly interpretable Spearman’s rho rank correlation for this pair was -0.829 at $p<0.05$) indicating that these two groups differ significantly in their requirements. Others do not correlate significantly. This means that the interests of decision makers and experts need to be traded-off and carefully balanced in the design of SATs.

Table 3 also indicates some of the links between user requirements and the Bellagio STAMPs; these could be discussed in further depth in follow-on work. Importantly, we identify an implicit distinction in how the different user groups weight the different sustainability principles – from the analysis above we see that this may plausibly be a significant distinction. This can be interpreted as also reflecting the trade-offs identified in the user requirements analogously to the example discussed above. There are solid grounds for positing the assumption that objectivity (to take one example) can only be achieved in a completely satisfactory manner by a trade-off against practicability.

Turning our attention again to actual SAT design, we expect that scientists and technical experts are determined to bringing in objectivity as reflected in their high ranking of this quality. Consultants, on the other hand, will seek to develop SATs that can be sold to decision makers and that are therefore practicable and accepted by these clients. If scientists wish to ensure that their tools can be used in a wider range of applied contexts, they face a trade-off between the normative and demanding Bellagio STAMPs and the practicability of the tools. Different SATs will reflect these trade-offs, as each one will tend to reflect specific principles or user requirements. What we can reasonably conclude from this, in effect, is that individual tools and methods are not equally useful for each user group. If decision makers were weighting what was most important for them, normative aspects step to the background over practicability and flexibility concerns. If tools are to be aligned to these user requirements, then we conclude from a theoretical stand point that there cannot be tools that comprehensively fulfil sustainability rules while at the same time meet decision makers' needs.

Our overall interim conclusion, then, is that SATs will be varied in their design, because they can only embrace either the one or the other principle or user requirement. So, is there a "silver bullet SAT" that manages to balance all existing requirements and principles? Tool design indicates, what is possible in achieving the silver bullet by best trading off the requirements and sustainability criteria. To offer some analytic examples, the next section assesses three tools in terms of their approach to this challenge.

7. Methods for assessing the sustainability of land use

Using selected studies, this chapter provides an overview of the ways in which sustainability assessments of land use can currently be carried out. Three tools are introduced as representative examples of typical techniques. They are then evaluated against the criteria of the different user groups identified in Section 5. Thus, they are also implicitly placed in relation to the normative principles as reflected in the stakeholder group selection and in the links between the user groups' requirements and the Bellagio Principles, as discussed above. It is not our intention to judge "how good" a certain tool was or might be for conducting a sustainability assessment in a specific land-use decision; rather, we wish to understand, based on the evaluation, how the tools deal with the dilemma of trade-offs identified in Section 6.

A wide ranging literature has evolved on methods for measuring sustainability that can be applied in SATs. The work done by Diefenbacher et al. (2001) enables us to highlight some of the key findings on potential sustainability assessments using indicator systems: i) *Easy methods*, including traffic-light or other diagrammatic methods helpful in symbolizing assessment results, are best suited to raise public awareness, though at the same time they bring the risk of oversimplification and concentration on spectacular corner solutions; ii) *Complex mathematical-statistical methods* (at the other extreme) have often been perceived as 'black-box' approaches – not helpful in policy advice or awareness raising among the general public, such complex techniques should be limited to the development phase of SATs, e.g. when selecting sound indicators; iii) *Simple mathematical-statistical methods* may be used for demonstration purposes and for identifying correlations between variables; however, empirical results need to be "embedded" in a theory of sustainability to arrive at a causal explanation; iv) *Network analysis* is a suitable method to further refine the detection of interactions in detail and to illustrate the complexity of these relations; v) *Discursive and participatory methods* of assessment may be less spectacular than simple graphical methods, but they are very fruitful in terms of understanding both the composition of the system itself and the actual results. Furthermore, discursive and participatory methods offer a kind of "bridge" to the concrete implementation of assessment based recommendations for decision makers.

We choose the following three distinct approaches and tools, reflecting to varying degrees the different approaches outlined above: (1) the 'Soil Value Balance' devised by the German Federal Environment Agency, a generic multi-focal, economic assessment and normative valuation approach; (2) the RESCUE-SAT produced in a five-year EU-funded research project, a participatory, deliberative and procedural approach; and (3) the SINBRA-SAT for city-planning purposes, a recently completed project funded by the German Ministry of Education and Research, representing a more focused, issue-specific and instrumental approach to quantifying components of land-use that are relevant to sustainability and are to be reflected in sustainable land-use decisions.

7.1 Soil Value Balance

A study on the *Revitalisation of brownfields vs consumption of greenfields* (Consortium, 1998) constituted the first major methodological contribution to comparing the sustainability impact of *brownfield* as opposed to *greenfield* re-development in Germany. The *Soil Value Balance* (SVB) that emerged from this is a decision support model which, alongside general sustainability aspects, also takes into account the indirect social costs of land use. This approach can be characterized as a generic multi-focal and norm-oriented assessment approach in an economic valuation tradition that strives to quantify (and indeed monetize) all the factors in a land-use decision involving a *greenfield* and a *brownfield* option that are deemed to be of importance taking a scientific system's perspective.

The SVB represents a type of SAT designed for local authority planning prior to new zoning as well as for deciding between *greenfield* and *brownfield* sites in cases of commercial development. It is designed in particular to help council planners, faced with a choice between two sites, to select the one where investment by the municipality will result in better sustainable development (Rüpke et al., 2000). In both its multi-focal and comprehensive ambition, the method explicitly considers the interests and value judgments of three hypothetical typical actors: (1) In *Site Potential* (*SP*), the value of a site to the *local authority* is calculated on the basis of the site's actual characteristics. (2) In *Exploitation Potential* (*EP*), the site's suitability for commercial use is assessed from the assumed viewpoint of *investors*. (3) *Site Value* (*SV*) serves to quantify the changes that would be caused in all the elements of the ecological, urban development and regional structure by the planned use compared to the status quo, viewed from the angle of *society as a whole*. The SVB allows for two separate assessment methods. The *Preference Index (PI)* method described below uses a multi-criteria scoring system to determine the better option. In the so-called *Resulting Monetary Value (RMV)* method, the factors of influence are additionally monetized (Consortium, 1998). The SVB, therefore, can be seen as representing Cost Benefit Analysis tools as they are increasingly sought for in practical regulatory impact assessment context. However, all criticism of monetization per se aside (cf. Lienhoop and Hansjürgens, 2010), what we are interested in here is the systematic objective approach itself, and so to enable a comparison with the other two multi-criteria SATs, the monetization method itself is not discussed any further.

The categories considered are specified using a total of 26 criteria individually prescribed by the designer. The two sites under consideration for a certain type of commercial development (generally a *greenfield* and a *brownfield*) are compared on the basis of these criteria. The user awards points on a three- or five-point scale for each of the criteria depending on each site's characteristics. Table 5 illustrates this procedure for the criteria "transport links" (from the investor's viewpoint *EP*) and "groundwater quality" (from the angle of society *SV*).

Table 5

Example of rating criteria in the Soil Value Balance based on Consortium (1998) and Consortium (2000, appendix II pp 6ff.).

Criterion	Points	Description
Traffic links	+4	Motorway access point can be reached in less than 5 minutes
	+3	5 to 10 minutes
	+2	10 to 30 minutes
	+1	30 to 60 minutes
	0	over 60 minutes
Groundwater quality	+2	Groundwater uncontaminated, quality at least meets requirements of TVO (German Drinking Water Ordinance)
	+1	Groundwater requires little treatment for upgrading to drinking water
	0	Groundwater with contamination, can only be upgraded to drinking water by fairly complex methods (contamination not ruled out for sure)
	–1	Contamination requiring decontamination regardless of usability
	–2	Extreme contamination requiring immediate safety measures

Having the nearest motorway access less than five minutes away, for example, is worth a score of 4 to investors, whereas the extreme groundwater contamination necessitating immediate safety measures is rated from the angle of the general public as –2 ('very bad'). To calculate the PI, the site's value from a public angle is assessed as most important factor describing its components before and after the commercial exploitation; the difference between these values is denoted as the site value delta ($SV_{\Delta}I$) (Rüpke et al., 2000). For the case of extreme groundwater contamination, reuse and remediation of the site to the level of groundwater requiring only little treatment for upgrading to drinking water quality leads to an improvement of +3 points in the $SV_{\Delta}I$ assessment, i.e. remediation of contamination on a *brownfield* is valued as desirable from a

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sustainable society's point of view (Table S2 contains an overview of all the criteria selected in the SVB – more detailed background is described in Consortium, 2000).

To enable consistent aggregation of the criterion scores, the categories were weighted according to their relevance as deemed scientifically justified by the SVB developers who argued for an objective and reliable assessment approach. At this point, which is of central importance for calculating the Preference Index, the weightings are specified for the user (right-hand column in Tab. S2). Since this *objective* approach is based on very detailed explanations described by the authors in their study (Consortium, 1998, chapter 6), the reasoning behind it is accessible to public debate – even though, later publications and promotions of the SVB do not point explicitly to this background information and reasoning.

The weighted and aggregated total score indicates the *Preference Index (PI)* in relation to the land preparation and remediation costs (*AC*, *RC*) as well as the possible sales revenue (*SR*) [in the dimension score*m²*$€^{-1}$]. The *PI* can be interpreted as a measure of the preference for a development option when comparing a number of sites. A positive *PI* can be interpreted as a sustainable yield of land development, while a negative *PI* as an absolute amount indicates the benefit of maintaining the status quo compared to the site being put to use. The site with the higher *PI* is to be preferred.

The *SVB* is designed to enable an *exhaustive* and *holistic* comparison of the anticipated consequences of commercial use (Consortium, 2000). However, some impacts for the local authority seen as important by other authors, e.g. De Sousa (2008), such as the effect of a site's development on municipal tax revenue are not taken into account. In other categories, too, it needs to be asked whether the losses in value caused by commercial development are included. For example, neither environmental nor social justice considerations are made explicit in the SVB despite their crucial importance when assessing sustainability. The assessment is emphasizing economic and environmental issues of development, but it arguably underestimates the social and cultural values. The SVB involves several arbitrary ratings and scores, reducing its transparency and making it liable to criticism. Nevertheless, the *PI* calculated with the SVB still appears to be a useful decision support tool, at least in the early phases of planning, since it can be used to gauge many relevant criteria of local spatial planning and site quality. Moreover, it encourages practical and scientific debate about the factors characterizing the sustainability value of land uses.

By way of summarizing our assessment of SVB, we find that it constitutes an attempt to a highly objective, practicable and transparent approach. The fixed set of indicators and the weighting method are its chief strength regarding objectivity and norm orientation, although they are also its major weakness, because they mean that it is not readily adjustable to different local or institutional contexts and some indicators can be argued are missing. The focus on a single land-use option also limits the scope of applicability. Different stakeholder interests are said to be reflected in the evaluation categories, yet there is no provision for true participation by wider publics. In terms of the Bellagio Principles, the SVB accords well with Principle 2 but does poorly on Principle 7.

7.2 RESCUE Sustainability Assessment Tool

The project RESCUE (*Regeneration of European Sites in Cities and Urban Environments*) studied several revitalization methods practised to encourage the sustainable use of *brownfields* and identified *best practices* for taking local sustainability into account in future revitalization projects. Based on an interdisciplinary approach, the aim was to draw up recommendations for actors in land revitalization. RESCUE regards the integration of aspects of land quality, development planning and citizen participation as the key to successful, sustainable land revitalization. RESCUE therefore proposed a more procedural approach that emphasizes the role of stakeholder involvement in the assessment of sustainability.

In order to carry out a revitalization project, RESCUE recommends a five-phase approach. The RESCUE-SAT is deployed upon conclusion of the initialization phase, in which the potential for a revitalization project is ascertained and a developer's project proposal is derived on the basis of regional development and zoning plans. Once a project idea has been specified, the developer enters the sustainability assessment process (Edwards et al., 2005). The RESCUE-SAT is intended for use in the context of an award of public funding, which the developer may request (Franz et al., 2007). However, the approach can be adapted further to land-use decisions faced by regulating authorities when tasked with approving certain developments, e.g. city planning, soil or community protection measures to name only a few. The SAT is based on the underlying assumption that sustainability criteria and weightings are not identical for each type of land development. Since different aims of heterogeneous interest groups have to be considered in connection with the different sites, their sustainability cannot be evaluated using a fixed checklist of indicators. Aims are specific to contexts and times and, therefore, need to be defined largely in relation to the priorities of local stakeholders. The final assessment of whether or not a project in a specific location is sustainable is the result of a process of communication and decision making in several stages based on a one-day workshop organized by a neutral facilitator. When all the locally relevant actors come together, their different interests need to be discussed open and honestly. The project vision of the developer and the sustainability goals of the RESCUE programme are explained to the participants (brownfield owner, developer, community and conservation organizations, residents, public bodies, NGOs, etc). The RESCUE objectives arise from the key challenges of *brownfield* revitalization such as social sustainability, profitability, job creation, ecology, and increasing the land's value. Various possible criteria each contributing towards a certain objective are summed up in checklists. As the sustainability of the project idea is determined by the local participants, at the workshop the stakeholders select the objectives and criteria which in their opinion are locally relevant. Then, they weight the selected objectives and the criteria by allocating points from a limited budget. All in all, this leads to the prioritization of relevant sustainability objectives in a manner specific to the stakeholder groups involved in for the development project being assessed. Each group is regarded as equal, i.e. each group has the same number of points to allocate (RESCUE, 2004).

After the workshop, the project developer rates the findings in quantitative terms. In his proposal for public funding, he comments on their viability on the basis of the scores obtained. He also has to explain how his blueprint takes the stakeholders' sustainability factors into account. His application is submitted to the relevant approval body (funding provider, planning authorities or EU institution), which then decides on a standardized basis how sustainable the project is and the extent to which it takes public interests into consideration. The approval body assesses on a scale from 0 to maximum 10 points the various objectives associated with the project respectively taking into account the project developer's qualitative explanations. The two sets of assessment (by the approval body and the stakeholders) are merged to form an overall assessment (Z), which is then compared to a fixed benchmark setting a minimum standard of quality. In the example given by RESCUE (2004), the quality standard is achieved if 650 < Z < 1,000 is satisfied. This result provides the basis for deciding whether funding is to be granted for the project. Table 6 demonstrates the evaluation of the overall assessment score (Z) for the case of four stakeholder groups (A–D), four local *objectives* and 40 points for each stakeholder group.

Table 6
Example for RESCUE-SAT assessment based on RESCUE (2004, 226ff).

	A	B	C	D	Average weights	Relative weights[a]	Funding body's assessment[b]	overall assessment score Z
Objective 1	6	16	8	4	8.5	*21.25*	*6*	127.5
Objective 2	31	9	2	10	13.0	*32.50*	*9*	292.5
Objective 3	1	4	21	0	6.5	*16.25*	*4*	65.0
Objective 4	2	11	9	26	12.0	*30.00*	*7*	210.0
Total	40	40	40	40	40	100.00		*695.0*

[a] Relative weights equal average weights divided by the budget (of assessment points, here 40) times 100.
[b] Funding body's assessment is between zero and ten points.

The *hierarchical assignment of importance* assures that the approval body is ranked higher than the project developer. Whether the developer receives funding for the revitalization vision he or she has put forward depends on their assessment together with the local sustainability evaluation. This prominent position in the decision-making process guarantees a minimum of sustainable development irrespective of the project developer's sometimes contrasting aims.

To conclude, the RESCUE-SAT is a fully participation-based approach. The methodology cannot fully satisfy the other criteria, as transparency is compromised at the later stages of the evaluation. Flexibility and practicability are related to high efforts due to the significant transaction costs, while objectivity in particular could be compromised and depends heavily on the way the assessment is conducted (e.g. selection of stakeholders and facilitator). In terms of the Bellagio Principles, the RESCUE-SAT differs from the SVB by addressing Principle 2 in a less comprehensive way while dealing fully with Principle 7.

7.3 SINBRA Sustainability Assessment Tool

A method for appraising the potential of developable land from the angle of sustainable urban development was originally developed by Stadtregion (2010) as part of the research project SINBRA. The SINBRA-SAT was then developed further by Schädler et al. (2013, 2012, 2011) and applied in the City of Indianapolis (cf. Müller and Rohr-Zänker, 2011; Harrell, 2012). In contrast to the other two tools outlined above, SINBRA focuses on municipalities and the administrative personnel responsible for deciding on land-use developments. The SINBRA-SAT can be characterized as a more focused and instrumental approach to quantifying relevant components of sustainable land-use in urban planning and politics.

The SINBRA-SAT approach is an evaluation system based on a framework of sustainable development objectives related to local factors. In this tool, the assessment of *site potential* is used to ascertain the types of use for which an area is suitable in connection with urban development objectives. The set of indicators chosen is intended to be used as decision support for sustainable land management. It focuses on a very early stage of the project in which a site's

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usage potential and impediments hereto are assessed before the land is used and future uses have been decided definitively. The method is intended to support local authorities and property developers in identifying and actively communicating the re-development potential offered by *brownfields* (Müller and Rohr-Zänker, 2011).

Based on five sustainability goals anchored in ICLEI (1994) and Agenda 21 (UN, 1993) (general goals of sustainable urban development), 17 sub-goals were identified for assessment in an interim stage (cf. Table S3). Using indicators easily identifiable with local knowledge, the aim is then to assess the degree to which the various sub-goals are achieved by a specific intended use. Only those objectives and indicators related to a specific site are taken into account. This exclusive focus excludes sustainability objectives not directly related to the area concerned (e.g. procedural goals).

The *site potential* is assessed by the user in a matrix that takes into account seven pre-defined types of use (cf. Fig. 3). The pre-selection of usage types is justified by Stadtregion (2010, 17-21) as being a consequence of having to differentiate between a multitude of possible land uses on a site, i.e. with regard to impacts on the land and the consequences for surrounding areas in terms of socially, ecologically and economically sustainable urban development. However, it is not reflected, whether an inherent bias is built into this model against certain land uses, e.g. those not considered by it. The suitability of the types of use is evaluated on a three-point scale denoting positive (+1), negative (–1) and no (0) foreseeable development of the sustainability indicators. Assessment leads to a ranking of usage types in descending order of their contribution towards use of the site for the aims of sustainable development. Figure 3 shows an example.

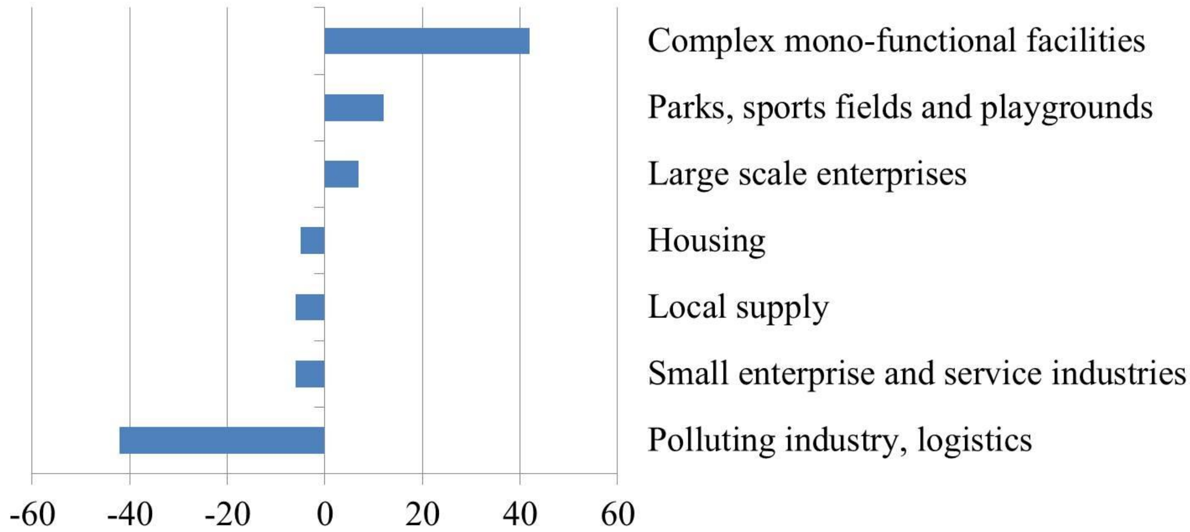

Fig. 3. Aggregated and weighted degrees of SINBRA-SAT indicators' fulfilments for the suitability of certain usage types for a specific site's development based on Harrell (2012, p 12).

As in the Soil Value Balance, the overall result is mainly determined by the weighting of the predefined general goals, sub-goals and indicators. In contrast to the SVB with fixed weights, however, the authors assume that decision-making regarding the actual weighting of the parameters will not be determined by scientific prescription but will rest with the decision-maker, e.g. the local authority. Whereas in the default form of the assessment algorithm the weightings of the five general goals are set equally at 20%, these and the weights of the sub-goals and indicators are not obligatory. This is in order to allow developers to address distinct local features and priorities by adapting weights to local perceived priorities. However, none of the goals may be discarded, the weightings may not be reduced below minimum thresholds, and any deviations from the default weights must be justified so that the assessment remains transparent and reproducible (Stadtregion, 2010). Supplementing the existing set of criteria and aims is not permitted. Normatively speaking, this is an important framework parameter as the authors of the SINBRA-SAT at one point considered abandoning the minimum thresholds. Had this occurred, the possibility of leaving out or marginalizing 'undesirable' goals by giving them a minimum weight might have jeopardized the method's sustainability.

To conclude, the SINBRA-SAT is a more instrumental approach. Its strength is its excellent practicability and high degree of flexibility given the ease with which different options for the limited set of indicators can be adjusted. However, the approach lacks any participatory ambition – in strong contravention of Bellagio Principle 7. This also calls into question the transparency and, even more so than in the RESCUE-SAT case, the objectivity of the tool. In terms of the Bellagio Principles, the SINBRA-SAT embraces most comprehensively Principle 6, effective communication and applicability.

8. Discussion and meta-comparison of the approaches and tools

Having presented different approaches to including sustainability assessments in decision making and having discussed end-user and stakeholder requirements for applying such SATs in practice, in this section we compare and evaluate the approaches in terms of the general criteria outlined in Section 5 in order to assess the quality of SATs based on the sustainable development principles.

In order to evaluate individual sustainability assessment methods – such as those described above – we need first to determine whether or not the individual criteria have been fulfilled. At the end of each tool description in Sections 7.1 to 7.3, we presented a brief assessment of how the SATs in question performed in relation to the user requirements and selected sustainability principles by referring to the tools' specific characteristics. Below we translate these qualitative assessments, in simplified fashion, into quantitative judgments using a marking approach on a six-point ordinal scale in which quality is rated as follows: 0 *very poor*; 1 *poor*; 2 *unsatisfying*; 3 *good*; 4 *very good*; 5 *excellent*. The aim is not to provide a summary assessment but to gauge and compare the relative importance of the criteria in the respective methods; this is taken to reflect the SAT designers' approach to crafting sustainability assessment instruments – and thus implicitly their focus on and weighting of the specific sustainability principles which ultimately should have guided the tool's design.

Table 7

Comparison of the three Sustainability Assessment Tools (SATs) (Preference Index of Soil Value Balance – PI SVB; RESCUE-SAT and SINBRA-SAT) based on authors' judgments using the empirically derived user requirements quality criteria.

	PI SVB	RESCUE SAT	SINBRA SAT
Objectivity	4	2	2
Transparency	3	3	3

Participation	2	5	1
Practicability	3	2	5
Flexibility	1	3	4
Institutional embedding	1	3	2

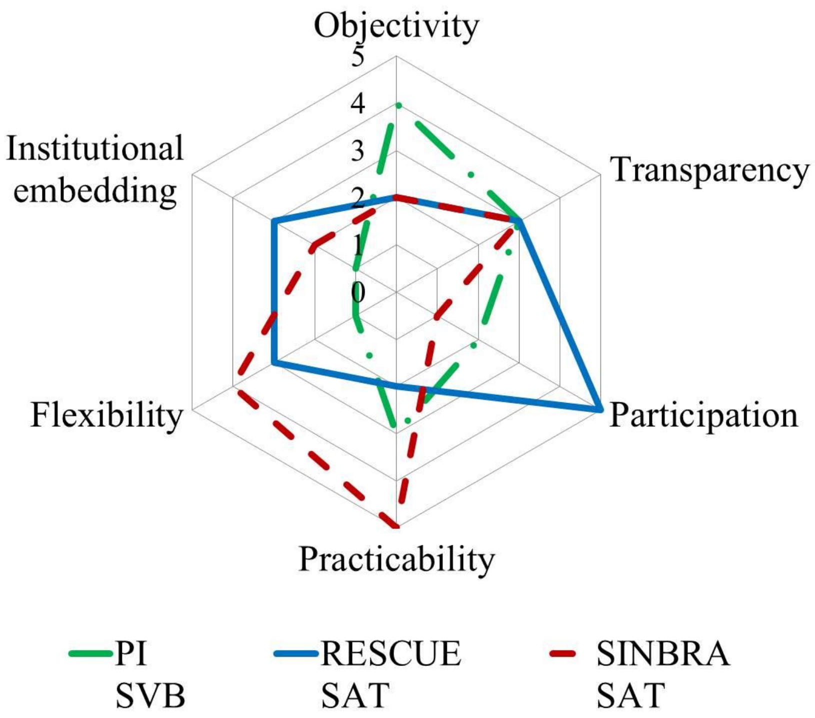

Fig. 4. Comparison of the three Sustainability Assessment Tools (SATs) (Preference Index of Soil Value Balance – PI SVB; RESCUE-SAT and SINBRA-SAT) based on authors' judgments using the empirically derived user requirements quality criteria.

An analysis of the methods examined in Table 7 results in the comparison illustrated in Figure 4 and described in the following. The data reveals some fundamental differences between the approaches and enables their strengths and weaknesses to emerge clearly. The different approaches and tools address different principles and hence perform to varied effect. Whether consciously or not, tool designers develop their SAT in a way that embodies norms geared toward either broader participation (Principle 7) or better practicability and flexibility (Principles 6 and 8) or again toward complying more systematically with a holistic perspective (Principle 2). Judging solely on the basis of the remarks above (in Section 7), the SVB can be described as the most 'objective' method since it excludes a priori any influence by interest groups and restricts users to previously defined scalar levels. However, this 'objective' approach is beset by drawbacks regarding the other assessment criteria. Flexible adaptation to local stakeholder groups is almost impossible and their scope for influence is very small. Weighting can only be adapted to changed conditions by discussing the fundamental aspects of the method per se. Consequently, the method's practicability can best be described as adequate given the specific combination of diverse local actors. This is borne out by the fact that this method has not caught on in practice over the past decade and that it lacks institutional embedding. This is also due in part to the large amount of data required to implement the method and to the fact that it demands a high level of user expertise. Another disadvantage is the method's insufficient transparency. In order to fully comprehend the results, the user is required to study the extensive assessment manual – a process which is time consuming and hence costly. As indicated above, the list of assessment criteria in its current form is arbitrary and needs to be re-thought with respect to normative issues.

A sharp contrast is the RESCUE-SAT, whose main strength is the transparent manner in which it incorporates diverse interest groups: it allows them to determine goals and criteria weightings depending on their specific interests and in accordance with local conditions. However, transparency is beset at the level of decision making of the approval body. Since the possibility of manipulation by the project developer or even the workshop facilitator cannot be ruled out, it must be assumed that the assessment findings are not necessarily impartial. At the same time, it can be assumed that sustainability objectives will not be flouted completely, because the approval body concerned occupies the supreme position in the decision-making hierarchy. The proposed method is eminently suitable for use with revitalization procedures involving relatively large areas. Its practicability is limited for smaller projects due to the costs of staging the workshop. In addition, the entire methodology has to be carried out in full for each assessment project. On the whole, though, RESCUE-SAT is beneficial due to its innovative participatory approach. Compared to other methods, a large number of actors are clearly and visibly involved in decision-making, significantly raising levels of acceptance of project development.

Finally, the SINBRA approach is convincing in its current form owing to its high degree of practicability. This is given due to the small number of interest groups involved (only local authority decision-makers), which by the same token is the method's main fault. The method is very flexible because most (though not all) criteria can be adapted to local conditions. At the same time, though, this greatly compromises impartiality and objectivity, and opens up the possibility of manipulation.

The above discussion may give the impression, that the SATs can be clearly distinguished from one another. If we test the independence of tools from the viewpoint of the performance assessment assuming quasi-cardinal character of the judgment marks in a Pearson's Chi-squared test, we find no significant ($p=0.646$) distinction and cannot reject the null-hypothesis. When we look at how the ratings correlate to one another, neither a significant distinction between the tools is found without making additional assumptions. However, this picture changes if we disentangle the elements and include users' requirements.

In a final step, the tool assessments reported in Fig. 4 and information on key user requirements reported in Fig. 2 are merged in order to facilitate an analysis of the fit between the latter and the approaches implemented in the example SATs. Scores are obtained by multiplying of the assessment rating for each criterion by its respective ranking position (to arrive at a standardized value, this figure is then divided by the total number of ranked criteria – detailed results are illustrated in Figure S1). If we wanted to link the ranking information with the assessments, it would be necessary to have cardinal figures, i.e. an understanding of the distances between both the user ranking steps and between the assessment ratings. Aggregations of the two rank-ordered variables in a simple multiplication approach is following on Cook et al. (1997), who justified this interpretation of ranked-ordered information.

Table 8
Rank correlations of quality judgments weighted according to three distinct user specific requirements for three Sustainability Assessment Tools (SATs) with the general ranking of the three user group specific requirements regarding the quality of SATs.

Correlation (Kendall's tau)	PI SVB	RESCUE SAT	SINBRA SAT
Decision makers	0.358	0.501	0.867 [a]
Scientists / Experts	0.867[a]	0.552	0.389
General public	0.643	0.828 [a]	0.593

a Significant at five percent significance level.

As reported in Table 8, now some significant distinctions are found (Fig. S1 provides user specific illustrations). Each user group shows a significantly strong correlation to the performance of one particular tool. We dare to interpret this as a matching – in other words, each group distinguishes clearly between some of the tools. We assume in this interpretation that they apply their requirements as revealed and discussed in Section 5 and share our assessment of the tools' performance with regard to the quality criteria as reported in Table 7 and Figure 4 above. This may be criticized as not being objective. As mentioned above, however, the authors' evaluation of how the different SATs perform in relation to the different requirements has been undertaken impartially to the best of our ability; nonetheless, ultimately it remains a subjective evaluation and one that is open to competing assessments. Yet even if the assessments were modified by varying each rating by one degree in a sensitivity analysis, the basic results would remain the same, indicating that at least one tool is significantly correlated with one user group's quality assessment weighted by their preferences. This differentiation between the decision makers, scientists/experts and the general public is driven by their different requirements for certain SAT characteristics. Clear evidence is found of significant correlations in the expected way, i.e. decision-makers tend to favor SINBRA-SAT, with its emphasis on practicability and flexibility, experts and scientists are drawn to SVB, with its orientation toward objectivity and comprehensiveness, whereas representatives of the general public strongly gravitate toward RESCUE-SAT and its insistence on broad participation. This powerfully reflects the underlying difference in emphasis between the tools regarding the different sustainability principles. By contrast, no further correlations are found between the stakeholders and the other approaches or – to put it rather more forcefully – the stakeholders do not accept or care about the other approaches. We conclude that the tools address different user needs inasmuch as they ultimately address different sustainability principles.

9. Conclusion

A number of SATs have been developed and yet only few have been implemented and embraced by practitioners. The reasons for the different degrees of take-up of the tools have been identified above. The diverse set of characteristics inherent to each tool arises from the tool designers' challenging task of incorporating not only heterogeneous sustainable development principles but also highly diverse user requirements in the SATs' design. To a certain extent these diverse requirements reflect the different weightings specific to each user group and hence give rise to trade-offs between the different sustainability principles. Consequently, any one tool's design will reflect the Bellagio STAMPs to varying degrees: as demonstrated, we find a comprehensive perspective pursued most fully in the SVB, broad participation in the RESCUE-SAT, and most effective communication in the SINBRA-SAT. The tools thus indicate what is possible in terms of combining sustainability principles and user requirements.

Is there, then, a 'silver bullet' assessment tool – a perfect tool that takes into account the significant distinctions between users and their SAT requirements? The assessment of the tools' various qualities must necessarily be guided by the normative vision of sustainability but at the same time be oriented toward the context of application and the individual applying the SAT, i.e. the user's diverse requirements. Many might not regard the method as 'good' that is actually taken up in practice, especially if normative principles are violated in the course of applying it. The criteria for sustainable development are normative and they determine top-down critical elements of SATs while user requirements determine bottom-up what a *useful* tool is. Tool designers develop their SAT (whether consciously or not) to fit a given norm-based vision that involves selecting certain sustainability principles over others, as discussed in Section 6, e.g. broader participation (Principle 7) or better practicability and flexibility (Principle 6) or more systematic compliance with a holistic perspective (Principle 2). Therefore, in tool design optimisation (in an economist's language) can only achieve a second best solution, because a first best solution, i.e. a true optimum defined as fulfilment of all principles at the same time, cannot be attained due to the trade-offs identified.

Whether or not a tool is 'good' could theoretically be assessed in an impartial evaluation as indicated here (or in Pediaditi et al., 2010). Our intention was not to choose 'the best' SAT out of a randomly selected sample subjected to analysis, but to show that, empirically speaking, there is no tool capable to fulfilling all user requirements and sustainability principles equally. On the contrary, the tools seem to be designed to address certain principles and requirements. So the answer to our "bottom line" question is decided by the empirical fact of whether or not a SAT is taken up, and this depends on the context and the extent to which the users' requirements are met. If a tool is taken up *and* adheres to basic sustainability principles, it is to be considered a 'truly good' SAT. However, this entails accepting that, due to the trade-offs involved, tool designers have to give up a certain degree of scientific and normative rigour in order to achieve practicability and long-term implementation. The development of a SAT will constantly be beset by the problem of the trade-off between impartiality (is sustainability required which has been deemed scientifically objective?) and extensive democratic participation that takes account of diverse local interest groups, divergent goals and varying circumstances.

Some authors, such as Seiler et al. (2009), stress the institutional embedding as important prerequisite for SATs implementation in land management. Indeed, in their current form, none of the SATs analysed have been convincingly integrated into institutional planning processes. The obstacles to institutional embedding can be found too in the trade-offs discussed, but are also to be seen in the willingness of politicians and decision-makers to implement sustainable development.

Ultimately, tools need to be applied by decision-makers. Hence, they need to be designed to meet their requirements. Sustainability principles cannot be reflected equally to their full extent going through the process of end-user specific design. We found significant differences between the *decision-makers* and *scientists/experts* groups in terms of their requirements regarding SATs.

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This raises the controversial question: Why should decision-makers consult experts at all? It should be noted here that we are not disputing the sustainability results per se; rather the difference refers to the SAT requirements and the instrumental usability. Decision-makers might greatly appreciate expert input on the criteria to be included in decision making, yet they need to make it clear that they want such criteria in an accessible and practical format.

Tool designers should be clear about the user group that they address. By showing that the requirements of users derived from the normative set do differ, we find that groups have dissimilar and even contradictory profiles when it comes to weighting criteria and implicitly therefore weighting the elements of the Bellagio catalogue. Hence, the Bellagio Principles cannot be fulfilled comprehensively if a tool is designed for one user group. Despite the needed orientation of a tool along specific user requirements, tool designers should as far as possible in a second step involve in their considerations on the tool design the interests of all other stakeholders/organizations that might potentially be concerned.

Consequently, tools suitable for application in practical contexts will not conform to sustainability principles in the best holistic way. If we accept this, then what is needed is a "second best" tool design that takes into account the inevitable trade-offs. Whether or not they can still be called 'sustainability'-oriented will require more detailed research on the trade-offs with the aim of establishing certain 'guardrails' to guide practicable tool design despite the required embodying of the sustainable development vision.

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