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Systemic Design for Food Self-Sufficiency in Urban Areas

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Abstract: This article adopts a systemic approach to address the problem of the operationalization of relationships between actors conducive to food self-sufficiency in urban areas. Through the use of Social Network Analysis (SNA), the literature on urban agriculture was analyzed, detecting eight key trends and topic areas. This information was used to design a generic recursive organizational structure with the identification of the key roles and functions for management and governance in the multi-level and multi-stakeholder relationships of a sustainable urban self-sufficient food production system, inspired by the principles of complexity management and organizational cybernetics. Methodologically, this is the first application that combines the exploratory capability of SNA and the recursive structure of the Viable System Model (VSM) to propose applicable organizational structures in any urban area, suggesting a new route for the study and application of systemic thinking in the development of urban agriculture schemes. However, due to the conceptual nature of this work, this study opens a discussion on how we can rethink interactions to seek continuous adaptation in food self-sufficiency, provide tools that foster inclusion, and adapt to every context to support the relevant actors and academics in urban agriculture.

Keywords: urban agriculture; food security; systems thinking; social resilience; networks

1. Introduction

According to Schwaninger [1], the current social context exhibits accelerated changes. In this environment, sustainability remains a challenge for different social groups, governments, and regions, regardless of their type or the sector in which they operate [2]. As a society, we are witnessing increasing amounts of waste, poor management of (limited) resources, the irrational use of biodiversity that disturbs the equilibrium between socio-ecological systems, restricted access to goods for human beings, and increasing scarcity [3]. Following this, Williams et al. [4] and Savaget et al. [5] stated that sustainability-related problems have been addressed mainly from a linear or reductionist perspective. In this regard, these possible solutions converge on the urgency of adopting a systemic perspective to deal with such situations, especially in problematic situations directly related to food self-sufficiency and the conceptual and operational frameworks to facilitate food supply.

Consequently, this paper aims to explore the application of a systemic approach to food sustainability. Likewise, we suggest applying the principles of organizational cybernetics through the

Viable System Model (VSM) as an alternative solution to the challenge of sustainability at different levels and, in turn, propose a recursive organizational structure that seeks food viability. Hence, within this systemic methodological framework [6], and considering the exploratory nature of this work, rather than a hypothesis, this article proposes the following conceptual proposal: the recursive structure of the VSM makes it possible to generate a framework of action and rethink the relationships between actors to promote food self-sufficiency. Consequently, the ideas developed in this article concern the organizational domain and use the agriculture in urban areas as a context for their application, aiming to ensure food self-sufficiency.

Focusing our research efforts on urban agriculture issues is necessary and urgent because current agricultural practices, especially those associated with large-scale or industrialized systems, are considered to have negative impacts on environmental, social, and health factors [7]. This relegates a large part of society to having a high dependence on industrialized food or living under a continuous state of scarcity, which is why it is considered necessary to adopt comprehensive approaches that make it possible to generate strategies and synergies aimed at ensuring food self-sufficiency in urban areas [8]. For this purpose, the objectives to guide this work are (a) performing a literature review through Social Network Analysis (SNA) to identify the communities or areas of knowledge related to the analysis and development of agriculture in urban areas; (b) proposing a conceptual model based on the functions of the VSM that serves as a guide to rethink and organize relationships aimed at ensuring food sustainability, as well as the components related to food management, as recently highlighted by Muñoz-Rodríguez et al. [9]. Notably, the proposed organizational structure seeks to benefit academics, civil organizations, and actors who have the decision-making power to implement changes in their communities. It should be added that both the VSM elements and the structural design in this article can be applied to an international context with minimal adjustments in each region. For this, the definition of each VSM component is provided to avoid confusion when making such adjustments.

2. Literature Review

This work explores the state of the art in the use of the systemic method and systemic tools for the design of food sustainability and self-sufficiency in urban areas (mostly through development based on urban agriculture systems). Some relevant works shed light on this problem using the naturalistic and structuralist approach of systems thinking to address social challenges [10]. There are various approaches to the issue of food sustainability, including quantitative [11], qualitative [12], mixed methodologies [13], environmental, and social [14]. Therefore, to achieve the stated objectives, it is necessary to conduct a literature review.

Society follows the definition of McGinnis et al. [15], in which the use of resources must be regulated to avoid an economic, social, and ecological imbalance. In this regard, Espinosa and Walker [16] highlight that there are still actions and research areas that must be addressed for sustainability. Following this idea, organizations such as the UN's Food and Agriculture Organization (FAO) [17] and the World Wildlife Fund [18] have warned about crises related to energy, financial systems, food shortages, and the lack of institutional coordination, which can increase the deterioration of these problems for sustainability [19,20].

In recent years, the interest in sustainable development and attention to problems related primarily to sustainability, insecurity, and food insufficiency has increased. However, integrative analyses for generating positive impacts in areas seeking to improve their security practices related to food supply have been neglected. Addressing this type of problem is considered relevant since economic, political, and social stability is highly important for the availability of essential food inputs [10]. In this regard, Le Tellier et al. [21] specified that companies and social groups are capable of achieving significant impacts in the dimensions mentioned above. In this sense, various efforts have been made at both a theoretical and practical level to support these actors [22]. For instance, in theoretical terms, the water–energy–food nexus approach can be used to estimate the degree of resource provisioning in some urban regions [23], the study of food self-sufficiency aspects can shed light on social factors that must be treated [24], and the concept of food sovereignty can be used as a conceptual framework to generate policies and agreements at the international level [25].

For practice-oriented efforts, Leonardo et al. [26] determined the variables needed to improve food availability through geospatial analysis to assess the utility of adopting urban plots [27]. In contrast, Ward et al. [11] suggested using linear programming to evaluate diet styles and determine the feasibility of urban agriculture modalities. However, Baer-Nawrocka and Sadowski [28] indicated that one of the factors that influences problems related to food self-sufficiency is the high concentration of the agricultural sector in related studies. Additionally, Montiel [29] considered another limitation as the attempts to understand the different factors in isolation and the low potential to handle multiple social and ecological interactions at the local, regional, and international levels.

There are different aspects upon which solutions to the current ecological crisis should focus. Authors such as Ward [30] and Weidner et al. [31] considered the answer to lie at the local or individual level, where the generation of ideas, the degree of organization, and the coordination of efforts can be achieved more rapidly; subsequently, the patterns of behavior or learning can be scaled to higher levels of any social organization [22]. In contrast, Li et al. [32] and Xie et al. [33] indicated that the design of improvements for sustainability problems can be found among international actors who have the resources to regulate this process effectively. This argument suggests a gap between the adoption of standards or tools and the implementation of sustainability practices. Thus, following Nunez Rios et al. [34], the search for answers must be multifaceted, meaning that the effort between researchers and society should be transversal to find and propose ways that mitigate, as much as possible, the negative impacts on the environment and positively influence the community [35].

3. Methodology

Food self-sufficiency issues are framed by a complex environment that demands the adoption of holistic perspectives. In this sense, a systemic approach is considered appropriate, since this approach addresses the components and complementary elements of any social system, such as relationships, structures, and functions [36], allowing the articulation of ideas to generate positive actions. It is essential to highlight that, as a research method, systems thinking seeks a synthesis between positivist, naturalistic, and critical research methods, thereby generating a flexible framework to integrate methodologies and models to study complex problems [37]. Considering this, we sought to develop a broad perspective on how food self-sufficiency and food sustainability has been approached based on the academic production in scientific articles. An approach based on SNA was thus designed and used [38].

There are different approaches for connecting systems-oriented thinking to sustainability [39]. The SNA was selected for its robustness in handling and visually presenting large amounts of relational data. Although the SNA methodology offers mathematical rigor, its flexibility allows its use with data to show the relationships between nodes rather than to focus purely on statistical analysis. SNA could be can also be used to represent systems shaped by different components [40]. In this case, we propose using SNA to draw a network constituted by documents and the authors' keywords.

In this context, to perform the literature analysis using SNA, the SCOPUS database was used following this analytic protocol:

- Establish the descriptors and search strategy: "food sustainability and systems thinking" (("food AND self-sufficiency" OR "food self-sufficiency" OR "food AND sustainability" OR "food sustainability" OR "food AND security" OR "food security") AND TITLE-ABS-KEY ("organization AND" management "OR" sustainable agriculture "OR" urban agriculture "OR" resources management") AND TITLE-ABS-KEY ("system" OR "system thinking" OR "organizational cybernetics" OR "Viable System Model")) both in the titles and in the abstracts and keywords. It is important to clarify that the search focused on detecting the application of tools belonging to systems science or systems thinking, especially organizational cybernetics, to problems related to food sustainability and urban agriculture. Moreover, the search strategy considered the ideas of Sánchez-García [41] and Romero-García [42].

- Inclusion criteria: articles with a scope based on sustainable operations or a systemic approach to food self-sufficiency or food sustainability without a restriction of countries were included.
- Set period and published language: our search strategy in SCOPUS yielded articles from 2015 to 2019 published in the English language.
- Based on an initial exploration of the density of publications relevant to the purposes of this research, articles that only addressed aspects of soil composition, spatial patterns, or food chemistry were excluded, as these technical components of the study of (urban) agriculture were not directly related to the observation of self-sufficiency from an organizational perspective.

Based on the above, the articles were first linked to the keywords listed in each one of them. Second, a network of co-words was built to find communities of related keywords. We adapted a two-mode network approach (see [43]) to create an undirected and weighted network in which the keywords are linked based on the recurrence of their use on papers. Considering the workflow of the SNA, an edgelist-type arrangement was followed to establish the article–keyword relationships, and a node file was also generated (both in CSV format). These files were later processed using the igraph [44] package in RStudio.

Third, the "fastgreedy" algorithm of communities' detection [45] was applied to the keyword network. These communities were interpreted by their trends or currents of analysis and their theoretical–empirical approaches to food self-sufficiency.

Additionally, the VSM was selected for this article because it is a robust theoretical model that has been validated in quantitative and practical terms [34]. Additionally, its design allows the diagnosis and improvement of practical fields—that is, it specifies the necessary and sufficient elements needed to guide any socio-ecological system and maintain both autonomy and constant equilibrium [46]. Returning to the ideas of Schwaninger [1], from the perspective of the falsification principle [47], serious attempts have been made to falsify the VSM [48]. These attempts found that the model passes all tests. Thus, VSM has not been falsified or proven to be wrong, and its results are considered to be true. Notably, the works of Núñez-Ríos et al. [49] and Sánchez-García et al. [50] have applied structural analyses that quantitatively show the suitability of the model.

Beer's model [39] uses a structuralist perspective that recognizes the recursive nature of systems: that systems exist holonically or in hierarchies and that their modalities of organization at a higher level are consistently repeated in other parts of the system. In this sense, viable systems exhibit the same organizational characteristics [51].

Before proposing the relationships that strengthen the organizational structure in the context of food self-sufficiency, the viable system model's components will be concisely defined to determine how the system can be used. The VSM is composed of five subsystems that can be understood as functions (Table 1).

The VSM assembly demands the prompt identification and understanding of the coherent and regulated relationships between the environment in which a particular system operates. VSM understands its organization and the management mechanisms that allow it to maintain balance within its context. Figure 1 shows the essential elements of the viable system model and how they are concatenated.

In the left part of Figure 1, the circle represents an organization, with its management (rectangle) nested in a specific environment (amoeba shape). In the central part of the figure, these components are shown separately to visualize their relationships, and the arrows represent the management and regulation of the input and output flow between these elements. The right section of the figure presents the unfolding of the system's complexity, one of the crucial steps for the development of VSM, based on an understanding that in a recursive organizational structure, any viable system contains and is contained in the viable system.

Table 1. Viable System Model (VSM) components.

Function	Definition
S1	This function is composed of all the elements that produce and deliver the goods or services that the viable system must generate to the environment. Each primary activity in System 1 is itself a viable system due to the recursive nature of the systems, as described above. These systems are concerned with performing a function that implements at least part of the organization's key transformation.
S2	This function represents the information channels, technical resources, and bodies that allow the primary activities in System 1 to communicate with each other to avoid operational conflicts. It represents, for instance, the scheduling function of shared resources to be used by System 1.
S3	This function represents the structures and controls that are put into place to establish the rules, resources, rights, and responsibilities of System 1 and provide an interface with Systems 4/5. S3 represents the present big-picture view of the processes inside System 1 (i.e., the here and now).
S3*	S3* represents a specialized function of S3. S3* is a support system that captures information on the operation of the S1 units, which the S3 cannot capture in the standard reporting channels.
S4	S4's main objective is to handle the future of the system or the organization. In this sense, it collects the information available in the environment that can be used in long-term strategic planning seeking viability. The relevant information that S4 identifies must be transmitted to influence the adaptability of S1 and the adequacy of S2 and S3.
S5	S5 constitutes the highest authority. It makes high-level decisions and defines the identity of the system and its purpose. S5 balances the present and future of the system by aligning the external and internal factors that may affect the total system.

Source: based on Beer [39].

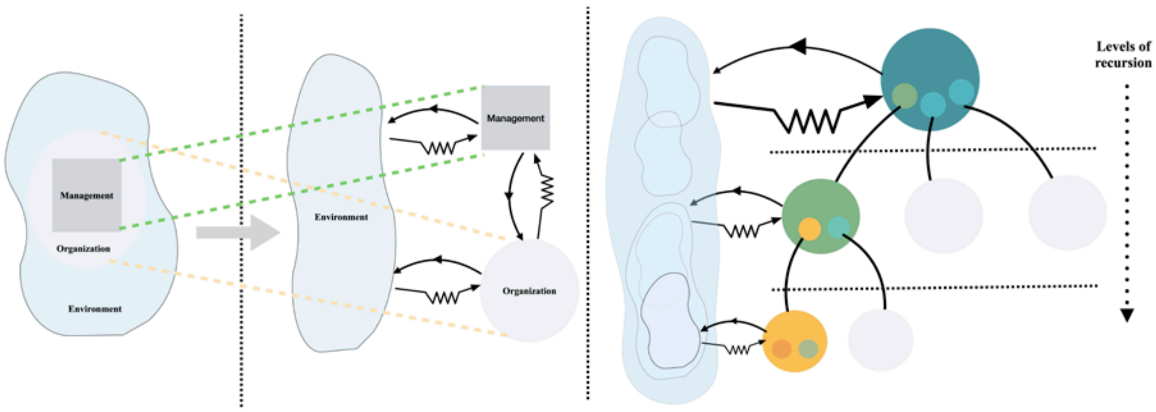

Figure 1. Viable system model's basic elements. Source: based on Pérez Ríos [52].

Thus, the viable system model proposal aims to suggest the ideal connections of different actors at different levels of recursion to promote food self-sufficiency in urban areas. This proposed design contemplates the components identified in the thematic communities detected by SNA. For this purpose, based on the methodology suggested by Espejo and Kuropatwa [53], the subsequent steps were as follows: (a) unfolding the complexity to show the relationships between the different levels of recursion of an ideal urban food system; (b) the use of a diagram for viable systems at each of the recursive levels to identify the relevant transformations and suggest which actors and components should carry out the necessary operations, as well as the functions of coordination, management, auditing, intelligence, or strategic planning and governance.

Considering the expressed ideas, the steps for developing the viable system model for this study can be summarized as follows:

1. Identify the purpose and recursive structure (unfolding complexity).
2. Diagnose the existing situation and provide recommendations for change (considering SNA support).
3. Also based on SNA, identify the critical functions, critical activities, and information requirements.
4. Using the Transformation, Actors, Suppliers, Customers, Owners, Interveners (TASCOI) mnemonic, identify the basic and necessary elements for modeling and propose new relationships under the organizational cybernetic framework.

4. Results

After processing the data retrieved from SCOPUS, two types of networks were generated and analyzed. The first network (Figure 2) is a two-mode network composed of the 212 articles (nodes in red) found in SCOPUS and 588 different keywords (KWs, nodes in blue), which were reported in the articles. Of the 212 documents, KWs were not recovered in 18 of them; therefore, these articles were excluded from the dataset, leaving only 194 articles in the network. This first approach allowed us to distinguish four main concepts: security, sovereignty, self-sufficiency, and sustainability (see the sizes of these nodes in Figure 2). Moreover, for visual purposes, we removed the labels of KWs with a low frequency of use and the labels of papers with few keywords.

The construction of this network allowed us to infer that, as a concept, food security and sovereignty are mainly linked in policy terms. The first concept refers to the existence of food that allows survival. The FAO [17] conceives food security as the physical and economic access that every person must have at all times to ensure their diets include safe and nutritious food, as well as the necessary food-supply preferences for living an active and healthy life, regardless of the origin of the food [54]. Meanwhile, food sovereignty is the right of a nation to maintain and develop its capacity to produce its own essential foods while respecting cultural and productive diversity. According to Patel [55] and Neilson and Wright [56], food sovereignty is a condition for food security, thereby affecting the interactions between food imports and food exports. These facts influence the concepts of self-sufficiency and sustainability, in which a population determines to what extent its food system, consumption patterns, methods, and techniques are articulated through the management and disposal of resources and food. Although each concept addresses different characteristics of the food system, they are not mutually exclusive, and existing relationships may affect the development of a population without overlooking agriculture as the basic component that contributes to reconciliation between the four concepts [57].

Subsequently, the network in Figure 2 was transformed into a network of co-keywords. This procedure is based on converting a two-mode network into a one-mode network [43], in this case, focused on keywords (KWs). Notably, performing this transformation can identify patterns and areas of knowledge related to the analysis and development of urban agriculture, food self-sufficiency, and, more importantly, the usage of systemic tools and thinking to address the problem. When two or more KWs were used in the same article, all of them were connected by a link, and this connection increased successively if another article also used them. As a result of that process, some KWs were found to be firmly connected with a higher usage than others. Thus, this procedure allowed us to observe the KWs that were rarely used and not very connected. Based on the above, the dataset was revised, and the KWs with a maximum of two links were removed. As a result of this process, some KWs were found to have close proximity to each other, forming a community (Figure 3). Under this SNA approach, 20 communities were detected and assumed to be thematic areas in which the topic of food self-sufficiency was developed. To detect these communities, we used the “fastgreedy” algorithm, which forms agglomerative hierarchical clusters (communities) [45]. In this second network, nine isolated communities were first identified not to be connected with other KWs, which means that they were KWs used in particular articles. Second, a very large component was composed of different communities. Third, eight superior communities contained 80% of the concepts. Approximation using these KWs units facilitated the study of the graph as a whole and allowed us to detect the edges of knowledge based on cohesion in the substructures.

Based on this information, and to deepen our understanding of the different aspects of this article's central idea, detailed observations of the KWs comprising the eight largest communities with high relevance are summarized in Table 2. Notably, the colors in this table are linked to the colors in Figure 3. Additionally, to prepare this table, the network was used as a basis to later search for the words within each article, review them, and connect them to determine their contributions.

Based on the previous information, we identified that a large portion of the critical body of literature that seeks to understand and provide solutions to global food problem through urban agriculture is centered in China, Europe, India, and Australia. This finding highlights the opportunity to design contributions that consider a broader scope of territories, as such environmental and social inequalities are global. Under this framework, the application of systems science or systems thinking to address contextual, structural, or relational issues in problematic situations with high social participation it is still rare. Considering the information that allowed us to apply the SNA approach, upon reviewing the components of the thematic communities, we identified that although there is an adoption of a systemic perspective in the literature, no contributions were observed to articulate the organizational links from the local level to the contextual and institutional levels to influence the problem of (urban) food supply or (urban) food sustainability.

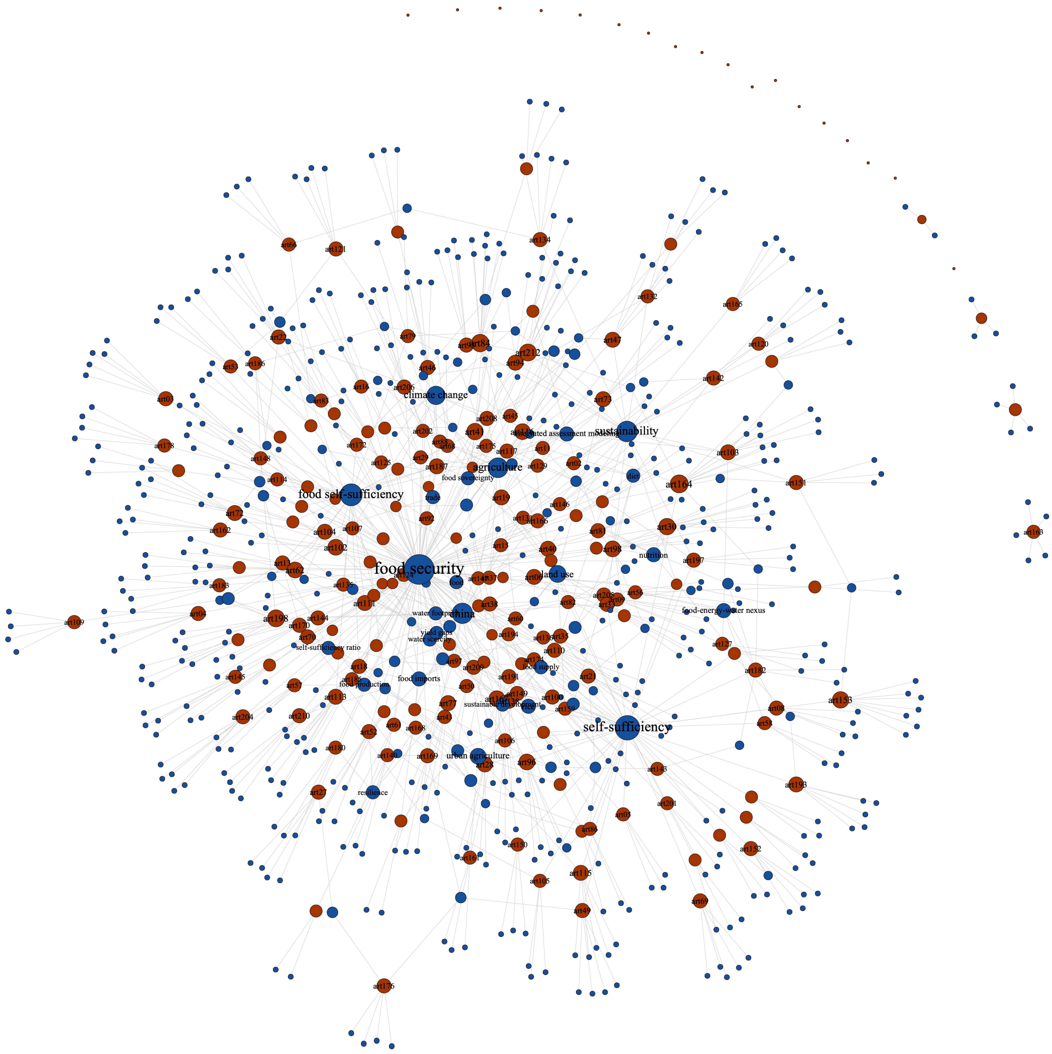

Figure 2. Two-mode network of articles and keywords.

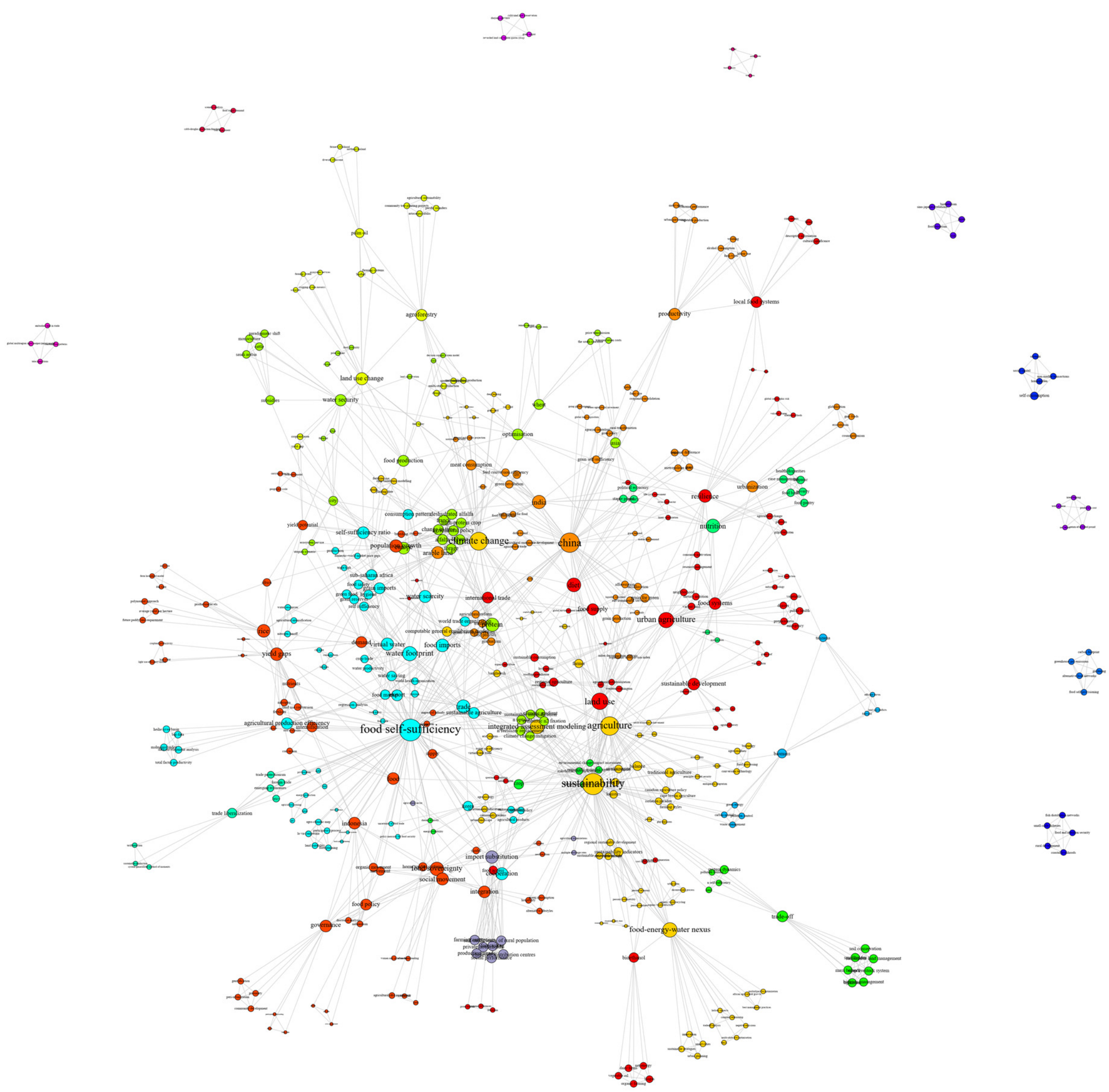

Figure 3. One-mode network of keywords (co-keyword network).

Table 2. Relevant communities based on the co-keyword network.

	Community	Size (Nodes)	Description
	Domestic production	64	This set of KWs connects works that identifies a strong dependence on imported food in areas with a high population concentration; despite the infrastructure, it is difficult to ensure the supply, consumption, and nutrients of such food [58,59]. On the other hand, the limited design of cultivation and food production in different areas of a country generates structural tensions for efficient agricultural production, increasing the scarcity and environmental impact of resources [60]. Other authors highlight the relevance of generating self-sufficiency and import mechanisms between the regions of a country. This method is a food security strategy that could guarantee a network of producers and products and could be associated with impacts on the efficient use of resources, the production of local products, local economic activation, and lower dependence on products from other countries [61–64].

Table 2. *Cont.*

	Community	Size (Nodes)	Description
	Society	60	The works linked in this subgroup all observe the social transformations derived from individuals' mobility between rural, peri-urban, and urban areas [65,66], which may indicate challenges in the supply and food-demand changes in consumption patterns. He et al. [67] found that the expansion of urban areas has impacted the production of rural plantations, stressing food production. In contrast, other studies indicate that these transformations have fostered an exploration of the region's potential within communities, mainly among those that live in urban areas, thereby improving technical knowledge, gender inclusion, and income generation [26,68,69]. Additionally, Steenbergen et al. [58] established that the interactions between local actors influence their relationships, resulting in improvements in the use of existing practices and generating long-term self-sufficiency.
	Food production	42	The relationship between work in this area is based on traditional methods for the intensification of agriculture. In this sense, this subgroup is related to actions to reduce the impact in the food system [12,57]. The contribution of Suter et al. [70] found that including a combination of plants can make sustainable products more efficient and reduce or replace the use of fertilizers. In contrast, Bucagu et al. [71], Ji et al. [72], and Traore et al. [73] considered the allocation of agro-ecological zones in cities through medium and small farms to represent an alternative for optimizing resources and spatial distribution, controlling production costs, improving the food distribution system, and reducing multiple exchange rates.
	Environment and nature resources	77	This was the most significant community that scientific research has focused on. These KWs also allowed us to detect works that address the global ecological crisis. This substructure allowed us to determine three factors: sustainability, climate change, and agriculture. For sustainability, proposals based on computable general equilibrium models and the circular economy were reported; these models promote consumer practices with social and natural benefits [2,31]. Climate change was identified as a relevant factor that affects the performance of grain and vegetable production [74]. In this framework, the link between energy, water, and food should be prioritized through technological proposals in regions with restrictions on these resources, or the consumption of such resources should be reduced [63,75,76]. Subsequently, improvements in agriculture enabled human activity to raise awareness of the environment to reduce the effects of waste and greenhouse gas emissions [77–79].
	Management	11	In the nodes of this group, contributions to sustainable management in agricultural processes were distinguished to improve the state of the soil and practices for the care and development of plantations, identify the main actors, and increase community awareness. Support models for decision making are one of the main components needed to handle and analyze a heterogeneity of data and problems related to the variance of resources, commercialization, and production trends [71,80–82]. However, no contributions were identified that indicate learning or mechanisms for the relationship management and intervention of different actors.

Table 2. *Cont.*

	Community	Size (Nodes)	Description
	Governance and policy	67	The KWs in this subgroup consider food regulations to be a critical issue for domestic agricultural production and the growth of food trade in any region. Additionally, a gap is inferred between the methodologies and practices used to achieve a food policy that regulates and monitors the four trends found in the group of security community nodes [69,83]: auto-sufficiency [61,84,85], sustainability [54,86,87], and sovereignty [88–90]. Schreer and Padmanabhan [14], Agarwal [91], and Li et al. [32] highlighted the effective application of food policies to strengthen the relationship between the four aspects. The contributions of Vaghefi et al. [92], Clapp [93], and Zhan [94] established the importance of encouraging and supporting small producers to incentivize domestic production against foreign products. In this way, Sapozhnikova [95] and Scharf [96] identified the government as an actor that facilitates the conditions for the development of small producers, not only in the economic sphere but also in achieving their organization and connections in the market. On the other hand, Schwanitz et al. [97] considers the synergy between food and energy policies as a method for the rational use of natural resources. In this matter, no contributions stand out for developing the mechanisms and processes for regulation and mediation, e.g., through government action at its different levels.
	Health and nutrition	12	This research focused on issues such as hunger, calorie deficiency, malnutrition, overweight, and obesity [98]. Martin et al. [99] highlighted the need to develop a basic food basket that can address the causes of hunger and improve the quality and diversity of diets; the authors also considered the adaptation of agriculture to increase food security, health, and the vital stability of societies. Petry [100] and Maltz [101] highlighted local production as an alternative to ensure the presence of nutrients in agricultural products and maintain resilience in urban areas.
	Urban agriculture	73	Urban dynamics establish the need to increase the food supply. In this sense, international organizations such as the UN and the World Bank highlight the importance of reducing the impact that cities have and helping them contribute to sustainable development. The contributions of Blandford et al. [102], Brombin [2], Ward [30], Huang et al. [103], Loon et al. [78], Nadal et al. [66], Wesener et al. [104], and Sapozhnikova and Ryazanova [95] identified some benefits in urban agriculture to support these issues, such as recycling and minimizing waste, efficiently using water, and conserving energy; reducing air pollution and soil erosion; urban beautification; community building, empowerment, and solidarity; biodiversity, adaptation, and resilience to climate change; disaster prevention and relief; ecological and social urban sustainability.

Structuring Food Self-Sufficiency in Urban Areas through the VSM

This proposed unfolding of complexity (Figure 4) takes advantage of the existing political-administrative structures/divisions in most cities, as well as the common resources and information channels, such as community boards, minor mayors, community centers, units of administration, and the management of public spaces.

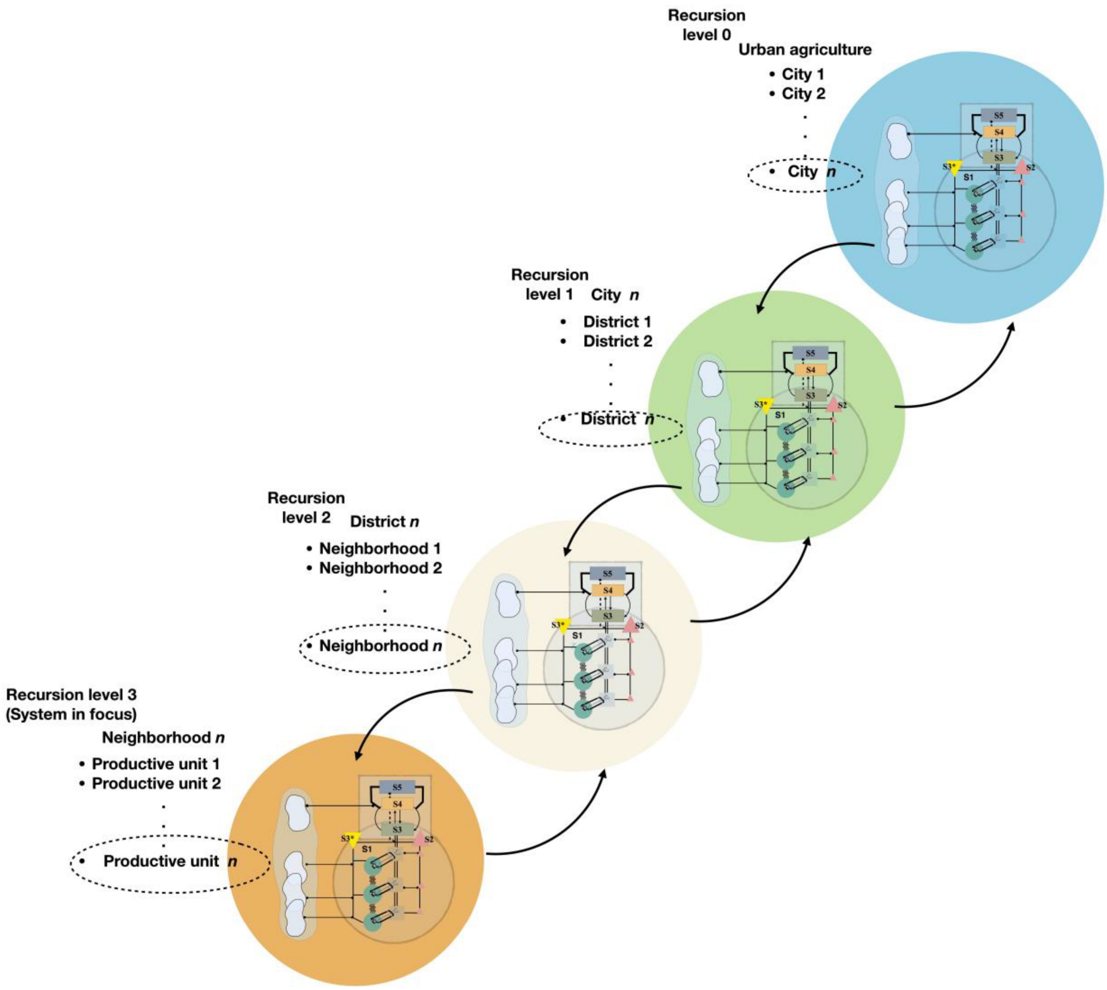

Figure 4. Unfolding complexity on food self-sufficiency in urban areas. Source: based on Espejo and Kuropatwa [53].

The entire system's basis is the "productive unit," which should ideally be constituted by an association of domestic producers, e.g., a local cooperative or neighbor farming association. The initial objective of these associations should be self-consumption, with the open possibility to offer the production surplus in the market to other productive units and the general public.

Based on the elements of Table 3, the design of the productive unit level (neighbors) is proposed, which is considered to be a 0 level or recursion (Figure 5).

Table 3. Productive Unit Transformation, Actors, Suppliers, Customers, Owners, Interveners (TASCOI).

Element	Definition
Transformation	Establish an efficient association for food production in a local urban environment
Actors	Members of the local association of producers (neighbors); local public administration, neighborhood inhabitants, urban farmers-contractors
Suppliers	Local authorities, neighbors, urban agro-contractors
Customers	Neighbors, neighborhood residents, other productive units
Owners	Neighbors
Interveners	Local authorities, local stores

Source: based on Espejo and Kuropatwa [53].

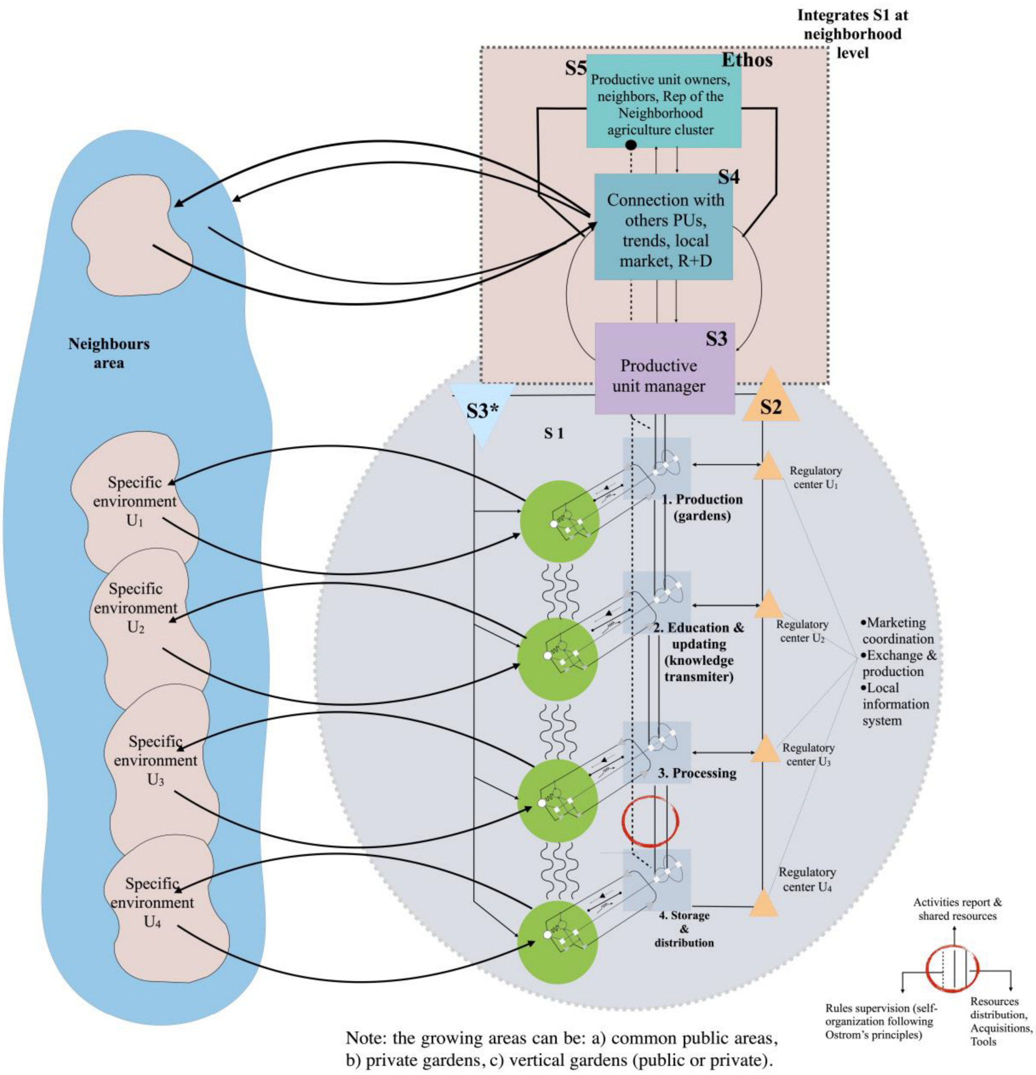

Figure 5. Viable System Model of a core productive unit.

The interactions between the components of the essential productive unit (neighbors) are explained in Table 4.

Table 4. Productive units VSM systems, roles, and functions.

System	Definition
S1—Production Area (e.g., garden)	Crop area—basic production unit at the local level (seed-harvest)
S1—Education and Updating (Knowledge Transfer (KT))	Educate and update urban farmers—knowledge transfer function
S1—Processing	Basic transformation—adding value to deliver to the local market
S1—Logistic Support	Transport of products and shared tools and implements
S2—Local Information and coordination	Local information system and artifacts, coordination of marketing, and exchange of products, implements, and tools
S3—Productive Unit (PU) Management	PU management and allocation of resources
S3*—PU Monitoring	Review of planned activities, crops, and farmer involvement
S4—PU Planning	Connection with other PUs among neighbors; observation of trends, local markets, and R + D
S5—PU Board	Definition of the ethos, identity, and rules of membership to the PU. Representatives of the local community and neighborhood agriculture cluster

As a basic unit, the zero-recursion level must be nested in an identical structure that allows it to fulfill its goal and generate synergy to positively affect food self-sufficiency in urban areas. In this sense, the components that interact in recursion level 1 (neighborhood level) are defined in Table 5 (Figure 6).

Table 5. Neighborhood level TASCOI.

Element	Definition
Transformation	Make neighborhoods sustainable, varied, and provide nutritionally balanced units of food production
Actors	Production units of the neighborhood, the local government of the neighborhood, neighborhood inhabitants, distribution channels, and neighborhood markets
Suppliers	Local mayor, production units, and public/private landlords
Customers	Units of the neighborhood
Owners	Productive units and local government
Interveners	Local stores, distribution, marketing agents, and community action boards

Source: based on Espejo and Kuropatwa [53].

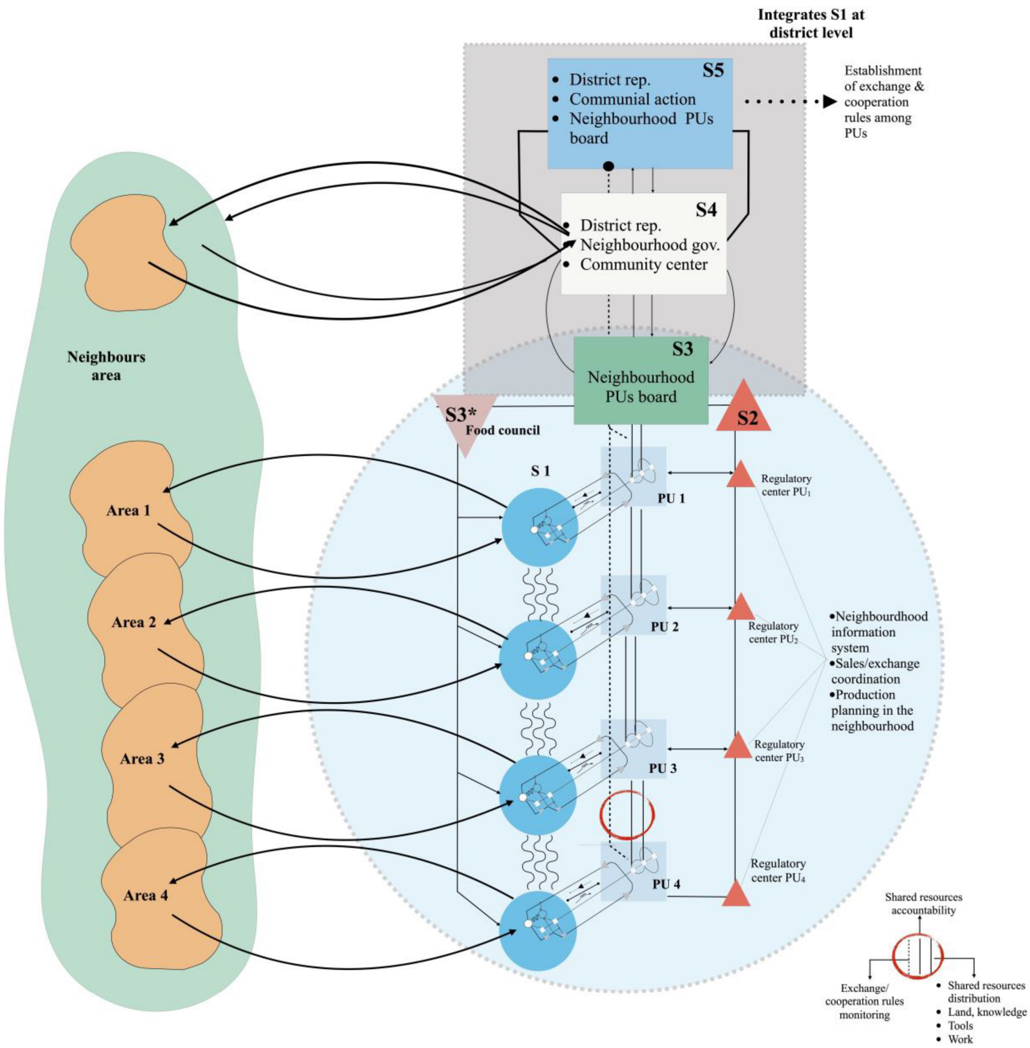

Figure 6. Neighborhood as a Viable System Model.

Table 6 suggests which actors must participate in certain VSM systems, along with their roles or functions.

Table 6. Neighborhood VSM systems and their roles and functions.

System	Definition
S1—Production Units	Crop area—basic production unit at the local level (seed-harvest)
S2—Neighborhood Information and coordination unit	Neighborhood information system and artifacts, coordination of crops, marketing and exchange of products, and implements between PUs
S3—Neighborhood Management	Neighborhood PU board/council, neighborhood food cluster administrator, allocation of shared resources, and coordination of the PUs in the Neighborhood
S3*—Neighborhood Monitoring	Review of planned activities, crops, and PU involvement
S4—Neighborhood Planning	Connection with other PUs in the neighborhood and the coordinators of other neighborhoods' observations of trends, markets, the district's food production and needs, and R + D
S5—Neighborhood food cluster Board	Definition of the ethos, identity, and rules of membership to the neighborhood food cluster. Representatives of the neighborhood government and civil representation, representatives of the PUs, and representatives of the district food cluster

To foster relationships that lead to sustainability, the spectrum of participants needs to be broadened (Figure 7). Considering this, Table 7 presents the second level or district level:

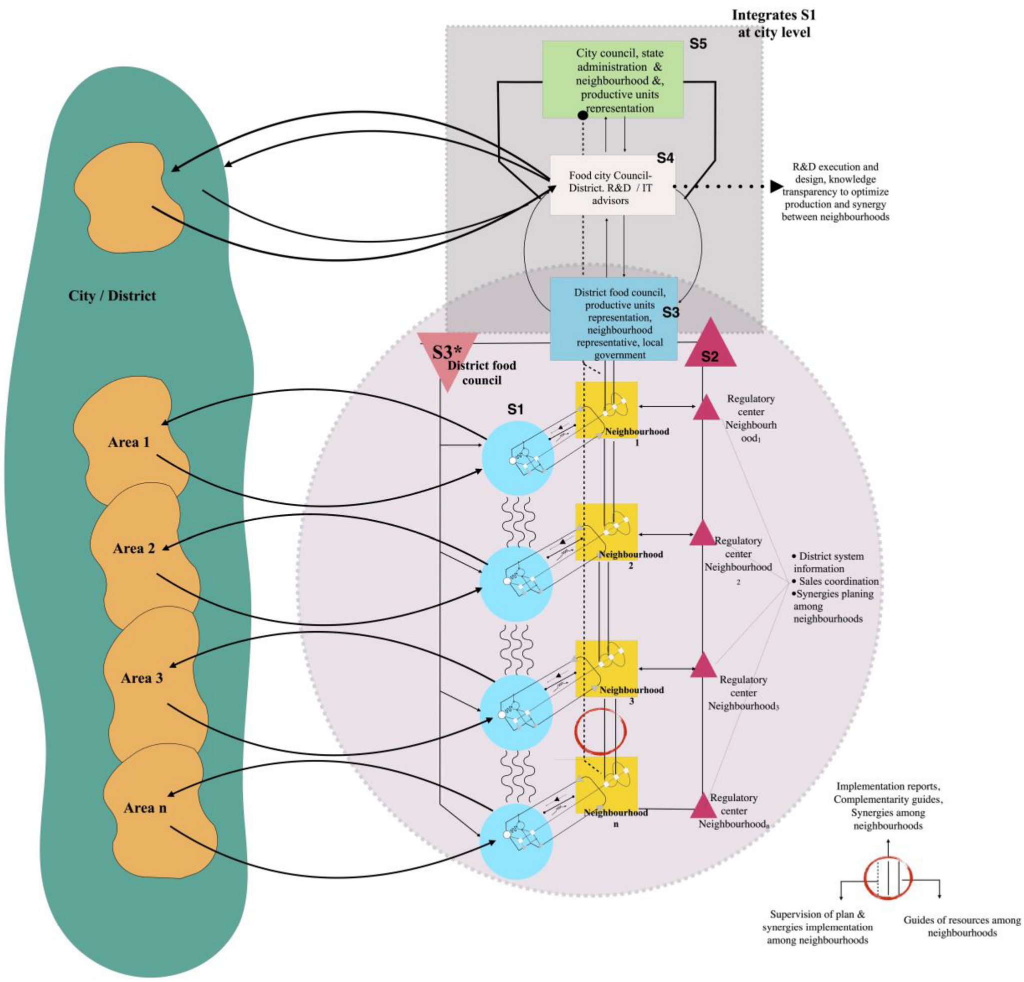

Figure 7. District as a Viable System Model.

Table 7. District level TASCOI.

Element	Definition
Transformation	Make districts integrate units that facilitate the resilience and complementarity of food production in their neighborhoods
Actors	Representatives of the city council, local governments of the neighborhoods, the local government of the district, representatives of the PUs, and operators and generators of research, development, and marketing
Suppliers	Representatives of productive units, research and development operators, and the food council district
Customers	Neighborhoods, food council, and representatives of productive units
Owners	District food administration and representatives of production units/neighborhoods
Interveners	District marketing and distribution operators and information systems

Source: based on Espejo and Kuropatwa [53].

In Table 8, the Viable System Model elements related to district level recursion are described:

Table 8. District VSM systems and their roles and functions.

System	Definition
S1—Neighborhoods Food Clusters	Neighborhoods food cluster coordination for production and trade
S2—District Information and coordination unit	District information system and artifacts, coordination of neighborhood-district food clusters, and the marketing and exchange of products
S3—District food cluster Management	District food board/council and district food cluster administrator. Allocation of shared resources and coordination of the synergies between neighborhoods food clusters
S3*—District Monitoring	Review of planned activities and neighborhood cluster involvement
S4—District Planning	Connection with other districts in the city and representatives of neighborhood clusters.Observations of trends, markets, district food production and R + D needs, and interactions with external experts
S5—District food cluster Board	Definition of the ethos, identity, and rules of membership to the district food cluster.Representatives of the district government and city government, representatives of the neighborhood food clusters, and representatives of the R + D and KT bodies

Finally, Table 9 outlines the components that should be considered at a higher level:

Table 9. City level TASCOI.

Element	Definition
Transformation	Make the city a sustainable and diversified food production space based on local synergies
Actors	Food city councils, districts, research centers, urban planning offices, food production and distribution units, and food safety, health, and sustainability offices
Suppliers	City council, land planning agencies, and universities
Customers	City districts, neighborhoods, and food councils at all levels, as well as representatives of productive units
Owners	City food council
Interveners	Universities and regulatory bodies

Source: based on Espejo and Kuropatwa [53].

According to the diagrams above, Table 10 describes the VSM elements that must be considered to propose city-level relations (Figure 8):

Table 10. City VSM systems and their roles and functions.

System	Definition
S1—Coordination of district food clusters	Coordination of the district food plans
S1—R + D/KT	Coordination, planning, and implementation of R + D/KT or the city's food system (through interactions with expert agents, e.g., universities and research centers)
S1—Planning office—land use	The administration and regulation of land use for food production (both private and public areas)
S1—Food Safety and health office	The regulation of the production and trade of locally produced food
S2—District Information and coordination unit	The city information system and artifacts, coordination of the city food production system, and an overview of the marketing and exchange of products
S3—City food council	City food board/council, district food system administrator, the allocation of shared resources, and coordination of the synergies between the district food clusters
S3*—City Monitoring	Review of planned activities and district cluster involvement; food safety and land use regulation enforcement
S4—City Planning	Connection with other districts in the city; representatives of neighborhood clusters, observations of trends, markets, district food production, and the needs of R + D; interactions with external experts
S5—City food council	Definition of the ethos, identity, and rules of membership to the city food system. Representatives of districts, cities, and regional governments; representatives of PUs and consumers; representatives of R + D and KT bodies

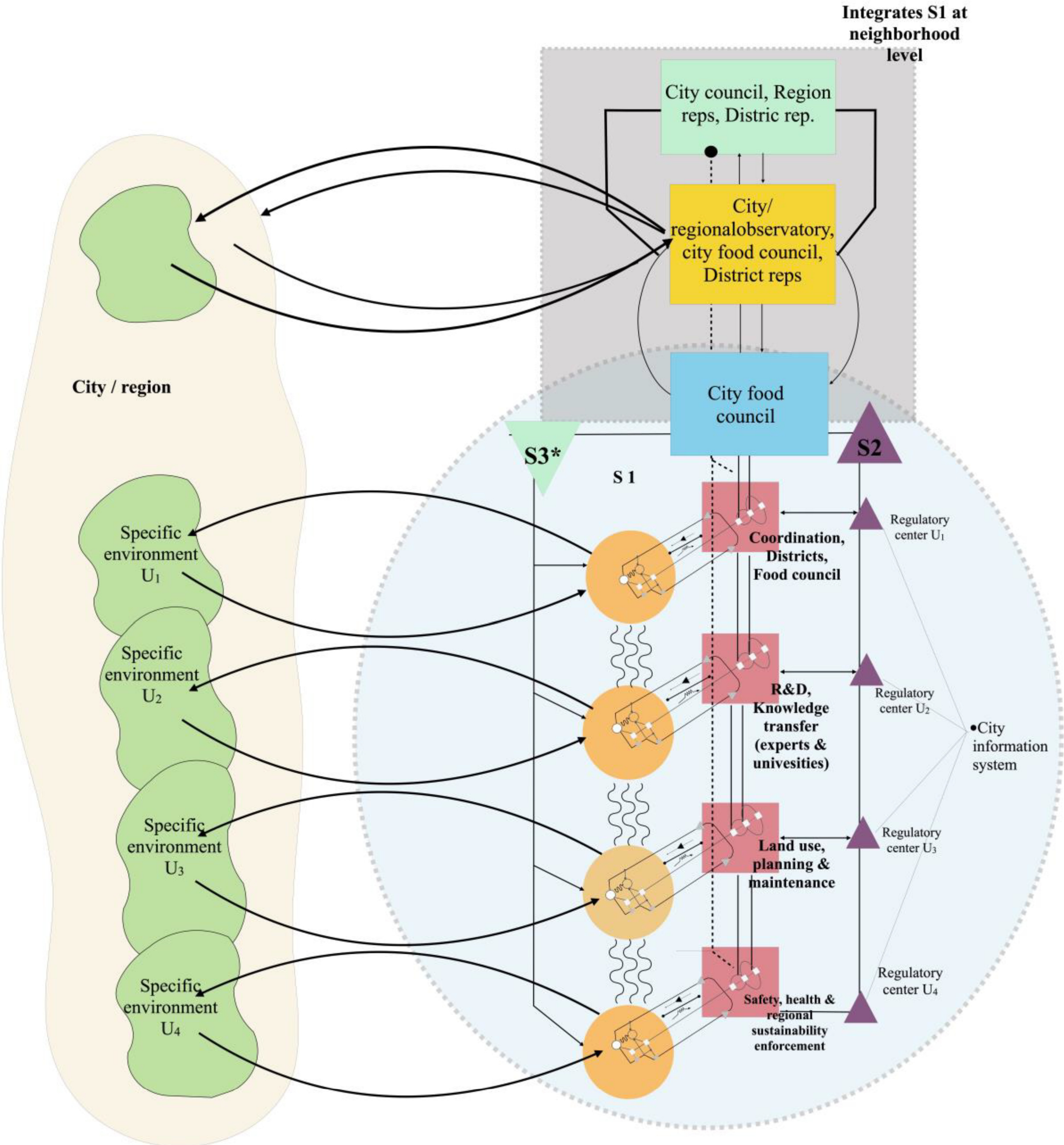

Figure 8. City as a Viable System Model.

In general, this recursive structure suggests the main communication channels and monitoring activities that can provide decentralized management and cohesive governance capable of responding to dynamic changes for sustainable urban agriculture. By providing the participation of key actors (e.g., local governments, R + D, and KT), this system could respond to challenges and limitations, such as urban planning and the use of land, through the use of an updated database of land available for use in food production, with the potential to inform policy, such as vertical and horizontal food production, related research, and the delimitation of safe areas of production, as well as the overall planning of crops and the knowledge transfer of novel food production techniques and exchange mechanisms and planning for the development of green and blue urban areas [105].

5. Discussion

Considering the methodology section, it is necessary to remember that the goal of this search was to identify patterns and the use of tools, particularly from the perspective of system science, in problems related to food sustainability and urban agriculture. Although the literature review did not focus exclusively on urban agriculture, the algorithm for community detection and its subsequent review indicated that the works that deal with urban agriculture as their central theme with a precise geographical context did not identify particularities in the spaces, techniques, forms of management, and organizational structures for food production in urban areas [10,19,28,54,105,106].

Based on the above, despite the fact that in operative terms, both the global North and South use similar spaces and techniques for urban food production (e.g., roofs, public and private urban land, vertical walls, abandoned or decommissioned urban infrastructure, hydroponics, permaculture, raised beds, square foot gardening, and crop rotation) and face similar challenges (e.g., soil and air pollution and limited space), important differences in the motivation to grow food, the technology used, the production scale, and institutional regulations and support are evident between these two contexts of urban agriculture. For instance, in cities in developing countries, the function of urban agriculture will usually be to fulfill food security and nutritional needs, usually in very limited spaces, as well as adopting innovative and often unconventional low-tech methods. In the global north, instead, urban agriculture has functions that are not strictly related to food security but instead relate to the adoption of sustainable lifestyles or the creation of social ties, such as green urban tribes, and access to high-tech solutions using intensively urban areas and infrastructures apt for, or adapted to, food production [19].

Problems related to sustainability, specifically those related to management mechanisms or urban food production and supply, present an opportunity to apply systemic thinking, more specifically, to address issues related to identifying the contextual variables that affect a problem's situation, locate unhealthy relationships, manage resources, and promote measures of control and regulation to generate actions and strategies that operationalize changes that positively affect the structure and sharing of a given system.

According to the literature review, the contributions by Steenbergen et al. [58], Viira and Roots [64], Agarwal [91], Lin [85], Zhan [94], Neilson [56], and Petry [100] made important efforts to characterize, from different perspectives, the components related to the problem of urban agriculture and how this type of agriculture can be established as an alternative for reducing the potential threats that the current provision of food generates in urban areas. Another aspect in which these authors agree (although it is an aspect that they leave unanswered) is the need to establish partnerships under a sufficiently robust organizational framework that does not depend on the kindness and goodwill of the actors but instead on systemic principles that promote autonomy and self-organization. A predominant trend was the adoption of theories or models with a reductionist perspective for the study of urban agriculture. This characteristic stood out when the studies focused on specific variables, sidestepping the relationship with the general context and when the proposals focused on solving a specific problem were out of alignment with their viability and the relevant transformation processes. Another aspect that emerged was the standard import—with some adjustments—of management or control models that were designed for other sectors or different contexts, producing imbalances in the organizations or communities in which they were applied. To narrow down the previous knowledge gaps, this article identified the minimum and sufficient structural and operational elements needed to characterize a viable urban food production system. The results suggest a socio-technical system capable of ensuring a food supply system based on its immediate context to reduce the impact of agricultural activity without neglecting the option of generating surpluses that allow those involved to operate sustainably.

Many other groups of contributions focused on the identification of actors and their involvement in the organization [14,17,20,25,39,44]. However, the mechanisms for monitoring, coordinating, and controlling each of the actors involved were not established. In this work, this last issue was solved via the presentation of a balanced organizational architecture with a generic definition of the agents, roles, and functions through the use of the VSM.

Diehl [13] identified the reasons for the associations between farmers in urban areas and how building links is a viable means of accessing resources and maintaining agricultural subsistence. The precision of this process is paramount, highlighting socio-cultural barriers as a dimension that many proposals do not characterize but which may establish greater cohesion and/or adequate ways of managing a project of this nature, as stated by Bucagu et al. [71], Niragira et al. [12], Suter et al. [70], Traore et al. [73], and Wesener et al. [104]. In this context, the present work addresses these issues and suggests some of the generic associations and links that should be present to provide cohesion and, ultimately, viability.

For the proposals that used an integral or systemic approach, the limits of the system or the object of study were often proposed as traditional organizational structures that relegate decision-making to external actors or those not closely related to the knowledge of the system. In addition, a gap in the feedback mechanisms was identified to support system problems and address their intermediate relationships with other actors in order to adapt to changes in the environment. The use of VSM corrected these issues since, by default, the design of the proposed organizational architecture provides a clear definition of its boundaries, recursive levels, and, at each one, the relevant mechanisms for monitoring and (self)governance with a multi-stakeholder and multi-level approach that matches the FAO Framework for the Urban Food Agenda [35]. Moreover, the recursive VSM architecture suggested in this work provides a generic, adaptable, and comprehensive platform for the operationalization of the FAO-Milan Urban Food Policy Pact (MUFPP; the proposed VSM architecture can simplify the mapping and implementation of all MUFPP monitoring framework indicators, with particular emphasis on those related to governance, food production, food supply and distribution, and food waste. It also offers the basic design for a multilevel information system that could facilitate the collection and consolidation of data for the remaining MUFPP indicators on sustainable diets and nutrition and social and economic equality [20], a capability not found in any other work in the reviewed literature.

The application of SNA allowed us to identify some convergences with the viable model proposed by the articles. For example, the model proposed by Scharf [96] established that the food system for urban areas requires profound changes and the adoption of a systemic perspective to plan long-term actions that contribute to sustainability in cities. In this sense, the proposed model suggests the creation of highly accessible spaces and platforms for the exchange of ideas and goods, regardless of linguistic, generational, or cultural backgrounds, as well as an increase in identification within the neighborhood, the positive impacts of the cohesion of the group (and local communities), and the connections between people. This model thus has value as a testing ground for sustainable practices and the local field of action. In this paper, the recommended VSM suggests organizational structures that could facilitate the emergence of previously identified spaces. In this sense, the VSM proposes the neighborhood as a critical building block of food self-sufficiency, considering it to be a conglomerate of interacting productive units, where the flows of raw materials, participation, motivation, and education can yield self-organization. In this context, awareness must be encouraged to achieve sustainability in terms of food production. This, in turn, will facilitate and support the agents involved in analyzing and understanding the context in which such interactions occur in their organizations.

This work coincides with that of Diehl [13], who proposed grouping typical forms of urban agriculture with community gardens, urban farms, school gardens, hydroponic systems on ceilings, and walls as the primary forms of production for a productive structure to respond to weather conditions and fulfill a specific function in a given community. Diel also suggested that urban agriculture must transition from a specific or local scope towards a scope that integrates broader geographical areas (the city-region). However, these contributions neglect the elements that would allow their implementation. Considering the above, the VSM presented in this article proposes a generic description of the different roles and functions that would allow the articulation of the basic productive unit (neighborhood) with other productive and administrative and operative levels (we did not, however, include the city-regional level). In this regard, we considered which systems and individuals should be applied as the actors that promote and regulate participation and the dissemination of knowledge.

Following Artmann and Sartison [10], urban agriculture must be integrated into society's dynamics while considering solutions based on nature. Consequently, the organizational models focused on articulating agriculture in urban areas need to address various social challenges, such as climate change, security and safety, ecosystem and biodiversity services, the control of agricultural intensification, resource efficiency, the renewal and regeneration of urban areas, land management, public health, social cohesion, and economic growth. In this context, engaging in efficient implementation requires the construction of an integrative framework, such as the definition of a clear vision for the challenges that the solution must address, the identification of the relevant actors and supporting instruments, and an evaluation of the appropriation of urban agriculture, e.g., the TASCOI in our proposed model. Following von Ow et al. [59], using the VSM, some socio-cultural and economic factors were identified. These factors are considered in our model, and we propose that they should be used to feed the channels of accountability—the transaction of resources—to improve the information capacities and the decision-making process at each level of recursion (from PUs to the city). In this case, a breakdown of the four levels of recursion favors the viability of each nested system responsible for the activities integrated into it, adding to the definition of the communication channels and the main topics to be discussed in these channels at each recursive level.

6. Conclusions

Using SNA to analyze the existing literature on urban agriculture, it was possible to form an overview on how, and with which tools, food self-sufficiency and urban agriculture have been studied. Moreover, SNA allowed us to identify the gaps that constitute an opportunity to contribute to further developing a dialogue, particularly in the organizational and structural domains.

In this sense, through the detection of thematic communities, it was possible to review contributions that identified components related to contextual, operational, and management elements. Subsequently, some of these thematic components were included in the VSM models for each level of recursion, and we sought to contribute to both by suggesting different interactions between the contextual and management elements mentioned by other authors for the proposal of generic operationalization including regulatory mechanisms via the VSM architecture. In this process, we discovered that the use of the VSM was effective and able to satisfy all the requirements for the management of sustainable urban food production systems according to the parameters stablished by the FAO.

From a methodological point of view, the integration of SNA and VSM enriched the application of a systemic perspective to the study of urban agriculture by providing a framework that includes the systematic identification of key factors, the construction of robust responsive organizational structures with a multi-stakeholder and multi-level approach and (eventually), the suggestion of generic (organizational) roles and functions that could facilitate the implementation of urban agriculture. In this sense, the general objective of this work was achieved.

Consequently, the proposed framework can support subsequent work that can be applied to various contexts of urban agriculture with minimal adjustments. In this sense, we believe that the ideas developed in this article may be useful to support actors involved in the study and promotion of urban agriculture by inviting further exploration of the use of systems thinking and organizational cybernetics, moving away from a reductionist or functionalist model to solve problems with a high impact on social systems.

In general, this works offers—and is limited to—a conceptual contribution to the study of the organizational aspects of urban agriculture, based on the design of an organizational artefact inspired by organizational cybernetics, for which key state-of-the-art design elements were incorporated from the literature published from 2015 to 2019. This limitation, however, invites the creation of further studies focused on the adoption of different approaches and the addition of other tools to the basic VSM design (e.g., using SNA to analyze the social interactions between the recursive levels, the use of partial least square modeling to identify key variables affecting the roles/functions at all recursive levels, and using the Systems Dynamics to model and assess the viability and resilience of urban food production systems). These additions to the current proposed use of VSM could enhance the understanding and management of urban food production systems, strengthen our ability to predict behaviors within these systems, and suggest/identify possible affiliations and links that could prevent problems and ruptures or enhance cohesion and resilience, ultimately sharpening the adaptation capacity, viability, and sustainability of any urban agriculture setting.

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