Article

Tools for edible cities: A review of tools for planning and assessing edible nature-based solutions

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Abstract:

In the last five years, European research and innovation programmes have prioritised the development of online catalogues and tools (handbooks, models, etc.) to facilitate the implementation and monitoring of Nature Based Solutions (NBS). However, only a few catalogues and toolkits within European programmes are directly related to mainstreaming of NBS for food production (i.e., edible NBS). Therefore, the main aim of this paper is to present existing NBS tools through the eyes of productive urban landscapes. We reviewed 32 projects related to NBS and 50 tools were identified and characterised. Then, the 6 tools already available, and providing indicators, were further analysed in terms of their format and knowledge domains. Our main conclusion demonstrates that there is a lack of tools capable of supporting users for planning and implementing edible NBS, calculating the food potential of the city and/or of individual edible NBS, including the needed resources for implementation and operation (water, nutrients, energy), and assessing their urban design value, environmental and socio-economic impacts. And when they do exist, there is a resistance to share the models and equations behind the tools to allow other projects to reuse or validate them, fact which is contrary to Open Science principles stood up by many research public agencies.

Keywords: nature-based solutions; productive urban landscapes, decision support systems; edible cities; urban agriculture; circular economy

1. Introduction

By 2050, 68% of the global population is projected to live in cities [1], highlighting the relevance of urban ecosystem services to support not only the quality of liveable urban spaces, but also local food provision and resilient urban food systems [2]. Therefore, several "environmentally friendly" concepts have emerged to address the side-effects of high urban population densities, especially regarding increased resource consumption and environmental degradation. Consequently, cities are starting to evolve their infrastructures to work in line with the preservation and increment of urban natural capital. At urban planning scale, key examples of such concepts are green infrastructure [3–5] and multifunctional landscapes [6,7]. These concepts have been put forward by different disciplines, such as planning, landscape architecture, ecology, biology, forestry, transportation and, due to their novelty, their definitions are still evolving [8]. However, neither of these green concepts explicitly mentions urban food production or other aspects of the urban food system [9].

In parallel with the above, several urban design approaches have emerged to articulate how urban food systems, and especially food production, can contribute to green infrastructure or multifunctional landscapes, e.g.: *Continuous Productive Urban Landscapes* [10], *Sitopia* [11], *Agrarian Urbanism* [12] and *Food Urbanism* [13]. These concepts and approaches include diverse urban agriculture typologies and food system activities as widely documented, for example in [14–18]. Spatial typologies, also known as edible green infrastructure [17], include allotments, urban farms, community gardens, school gardens, domestic gardens, edible urban forests, rooftop farms and vegetable raingardens, edible green walls and façades[17], whereas growing typologies include hydroponic and aquaponic systems, open and covered rooftop farms and soil-based food growing. As an urban design typology these interventions are referred to as productive urban landscapes.

All these concepts and approaches also qualify as nature-based solutions (NBS) which conceptualise technological/spatial units and interventions [19], landscapes and actions as *'solutions inspired and supported by nature'* [20]. To highlight the necessity of engaging with the urban food question and to better distinguish different NBS, we propose the term *'edible NBS (eNBS)'* when referring to NBS that have the purpose of food production. Like NBS, eNBS have great potential to provide a series of co-benefits (e.g., wellbeing and biodiversity) enhancing the natural capital and management of urban resources but with a focus on the food system. This concerns mainly water, nutrients, and energy and can contribute to a more circular urban metabolism and circular economy principles [21].

In the last five years, European research and innovation programmes have prioritised the development of online catalogues and tools (handbooks, models, etc.) for NBS, mainly due to the demand of public, private and research organisations concerned with the existing gap of knowledge and successful case studies regarding the planning, implementation, and monitoring of NBS for the development of more sustainable and resilient cities. The tools are now so numerous that even a catalogue of tools was developed to assist users in selecting the most appropriate one for their needs. This catalogue, developed in the project ACTonNBS - Adaptive Cities Through Nature Based Solutions, includes around 70 tools to take up NBS and enhance climate resilience in cities. Even though urban food production is beginning to be recognised as an important component of sustainable urban ecosystems, most of the current available tools on NBS support the design, implementation and monitoring of NBS in general, with no special focus on the edible potential of a number of these solutions. Only a few catalogues and tools within European programmes are directly related to mainstreaming eNBS. Such resources are still mainly found in connection with individual projects by urban agriculture practitioners, such as Farming Concrete in New York (https://farmingconcrete.org/), and/or are linked to individual cities. Moreover, there are several indicator frameworks to assess urban water management (e.g., the City Blueprints) or city sustainability (e.g., Green City), where NBS impacts are directly included (e.g., via percentage of green spaces). However, edible facets are not explicitly included in these frameworks, although they would have a direct impact on some of their indicators.

Therefore, the main aim of this paper is to present existing NBS/eNBS tools through the eyes of productive urban landscapes. To the best of our knowledge, so far, no publication reviews the existing tools to support the implementation of eNBS as well as its features, content, and facets. In this sense, we reviewed 50 identified tools in 32 different research and development projects financed by national or international organisations such as NGOs, governmental organisations, and European Commission, with three main purposes: (1) to identify and classify operational tools with potential to support eNBS implementation beyond the project scale; (2) to know to what extent those tools could be (maybe partially) adapted or reused by other projects; and (3) to identify the gaps in

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existing tools and then the needs for developing new tools for eNBS with a holistic focus from planning to implementing and monitoring. Additionally, we analysed which indicators have already been used for such purposes and selected a set of indicators that most holistically assess the eNBS. In addition, all underlying data is provided as supplementary material.

2. Conceptualization

To facilitate a better understanding of our study, in this section we briefly explain the terms Tools (section 2.1) and Indicators (section 2.2), both applied under the framework of planning, design, implementation and monitoring of eNBS, as environmental measures to address urban challenges.

2.1. What do we mean by tools?

In environmental sciences, there are different understandings and classifications of tools and no unique definition. Moreover, the complexity level, structure and purpose of the tools can vary greatly. For example, more complex tools are based on analytical methods (e.g. LCA), indicators and/or mathematical models (in a form of mathematical equations) to design, plan and/or evaluate a specific socio-economic and environmental performance (e.g., Parcels: http://www.parcel-app.org). In contrast, less complex tools can be based on informative approaches such as web-based catalogues of information (e.g., NBS knowledge hub: https://platform.think-nature.eu/nbs-projects) which can offer search options (e.g., Naturvation Atlas: https://naturvation.eu/atlas; EdiCitNet Toolbox: https://toolbox.edicitnet.com). Nevertheless, all types of tools, regardless their level of complexity, are usually designed as ICT-based clusters of information or software applications that help in decision making, planning, design or evaluation of socio-economic and environmental impact.

In this paper we divided the tools dealing with NBS into two major groups: (1) **information-based tools** that include different textual, visual and/or graphical data, and in most cases also search options, and (2) **model-based tools** that include one or more mathematical models to calculate specific outputs. Therefore, a tool in this context provides users with information and/or quantitative assessments based on provided input data. These assessments are related to food production/activities, impacts (environmental, urban design, social, economic) and/or estimation of relevant indicators for sustainable resources management in cities.

2.2 What do we understand as indicators?

According to OECD [23], an indicator is a parameter, or a value derived from other parameters, which provides information about the state of a specific system. The impacts of a particular environmental measure (e.g., eNBS) can be assessed quantitatively and/or qualitatively by adopting key performance indicators (KPIs), a set of parameters providing the means to assess particular attributes to meet an explicit objective. In this regard, the performance of an eNBS can be defined as the degree to which the eNBS addresses urban challenges (e.g., climate resilience or social justice) and/or fulfils a specified objective in a specific context. The KPIs can be, for example, biophysical, social, or economic indicators which are targeted for specific aspects of the eNBS's effectiveness. In addition, a new generation of indicators is emerging which are also looking at institutional and governance aspects [24].

If several KPIs are applied, we refer to indicator frameworks (also termed indicator sets, or systems), which can be used for monitoring and providing feedbacks needed to accomplish the desirable state of urban sustainability [25]. Moreover, indicator frameworks can be used to evaluate the impact of specific measures at city scale. Some examples are: City Blueprints [26], EEA Urban Metabolism Framework [27] and European Green City Index [28], which are able to compare performance between similar cities [29].

3. Materials and Methods

The reviewed projects were selected using the NBS projects database elaborated under the scope of Cost Action Circular Cities (CA17133) [22], which was extended to other projects related specifically to eNBS identified by the partners of the EdiCitNet project (EU H2020 project GA 776665). Two criteria were used for this selection: (1) projects offering tools focused on urban farming; and (2) projects offering tools focusing on NBS but potentially enabling urban farming. The tools provided or used by each project were identified by browsing project websites and reading related publications. The database of analysed projects and related tools is provided in the appendix 1.

In the following sections, we describe characterization of identified tools (information- and model-based) according to five main characteristics (section 3.1), systematic selection of tools based on their accessibility, operability and availability of data and calculation methods (section 3.2), and description of parameters used for further analysis of finally selected tools (model-based) (section 3.3).

3.1. Characterization of tools

To characterise different tools, we applied an end user-centred approach, by imagining the scenarios under which users with different backgrounds and aims (e.g., urban planners, scientists, civic society, community led organizations) might wish to access the content and format, most appropriate to their needs. For example, an agronomist seeking specific crop yield data would require production metrics (e.g., quantitative data), whereas a community led organisation may find a narrative description about the production more useful. In this regard, we departed from Katsou et al [22] and formulated five main characteristics of the identified tools:

1. **Typology of the tool:** *Information-based tools* which organize and display information, by providing visual and consultative outputs such as catalogues or handbooks. *or model-based tools* which provide quantitative estimations of performance and impacts expressed as indicators, models or equations (e.g., estimating yield or water needs).
2. **Geographical level of policy or regulation**: *Local or regional*, *national*, *European* or *international*.
3. **Phases of the eNBS full cycle implementation assessed by the tool**: *Planning & Design* (e.g., estimating needed resources or aiding design), *operation* & monitoring (e.g., data collection, operational and maintenance tasks such as harvesting or events), *assessment* (impact, performance indicators) and *communication* (e.g., aiding in the dissemination of eNBS).
4. **Sustainability dimensions addressed:** *Social* (addressing aspects related to wellbeing and equity, social cohesion, cultural values), *economic* (dealing with aspect related to jobs creation or businesses potential) or *environmental* (addressing environmental aspects such as carbon sequestration, air quality, water management or biodiversity).
5. **Type of provided support or stakeholders' engagement**: *Inform* (one-way communication from project to citizens, e.g., handbook), *consult* (two-way communication where stakeholders can provide their opinions, e.g., survey), *involve* (stakeholders are passively engaged in the project, e.g., focus groups), *collaborate* (stakeholders are actively engaged in the project, e.g., collecting data) or *train* (the tool is used to enable skills and capabilities).

The tools were characterised using publicly available information, tools testing, when possible, and direct contacts with tool developers (email exchanges and virtual meetings), when necessary.

3.2. Systematic selection of tools

From the tools identified in the reviewed projects, we selected a reduced number of tools according to the following criteria:

- **Accessibility:** the tools can be used by the general public (through open access or by using a license).
- **Fully operational:** the tools are finished and fully working.

In order to analyse to what extent the tools could be reused, the data was further analysed considering inputs (data provided by users or external databases used) and outputs (indicators or variables computed by the tool) as well as potential geographical constraints for reuse of the tool (e.g., use of external datasets existing only in some countries).

Then, for further analysis, we selected only the tools that were model-based in order to extract the indicators that those were providing. Therefore, the main outcome was one or several indicators calculated based on the input data. A graphical representation of the method applied to characterize and select the tools for further analysis can be seen in Figure 1.

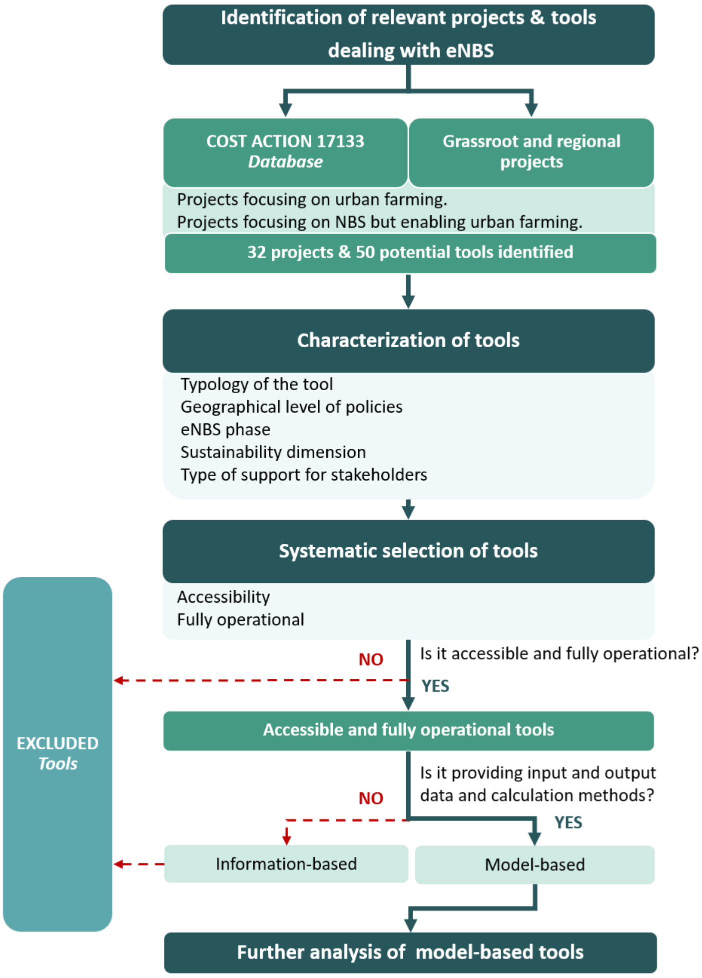

Figure 1. Graphical representation of the method applied to select, characterise and analyse the tools.

3.3. Further analysis on model-based tools

In undertaking this review and analysis we were conscious of the different end users likely to use the tools, primarily from the environmental sciences regarding quantifying impacts or from the design disciplines regarding how eNBS and productive urban landscapes can be implemented. The different cognitive approaches of scientific and design disciplines [30,31] whereby scientists often start from a problem analysis perspective, often quantifiable, and designers start from a solution-oriented approach informed the way we analysed exiting tools, seeking to evaluate them in relation to the kinds of content different users would find useful. This led to a matrix of categories generated through an iterative process of deep analysis from which we defined knowledge domains and format domains that address analytical approaches (e.g., metrics and systems) and solution approaches (e.g., design and policy). In doing this we acknowledge the fuzzy nature of this categorisation, an objective being to encourage the breaking down of artificial disciplinary

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boundaries. The first axis of the matrix represented the type of knowledge sought (knowledge domains) and the second axis represented the format within which the knowledge was made available (format domains). This provided 7 categories for Knowledge Domains and 9 categories for Format Domains, resulting in a 63-cell table, each cell representing a particular knowledge type and format for that knowledge (table 1).

By the nature of the subject, this categorisation is somewhat fuzzy but convenient in providing an overview of the domains in which the tools are useful. It is to be understood in relation to a user wanting to find out more about the eNBS.

 doi:10.20944/preprints202105.0747.v1

Table 1. Description of matrix categories used to classify the analysed tools.

	Domain	Topics
KNOWLEDGE DOMAINS	**Environment**	Tools covering the conceptual role of eNBS in terms of enhancing environmental sustainability, e.g., preserving and enhancing biodiversity, promoting a sustainable drainage, or reducing diffuse pollution.
	Social	Tools that relate to demographic aspects, groups or personal relationships and number of jobs created to a certain type of eNBS.
	Economic	Tools dealing with economic values of eNBS and economic mechanisms (nonprofitable, business focused).
	Systems	Tools providing insights about interrelations between urban metabolism, circular systems and eNBS.
	Policy	Tools providing examples and guidance in terms of urban planning and wellbeing policies relayed to implementation and functioning of eNBS.
	Production	Tools providing information on production and processing of edible goods in eNBS.
	Spatial	Tools dealing with information regarding size, arrangements, sites and locations of eNBS.
FORMAT DOMAINS	**Typology**	Tools proposing a classification for eNBS in terms of users' motivations, used technologies, urban design approaches, etc.
	Design	Tools showcasing case studies of landscape, architectural and urban design processes of eNBS.
	Social media	Tools including an informal space for user interaction and knowledge exchange, such as blogs or forums.
	Guidance	Tools providing step by step guides in terms of, for example, gaining finance or improving yields.
	Metrics	Tools providing numeric evidence (raw data or indicators) in terms of, for example, biodiversity, number of users or yield.
	Narrative	Tools providing a narrative evidence of eNBS (e.g., fact-sheets, case studies) in terms of, for example, biodiversity, number of users or yield.
	Impact	Tools providing an impact assessment (qualitative or quantitative) of eNBS in terms of environmental and socio-economic effects and benefits.
	Bottom-up	Tools that include processes led by individuals or community groups.
	Top-down	Tools that include processes led by institutions, municipalities, governments, etc.

4. Results

The following sections present the characterization of the 50 identified tools, describe the systematic selection of tools and provide details on the further analysis carried out for the model-based tools.

4.1 Characterization of tools

Most of the 50 tools reviewed are aiming to support decision making process with interactive software applications or guidance documents either in the informative way, providing guidance toolkits or case studies, sometimes supported by interactive catalogues enabling geographical or keyword search (33 tools), or via mathematical models (e.g., for calculation of indicators), falling under the model-based category (17 tools).

The information-based tools include a wide range of knowledge, e.g., data and indicators, which are usually provided in textual documents (reports or case studies) and thus more difficult to exploit than when resulting from model-based tools.

The majority of tools consider the importance of policy and regulation for the deployment of eNBS (84%) by providing qualitative recommendations (e.g., to improve participation and governance) or impact indicators relevant for policy (e.g., Urban Foodprint). The recommendations are mainly referring to local or regional level (60%) indicating the importance of policies directly connected to the implementation of eNBS (Figure 2).

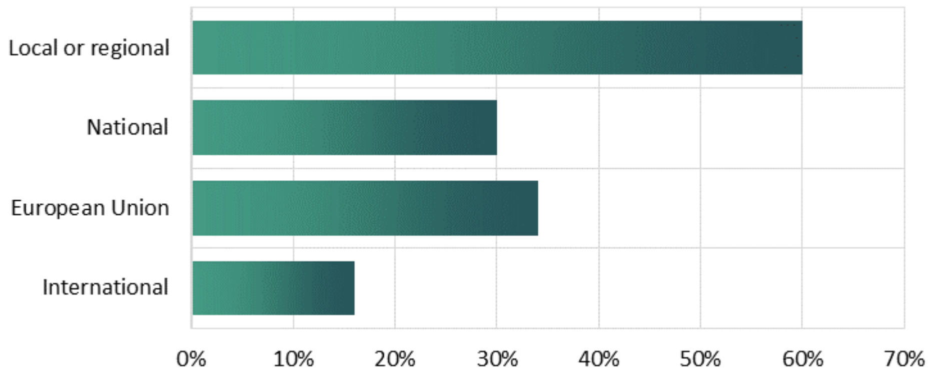

Figure 2. Level of policies addressed.

The reviewed tools are providing support for different phases of eNBS implementation, from *planning & design, operation*, to the assessment as well as communication (Figure 3). Very few are supporting all the phases (16%). In general, evaluated tools are more oriented to planning/design and communication than to operation/monitoring and assessment.

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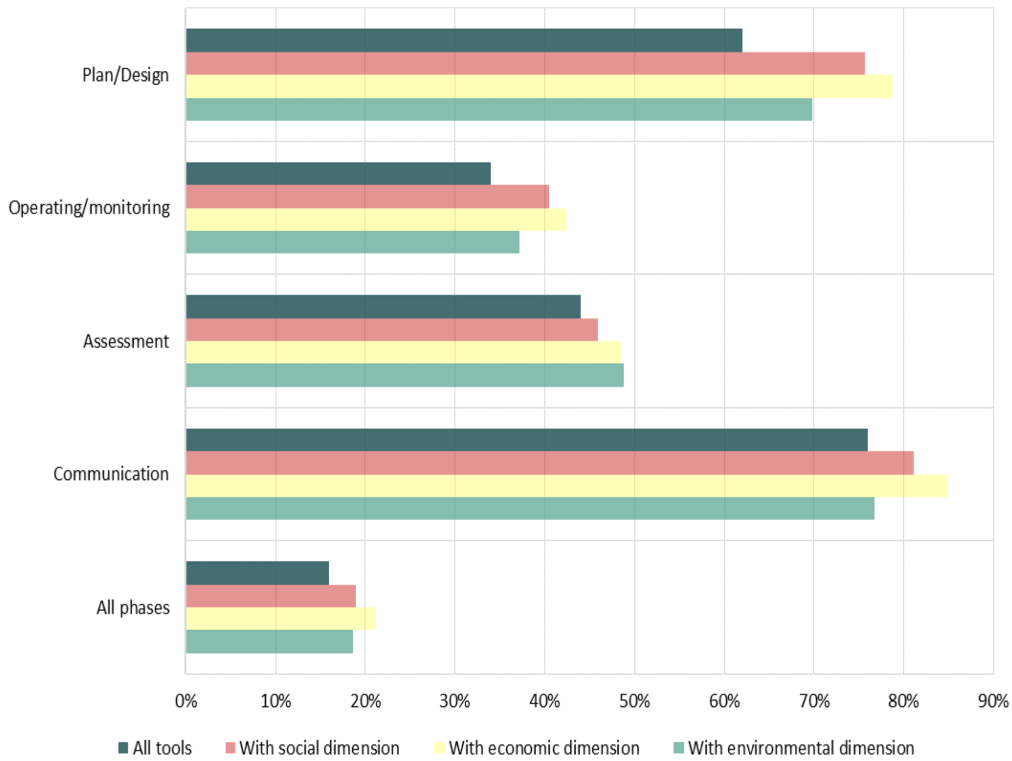

Figure 3. Phases of eNBS implementation addressed by the tools.

Sixty-two percent of the tools deal with all three sustainability dimensions (Figure 4). However, the reviewed tools mostly address the environmental dimension of sustainability (86%). Moreover, even though social issues are the main concern of local governments when developing urban agriculture initiatives [32], this is less reflected in the support offered by the tools reviewed (74% vs 86% on environmental issues). Likewise, although urban food production can improve economic sustainability of a city [33], the economic dimension is least represented among the studied tools (66%).

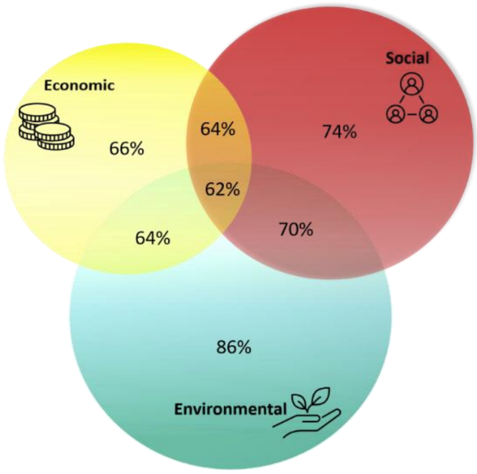

Figure 4. Sustainability dimensions covered by the tools.

Looking at the type of support the tools provide in terms of stakeholders' involvement (Figure 5), it appears that most of the tools are supporting a one-way communication (information diffusion), while 13% of the tools provide no support for engagement. The majority of the tools addressing social issues are providing support for community engagement. Tools with social and economic dimension (yellow and red bars in Figure 5) are more oriented to stakeholder involvement compared to tools with emphasised environmental dimension (turquoise bars in Figure 5).

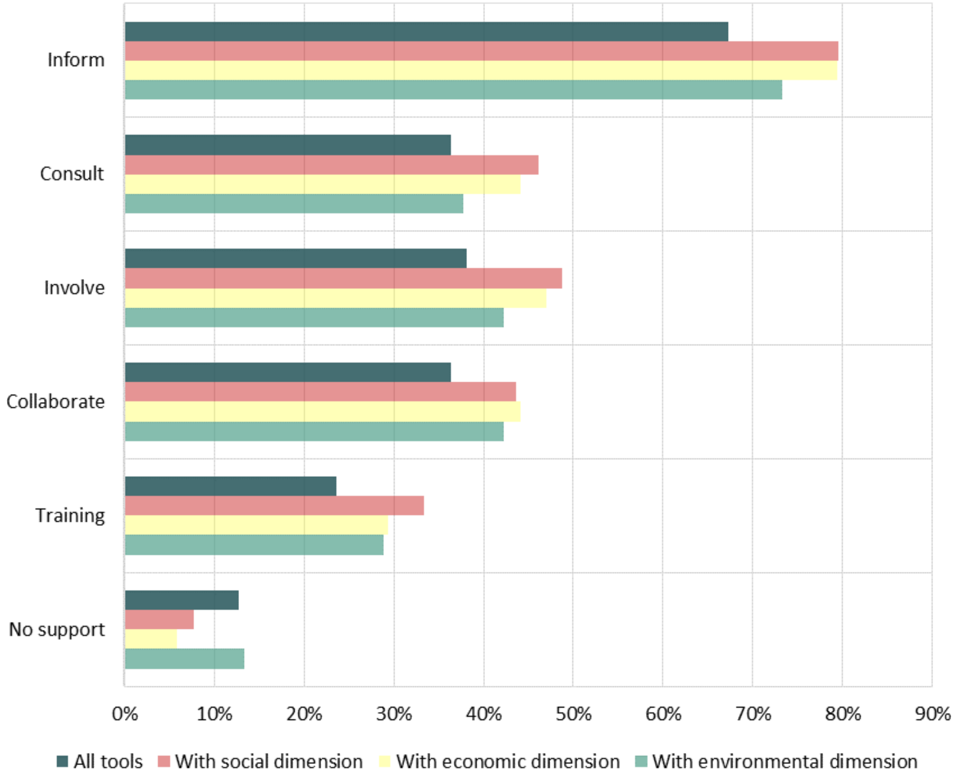

Figure 5. Stakeholder's level of involvement provided by the tools.

4.2. Systematic selection of tools

Out of 50 tools, 29 accessible and fully operational tools were shortlisted. A good indication of rising importance of tools to support implementation of eNBS is that most of model-based tools (66.6%) and information-based tools (69.5%) are focused in eNBS (Figure 6) and not on general NBS that potentially can enable sustainable urban farming. Among these 29 tools, only six of them (approx. 20% of total tools) are model-based tools (Figure 6), mainly focusing on very specific components (e.g., crops or geothermal energy for food production or farm management) rather than providing a more holistic support to urban planners. The remaining 23 tools are information-based tools such as catalogues (case studies, projects, business models), guidelines, interactive forums, or networks (e.g., Red de Ciudades por la Agroecología). The level of interaction is variable, from classical bookshelves consultation to multicriteria search (e.g., topics, location, type of stakeholder). This type of tool is very useful to gain knowledge (e.g., for defining indicators) and learn about know-how, but the lack of unified approach in the analytical method used may create confusion and difficulties in comparing the results obtained. In addition, searching for relevant information can be time consuming and can represent an important barrier for practitioners, in particular when searching for food related information within the NBS tools.

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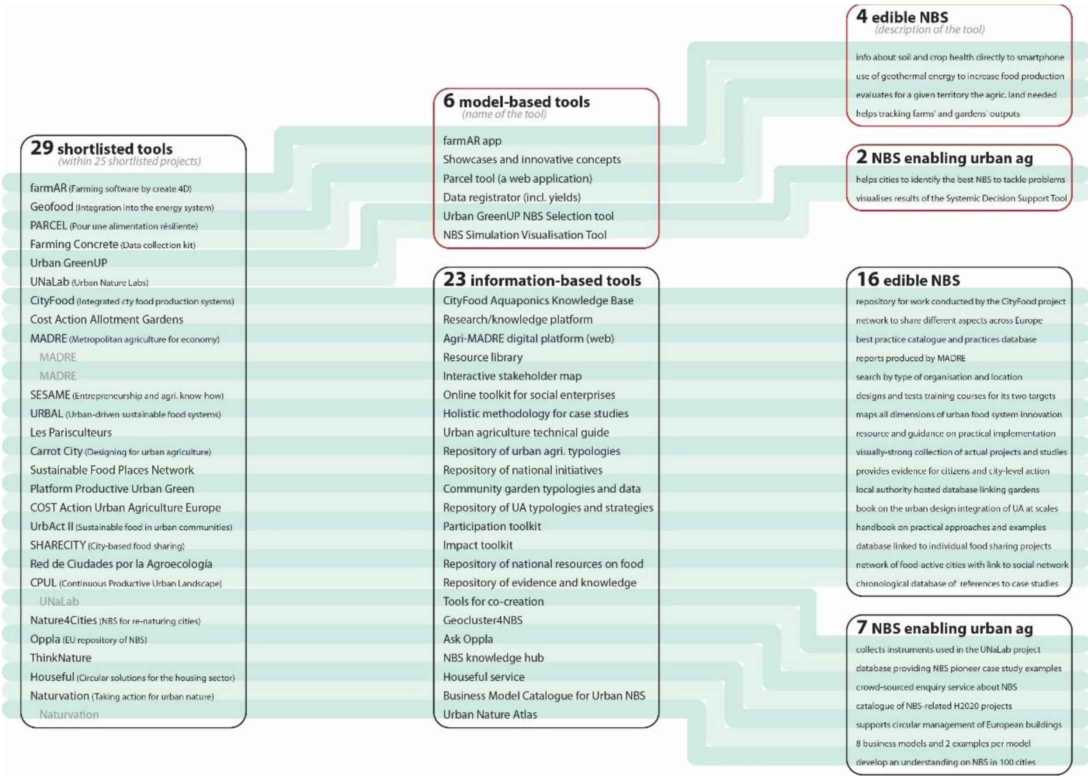

Figure 6. The 29 shortlisted tools supporting model-based and information-based decision processes for implementation of eNBS and NBS enabling urban agriculture.

The screening of data and indicators used by the 29 accessible tools resulted in 4 main types of data (underlying data is provided in Appendix 2):

- Input data provided by the end-user to specify its needs, such as geographical location (e.g., city or region), boundaries of the area, (e.g. digital map layer), urban challenge to be addressed, and local population.
- Monitoring data: e.g., honeybee activity, "Lnight" and "Lden" for environmental noise[1], electrical conductivity, pH, or water infiltration rate.
- External data sources, such as meteorological data from public stations or satellite imagery.
- Calculated impact indicators, e.g., life cycle assessment/analysis, economic evaluation of the eNBS, urban food production, urban food demand, space availability, carbon footprint, jobs created (full time equivalent), inflow of mass and energy, estimated limit of sustainable energy production and total energy in the reservoir, crop yield indicator, spatial footprint indicator, and cultivated area. The method used by the tools for calculating the impact indicators is usually not provided, except for grassroot tools such as Farming Concrete allowing local communities to make rough estimates.

4.3 *Further analysis of model-based tools*

A short description of six model-based tools selected for further analysis can be seen bellow:

- **FarmAR app:** A smartphone application that provides information about soil and crops health by using remote sensing product databases.
- **Farming Concrete:** A web-based toolkit calculating indicators based on data provided by more than 400 community gardens. Moreover, the toolkit offers a total of 18 very practical data collection methods to support local communities in monitoring their eNBS. Collected data are organized into five categories:

1 Indicators defined by EU Environmental Noise Directive (END): for the day, evening and night periods (Lden) and for night periods (Lnight)

food production data, environmental data, social data, health data and economic data.

- **GeoFood**: This tool provides innovative concepts illustrating how to increase the economic viability of joining geothermal heat infrastructure and circular food production systems for aquaculture.
- **UrbanGreenUP**: NBS Selection tool (**UGU NBS**) is recommending NBS for a selected city, based on specified challenges and the capabilities of a particular organisation; It helps cities to select the most appropriate NBS to tackle identified environmental problems and to become more resilient to climate change.
- **UNaLab:** NBS Simulation and Visualization Tool (**UNL – NBS-SVT**) can be used to visualise the results of a decision support tool based on a geodatabase. Different scenarios can be simulated and visualized, i.e., a reference scenario, nature-based scenarios, population growth scenarios, climate change scenarios and combined scenarios. Additionally, results can be provided for different time periods.
- **Parcels**: For the selected area and number of inhabitants, this tool calculates the agricultural land needed to achieve food self-sufficiency. Moreover, it provides information on the agricultural jobs potentially created and the ecological impacts (e.g., greenhouse gas emissions, pollution of water resources, and effects on biodiversity) associated with possible changes in food production methods and/or in dietary habits.

The six model-based tools are fully described in Appendix 2 with the list of data they are using and providing. Four tools (Parcels, UNaLab, UrbanGreenUp and GeoFood) are ex-ante tools supporting planning and design by for example allowing estimations of the requirements for moving towards food self-sufficiency (Parcels' tool), while two tools (Framing Concrete and FarmAR app) can support local practitioners in the daily management of their eNBS by for example providing low tech methods for collecting data and an online repository to store and aggregate crop yield data (Farming Concrete).

Looking at the metrics provided, the selected tools are mainly focusing on spatial (e.g., area cultivated), production (e.g. yield) and environment (e.g., water abstraction), rather than on social, policy and economic knowledge domains (Figure 7). In contrast, the three tools falling under the narrative format domain (i.e., UNaLab, UrbanGreenUp and Parcels) are mainly devoted to policy topics. The Parcels tool is covering the largest amount of knowledge domains in different formats while other tools are narrower in their delivery of knowledge items (e.g., UNaLab). On the opposite, GeoFood tool has a narrow knowledge focus, supporting the design phase of aquaculture. For a specific knowledge domain, the tools follow either a bottom-up or top-down approach, except for the spatial dimension where both approaches are necessary.

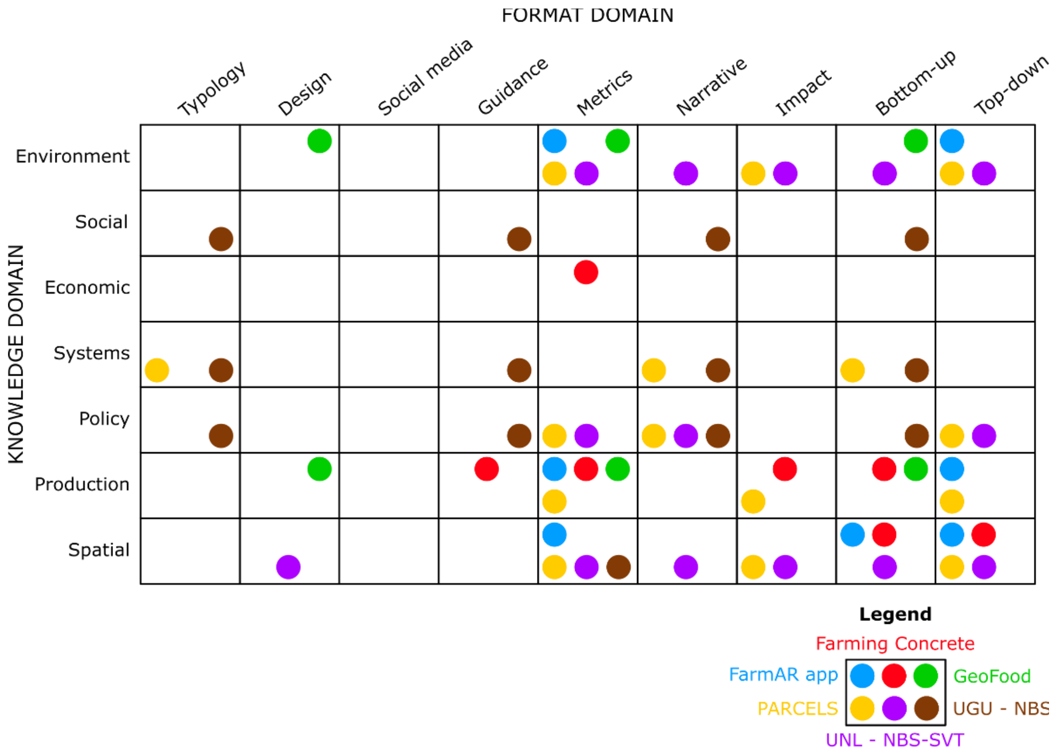

Figure 7. Location of tools in a two-dimensional grid where the x axis represents the format domains and the y axis represents the knowledge domains.

The matrix, furthermore, indicates that design is only highlighted in two of the model-based tools, reinforcing the existing gap between science and design disciplines [30,31] and thus, highlighting limitations regarding the much-needed multidisciplinary approach to successful implementation of eNBS. The absence of tools utilizing social media and promoting model-based tools further evidences the more science-based discourse about the eNBS.

5. Discussion

In the ACTonNBS project, which reviewed around 70 NBS tools to enhance climate resilience in the cities, the tools were classified according to their purpose, where 32% of addressed tools provide planning and design support for NBS implementation, while other tools are informative (29%), enable analysis (20%) or are inspirational (18%) to foster NBS implementation [34]. Although our classification is different, we can draw a comparison. Namely, among the identified eNBS tools, there is a much higher share of tools supporting planning and design (more than 60%) and assessment (more than 40%) compared to NBS tools for climate resilience. This indicates that eNBS tools may be more practically oriented and more specific than general NBS tools thus offering more tangible results to the end user. Furthermore, we found that topics covered in planning/design tools and in modelling tools do not refer to the interdependence of planning/design and modelling of eNBS. This reveals a significant potential for future research and practice aimed at breaking down disciplinary barriers to enable the lasting implementation of eNBS and productive urban landscapes.

Moreover, existing tools provide limited guidance concerning resources needed for sustainable urban agriculture and their management in the sense of resources recovery. This can be considered as an important gap, despite the significant role of urban agriculture in increasing self-reliance of urban food system. Implementation of urban agriculture depends on a great variety and amount of resources such as water, energy and nutrients [35]. Therefore, if eNBS are to be integrated as a solution to sustainable resources management in cities then the tools need to integrate knowledge from the field of water, energy

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and wastewater management, such as hydrology (surface runoff, water balance), and nutrient balance modelling for estimating the reuse potential (e.g., from wastewater). While models for sustainable urban water management are being developed that take into account wastewater reuse and rainwater harvesting [36], the review within this research reveals that none of the eNBS tools includes such integration. This is somehow expected, as it requires strictly cross-disciplinary approach and as such represents a gap towards creating complete urban resources management-oriented tools. Another potential reason for a limited integration of environmental disciplines in the framework of existing tools is that eNBS are still not seen as serious mitigation measures for resources management but rather as tools for addressing self-reliance of urban food systems, social challenges and integration [37–39]. This yet again calls for quantitative tools that can realistically estimate the impact of eNBS on sustainable resources management (e.g., reducing the ecological footprint of cities).

In this sense, EU H2020 project EdiCitNet (Edible Cities Network – Integrating Edible City Solutions for social, resilient and sustainably productive cities) provides a series of tools (via an open data portal: https://toolbox.edicitnet.com/) to help city planners, urban agriculture communities, and individuals to plan and assess eNBS benefits in their cities and to facilitate sharing of data, knowledge and experiences. One of the tools is focused on providing guidance for design and planning of eNBS, and is thus putting forward valuable insights about resources needed and expected food potential. Moreover, the EdiCitNet toolbox will also allow a participative planning approach and training of eNBS dealing with urban challenges. Setting the objective to meet the needs of such a wide range of potential stakeholders is important at this stage in the evolution of eNBS because the practice, although growing, is by no means normative and multiple players are seeking to evaluate the case for their implementation. As a result, the level of pre-existing knowledge of a potential user of the toolbox will vary from someone wishing to gain an overview to others requiring detailed knowledge.

Another way to quantify the impact of eNBS on urban resources management is via indicators. Cities have developed different indicator schemes to assess their sustainability (e.g., City Blueprints [26], EEA Urban Metabolism Framework [27] and European Green City Index [28]). Although they include many indicators related to sustainable management of water, indicators for the success of resources recovery, green spaces, and other relevant urban measures related to sustainability, urban agriculture is not explicitly included in these schemes as one of the measures for resources management or for urban sustainability. Besides, the handbook for NBS monitoring recently published illustrates the lack of specific indicators related to urban food production [40]. This review shows that only six tools related to eNBS are potentially linked to city indicators. Thus, there is a need for an update of existing city sustainability indicators and consequently a link of future eNBS related tools with such indicator schemes.

Another relevant point is the lack of tools estimating the socio-economic impact or benefits of eNBS, probably because these impacts are also hardly quantified for general NBS. Thus, there is the need for tools and models to be able to quantify NBS co-benefits and to illustrate whether these models can be directly applied to eNBS or whether they will require some previous adaptation. Our deep analysis on the type of support provided also reveals a need for tools helping on the training and collaboration among stakeholders when dealing with eNBS.

Moreover, one of the important aspects to consider when selecting a tool or an indicator framework is data availability. Without proper data, based on monitoring, it is not possible to develop indicators or use specific tools. There is often little or no consideration of what data is readily available when the indicator framework or tool is proposed. City Blueprints is a classic example: despite planning the indicator set around publicly available data, they struggled to obtain the data required to complete the assessment of Rotterdam's water sustainability [26].

Nonetheless, when the proper tools exist, an important issue is the difficulties in obtaining specific equations and models to replicate, reuse or validate those tools. Open science is a growing movement, and the advantages of open science are more than demonstrated. For instance, it has been evidenced how open science can accelerate research [41] or how it increases the impact of publications [42]. Likewise, most public funding agencies are including open science principles and requirements in their funded research, such as the FAIR principles advocated by the European Commission, whose main goal is the reuse of valuable research objects [43]. However, our experience in this review of tools was quite the opposite. Since our goal was avoiding reinventing the wheel, we looked for and even, in some cases, explicitly asked for the models and equations behind the tools that could be useful for us, but no equations or models were given in almost any case (only UNaLab, UrbanGreenUp and Parcel provide documents describing models in detail). Unfortunately, this is coherent with other studies that found that nearly 80% of research datasets are not properly shared [43]. Notwithstanding, this is surprising considering that most of the reviewed projects were funded by public agencies that promote open science. So, why researchers are not sharing their models with other projects that could reuse them? In some cases, there is a common perception that open practices could present a risk to career advancement [42]. In others, the researchers believe that sharing may foster unwelcomed competition [44]. However, this is resulting in public agencies (i.e., taxpayers) paying more than once for the same job done by different researchers. Consequently, the avoidance of time-wasting and, thus, of public money, would be a first return on investment in real open science requirements [43].

Furthermore, perhaps the greatest challenge in comparing tools is to evaluate the reliability, breadth and depth of data presented in a tool as well as their user friendliness. Reliability and level of uncertainty are particularly important for decision making when designing and assessing eNBS; however, the quality of the tools and data provided was out of the scope of this paper that focuses on clustering and analysing the type of services provided.

6. Conclusions

Nowadays there are a reduced number of tools, methodologies, and indicator schemes capable of supporting users in planning, design, and implementation of eNBS. To facilitate the transition towards more edible and resilient cities, such tools should be able to calculate the food potential of the city and/or of individual eNBS, include the needed resources for implementation and operation (water, nutrients, energy) and assess environmental and socio-economic impacts. Moreover, if eNBS are to contribute fully to the realisation of productive landscapes in cities that are sustainable and desirable, model-based tools, such as those analysed in this paper need to be linked back to design and resources aspects.

Furthermore, the difficulties in reusing models and equations from other tools caused, in the last term, a waste of time and public money. European Commission is advocating for FAIR principles that pursue a proper data sharing. In response to that, the publications that include a dataset published in an open repository are increasing. Open datasets are very welcome, but most data related to environmental sciences is context-specific, thus the datasets are often only reusable in the same context where they were collected. Therefore, we stand up for a step forward, sharing models and equations used to estimate data along with datasets. Most of models are not context-specific and can be reused in any context provided they are fed with the proper data. And when they are, they offer at least a basis for creating a new model adapted to the study's context. Although there are some interesting initiatives in this direction, like the ActonNBS catalogue, the models and equations used by the catalogued tools are usually not available. In summary, public agencies must continue encouraging data sharing but models behind the tools should be open as well, since they are, at least, as useful as datasets.

Author Contributions: Conceptualization, E.M., J.P., M.S., J.A.C., A.V., D.I., N.A., K.B., J.C.; methodology, E.M., J.P., M.S., J.A.C., A.V., D.I., N.A., K.B., J.C.; formal analysis, E.M., J.P., M.S.; investigation, E.M., J.P., M.S., A.V., D.I., N.A., K.B., J.C.; resources, E.M., N.A., J.C.; data curation, E.M.; writing-original draft preparation, E.M., J.P., M.S., J.A.C., A.V., D.I., N.A., K.B.; writing-review and editing, E.M., J.P., M.S., J.A.C., A.V., D.I., N.A., K.B., J.C.; visualization, E.M., J.P., J.A.C., A.V., K.B.; supervision, N.A., J.C.; project administration, N.A., J.C.; funding acquisition, N.A., K.B., J.C. All authors have read and agreed to the published version of the manuscript.

Data availability statement: The underlying data of this article is provided as supplementary material.

Funding: This research and the APC were funded by EU Horizon 2020, grant number 776665 (EdiCitNet project). Part of the work was performed within the COST Action CA17133 Circular City ("Implementing nature based solutions for creating a resourceful circular city", http://www.circular-city.eu, duration 22 Oct 2018 - 21 Oct 2022). COST Actions are funded within the EU Horizon 2020 Programme.

Acknowledgments: We want to acknowledge the several projects and researchers that answered our questions about the tools they have developed or were developing.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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