

Article

# From Cascade to Bottom-Up Ecosystem Services Model: How Does Social Cohesion Emerge from Urban Agriculture?

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**Abstract:** Given the expansion of urban agriculture (UA), we need to understand how this system provides ecosystem services, including foundational societal needs such as social cohesion, i.e., people's willingness to cooperate with one another. Although social cohesion in UA has been documented, there is no framework for its emergence and how it can be modeled within a sustainability framework. In this study, we address this literature gap by showing how the popular cascade ecosystem services model can be modified to include social structures. We then transform the cascade model into a bottom-up causal framework for UA. In this bottom-up framework, basic biophysical (e.g., land availability) and social (e.g., leadership) ecosystem structures and processes lead to human activities (e.g., learning) that can foster specific human attitudes and feelings (e.g., trust). These attitudes and feelings, when aggregated (e.g., social network), generate an ecosystem value of social cohesion. These cause-effect relationships can support the development of causality pathways in social life cycle assessment (S-LCA) and further our understanding of the mechanisms behind social impacts and benefits. The framework also supports UA studies by showing the sustainability of UA as an emergent food supplier in cities.

**Keywords:** cultural ecosystem services; benefits; emergent behavior; life cycle assessment; sustainability assessment

## 1. Introduction

Urban agriculture (UA) is an emerging alternative to conventional farming, especially as a potential aid for cities to meet the Sustainable Development Goals [1] related to food and sustainable communities. In 2050, up to 7.4 billion people are expected to live in urban areas [2]. This number implies that 66% of the global population will live in conglomerated areas far from traditional areas of food production. Many communities have responded to increased urbanization and global pressures by doing more UA, creating an UA renaissance that is reshaping how we think of food production. A preliminary national-scale estimate suggests that most cities in the U.S. could meet 100% of their population's vegetable needs if all land within a 50-mile radius from the city was devoted to use as cropland [3]. These promising numbers are further supported by bottom-up studies that show that a significant fraction (10 to 50%) of the vegetable demand of a city can be met using the city's available vacant land [4–8].

Given the rapid expansion and promise of UA, understanding its sustainability implications is crucial. Yet, the results from environmental life cycle assessment (LCA) studies are somewhat contradictory. UA can potentially increase net carbon emissions because of its smaller scale production which is typically done under less favorable conditions that require more energy and fertilizer [9,10]. Additionally, Weber and Matthews [11] found that the greenhouse gas emissions associated with the transportation of food from producer to consumer constituted a mere 4% of the food's entire life cycle chain. In contrast, some studies have found that UA might reduce the environmental impacts of food production with respect to conventional supply chains in terms of production systems, reduced packaging, transportation, and product losses [12,13]. UA also provides a number of ecosystem services (ES), i.e., benefits to human well-being including provisioning, regulating, supporting and cultural ES [14], such as climate regulation, habitat conservation, or recreational opportunities [15,16]. While LCA was originally designed to quantify environmental impacts [17], the negative footprint results from an LCA (or avoided burden) can be interpreted as benefits, similar to the benefits of ES. The LCA community has developed models which integrate the potential environmental impacts and benefits of a system on ES-providers, such as the ecological soil quality, biotic production potential or biodiversity (e.g., [18–20]). Hence, life cycle and ES approaches are complementary tools that can help to better understand the environmental implications of UA.

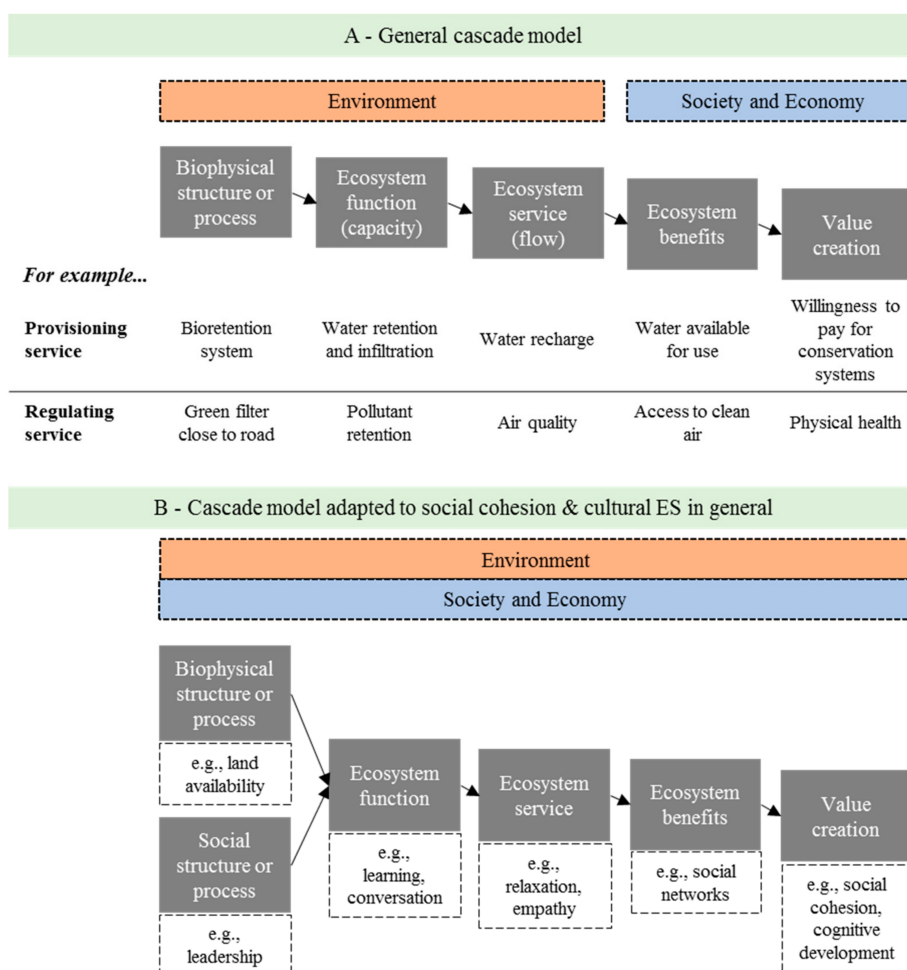
UA can have significant social implications, but this aspect has not yet been modeled using social life cycle assessment (S-LCA) [21]. It has been established that local food production can enhance a community's social fabric, promoting resiliency and self-sufficiency while giving consumers the chance to re-connect with producers [22–28]. Other social benefits include both a reduction in 'food deserts' and a growth in food justice by providing food access to low income families [29,30]. Perhaps the most important prerequisite for a sustainable society is social cohesion, i.e., 'the willingness of members of a society to cooperate with each other in order to survive and prosper' [31]. UA can play a critical role in this respect. Previous analyses have proved that UA helps to build relationships and trust among community members, encourages civic engagement, increases well-being, and might reduce socio-economic barriers [32–35]. For instance, Camps-Calvet et al. [16] found that UA users in Barcelona highly valued cultural ES, particularly social cohesion, integration and education.

To date, social cohesion concepts have not been captured in life cycle research and are only briefly mentioned in ES studies [36–38]. In the context of S-LCA, social cohesion could be seen as a midpoint/endpoint indicator related to local community stakeholders [39]. S-LCA research has identified some challenges when deriving social impacts or benefits from social variables [40], not to mention defining the causality and impact pathways that connect social indicators with areas of protection (AoP), such as human well-being [39,41,42]. A combination of ES and LCA knowledge might provide some hints. But how does one trace the causal chain that connects UA to social cohesion? And how could this and other cultural ES be included in S-LCA and integrated sustainability assessments? In this study, we address this question by proposing a new framework that links our understanding of social cohesion to the popular ES cascade model [43]. Recently, Maia de Souza et al. [44] combined the cascade model with LCA to identify ES in different life cycle stages of biomass-related products. In our new framework, we explain how adopting the cascade model for social cohesion requires the incorporation of both biophysical and social structures and processes that propagate through the benefit chain. On the basis of existing ES research and several UA case studies, we show how social cohesion emerges as a bottom-up behavior in UA. As Costanza [45] demonstrated in his ES classification, cultural ES are non-excludable. Social cohesion is a public service and users should not be deprived of its benefits. Accordingly, understanding how this type of benefit emerges is essential for policy-making. Finally, we discuss the need to integrate this framework into existing life cycle tools to estimate the overall net sustainability of UA strategies.

## 2. Logic and Adaptation of the Cascade Model to Cultural ES

The cascade model was first presented by Haines-Young and Potschin [43] to link ecosystems to human well-being. This model was meant to assist in understanding how the Millennium Ecosystem Assessment (MEA) [14] report classified nature’s services in categories of supporting, provisioning, regulating, and cultural ES. Wallace [46] argued that, on the basis of MEA typologies, it is difficult to find the difference between the services that people benefit from and the processes that generate these services (i.e., the means and the end). For this reason, the cascade model intends to operationalize ES so that decision-makers can put the ES approach into practice more easily.

In the original cascade model and its subsequent applications [47–49], the first step of the chain focuses on biophysical structures or processes, leading to ecosystem functions, services, benefits, and values. Figure 1A provides two examples of this chain for provisioning and regulating services. Here, the first three steps are related to the environment, whereas benefits and values are those perceived by the socio-economic system [50]. In general, most ES studies focused on ecological aspects of a particular component of the cascade [51]. However, this framework is flexible enough to adapt these concepts to different contexts [50]. For instance, Langemeyer et al. [52] indicated the need to include the effects of goals and planning in the framework when dealing with policy-making in urban areas. In another case, public and community governance was added as a preliminary step of the cascade [50].



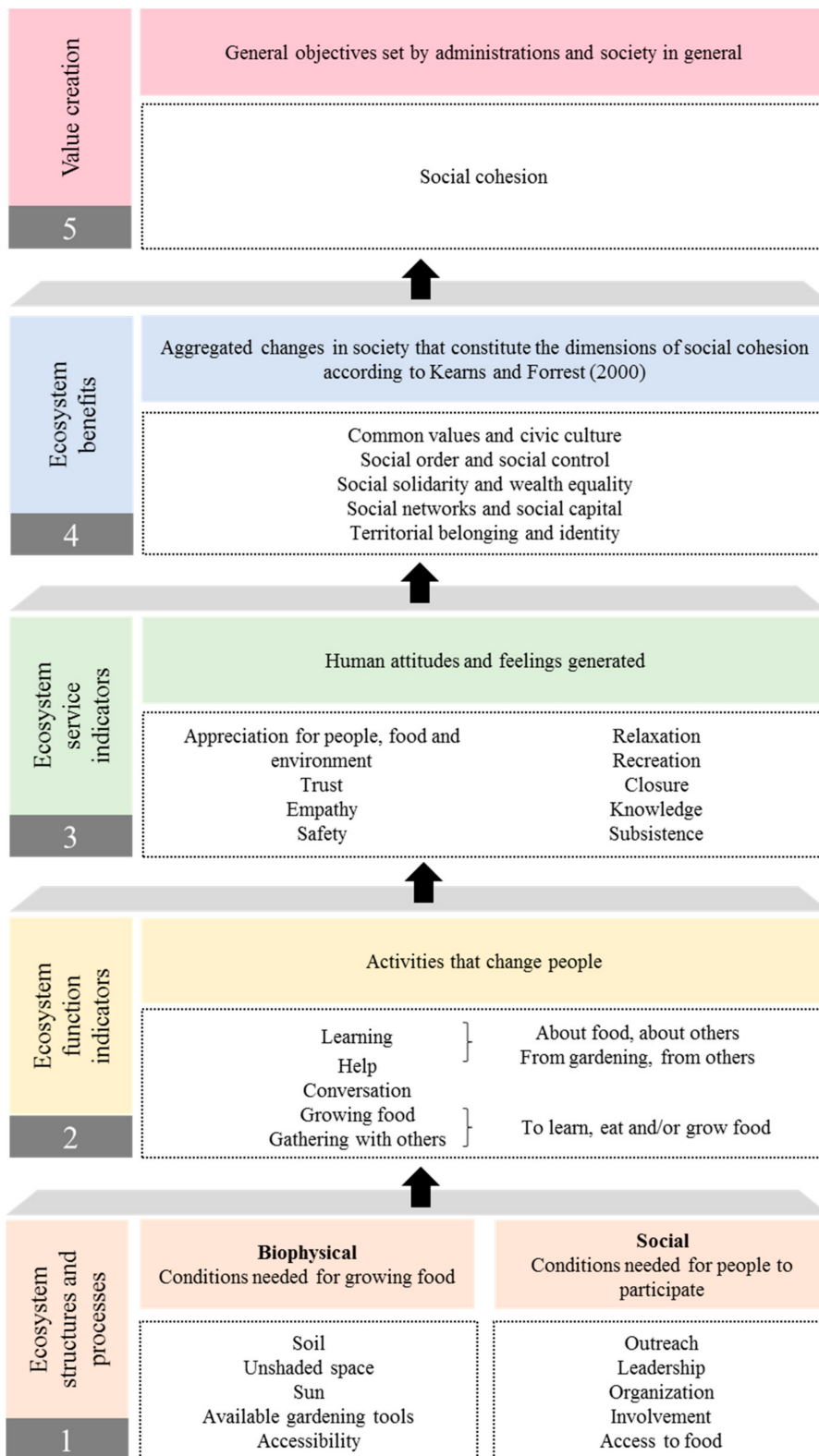
**Figure 1.** Original cascade model (A) and its adaptation to social cohesion (B) based on Haines–Young and Potschin, de Groot et al., Spangenberg et al., and van Oudenhoven et al. [43,47–49]. Social properties are the novelty of this approach when dealing with social cohesion and cultural ES.

In the case of cultural ES, there is still little consensus on how they should be categorized through the cascade model [53]. According to previous applications, this framework involves an unidirectional flow from left to right [54], i.e., from ecological systems to humans who benefit from their services. However, because services are provided in a socio-ecological context, cultural ES cannot be delivered without an investment in human energy [54,55]. Similar to a person's mind-body relationship, biophysical properties are combined with social elements during the ecosystem supply and demand process [56]; for example, humans can identify that the potential use of certain ecosystems might result in benefits and have value to people [48]. This is the case of social cohesion, which is the dimension that we cover in this article. For this reason, we propose an adaptation of Haines-Young and Potschin's [43] framework to better illustrate how human interventions should be viewed when assessing social cohesion drivers or cultural ES in general (Figure 1B).

We submit that structures and processes not only consist of biophysical parameters, but also social constructs, as the conditions needed to achieve social cohesion are directly affected by the different roles played by community members, users or visitors. For instance, Fischer and Eastwood [57] showed that the interactions between people and a forest are determined primarily by people's identity and capabilities. Hence, humans could be considered service-providing units (SPU), as they are a fundamental unit that contributes to the generation of services [58]. Given this perspective, in Figure 1B, we illustrate the cascading of the social dimension through the other steps of the causal chain. As a social network is an expected ecosystem benefit in the example, it is clear that availability of land is not sufficient to achieve this goal. Individuals with leadership skills may also need to intervene, for instance, seeking access to public resources to promote learning and social interactions [59]. This potentially may lead to the generation of new feelings among the users such as relaxation and empathy. Ultimately, these cascading events can create the social networks resulting in social cohesion, a fundamental value in a society as a way for people to define themselves and provide sense to their existence [60].

### 3. Illustrating the Social Cohesion Cascade Model for Urban Agriculture

As discussed in Section 2, we propose an adaptation of the cascade model to capture the role of humans not only as ES beneficiaries, but also as SPUs. In doing so, we also link this perspective to a bottom-up emergent behavior to be included in the ES model. In the field of landscape management, Spangenberg et al. [48] argued that human demand is the starting point on the basis of social and political aspects. The authors reversed the cascade and turned it into the stairways of landscape management. In our adaptation, we also reversed the cascade model, this time to show both a bottom-up and emergent perspective. These two perspectives are important in characterizing complex systems in which autonomous agents at the bottom of a hierarchy interact to develop emergence and self-organization at a different level of observation than the agents themselves [61]. A set of micro-behaviors which trigger a macroscopic behavior is widely known in agent-based modeling and network dynamics [62] but previously had not been implemented in an ES framework. In Figure 2, we present the bottom-up and emergent version of the cascade model for cultural ES, which in this case was applied to the development of social cohesion through UA. This chain represents the concept of emergent behavior of a complex system. As such, the most fundamental properties of the system result from its basic structure leading to certain functions. These then lead to specific services and, ultimately, values. On the right side of Figure 2, we present interpretations and examples of how the model would apply to UA based on literature.



**Figure 2.** Application of the bottom-up ES cascade model to urban agriculture and social cohesion. Examples are provided in white boxes to explain each step of the chain.

Focusing on UA, the first step towards a cohesive community refers to the biophysical and social structures and processes that define the ecosystem. We also refer to these as the biophysical conditions



(e.g., soil, sun, unshaded space, tools, and accessibility) as well as the social conditions (e.g., access to food, leadership, involvement, organization, and outreach) needed for growing food. In an urban garden, these biophysical and social conditions are supposed to be attractive to the users, encouraging them to garden at this specific site. For instance, gardening should take place in an area that is free from pollution in the water, air and soil so as to not compromise the users' health [59]. It should also be readily accessible and provide enough sunlight for crop growth. However, cultural ES result from information [63] produced both through perceptions of the environment and from other people. In this sense, we argue that outreach and (innate and learned) leadership, for instance, are some of the social processes that influence the degree of participation in UA. These ecosystem structures and processes might be conducive to a set of functions or activities that change people. For example, UA users may learn about each other and about growing food as a natural result of UA practices and the help and conversation generated during these processes (e.g., talking when weeding). As discussed by Altieri et al. [64] in Cuba, some migrants from rural areas applied their skills in tending urban gardens while those born in the city had the opportunity to learn new gardening skills. In Brooklyn (New York), some community gardens connect youth with older gardeners who need help to look after their plots [30]. These connections can encourage conversation, education, and companionship.

We defined ecosystem services as the feelings and attitudes that arise from ecosystem functions. Some of the ES defined by Costanza et al. [65] and the MEA [14] can be included in this step, such as recreation, education, and cognitive development. Here, cognitive development was split into more nuanced services, such as trust, appreciation, or empathy. For instance, a direct ES that might result from the physical and social conditions of community gardens, together with knowledge, is appreciation for the environment, food, and people. As pointed by Hagey et al. [30], UA enables the residents to 'rediscover their food culture' through a connection to a garden's elderly users and might also extend to a switch to a healthier diet, for example.

All of these potential services enable the generation of ecosystem benefits. It is in this step that the cascade usually puts social aspects into play. However, we have previously argued that social structures and processes lead to functions or activities, such as growing food with others, that might change an individual's attitudes or feelings towards other people. Hence, individual social changes might lead to ecosystem benefits, which in this case comprise the five social cohesion dimensions defined by Kearns and Forrest [66] and are drivers towards social cohesion—the ecosystem value in this approach. These benefits are common values and civic culture, social order and social control, social solidarity and wealth equality, social networks and social capital, and territorial belonging and identity. According to these concepts, UA is conducive to a cohesive community that has a common view and code of conduct, it is more cooperative, contributes to food security, and provides a sense of place, among other features. The bottom-up process might be clearer in the case of social capital, which was defined by Putnam [67] as the 'features of social organizations, such as networks, norms and trust that facilitate actions of cooperation for mutual benefit'. UA may be responsible for bonding and bridging social capital, i.e., linking individuals from similar and different backgrounds, status and religions, respectively. For instance, gardeners interact with people in the community garden that they would have not approached outside of the garden [35].

The final step of the model is value creation, which in this study is social cohesion, a general objective pursued in the society. The MEA [14] defines social cohesion as a constituent of human well-being. The indicators identified through the cascade model describe potential drivers towards the desired value. Chan et al. [36] discussed the nature of ecosystem values, i.e., instrumental or intrinsic. We argue that social cohesion itself might constitute a final (intrinsic) value because it is a desired objective for a society. However, it might also be viewed as instrumental if it leads to other desired actions, such as the increase in local food production thanks to a greater community involvement. In this sense, users might directly or indirectly perceive the value of UA in terms of social cohesion but greater consequences might arise once community managers and policy makers enhance the implementation of UA for this purpose. These consequences and feedback loops might be positive if

they increase social cohesion, but negative effects are also possible. For instance, land management might improve or worsen the environmental status of the community or increase social conflicts to acquire a piece of land for gardening. Value perception, policies, and pressures are not the focus of this analysis but should be considered to envision the entire chain.

#### 4. Implications of Adapting the Cascade Model to Social Cohesion and Other Cultural ES

Thus far, research has tried to understand the role of cultural ES in socio-ecological systems. Studies on social relations and cultural diversity are still scarce [36–38]; however, they are key for understanding the role of ecosystems in breaking down social barriers and bringing citizens together, as shown in Section 3. Additionally, the methods applied in cultural ES research are very heterogeneous and most analyses do not provide fully developed conceptual frameworks and definitions [68]. For this reason, we submit that the bottom-up model discussed in this paper could be of interest to cover existing research gaps and enhance social science research and the operationalization of ES.

This process might also help support the elaboration of indicators aimed at policy-making. Current attempts at quantifying cultural ES do not seem to account for the social structures and processes involved in the creation of these services. For instance, Andersson-Sköld et al. [69] related cultural ES to abundance indicators (e.g., leaf area) through the cascade model, but social parameters were not specifically assessed. In this sense, quantifying the benefits and values that result from cultural ES is not straightforward. In the case of social cohesion, an additional challenge is the categorization of this concept. Leisher et al. [70] found that sixteen human well-being indices accounted for social cohesion; the authors categorized this concept on the basis of social relationships, community, connectedness, intergroup cohesion, and social capital. Others have accounted for social capital and cohesion and have assigned an intrinsic value to social cohesion (i.e., the desired ends), such as trust or cultural norms, as well as an instrumental value to social capital [36]. Similarly, Barnes-Mauthe et al. [71] measured social cohesion as a dimension of social capital. Some have suggested that local conditions should be the basis for defining social capital indicators, as the context highly determines the results [70,72]. Here, we applied the dimensions proposed by Kearns and Forrest [66] to interrelate the potential benefits from UA with the creation of social cohesion values.

We believe that using the bottom-up model (Figure 2) might enable the detection of potential conflicts between concepts and finally determine the benefits and values that we seek to transfer to policy. Existing research has already sought to connect the cascade model with policy frameworks [73,74]. However, it seems that the scientific community is still struggling with the steps of the cascade model, as each case study might require a particular adaptation of the conceptual framework [50]. Thus, we aim to improve the understanding and applicability of cultural ES by integrating social structures and processes into the cascade model. In the particular case of UA, we need to provide decision-makers with tools that support the evaluation of this emerging production system in the context of sustainability; for example, if research determines that education and/or income status affect urban gardening practices and soil properties [75], socio-economic properties are the processes that trigger potential benefits or conflicts in UA. Clearly, these processes should be considered in social science studies, but the previous example also suggests that they can influence other ES types.

#### 5. Linking the Cascade Model to the Sustainability Assessment of UA

In the case of UA, life cycle tools are broadly applied to depict the potential environmental friendliness of a system with respect to another (Section 1). However, S-LCA research is yet to be applied to UA to understand the potential social impacts and benefits that result from urban gardening. In general, discussions on the integration of ES into life cycle management have focused on environmental parameters, such as biodiversity and land use change (e.g., [19,76–79]). In the case of cultural ES, Zhang et al. [80] suggested that they could be better evaluated through monetary methods because they are ‘truly anthropogenic in nature’. Again, measuring social cohesion in an urban garden is not an easy task which is why most cultural ES studies have focused on recreation and eco-tourism

instead [36–38]. Hence, a more extensive analysis on cause-effect chains in the context of life cycle management [78] might be an effective first step.

In this sense, the proposed bottom-up model might be of particular interest to the S-LCA community. Potential pathways and characterization of indicators are still under discussion in this field [39]. So far, the UNEP-SETAC Guidelines on S-LCA [81] have defined two different types of impact categories, i.e., Type 1 and Type 2. Type 1 categories are the most common in modeling and aggregate results within themes, whereas Type 2 categories model the subcategories that have a causal relationship [81]. Our bottom-up approach could help define sources of stressors that induce a set of social impacts and benefits [40]. Additionally, it might feed emerging models [82] which estimate potential social impact pathways connecting inventory indicators to midpoints and endpoints in the development of Type 2 categories. As an example, social cohesion might be viewed as a midpoint or endpoint indicator that is emergent from a causal chain that combines both social and biophysical parameters. This is under discussion and may depend on how the AoPs are defined. For instance, Jørgensen et al. [42] compared two AoPs, i.e., individual well-being and societal wealth. On the basis of this classification, we argue that social cohesion could then be either a midpoint or an endpoint depending on what we seek to protect. If we are interested in fostering individual well-being, social cohesion might be a midpoint that is conducive to a better individual standard of living. In contrast, if societal wealth is the main goal, social cohesion might be an endpoint.

Research and training in this integrated dimension of benefits and impacts is still growing. Higher education programs on ecological engineering [83] are including ES theory and academia continues to discuss new concepts, such as the handprint (as opposed to the footprint) [84]. In this sense, the handprint or benefits might act as an effective complement to other methods, such as life cycle sustainability assessment (LCSA), which seeks to ‘include other than just technological relations, e.g., physical relations, economic and behavioral relations, etc.’ [85]. With this contribution, we provide a starting point for future sustainability assessments that account for the effects of ecosystems (in this case, urban gardens) on social parameters such as social cohesion.

## 6. Conclusions

In this paper, we added social properties to the ES cascade model and turned it on its head to create a bottom-up approach. We built upon the existing concepts of emergent behavior and the ES cascade model to show how social cohesion can be generated in UA. Our concept suggests that activities that change people emerge from the biophysical and social conditions present in UA. These activities contribute to human attitudes and feelings, which, when aggregated, create social cohesion. Our bottom-up emergent UA model was not applied to a specific case study. Future research could further develop our conceptual model using simulation tools. For example, future studies could construct an agent-based model using existing social complexity [86], social epidemiology [87,88], and LCA [89,90] literature and validate the structure and causality of our model [91] for different case studies.

In terms of accounting, if the environmental impacts of UA settings can be determined through LCA, additional environmental, economic, and social benefits can be tracked through our adaptation of the ES cascade model to capture impacts that have not previously been modeled in LCA, such as social cohesion. UA is only one example. In general, implementing and managing emerging technologies and production systems is not straightforward. Hence, mapping all potential impacts and benefits from the ground level can help obtain a general picture of cause-effect factors that other tools might not completely cover. In this sense, the attributes and indicators generated through this approach need to align with the interests of stakeholders. This is another recommended research pathway from which UA can benefit to increase the understanding of this grass-roots movement which has the potential of turning into a relevant food supplier in cities.

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