Review

Urban Resource Assessment, Management, and Planning Tools for Land, Ecosystems, Urban Climate, Water, and Materials—A Review

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Abstract: Increasing awareness of global and local climate change and the limited resources of land, surface, water, raw materials, urban green spaces, and biodiversity alter the exigencies of urban development. Already perceivable local climate changes such as heavy rains, droughts, and urban heat islands urge planners to take action. Particularly in densely populated areas, conflicting interests are pre-programmed, and decision making has to include multiple impacts, mutual competition, and interaction with respect to investments into provisioning services. Urban planners and municipal enterprises increasingly work with digital tools for urban planning and management to improve the processes of identifying social or urbanistic problems and redevelopment strategies. For this, they use 2D/3D city models, land survey registers, land use and re-/development plans or other official data. Moreover, they increasingly request data-based planning tools to identify and face said challenges and to assess potential interventions holistically. Thus, this contribution provides a review of 51 current tools. Simple informational tools, such as visualizations or GIS viewers, are widely available. However, databases and tools for explicit and data-based urban resource management are sparse. Only a few focus on integrated assessment, decision, and planning support with respect to impact and cost assessments, real-time dashboards, forecasts, scenario analyses, and comparisons of alternative options.

Keywords: urban resource management; software; web tools; urban green spaces; land use; water; material/waste; urban climate; review

1. Introduction

Cities are facing multiple challenges with respect to climate change adaption, land, surface and space use, water supply and use, material and waste management, urban green spaces, and biodiversity, just to name a few. Furthermore, continuous urbanization, a high demand for residential areas, and the densification of cities are further driving forces for urban transformation. The UN Sustainable Development Goals (SDG) and energy and mobility transitions as well as the associated attention of the public (COP26 and Friday for Future) lead to further demands and complexity with respect to urban planning [1]. A multitude of methods and tools are available for analyzing urban processes and activities. However, urban policymakers tend to use best management practices rather than quantitative data to support policy decisions [2,3].

Nature-based solutions (NBS) or blue-green infrastructures (BGI) are seen as key aspects to make urban areas more sustainable, e.g., healthier, more biodiverse, and attractive, and to make cities more resilient with respect to urban heat island effects, extreme weather, and climate change [4,5]. These challenges need to be addressed and systematically worked on in urban planning. The main tasks are to formulate goals and to derive operational targets, projects, and milestone plans for the demanded urban transformation in different fields. However, cities also experience major challenges with climate adaptation measures:

resource availability, a lack of expertise, institutional settings, and collaborative governance and planning [6]. Furthermore, urban transformation is not limited to climate adaptation challenges but requires integrated urban development strategies and operational approaches considering multiple challenges at once [6].

Geographical data are changing how cities and urban districts are planned, monitored, and managed [7]. More and more cities provide open data on their built environment, development plans, local climate and heat islands, CO_2-emissions, many other pollutants, biodiversity, urban green infrastructure and water bodies, and others. Moreover, other service providers provide data on cities, such as 3D models from federal/state agencies, satellite and ortho images, local weather data, and semantic and labelled maps, that give further information on urban areas. Furthermore, standardized data models, exchange formats, and processes are under development and are used for efficient urban planning (e.g., XÖV and XPlanung; XPlanung is a standard for urban land use planning in Germany. Since 2018, it is obligatory for communities, with a 5-year transition period. XÖV is a standardized XML format for public administration in Germany). Moreover, atlases or apps show the most important points and services of general interest [8,9], social and urban planning problems or solar potentials (solare-stadt.de), monitor urban development [10,11] (e.g., KomMonitor is an interactive GEO-based tool focusing on the monitoring of the demography and social structure; it allows for statistical analysis and time series and shows points, lines, and areas of interest [10]), and help search for affordable housing or enable digital citizen participation [12]. Geoportals offer many open data on cities, e.g., on noise [13,14], public tree inventories [13], standard ground values [15], water infrastructure [16], energy, water, and greenhouse gas performance [17], and air quality or demographics. Others also show improvement potentials, e.g., concerning solar heat or power generation, related potential CO_2 savings, and the exhaustion level of the full potential [18–20] or potential for green roofs and unsealing ground [21], with examples in [22,23]. However, the information availability and granularity of urban data differ, and only a limited number of studies include spatially explicit data to inform planning practitioners [24]. Some cities offer information on contaminated sites and individual plot geometries/polygons (e.g., [25]), while others do not share such data (classified due to data protection). Some extend to the surrounding regions up to the state level (e.g., [26]), while others are restricted to the urban or metropolitan areas.

Furthermore, urban data and, in particular, the monitoring and performance evaluation of concepts and measures are crucial to manage and measure urban transition [27]. GIS-based planning, monitoring, and management tools for a more sustainable urban resource management and development have to consider a multitude of factors and their complex interplay. They should be able to consider local conditions (e.g., ecosystems) and to pursue the realization of communal goals. Moreover, such tools can help to share information, to improve planning processes, and to enable quantification, resource monitoring, and management in (almost) real time. Tool addressees are researchers, municipalities, and their administrations as well as urban planners and consultancies. These tools are not solely for analysis and administration purposes; they also facilitate the public display of urban data and maps, which could contribute to citizen engagement, e.g., data collection and feedback on current developments. Specific and integrated urban planning and decision making could also be supported by tools that allow for the identification of suitable locations of additional NBS (potentials); the quantification of services, disservices, and cost (see e.g., [5]); the consideration of interactions with water/materials, ecosystems, and other aspects; or the inclusion of NBS in inter-/trans-sectoral urban planning and governance strategies/funding programs. "A large variety of tools have been developed worldwide to support the mainstreaming and uptake of NBSs in cities, ranging from methodologies, software, catalogues, repositories and e-platforms, to guidelines and handbooks. [. . .] Tools can, for example, inform and aid the planning processes by selecting and evaluating NBSs, simulating NBS implementation, calculating the costs and benefits of NBSs, supporting stakeholder involvement and facilitating collaborative processes" [6].

However, in the literature only a few papers are available that collect and review the existing tools [5,6,28]. Saikia et al. stated "an increasing demand for innovative tools and guidance to apply water resilience concept in practice" [29]. Din Dar et al. found "a major gap in performance evaluation of different BGI technologies" that they attempted to close by discussing the available modeling tools [5]. Despite their extensive review, the authors of [6] focused on how existing tools can meet the implementation/use challenges instead of assessing their capabilities and quality in detail. In addition, important academic and commercial tools are lacking, such as PALM4U and ENVI-met. Ataman and Tuncer performed a systematic review on urban interventions and participation tools [28]. They found that more studies on urban data, tool development, and stakeholder involvement are required. Frantzeskaki et al. elaborated on advances in planning, knowledge coproduction, indicators, big data, and novel financing models to mainstream NBS [4]. Thus, existing and developing tools require a classification, characterization, and review of their capabilities, e.g., with respect to the precision of simulations/forecasts and cost estimations. To face these challenges with suitable tools, an overview on the available tools as well as an assessment/review of their field of application, capabilities, technology readiness level (TRL) status, and availability is provided in this study and complements the mentioned reviews. In contrast to [6] and other reviews, this study focuses on software instead of methodologies, catalogues, repositories, e-platforms, guidelines, or handbooks, which are increasingly available. Furthermore, this review focuses not only on NBS but also on technological solutions and water and materials. In addition, we include tools developed and used outside Europe.

This study aims to answer the following research question: Which urban planning tools are spatially explicit, quantitative, and capable of supporting the multi-disciplinary urban planning fields of land use, water, materials, and urban ecosystems? Further sub-questions that arise naturally are also addressed:

- Which application areas can be distinguished, or do overlaps exist?
- Which are the primary tool capabilities that can be distinguished?
- What technology readiness levels do the tools have?
- Which tools are freely available, and which are commercially available?
- At which scale does the tool assess, operate, and plan?
- Do the tools allow for monodirectional or bidirectional communication with stakeholders?

The remainder of the study is organized as follows. First, we will elaborate on the approach and review method (Section 2). Then, we will present the developed classification and subcategories as well as the classification results (Section 3). This is followed by a review of each application area of the most relevant tools. The study closes with a discussion (Section 4) and a conclusion section (Section 5). The target group is urban planners.

2. Materials and Methods

In this study, we conducted a comprehensive search, collection, and analysis for communal resource planning, monitoring, and management tools. For this, we researched German and English literature as well as national and international online platforms. First, we searched within scientific databases (Sciencedirect and Scopus). A search with the keywords "urban management tool" and "urban resource management tool" at Sciencedirect and Scopus (within the title, abstract, and keywords) led to several thousand entries (see Table 1). However, by scanning the first pages of the search results, only a few suitable studies could be identified and added to the collection of reviewed tools. The suitability of a contribution or tool for this review was determined by whether it has a spatial and/or georeferenced database, a quantitative approach, and a model- or software-like applicability in the urban planning process. From expert interviews, we learned that these properties are seen as very helpful for urban planners to support a district assessment, a potential analysis, and political decision making.

Table 1. Search results by database and keywords (Status: 16 November 2021).

Keywords	Sciencedirect	Scopus
urban management tool	141,317	11,431
urban land use tool	66,234	2230
urban water management tool	79,426	3158
urban green management tool	48,760	789
urban materials management tool	83,452	669
urban ecology management tool	23,703	468
urban resource management tool	64,376	2674

Due to manifold contributions and analyses existing on communal energy planning (e.g., [30–39]) and transportation/mobility (e.g., [40–44]), such tools were explicitly excluded from this review. Similarly, tools with their main focus on stakeholder participation, such as those reviewed by Ataman and Tuncer [28], are not the focus of this review.

It became clear that most of the found studies (particularly in the scientific databases) host scientific concepts rather than applicable or applied models, tools, or software applications for said purposes. Thus, we supplemented the retrieved results from the scientific databases with an extensive and explorative search mode including EU, US, and other national project websites, national funding programs, reputable institutions' websites, city websites (geoportals), and other platforms. The main sources of the listed tools below were the Cities4forest toolbox, the German Federal Ministry of Education and Research (BMBF) funding programs RES:Z on "Ressourceneffiziente Stadtquartiere" (Resource efficient urban districts), and "Stadtklima im Wandel" (Urban Climate under Change) as well as their inherent research projects (e.g., [45,46]) and other national and international projects. This search was followed by a snowball system that was less controlled and more random than a structured database request from scientific databases since no review or structured overview on the available tools were available.

Then, we classified the found tools to answer the following questions: In which application areas can tools be divided? What are the major capabilities that can be distinguished? What technology readiness level do the tools have? We identified gaps and development needs in the fields of application and other identified categories relevant for urban planners (Section 3.1) and reviewed them (Sections 3.2 and 3.3).

3. Results

3.1. Classification

Based on the collected tools, we developed a classification scheme to classify the tools into different fields of application, type, availability, scale, and dimensionality (directionality). Within the categories we found different subcategories (see Table 2). Due to the broad fields and challenges of urban planning, we focused on tools addressing land use, water, urban green spaces (UGS), materials, and their nexuses, e.g., with urban climate. We classified the found tools accordingly (see Table 3). Then, we differentiated the tools' capabilities with respect to static assessment and viewers (e.g., geoportals), the dynamic monitoring and management of existing resources (e.g., dashboard), and the planning of new resources or changes/transition (area/UGS and items). Considerable other capabilities (e.g., routing) were not included in the review. Next, we classified the tools according to their technology readiness levels (TRL) as scientific concepts (TRL3), scientific codes (TRL4), standalone software or web-based or app-based tools (TRL5 to TRL7), or as qualified tools (TRL8 to TRL9). Furthermore, we identified whether the tool is available freely (open-source) or commercially or if it is unavailable for use or further development. Then, we differentiated the scale addressed by the tool. This ranged from the building scale or lower (single UGS or partial surfaces) to the city block scale, district scale that includes multiple building blocks and UGS, city scale, and whole metropolitan areas. The national scale was used for some kinds of key performance indicators or management purposes (e.g., SDG reporting), but it was outside of the scope of this study. Finally, we assessed the directionality of the tool,

which describes if a tool is providing information from one stakeholder or a stakeholder group only (one-directional) or if it allows for communication/interaction (bi-directional) between different stakeholders. For example, geo-portals could either provide administrative information to the citizens (one-directional), e.g., [13,25,47,48], or they can also ask for data or feedback from citizens (bi-directional), e.g., 3D Public Survey [49–52], DIPAS [53,54], or CITY_CODE [55,56], which could improve citizens' participation, governmental processes, and actions. We excluded simple information web tools from the subsequent review and focused on assessment, monitoring/management, and planning tools.

Table 2. Classification scheme for urban resource management tools.

Application	Capability	Technology Readiness Level (TRL)	Availability	Scale	Directionality
• Land use • UGS • Urban climate • Water • Materials	• Static assessment, viewers • Dynamic monitoring/management • Planning	• Scientific concept (TRL3) • Scientific code (TRL4) • Standalone software, app, or website (TRL5-7) • Qualified tool (TRL8-9)	• None • Open-Source • Commercial	• Building • City block • District • City	• One-directional • Bi-directional

Table 3. List of identified and reviewed tools for urban resource monitoring, planning, and/or management.

Tool (Source, Developer/Operator)	Application					Capability			Type				Availability			Scale				Dir.
	Land/surface/space use	Urban Green Space	Urban climate	Water	Materials/Waste	Assessment/Viewer	Monitoring/Management	Planning/Simulation	TRL3/4: Scientific concept/code	TRL5/7: Standalone software	TRL5/7: Web-based tool/app	TRL8/9: Qualified tool	None	Open source	Commercial use	Building	City block	District	City	One or two
namares [57,58]	x	(x)	(x)	x	x	x	x	x	x	-	x	-	x	-	-	x	x	x	x	1
PALM4U [59,60]	x	x	x	x	x	-	-	x	x	x	-	x	-	x	-	(x)	x	x	x	1
ENVI-met ** [61]	x	x	x	(x)	-	-	-	x	-	x	-	x	-	-	x	(x)	x	x	x	1
INKAS [62]	-	(x)	x	(x)	-	-	-	-	-	-	x	-	-	x	-	-	x	x	x	1
MeinGrün App [63]	-	x	-	(x)	-	x	-	-	-	-	x	-	-	x	-	-	-	-	x	1
Kommunaler Flächenrechner 2.0 [64,65]	x	-	-	-	-	x	x	x	-	-	x	?	-	x	-	-	-	-	x	1
GREEN-AREA [21]	x	x	-	-	-	x	-	x	-	x	x	-	-	-	x	x	x	x	x	1
Labs: Tree Canopy [66,67]	-	x	-	-	-	x	(x)	-	-	-	x	-	-	x	-	-	x	x	x	1
HydroWebView/ STORM [68]	x	-	-	x	-	-	x	x	-	x	-	-	-	-	x	-	?	?	?	1
WABILA-Expert [69]	-	x	x	x	(x *)	-	-	x	-	x	-	?	-	-	x	-	x	x	x	1
Storm Water Management Model [70,71]	-	-	-	x	-	-	-	x	-	x	-	?	-	x	-	-	x	x	x	1
SWMM-UrbanEVA [72]	-	x	x	x	-	-	-	x	x	-	-	-	-	x	-	-	x	x	-	1
Versickerungs-Expert [73]	-	-	-	x	-	-	-	x	-	x	-	?	-	-	x	-	x	-	-	1

Table 3. *Cont.*

Tool (Source, Developer/Operator)	Application					Capability			Type				Availability			Scale				Dir.
	Land/surface/space use	Urban Green Space	Urban climate	Water	Materials/Waste	Assessment/Viewer	Monitoring/Management	Planning/Simulation	TRL3/4: Scientific concept/code	TRL5/7: Standalone software	TRL5/7: Web-based tool/app	TRL8/9: Qualified tool	None	Open source	Commercial use	Building	City block	District	City	One or two
Planungshilfe Abfluss-Steuerung (PASST) [74]	-	-	-	x	-	-	x	x	x	-	-	?	-	x	-	-	x	x	x	1
SAmpSONS2 [75]	-	-	-	x	x	-	-	x	-	x	-	?	-	x	-	-	x	-	-	1
TransMiT WebViewer [76]	-	-	-	x	-	x	-	x	x	-	x	-	-	x	-	-	x	x	-	1
Greenscenario [77]	-	x	x	x	-	-	-	x	-	-	x	-	-	-	x	?	x	x	-	1
ECOPLAN Tools ** [78,79]	x	x	x	x	x	x	(x)	x	x	-	-	-	x	-	-	?	x	x	?	1
CityCode/ DATA4CITY [55,56]	-	-	-	-	-	x	-	-	-	-	x	-	-	-	x	-	-	-	-	2
City Water Resilience Framework (CWRF) [29]	-	-	-	x	-	x	-	x	x	-	-	-	x	-	-	-	-	-	x	1
Siedlungsflächenmonitor web GIS [11]	x	-	-	-	-	x	x	-	-	-	x	?	(x)[1]	-	-	-	-	-	x	1
Collect Earth [80]	x	x	-	-	-	x	x	-	-	x	x	-	-	x	-	-	x	x	x	1
Green Infrastructure Toolkit [81]	x	x	-	x	-	x	x	x	-	x	x	x	-	x	-	-	-	x	x	1
Urban Forest Management Plan Toolkit [82]	x	x	-	-	-	-	-	x	x	-	-	-	-	x	-	-	-	x	x	1
i-Tree Eco [83]	x	x	x	x	-	x	x	x	-	x	-	x	-	x	-	x	x	x	x	2
Healthy Trees, Healthy Cities [84]	-	x	-	-	-	x	x		-	-	x	?	x	-	-	x	x	x	x	2
Treeplotter [85]	-	x	-	-	-	x	x	x	-	-	x	?	-	-	x	x	x	x	x	2
Urban Tree Canopy Assessment [86]	x	x	-	-	-	x	x	-	x	-	-	-	x	-	-	-	-	x	x	1
Toolkit for Community Participation in Pocket Parks [87]	-	x	-	-	-	-	x	x	x	-	-	-	-	x	-	x	x	-	-	2
Community Assessment & Goal-Setting Tool [88]	-	x	-	-	-	x	-	x	x	-	x	-	-	x	-	-	-	x	x	1
SolVES [89]	x	x	-	x	-	x	-	x	-	x	-	x	-	x	-	-	-	x	x	1
Learning for Nature [90]	x	x	x	x	-	-	x	x	x	-	-	-	-	x	-	-	-	-	x	1
Aqueduct Global Flood Analyzer [91]	-	-	-	x	-	-	x	x	-	-	x	x	-	x	-	-	-	x	x	1
Green-Gray Assessment Guide [92]	-	x	-	x	-	x	-	x	x	-	-	-	-	x	-	-	-	-	x	1
WaterWorld [93]	x	-	-	x	-	-	x	x	-	-	x	?	-	x	-	-	-	-	x	1
Co$ting Nature [94]	x	x	-	-	-	-	x	x	-	-	x	?	-	x	-	-	-	-	x	2
Water Funds Toolbox [95]	x	-	-	x	-	-	x	x	x	-	-	?	-	x	-	-	-	-	x	1

Table 3. *Cont.*

Tool (Source, Developer/Operator)	Application					Capability			Type				Availability			Scale				Dir.
	Land/surface/space use	Urban Green Space	Urban climate	Water	Materials/Waste	Assessment/Viewer	Monitoring/Management	Planning/Simulation	TRL3/4: Scientific concept/code	TRL5/7: Standalone software	TRL5/7: Web-based tool/app	TRL8/9: Qualified tool	None	Open source	Commercial use	Building	City block	District	City	One or two
i-Tree Hydro Plus [96]	x	x	-	x	-	x	x	x	-	x	-	x	-	x	-	-	-	x	x	2
Biodiversity A-Z [97]	x	-	-	-	-	-	-	-	x	-	-	-	-	x	-	-	-	-	x	1
Global Forest Watch [98]	x	x	-	-	-	x	x	-	-	x	x	-	-	x	-	-	-	-	x	1
Complete Streets [99]	-	x	-	-	-	-	-	x	x	-	-	-	-	x	-	-	-	x	x	1
InVEST [100]	x	x	x	x	-	x	x	x	-	x	-	?	-	x	-	-	x	x	x	2
The Atlas [101]	x	x	x	x	x	-	x	x	x	-	-	-	-	x	-	-	x	x	x	1
ROAM [102]	x	x	-	-	-	x	-	-	x	-	-	-	x	-	-	-	-	-	x	1
Stewardship Mapping and Assessment Project (STEW-MAP) [103]	x	-	-	-	-	x	-	-	x	-	-	-	x	-	-	-	-	x	x	1
GI Valuation Tool Kit (GI-Val) [104,105]	x	x	-	-	-	x	-	-	x	x	-	-	-	x	-	(x)	x	x	x	1
Forecast reference evapotranspiration tool (FRET) [106,107]	x	-	-	x	-	-	-	x	x	x	-	?	-	x	-	-	-	x	x	1
Worksheet for Review of Municipal Codes and Ordinances [108]	x	x	-	-	-	-	x	x	x	-	-	-	-	x	-	-	-	-	x	1
Integrated Urban Metabolism Analysis Tool (IUMAT) [3,109,110]	x	-	-	-	x	x	-	x	x	-	-	-	x	-	-	x	x	x	x	1
Smart Urban Metabolism (SUM) [111]	-	-	-	-	x	x	-	-	x	-	-	-	x	-	-	x	x	x	-	1
Greenpass [112,113]	-	-	x	-	-	x	-	-	-	x	-	(x)	-	-	x	x	x	x	-	1

x: category applies; (x): category partly applies; -: category does not apply; ?: unclear/insufficient information; *: pollution; **: incl. energy aspects; [1] restricted access; Dir. = directionality.

3.2. Review of Each Field of Application

3.2.1. Land Use, Surface Use, and Urban Green Tools

Tools for planning land and surface (roofs and facades) use in urban areas are manifold. Numerous tools are available to estimate the benefits obtained from urban green spaces and/or to figure out the management needs for UGS maintenance [5]. With the substantial number of tools, there are also various themes that the tools are somewhat connected with. Monitoring is an integral part of the management of UGS, and with the focus on the benefits of green spaces to urban quality of life, aspects such as usage, experiences, and accessibility are also considered. Overlaps exist, mainly with water and urban climate tools. In the following section, the reviewed tools are described in detail.

Collect Earth [80] is a satellite image viewing tool and interpretation system developed by SERVIR Global (NASA and USAID initiative) and FAO that enables users to analyze land use/land cover (LULC) change from high and very high resolution satellite imagery

sourced from Google Earth, Bing Maps, etc. [114]. It can help identify and monitor urban green spaces and their implementation progress in an efficient manner. **Resource Watch** is another such monitoring tool. However, it is a tool that operates at a macroscopic level [115]. It features hundreds of datasets that help users visualize the state of the planet's resources and people. Using this, benefits from the implementation of urban green spaces can be estimated at a regional scale with the help of Collect Earth. Similarly, The U.S. **Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions** is also a potential resource for the monitoring of urban green spaces [116]. However, rather than directly aiding in the process of monitoring, it instead offers the advanced methodologies and the best practices to assist local governments in measuring and reporting area emissions. This tool is particularly useful to assess the effects of urban green spaces in a localized region. **Kommunaler Flächenrechner 2.0** is a national and regional tool for the depiction of current land use designation and for a top-down derivation of a communal land use budget to meet national goals [64,65]. **Siedlungsflächenmonitoring NRW** [11] is a web-GIS tool that focuses on regional and communal land use monitoring and management by depicting land reserves per use categories in the land development plan and redesigned areas. Mapping tools such as **Treetect [117]** or remote sensing products are mapping urban green spaces from satellite data, e.g., via machine learning/neuronal nets (except a few difficult cases); however, they do not yet quantify other parameters such as species type, canopy size or leaf area, which are relevant for urban climate modeling. Other monitoring tools also include **Urban Tree Canopy Assessment** [86], which can measure the extent of the tree canopy and help communities understand their total tree and forest resources and establish tree canopy goals as part of broader urban greening and sustainability initiatives.

Various tools offer similar advisory utilities, such as the **Green Infrastructure Toolkit [81]**, which highlights the common approaches taken in cities across the world to integrate green infrastructure and spaces to manage stormwater runoff, thus aiding local governments to compare and analyze the best-suited option according to their requirements. Tools can also have a more direct contribution to the planning of urban green spaces, such as the **Urban Forest Management Plan Toolkit** [82] by the Inland Urban Forest Council that outlines a structured plan for designing and implementing an urban forest management plan. Likewise, the **Urban Forestry Toolkit** also provides a step-by-step guide to planning and implementing an urban forestry project. On the other hand, tools such as **i-Tree Eco** are more user-driven in their approach. i-Tree has five core tools that are used to analyze and assess urban and rural forestry. **i-Tree Eco** is their flagship tool, and it utilizes data collected in the field from either single trees, complete inventories, or randomly located plots to quantify forest structure, environmental effects, and the value to communities [83]. **Healthy Trees, Healthy Cities** also undertakes a similar user-driven approach, as it enables users to undertake the sampling and data collection process of individual trees to create an inventory of urban trees and their health indices [84]. **Treeplotter** is another tool that creates urban tree inventories and helps in the management of urban forests but is instead dependent on GIS for data rather than on the users [85]. **Tree Canopy** [66,67] analyzes aerial data together with other public data (e.g., 3D digital surface models and socio-economic data) to map a city's tree coverage, the average land surface temperature, and population density.

The collection of data from users can be an integral part of urban green space management, and tools are not just capable of utilizing such data but can also organize community efforts. The Toolkit for Community Participation in **Pocket Parks** helps in the design, execution, and development of small-scale urban 'pocket parks' with the help of community participation [87]. The Stewardship Mapping and Assessment Project (**STEW-MAP**) by the USDA Forest Service is capable of studying how civic groups are working towards the fostering of stewardship in cities [103]. Upon the analysis of 28 criteria, **The Community Assessment and Goal-Setting Tool** [88] can assess the community for the development and management of urban green spaces. Such tools can be indispensable for administration, and tools such as SolVES are designed to aid decision makers. **Social Values for Ecosystem**

Services (SolVES) is a tool that is capable of assessing, mapping, and quantifying the perceived social values of ecosystem services, thus helping administrators to make informed decisions while implementing urban green space measures [89]. Similarly, **Learning for Nature** by the UNDP [90] connects biodiversity policymakers, change makers, and on-the-ground subject matter experts to promote biodiversity conservation and facilitate the achievement of the Sustainable Development Goals. The tool **GREEN-AREA** is a commercial service that assesses the potential of urban greening measures on building roofs and impervious soil surfaces [21,118,119]. The viewer-based service allows for georeferenced individual plot assessments of their technical potential and simplified greening impact for green roofs and unsealing ground (for examples see [22,23]).

The utility of tools for administrators in urban green spaces is not just limited to the domain of community management. **WaterWorld** and **Co$ting Nature** are two analysis tools to explore ecosystem services using spatial data as well as models of biophysical and social systems. Co$ting Nature can help cities understand the value of forests at multiple scales since users can try alternative scenarios based on different policy options [94]. For other tools of water such as **WaterWorld** [93], **Aqueduct Global Flood Analyzer** [91], the **Green-Gray Assessment Guide [92]**, the **Water Funds Toolbox [95]** or **i-Tree HydroPlus [96]**, see Section 3.2.2.

Although not directly relevant to urban green spaces, tools such as **Biodiversity A–Z** [97] can assist in the maintenance of urban green spaces. The database website provides information about regional biodiversity and biodiversity conservation. Similarly, **Global Forest Watch** [98] can analyze forests and forest trends, which can be useful in realizing appropriate conditions for maintaining urban green spaces. **Restoration Opportunities Assessment Methodology (ROAM)** can also be used as a reference for the development of urban green spaces, as it provides a framework for building a forest restoration program from the ground up [102].

Particular tools can also help in the integration of green spaces into urban settings. **Complete Streets [99]** is a global transportation design and policy approach that ensures safer, convenient, and accessible transport and fosters the introduction of trees on urban streets, thereby contributing to the growth of urban green spaces. **InVEST** (Integrated Valuation of Ecosystem Services and Tradeoffs), developed by the Stanford University National Capital Project, helps map and quantify the natural resources and services that help sustain human life and the health of the ecosystem [100]. **The Atlas** [101] is another tool that can support decision makers, as it provides an online community for local government leaders to browse case studies, follow topics, and crowdsource ideas and advice. The **Worksheet for Review of Municipal Codes and Ordinances** similarly helps to assess the environmental friendliness of policies and regulations. It seeks to provide guidance to maximize tree cover while considering public safety, visibility, access, and economic value [108].

MeinGrün App is a web-based tool available for the German cities Heidelberg and Dresden that helps citizens to find urban green spaces with particular points of interest and furnishing/equipment or that are most suitable for their leisure [63]. It includes multiple characteristics such as grass, trees, water, animals, slope, size, shade, quietness, fitness equipment, sport facilities, benches, or waste bins.

3.2.2. Water Tools

Water-related planning tools range from groundwater simulations to rainwater and dirt water runoff and treatment systems (incl. pollutant extraction), infiltration systems, evapotranspiration, and urban water inventories. Thus, it has overlaps with land use regarding the imperviousness and infiltration of surfaces, with urban green and blue-green infrastructure (BGI), local urban climate models (evapotranspiration), and with material flows.

WABILA-Expert is a water balance model to realistically depict the local water supply and inventory and to support rainwater management [69,120]. It can also compare differ-

ent alternative options of rainwater usages that are in accordance with local conditions. The **Storm Water Management Model (SWMM)** is a dynamic rainfall–runoff–subsurface runoff simulation model with extensive functionalities for single event to continuous simulation that can plan and size components and retention devices of the drainage system for flood protection in urban areas [70,71] (Further useful models from the EPA in particular on stormwater but also on watershed management, ecosystems, and green infrastructure can be found here: https://www.epa.gov/water-research/green-infrastructure-modeling-toolkit (accessed on 16 March 2022). Furthermore, it maps potential flooding areas of natural canal systems and includes pollution, controls property runoff, and evaluates best practices to reduce pollution during rains. **SWMM-UrbanEVA** is a fully integrated extension of SWMM with improved simulations for shading and evapotranspiration of urban vegetation [72]. **Versickerungs-Expert** is a tool to plan, construct, and operate systems for the infiltration of rainwater, including area infiltration; infiltration basins; trench, pipe trench, and hollow-trench infiltration; shaft infiltration; edge, pointed, and hollow channels; and the dimensioning of drainage channels. Furthermore, it can import KOSTRA rain data from Deutscher Wetterdienst (DWD). **Planungshilfe Abfluss-Steuerung (PASST)** is a rather simple checklist and evaluation table to improve and make the rainwater and dirty water runoff more flexible [74]. Flood warning system **HydroWebView** software (including rainfall–runoff modeling with STORM.Design, STORM.Sim, and STORM.Pro) is a comprehensive planning tool for the planning of sustainable rainwater management, general drainage planning, and aspects of water ecology and flood protection with a graphical user interface and GIS interface, import and export functions, and automated reporting. It provides simplified flooding evidence according to the German standard DIN 1986-100 and the preparation of water balances [68]. **SAmpSONS2** is a simulator to visualize material flows in resource-optimized sanitary systems and can consider up to eight trace elements/micropollutants as well as technologies for nutrient recovery [121]. As a result, it produces Sankey diagrams but no dynamic simulations of the sewage systems [75,121]. The **TransMiT WebViewer** shows a surface model of an urban district with a simulation of potential flooding, surface roughness, and emergency water runoff paths on the surface [76]. The **Forecast Reference Evapotranspiration Tool** (**FRET**) provides evapotranspiration forecasts at a 2.5 km grid resolution for the U.S. [106]. Based on FRET, Hamouda et al. assess forecasts for evapotranspiration to enable prospective irrigation scheduling for different microclimate regions. However, this focuses on crops rather than on urban vegetation [107]. Vystavna et al. developed a tool for urban groundwater resource management with respect to contaminants, tracing sewage leakages to groundwater [122]. The **City Water Resilience Framework (CWRF)** is a governance-based water resilience planning tool that enables cities to collectively assess and plan for strengthening urban water resilience [29]. The **Aqueduct Global Flood Analyzer** [91] assesses the current and future risks of flooding and monitors the effects of climate change. The tool can help users understand and estimate the effectiveness of UGS in mitigating floods in flood-prone cities. The **Green-Gray Assessment Guide** by the World Resources Institute [92] can be used for investigating and valuing the costs and benefits of integrating green (or natural) infrastructure into existing water supply systems to improve their performance. **WaterWorld** allows the user to test out alternative management strategies and understand how these decisions would impact the ecosystem services provided by water resources [93,123]. The **Water Funds Toolbox** helps in implementing the Water Funds model that unites public, private, and civil stakeholders for the mutual aim of water security through natural solutions and by managing watersheds in a sustainable way [95]. The **i-Tree HydroPlus** tool allows for the comparative analyses of different land cover scenarios and their hydrological impacts at various scales [96]. The **GI Valuation Tool Kit** (GI-Val) evaluates the social and environmental benefits of BGI [104,105,124].

Further tools on BGI and, in particular, on hydrological impacts (in urban areas), sewer overflow, stormwater pollution control and vegetative filters, water quality, and the estimation of surface water runoff and runoff reduction such as **VFSMOD** or **Long-Term**

Hydrologic Impact Assessment (L-THIA) for its impact on soil, land use, and long-term precipitation can be found in [5,125]. Other models and tools focus on the energy and water nexus, such as SIMGRO and SUEWS, e.g., see [126–128]. These tools are not further considered here.

3.2.3. Material/Waste Tools

The tools simulating material and waste can range from the pollution of single chemical elements (trace elements), micropollutants, and chemical compounds or gases (particles and aerosols) to larger mass flows in the air, water, and soil (eluate and waste). Furthermore, it can include construction material stocks (urban mines) and flows as well as waste stocks and flows. "Urban metabolism (UM) is fundamentally an accounting framework whose goal is to quantify the inflows, outflows, and accumulation of resources (such as materials and energy) in a city." [129] This includes the macro material/waste stocks and flows that supply a city with demanded goods (incl. energy and water) and relieves it of waste but also micro stocks/flows such as greenhouse gas emissions or pollutants (e.g., see [130]). This field has overlaps with some overarching tools that include trace elements, aerosols, and particle simulations (e.g., ENVI-met and PALM). A similar concept comprises the urban industrial symbiosis [131], which is based on material flow analysis and energy balancing. However, other aspects, such as urban land use, urban climate, or urban green spaces, are often excluded from the urban metabolism or the urban industrial symbiosis concepts as well as spatially explicit modeling. Furthermore, the data availability of urban metabolism models is an issue, so most studies focus on a limited set of resources—materials (particularly metals), energy, water, and nutrients—and a single time period [129].

Mostafavi et al. developed an **Integrated Urban Metabolism Analysis Tool (IUMAT)** [3,109,110], which provides a quantitative approach to assessing the sustainability indicators in a city. The IUMAT covers land use/cover, transportation, and energy/water/resource use as well as the inter-dependencies between them. Zhu et al. [132] analyzed how geographical information systems can support urban mining assessment. Badach et al. [133] developed a QGIS-based urban planning tool for air quality management zones, including ventilation potential and human exposure to pollution. However, the simulations use a grid size of 200m x 200m and thus have quite a low resolution and are not further considered here.

The **BRIDGE** project [134] developed a GIS-based decision support on urban metabolism to assess urban planning alternatives but empathized the need for a local focus [125,128]. Their **Smart Urban Metabolism (SUM) model** can provide real-time feedback on energy and material flows from the household to the urban district level [111]. However, none of these models seem to be readily available for urban planners and decision makers. Otero Peña et al. [24] provided a GIS-based resource efficiency analysis and urban metabolism study on the city scale of Mexico City. However, its spatial granularity is relatively low.

Further academic models on material flow accounting models include, e.g., the urban metabolism analyst (UMAn) [135], urban industrial symbiosis [131], and urban material or waste flow analysis [136–141] in respective case studies that are not necessarily spatially explicit and are not further assessed here.

3.3. Overarching Tools

PALM4U is a capable urban climate model for the simulation of urban atmospheric boundary layers and to support practical city planning related to the urban microclimate and climate change [59]. Currently, it includes seven modules of urban surfaces, chemistry, technical solutions, radiation, impact, vegetation, and soil. It has turbulence simulations, domain size definition, energy balance solvers, wall material and heat transfer models, indoor climate, radiative transfer, reflections and canopy shading, chemistry transport and reactions, roots, soil temperature and moisture, and a multi-agent system of urban residents as well as analysis tools and a GUI. The model is not limited to urban areas. However, this academic model is not easy to handle and does not work on administrative/governance

levels such as individual buildings or plots. The model is based on PALM version 5.0 and is modelled in FORTRAN code [142]. Further information (handbook, etc.) can be found in [60,142,143].

ENVI-met is a leading software in analyzing the effects of architecture and urban planning [61] in an urban microclimate model. It includes a solar analysis with long- and short-wave radiation, shading and reflections, evapotranspiration and plant water demand, the temperature of surfaces, green façades and roofs, wind flows and patterns in complex environments, comfort, and the emission and transport of particles/aerosols and NO, NO_2, and O_3 as well as biometeorological indices that can be calculated. Furthermore, plant growing conditions, wind stress, tree damage, and a simulation of their water demand are included, and built density and urban morphology can be assessed [144]. Moreover, it is coupled with a multi-criteria decision analysis for different interventions in case study districts, e.g., [145]. The commercial tool can visualize data and can be connected with Python code.

The **namares** tool is dedicated to assessing land use, water, ecosystem services, material aspects, and intervention (improvement) measures on the district level down to individual buildings and plots as well as their partial surfaces [57,58]. The tool enables technical, economic, and environmental assessments of the surface inventories and of the potential of different sustainable development interventions within a city. For example, it quantifies the actual degree of land sealing and the required area for cars and waste bins per plot. With this information, it calculates predefined resource enhancement potentials and the efficiency of improvement interventions such as the de-sealing of soil, the installation of green roofs and facades, photovoltaic (PV) and solar thermal installations, or a combination of PV and green roofs. The calculated indicators per intervention and building, plot, or partial surface are, among others, the sealing degree of the soil; the number of private trees; the ecoscore; evapotranspiration; cooling; biodiversity gain/loss; CO_2 fixation; the effects on fine dust; NO_2 (nitrogen dioxide), SO_2 (sulfur dioxide), and O_3 (ozone) levels; induced mass flows of materials; and cost (incl. investments and funding). The tool is applied to a case study in Germany but is under development and not yet available.

The simulation software **Greenscenario** is an integrated planning method for concepts of water-sensible and climate-adapted urban redevelopment that visualizes the impact of single measures quickly and comprehensibly. It allows a comparative assessment and the identification of optimization potentials [77]. However, it only includes the assessment of BGI and requires data acquisition and entry. In addition, it seems that it is not working with existing urban data (3D models) but requires prior modeling. Reference projects in larger European cities range from 1–95 ha.

The **Greenpass** [112] assessment toolbox allows a rough evaluation of the climate resilience of buildings, urban districts, and open spaces via five indicators and based on machine learning and database requests. It works with LOD 0 (2D floor plans and building height) and can be applied both to existing and new districts. Greenpass calculates the thermal exhaust air stream, thermal comfort, run-off coefficient, CO_2 fixation, and thermal storage capacity based on a simulation database powered by ENVI-met and urban standard typologies [113]. Moreover, the initiative offers a pre-certification and certification with up to 28 indicators, but it is limited to a district size of ca. 4 ha and cannot simulate the actual project situation.

ECOPLAN tools aim to fulfill different urban planning requirements and have several modules for monitoring, trade-off, participation, or simulation [78]. They follow a classical planning procedure: First, a principal decision is required with respect to a certain objective, e.g., regional development or ecological objectives. Then, alternative options, in particular on land cover, land-use change, and the integration of ecosystem services, are developed, compared, and evaluated, followed by decision making and implementation. The tools include an ecosystems services interaction database as well as a scenario evaluator as a QGIS plugin [79]. The web viewer version seems to consist of different layers but was not accessible at the time of research.

INKAS and INKAS-NRW are climate adaptation tools of DWD that provide information, district consulting services, and planning support for urban planners and citizens to develop urban climate adaptation measures and heat-adapted districts [62,146]. The tools analyze different urban fabrics and the effects of urban heat island reduction measures for each urban fabric type. Furthermore, INKAS provides information on the degree of sealing and the average building height. However, the INKAS tool is not spatially explicit but a general information tool, while INKAS-NRW (Fachinformationssystem Klimaanpassung) is a map-based geoinformation portal with climate adaptation information, e.g., on climate impact (today and expected), building densities, green roof cadasters and potentials, human health, and the soil moisture applied to North-Rhine-Westphalia (NRW), Germany [147]. However, not all intended categories are coved with data yet (e.g., drought, biodiversity, flooding, agriculture, and forestry).

CityCode assesses the "urban quality index" with urban city monitoring and hyper-local questionnaires comprising the fields of attractiveness, cleanliness, safety, service, and environment [55,56]. Furthermore, it allows for crowd geo-mapping and commenting by citizens. This is transferred to a georeferenced forum to collect, exchange, and evaluate ideas in a participative co-design process with citizens to improve city life and conditions in succeeding (construction) projects. It is implemented in a native app (IOS and Android) and City cockpit with APIs for sensors or other platforms. However, this tool does not use any climate, building, or infrastructure stock data.

4. Discussion

4.1. Communal Assessment and Information Viewer (Web) Tools

Publicly accessible communal assessment tools often comprise land use cadasters and maps showing potentials for change and interventions on both the aggregated and disaggregated levels. However, this is not a detailed city inventory on the plot level but an aggregated depiction of the situation depending on the considered aspect as well as on data protection aspects. The underlying data/information are often not publicly revealed or can be extracted for further assessment, data merging, or use. Furthermore, most tools focus on specific fields or planning aspects but lack an integrated perspective that explicitly considers the interdependencies. Thus, newer approaches propose a systems approach [1] including multipurpose cadasters, open data, and collaborative participation interfaces (e.g., [148]).

Publicly accessible communal information web tools mainly have simple features based on a static assessment. Only a few accessible communal information web tools are integrated to their full extent. Web viewers are usually specialized in showing different layers or point features. Databases often only offer full datasets that are not converted, unified, or filtered. The information in publicly accessible communal information webtools is mostly static and historic. The timeliness of the data depends on data updates; (almost) real-time data are not shown in such systems. Analysis features contain mostly point, line, or area marking functions, distance and area measuring functions, or sometimes elevation profiles and similar functions. Only a few tools comprise a participation module where stakeholders can add data or suggest recommendations for action.

4.2. Communal Monitoring and Management (Web) Tools

Among the identified and reviewed tools, we did not find any real-time monitoring tools that map and assess the existing building and infrastructure stock with respect to its current resource use over a longer time period. The available static information on this is distributed in different GIS layers (solar, green roof, or tree cadasters) or other datasets (waste generation/collection, ground surface permeability, rainwater harvest, and runoff). Sensors are available that measure urban climate or traffic emissions in a higher or lower resolution depending on the sensor grid. However, these are often only installed at scarce locations and in neuralgic points, not covering whole city districts or cities, and their sensor information is not yet merged into a digital urban twin allowing for integrated

modeling, planning, and decision-making support. Furthermore, a finer spatio-temporal resolution is recommended by [149] for monitoring energy and water flows in order to develop interventions to optimize resource flows.

Management approaches are restricted to tools that can compare different invention designs, investments, or decision-making options. Some include multi-criteria decision approaches. However, we did not find integrated management tools, e.g., that support the operationalization of city strategies (e.g., climate neutrality or resilience goals); the derivation of road maps, action plans, or concrete interventions; or supportive functions for an integrated project or intervention management (e.g., joint data management, contact data, collaboration support for city departments, reminders, and success indicators).

4.3. Communal Planning and Simulation (Web) Tools

Tools for land use, urban green spaces, water management, and flooding protection are extensive and available, including detailed planning. Newer tools include ecosystems and ecosystem services, but they are not covered extensively by any of the reviewed applications. Moreover, a few integrated or multi-purpose planning approaches or designs of multifunctional surfaces (e.g., [150]) are mentioned but not yet broadly supported by commercial digital planning tools.

The reviewed assessment, planning, and simulation tools focus on ground surfaces and roofs where spatial information can be captured easily from aerial or satellite data. Surfaces on facades are rarely considered in the reviewed tools. Only ENVI-met, namares, and PALM4U are considering building facades in their models. Simulation tools such as ENVI-met or PALM4U use simplified urban 3D models instead of actual and detailed urban 3D models (LOD3). The optimization of the interplay of the different application areas and fields of view are only rudimentarily recognizable in simulations by PALM4U, ENVI-met, namares, and GreenScenario, for example, via an intervention design or scenario comparison. However, according to the available information, GreenScenario seems to be a conceptual vision and not fit for action (in operation).

The existing planning and simulation tools mostly operate on a city block scale and not yet on the surface and plot scales (except for namares). However, only the latter detailed planning level allows for an actual plot- and stakeholder-specific information that can support decision making and change easier than voxel-wise or block-wise simulations and assessments.

4.4. Identified Research and Tool Development Gaps

The reviewed tools largely cover the fields of urban land use and water management as well as integrated urban climate modeling, while the fields of materials and material flows from buildings, infrastructures, and municipal, commercial, or industrial waste are underrepresented. Furthermore, the investigated tools mostly use official data (e.g., georeferenced data and statistics) or citizen information (open source, sentiments, and proposals) instead of sensor data (e.g., from smartphones, meters, or air, temperature, or weather sensors). Sensor data on urban climate are few since integrated and broad sensor networks are in installation in urban areas to provide information for smart city models. Moreover, tools mostly operate on the city (block) scale and not yet on the partial surfaces, building, and plot scales. However, only the latter detailed planning level allows for actual decision support in urban development processes.

Furthermore, our research experiences indicate that data from different city departments are often not shared or merged to enable the generation of data pools, digital twins, or other smart city models. It remains unclear why this is the case—a lack of staff, expertise, or willingness.

Public urban green space is often registered and inventoried, and its data are publicly available (e.g., tree inventories), while private urban green space is rarely mapped even though it constitutes a large share of urban green space in dense inner-city districts, e.g., ca. 50% in [151]. Additionally, the evapotranspiration of (street) trees should be integrated with

their water demand and their potential cooling during the hot and dry seasons in existing models. In addition, a discussion on economic assessment or the appropriate monetization of urban ecosystem services is lacking, which could be included in a monitoring, planning, and decision support system that also covers the economic perspective.

Moreover, integrated and spatially explicit inventory assessment tools of urban districts are lacking that comprise more than a few indicators, that include the assessment of the economic impacts and social perspectives of interventions and improvement measures, have a multi-criteria decision support approach, include project/intervention management support, and use actual building stock data instead of urban fabrics or urban standard types. Moreover, optimization approaches to the interplay of the different application areas and fields of view are lacking. In addition, a joint database, for example, in a city information model or digital twin (see, e.g., [152]) and a joint modeling environment or interfaces between the sectoral tools, particularly from water, land use, climate, and ecosystems are required to combine the existing data and tools in an adequate and efficient way. Furthermore, many planning tools are available, but (real-time) monitoring or management tools that can quickly identify, organize, and realize maintenance and improvement projects are rare. Moreover, objective comparisons of the available tools' capabilities are missing with respect to spatial and temporal resolution, simulation precision, and uncertainty, e.g., on the same open dataset or case study.

Moreover, dynamic modeling and monitoring or assessments over several time periods should be considered to actually reflect and measure a system change and urban transformation, e.g., the impacts of urban interventions/improvement measures.

Furthermore, an overarching general framework of the calculated indicators or at least a minimum collection of "must-have" indicators (as an overview) provided by existing web-based tools and assessment methods is missing. Instead, every tool and every community are using their own data structure, data formats, and indicators, hampering standardization and comparison. Recently, respective typologies of indicators were published [153,154], and a standard (DIN SPEC 91468 [155]) is under development. However, these indicator catalogues or guidelines are not harmonized, scientifically published, or internationally agreed on.

4.5. Limitations

Although our study showed numerous results, it was also restricted. The limitations of our study were the exclusion of energy or mobility tools and tools focusing on citizen participation as well as models and tools covering other/neighboring fields, such as air emissions and clean air strategies/interventions, chemical distribution and monitoring, detailed urban climate modeling, and biodiversity monitoring (incl. faunistic aspects). Furthermore, tools and models used on a national level could have been included but were seen as outside of the scope of this study since the focus lay on urban districts. In addition, due to the investigative and explorative character of this review using the snowball method, the list of reviewed tools is not exhaustive (e.g., see [6]). Some tools might have been missed and were not covered in this study. Furthermore, the classification of tools could have been conducted differently, e.g., thematically through the target user group or the input data requirements.

In addition, urban datasets are structured in different ways. In Germany, a standard is under way (see introduction), but other countries might have different geospatial data structures, data protection and ownership rights, statistics, etc., which might influence the usability of the reviewed tools.

Despite the data management and assessment of buildings, districts, and cities being a useful decision support, urban data collection is effortful. In the case of biodiversity and habitat data, however, this will be often required since comprehensive data, particularly on private areas, are often not available. Furthermore, we learned that urban data are underused due to capacity challenges, data ownership issues, and privacy concerns within city administration [27].

5. Conclusions

Our work summarizes the status quo and research gaps in communal urban tools for assessment and information viewers, monitoring, and management as well as planning and simulation. We identified and reviewed 51 tools and classified their fields of application, their capabilities, their types and TRL levels, their availability for users, the scales they cover, and their directionality.

The remaining open challenges include (1) the localization of SDG fulfilment efforts in the form of concrete interventions, e.g., by using a data-based approach that facilitates localization [27]. For this, near-real-time information would be required to actually design the interventions appropriately and to allow the planning based on this information and the monitoring of the interventions to also be close to real-time. (2) Furthermore, data acquisition, updating, and validation approaches are associated with a high level of effort. Thus, efficient acquisition and updating methods need to be developed for the urban data that are required and used by (academic) urban tools but are not yet available or updated in all communities and cities. In addition, data sharing within city departments or with other authorities (e.g., from the region or federal state) and automated image or data processing could help to support this. (3) Methods and tools to facilitate data management and the maintenance of official urban data are required, e.g., via automation, which could relieve administrative staff so that they would have more capacities for project and intervention management, stakeholder communication, or participation processes. (4) To deal with data-based approaches, the enhancement of equipment, interdisciplinary skills, and involvement in localities/communities and their planning departments is required. In addition, a clarification of privacy issues and data ownership (e.g., between city departments) would be helpful to remove doubts. (5) More collaboration between science and practice would help to co-develop tools that address the problems and challenges of urban planners. This would lead to higher usability and practicability in urban planning and urban transformation processes, particularly with intersectoral functionality, project/intervention management support, and stakeholder participation. This should also include tool development from current static or single-period assessments to more dynamic and near-real-time dashboards/assessments and from aggregated input–output models or stock and flow models to spatially, explicitly, and highly resolved models on real urban data (see also [128]).

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