

Article

Integrated Decision-Making of Urban Agriculture within the Greyfield Regeneration Environments (UAGR)

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Abstract: Various urban environmental and social challenges have emerged during the rapid urban development. Urban agriculture has emerged as one of the practical solutions to address these urban issues and climate change. This study aims to establish a decision model for urban agriculture regeneration that can be applied to improve the implementation of related projects. The study first reviews existing research on Urban Agriculture within the Greyfield Regeneration Environments (UAGR) and outlines the processes involved, including project initiation, construction, and operation management. It identifies 25 factors influencing UAGR and employs the Fuzzy Delphi method (FDM) to prioritize them based on expert judgments. Subsequently, the interpretative structural model (ISM) analysis method is applied to analyze the interrelationships among the 11 most important factors. Matrix operations and MATLAB programming are utilized to establish the influence relationship model based on expert questionnaires to determine the influence between each pair of factors. This results in a hierarchically structured decision model for UAGR. Finally, the decision-making model is applied to analyze the case study in Shanghai and Hangzhou. As urban agricultural activities are proliferating in rapid urbanization, the establishment of a decision-making model for UAGR can offer practical guidance to practitioners, facilitating the development of urban agriculture and mitigating climate change.

Keywords: urban agriculture; urban regeneration; fuzzy delphi method (FDM); interpretative structural model (ISM); decision-making



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1. Introduction

1.1. Background and Problem

1.1.1. Crisis in Contemporary Urban Development

Urbanization, a significant trend since the twentieth century, has led to rapid urban population growth and expansion. However, this growth is not without its challenges. The increasing demand for resources like food, water, and energy places immense strain on the Earth's ecosystem, as urban areas rely heavily on industrialized production and global trade. This reliance contributes to unsustainable resource usage, leading to environmental degradation and climate change. Urban areas also face various challenges, such as water scarcity, pollution, and heat islands.

In response, many countries are shifting their urban land policies towards managing existing resources rather than expanding further. Strategies include reclaiming abandoned land and revitalizing built-up areas through brownfield and greyfield regeneration, as well as infilling vacant lands [1]. This urban regeneration is essential for enhancing regional development competitiveness and aligning with sustainable development goals, addressing environmental and social concerns. Such initiatives, often driven by government intervention, aim to improve urban areas and promote a more sustainable urban development model [2].

1.1.2. Urban Agriculture on the Rise

Since the 1960s, modern agriculture has heavily relied on chemical fertilizers, pesticides, fossil fuels, and gene technology, prioritizing efficiency over sustainability [3]. While this approach has boosted food production, it also contributes significantly to greenhouse gas emissions, with the agricultural sector alone responsible for a considerable share, especially in countries like China. Moreover, urban expansion encroaches on agricultural land, threatening food security and prompting the search for self-sufficiency solutions. Urban agriculture, exemplified by projects like the Southeast False Creek Olympic Village in Vancouver, offers promising alternatives, promoting food self-sufficiency and community well-being [3].

Urban agriculture, also known as metropolitan agriculture, encompasses practices such as urban farming and is defined as a specialized form of agriculture found within or on the outskirts of cities. The term was officially documented in Japan in 1930, with Shiro Aoshika providing a definition in 1935, describing it as agriculture occurring within industrial, commercial, and residential areas within a city, directly influenced by the urban economy [4]. Since 1977, when American agricultural economist Alanis introduced the concept, urban agriculture has garnered attention in the urban studies community [5]. This paper adopts Mudgett's definition, stating that urban agriculture is an industry situated within or on the outskirts of cities and towns, utilizing natural and human resources to produce, process, or sell various food and non-food products or services for the city. The focus is on agricultural activities within the built-up area of the city, as these activities are more closely intertwined with urban development and, thus, more valuable for study.

In China, urban agriculture represents an integrated approach primarily observed in large- and medium-sized cities. This involves the direct production and processing of agricultural goods for urban consumption alongside ecological buffering and waste reduction [6]. Additionally, it serves various service functions, such as tourism and recreation. Urban agriculture places significant environmental demands, particularly concerning soil quality and irrigation water. Hence, grey and vacant lands play a crucial role in urban agriculture development, offering opportunities for socio-environmental benefits within urban areas. This interdisciplinary approach underscores the potential of urban grey land regeneration to yield positive outcomes within urban landscapes.

1.2. Urban Agriculture in Regeneration Environments

1.2.1. The Intersection of Urban Regeneration and Urban Agriculture

Over time, the relationship between agriculture and urban planning has evolved significantly. Concepts such as sustainable agriculture and agro-urbanism have emerged, emphasizing the integration of agricultural practices into urban areas [7]. While efforts to repurpose abandoned urban land have been made, challenges persist due to contamination and high remediation costs. Recent research explores dynamic process planning and the combination of phytoremediation techniques with agriculture to transform contaminated urban areas into productive spaces [8]. Despite this progress, there remains a need for a comprehensive theoretical framework and practical projects for urban agriculture utilizing the vacant area. This research aims to explore the potential of integrating agronomy and urban planning in urban regeneration processes. Studies have demonstrated that integrating planning and technology can overcome challenges and optimize sites, inspiring new approaches to urban regeneration with agriculture. For example, Whiteman proposed decision strategies for vacant lot reuse in managing urban vacancy [9].

1.2.2. Decision-Making of Urban Agriculture in Regeneration Environments and Progressive Urban Regeneration Processes

Decision-making, in this study, termed "programming," aims to provide a scientific basis for future project design and operation, utilizing rational analysis and empirical testing to quantify objectives and address subjective biases [10]. Agrarian urban regeneration involves revitalizing abandoned urban land parcels for agricultural cultivation,

typically on disused commercial and industrial sites [11]. The decision-making process for urban agriculture in Greyfield Regeneration Environments involves making scientific arrangements for projected objectives, planning, design, implementation, and follow-up management before project implementation.

Progressive urban regeneration processes are essential for advancing urban agriculture development. Flexible approaches in planning accommodate the dynamic nature of urban development, maximizing benefits and minimizing drawbacks. Complexity-based decision-making frameworks address the diverse range of stakeholders and considerations involved in greyfield regeneration, ensuring successful and sustainable outcomes.

1.3. Research Aim

The objective of this study is to establish an Urban Agriculture in Greyfield Regeneration Environments (UAGR) framework using the Integrated Multi-criteria decision-making (IMCDM) method. Specifically, develop a logical decision-making framework based on a dynamic decision-making model. This framework serves as a tool to explore whether decision-making processes and strategies, including the embedding of agricultural activities in various phases of urban greyfield regeneration, can achieve sustainable benefits across social and environmental aspects and adapt to and mitigate the effects of climate change. It encompasses qualitative regeneration objectives, a regeneration process system, and their interrelationships.

1.4. Research Design and Methodology

The research design consists of four interconnected components. Firstly, systematically studying various aspects of the urban regeneration process in urban agriculture and analyzing the influencing factors. Dimensions of evaluation are identified through a comprehensive literature analysis, encompassing Internet publications, project outcomes, case studies, the academic literature, and trade journals. Second, establishing a realistic decision-making model for urban regeneration with agriculture using modern mathematical tools. Key indicators are chosen within the intention model using the fuzzy Delphi method (FDM). FDM integrates fuzzy set theory and the Delphi method, employing cumulative frequency distribution functions to convert expert predictions into fuzzy numbers. Through fuzzy synthesis, the maximum–minimum range is established to optimize key objective selection, mitigating vagueness and uncertainty inherent in survey responses. Then, Interpretative Structural Modeling (ISM) is employed to analyze interdependencies between indicators for decision-making on UAGR. ISM elucidates the impact of one assessment indicator on others, clarifying the evaluation model's order and direction based on system relationship complexity. Finally, apply the established UAGR Decision-Making model to analyze the actual case in Shanghai and Hangzhou and derive practical suggestions for practice. Multi-criteria decision-making can effectively address the complex and multi-attribute issues in the UAGR process. Therefore, it is used for result determination. Decision-making information is obtained by organizing basic information and conducting necessary investigations.

2. Literature Review on Urban Agriculture: A Corresponding Strategy for Cities in the Context of Climate Change?

2.1. Impacts of Climate Change on Urban Agriculture

Evidence shows that climate change results in shorter cold periods in semi-arid areas, hotter summers, more frequent floods and droughts, increased pests and diseases, coastal erosion, and saltwater intrusion in low-lying areas, reflecting a significant warming trend in the region [12]. Evidence shows that climate change impacts urban agriculture with consequences such as reduced precipitation, higher temperatures, and decreased bore-hole yields. Farmers adapted by repeatedly planting, watering plants at night, renting animal space with better water access, buying supplementary livestock feed, promoting drought-tolerant seeds, enhancing water harvesting, and implementing better livestock

management practices [13]. The findings underscore the importance of carefully selecting crops for urban agriculture and using environmentally sustainable water sources to potentially decrease future water and energy footprints [14]. Despite climate challenges, urban agriculture mainly involves raising animals like chickens, sheep, and goats alongside growing crops such as maize, yam, beans, cabbage, and pumpkin [15]. People also found that southern areas have better environmental performance than urban agriculture in northern climates [16]. Overall, the reviewed literature agrees that climate change impacts urban agriculture across all stages, from production to processing, storage, and distribution, with variations in the extent and severity of these impacts among different regions, emphasizing the need for context-specific adaptation and mitigation strategies rather than universally applicable ones [17]. Methodologically, Google Earth Engine was usually employed to investigate the intertwined impacts of urbanization and land cover change on urban climate and agriculture by determining the urbanization and greenness indices using scripts [18]. Lahcene uses three interconnected indicators, population growth, climate change effects on agriculture, and the NDVI (Normalized Difference Vegetation Index), and reveals the impact of these factors on agricultural practices [19].

2.2. Impact of Urban Agriculture on Climate Change Mitigation

The literature on urban and peri-urban agriculture (UPA) shows growing consensus on its potential for adaptation but less agreement on its role in mitigating climate change [20]. UPA is an emerging field aiming to enhance food security and reduce the impacts of climate change, thereby improving urban resilience and sustainability. Studies estimate the potential for climate change mitigation, such as CO₂ reduction and sequestration, and adaptation measures, like reducing Urban Flooding and Urban Heat Islands through the development of new UPA areas. Despite the urban density, these areas have the potential to produce enough vegetables for residents and enhance climate change mitigation and adaptation if converted into agricultural zones [21]. Mensah, J.K. explored the potential of urban agriculture (UA) in enhancing urban economies and microclimates [22], especially in terms of water productivity in urban rooftop agriculture [23]. Different irrigation methods also impact plant water productivity in urban rooftop agriculture. Other authors are investigating the hypothesis that food production in high-demand locations can mitigate climate change and address food insecurities by exploring new cultivation methods [24]. Urban agriculture and agroforestry systems, as part of multifunctional landscapes, offer various benefits, including supporting urban climate improvement, short food chains, fresh food provision, economic growth, biodiversity conservation, and therapeutic qualities [25].

2.3. Climate Adaptation in Urban Agriculture

Urban and peri-urban agriculture are increasingly recognized as solutions for adapting cities to global climate change and addressing food insecurity in impoverished areas [26]. Strategies such as knowledge management for climate change adaptation are being implemented to enhance urban farming [27], along with Climate Smart Agriculture practices bolstering resilience [28]. While still gaining traction, there is a growing acknowledgment of urban and peri-urban agriculture (UPA) as crucial for both climate change adaptation and mitigation efforts [29]. In this regard, UPA is recognized as a resilient agro-urban system, yet agricultural practices can disrupt the local ecosystem, emphasizing the need for balanced development between built environments and agriculture in peri-urban areas [19].

Nevertheless, research has also discovered that urban agricultural expansion and climate affect nutrient cycling and loss in urban ecosystems [30]. Climate change and urban growth may also lead to water competition between cities and agriculture [31]. Climate policies could lead to uneven socio-economic impacts across different regions, potentially hindering their effective implementation if not properly addressed [32]. These findings display a synergistic perspective on urban agriculture and urban development.

3. The Processes and Influencing Factors of UAGR

3.1. Identification of Multiple Benefits from UAGR

From a sociological standpoint, UAGR can mitigate excessive gentrification and promote equitable development by preserving social spaces, enhancing quality of life, and addressing the needs of vulnerable groups. Urban regeneration, inherently dynamic and multifaceted, often exhibits tendencies toward gentrification and social exclusion in certain areas. To counteract this, policy-makers must adapt strategies to optimize neighborhood spatial structures and ensure the compatibility of agricultural and cultural activities within urban agriculture development. By incorporating agriculture into greyfield regeneration projects, cities can effectively retain the original labor force, mitigate population displacement, and maintain social cohesion by preserving local social networks. Moreover, such initiatives foster social and environmental justice by enhancing accessibility to green spaces, thereby safeguarding the quality of life, material security, and decision-making rights of marginalized communities. Additionally, UAGR can address the needs of aging populations by providing employment opportunities, educational functions, and therapeutic benefits, ultimately contributing to their overall well-being [33]. Alon-Mozes examines urban agriculture in Israel as a form of civic agriculture [34]. It emphasizes the role of civic agriculture as promoting civic values, such as commitment to the public at large, as well as enriching self-fulfillment, rather than emphasizing the more common civil agriculture aspects of production and marketing. The paper suggests three cycles of civic agriculture expressions: the national, the community-based, and the personal.

Studies on urban agriculture suggest that developing agriculture on grey and vacant land can mitigate biological and chemical food pollution, making it a preferable option for urban agriculture within built-up areas. Urban agriculture benefits from scientific and technological advancements, as well as locational advantages, facilitating safe food production and transportation within urban environments while minimizing biological food pollution. Unlike brownfield sites, which often harbor industrial or urban pollution, grey and vacant lands offer less contaminated soil, reducing the risk of chemical food pollution from soil, irrigation water, and fertilizers. Thus, prioritizing agriculture on such lands aligns with environmental sustainability goals and ensures food safety in urban areas.

Besides the socio-environmental benefits, renewing land with agricultural activities also contributes to the comprehensive utilization of urban space, the development of green infrastructure, and the creation of livable cities, fostering coordinated urban–rural development. Urban agriculture optimizes spatial planning and design by efficiently utilizing underutilized urban spaces, such as roofs, walls, and roadside areas, for agricultural purposes. Moreover, UAGR enhances the sustainability of urban infrastructure systems, contributing to climate optimization and sustainable urban development. From a smart growth perspective, integrating agriculture into urban neighborhoods enhances community vitality, promotes economic opportunities, and fosters environmental benefits. Additionally, UAGR preserves traditional lifestyles and values in declining areas, promotes urban–rural integration, and balances the allocation of public resources, ultimately fostering a harmonious relationship between urban and rural areas.

3.2. Identification of the Process for Urban Regeneration in Urban Agriculture

Urban agriculture and urban regeneration (UAGR) aim to combine urban agriculture with urban regeneration to develop urban agriculture and enhance the urban environment within the city's built-up areas. Currently, urban regeneration activities often rely on subjective empirical judgments, which can lead to project failure without clear decision-making structures. Therefore, establishing an objective and reasonable decision model is crucial for assessing the role of various influencing factors in the urban regeneration process. Research on decision-making in urban regeneration with agriculture is limited. Atkinson proposed a brownfield urban regeneration model focused on the pathways of benefits conveyed during the regeneration process to inform decision-making and avoid discrepancies between preset targets and actual implementation [8]. The study

emphasizes identifying social and environmental benefits arising from urban brownfield site regeneration and distinguishing between outputs and outcomes. The process of UAGR involves distinct phases, including project inception, regeneration construction, and operation and management. However, there is a tendency to focus on abstract outcomes rather than concrete outputs, leading to a lack of regeneration results. This paper delineates the UAGR process into these three main stages based on the existing literature.

3.2.1. Inception Phase of UAGR Project

During the UAGR Project Inception Phase, a thorough analysis of the physical and social environment is imperative to inform project planning and design. This involves assessing the ecological condition of the site; monitoring air, soil, hydrology, and biodiversity indicators; and understanding land ownership and surrounding facilities. Equally important is understanding local laws, regulations, and government support, as well as fostering community engagement to establish communication channels and garner support from residents and community organizations.

3.2.2. Construction phase of the UAGR Project

In the construction phase, project design and construction are executed based on the insights gathered during the inception phase. Design considerations include remediation of site contamination, integration with local needs and environmental conditions, and provision of green spaces and agricultural facilities. Construction involves implementing the site design, including landscaping, soil preparation, procurement of agricultural tools and seeds, and construction of pollution treatment and waste management facilities.

3.2.3. Operation and Management Stage of UAGR Project

In the UAGR operation and management stage, a dedicated management team is established to oversee daily operations, facilitate resident engagement, and organize community activities. This team plays a crucial role in coordinating farming activities, managing waste disposal, and organizing agricultural product fairs. Additionally, efforts are made to promote community cohesion through cultural events, agricultural skills training, and science education programs. Effective external communication and publicity efforts are essential to maximize the project's impact and foster further development. Overall, the process of UAGR involves comprehensive planning, stakeholder engagement, and sustainable management practices to create vibrant and resilient urban agricultural spaces.

3.3. Identification of Factors Influencing Decisions in UAGR

The research topic of this paper revolves around the decision-making process of UAGR, aiming to identify and analyze the influencing factors that affect the regeneration process and outcomes. To achieve this, the study focuses on extracting relevant factors based on the stages of UAGR and analyzing their interrelationships. Through this process, the author identifies 25 influencing factors, outlined in Table 1, to form a theoretical model that aids in the decision-making of UAGR.

Table 1. Initial framework for potential factors affecting UAGR.

Phases of UAGR	Factors
Project initiation phase (A)	Permissibility of local regulations (A1)
	Local government regulatory tolerance (A2)
	Clarity of land tenure relationships (A3)
	Original environmental condition of the land (A4)
	Land location conditions (A5)
	Strength of ties with the local population (A6)
	Strength of links with local community organizations (A7)

Table 1. Cont.

Phases of UAGR	Factors
Updating the construction phase (B)	Degree to which the design incorporates the needs of the population (B1)
	Degree of design integration with original site (B2)
	Degree of design integration with the local environment (B3)
	Design aesthetics (B4)
	Quality of site construction (B5)
	Filled soil mass (B6)
	Utility of agricultural tools (B7)
	Utility of pollution treatment facilities (B8)
	Sustainable facility utility (B9)
Operations management phase (C)	Operational capacity of managers (C1)
	Participation of the population in planting (C2)
	Environmental adaptation of planted crops (C3)
	Crop diversity (C4)
	Extensiveness of agricultural marketing channels (C5)
	Degree of implementation of agricultural knowledge and skills training (C6)
	Degree of popularization of science education for children (C7)
	Degree of community cultural activities (C8)
	External visibility (C9)

4. Integrated Decision-Making Methods

4.1. Overview of Decision-Making Methods in Urban Agriculture

Studies often focus on combining geographic information technology with multi-criteria decision modeling at the spatial planning level. For instance, Haloui et al. utilized field surveys and spatial multi-criteria decision-making analysis to prioritize neighborhoods for community garden design [35]. Other studies employ a Geographic Information System (GIS), Analytical Hierarchy Process (AHP), and Multi-criteria Evaluation (MCE) for determining suitable locations for urban farming, pollution avoidance, and land-use planning [36–39]. Collaborative and participatory models are also considered for urban forest management [40], and systematic stakeholder-driven approaches are used for strategic siting through Multi-criteria Decision Analysis (MCDA) [39]. In recent years, there has been an emergence of studies focusing on modeling and visualizing decision-making processes using agent-based modeling [41], Interpretive Structural Modeling [42], robust optimization [43], and spatio-temporal modeling [44]. However, fewer studies consider the entire decision-making process of urban agriculture at the regeneration level. Hosseinpour proposed a decision-making framework integrating Value Engineering, Risk Management, and multi-criteria decision-making techniques for urban park development based on urban agricultural principles [45]. Since their proposal, the fuzzy Delphi method and explanatory structural model have found widespread application across various fields. However, in the realm of urban regeneration decision-making, their use remains limited. Wang (2012) developed a decision analysis model for district revitalization and regeneration (DRAR) using the fuzzy Delphi method combined with Interpretive Structural Modeling (ISM) and network analysis based on benefits, opportunities, costs, and risks (BOCR) [46]. This approach aims to simplify complex multi-criteria decision-making problems such as urban regeneration into quantitative analytical problems, providing assistance to decision-makers in this field.

The fuzzy Delphi method and ISM have increasingly been adopted in urban regeneration research. Dong optimized the evaluation content and standard system for historical and cultural city protection planning using the fuzzy Delphi method [47], while Yang constructed a framework for evaluating cognitive differences in neighborhood conflict behaviors based on the fuzzy Delphi method [48]. Liu applied ISM to analyze risk factors affecting demolition and reconstruction projects in old urban residential areas [49]. Cheng used ISM to construct a structural model of factors influencing the level of service of public bicycle stations [50]. Xie employed the ISM-ANP-Fuzzy method to evaluate interface

risks in urban rail transit PPP projects [51], and Sun Ye developed a comprehensive risk evaluation model for urban rail transit projects in PPP mode based on ISM-ANP-gray clustering [52].

4.2. Fuzzy Delphi Method (FDM) Methodology

The fuzzy Delphi method, an evolution of the Delphi method, utilizes multiple rounds of anonymous expert opinions to reach a consensus. Traditionally employed for forecasting, it also aids in establishing evaluation index systems and determining specific indicators. However, the Delphi method suffers from drawbacks like time consumption, high costs, low response rates, and potential opinion distortion [51]. In response, the fuzzy Delphi method integrates fuzzy set theory to address complex problem-solving, incorporating fuzzy metrics, identification, reasoning, control, and decision-making [53]. By applying statistical analysis and fuzzy operations, expert opinions are transformed into fuzzy numbers, facilitating more objective and reliable conclusions. This study employs the double triangular fuzzy number method, which assesses consistency through gray zone checking values, streamlining traditional approaches for quicker and more accurate conclusions. See Figure 1 for a geometric schematic of the double triangular fuzzy number method, with the method's steps outlined below.

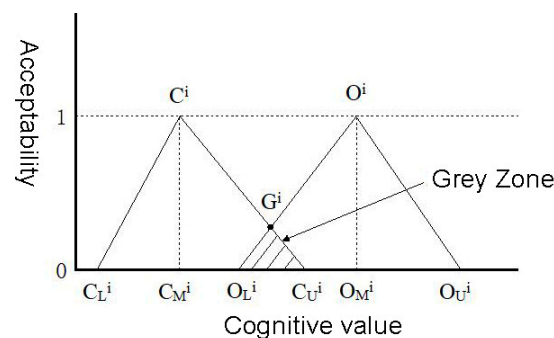


Figure 1. Schematic diagram of double triangular fuzzy number [49].

(1) To begin the evaluation process, we list all indicators to be assessed and establish scoring rules. The importance of each indicator is expressed as a natural number, with higher numbers indicating greater importance. Experts are asked to provide a scoring range for each indicator, where the smallest value represents the most conservative assessment, and the largest value denotes the most optimistic assessment. Experts must then select a single value within this range to indicate their compromise assessment of the indicator.

(2) The evaluation results from all participating experts were subjected to statistical analysis, where optimistic, conservative, and single evaluation values for each indicator were computed separately. Extreme values, excluding those exceeding twice the standard deviation of each statistical indicator, were eliminated to prevent them from unduly influencing the statistical outcomes. For each indicator, the minimum conservative assessment value is represented as C_L^i , the geometric mean as C_M^i , and the maximum as C_U^i . Similarly, the minimum optimistic assessment value is denoted as O_L^i , the geometric mean as O_M^i , and the maximum as O_U^i .

(3) The gray zone test value is computed to ascertain the convergence of expert opinions. This value is determined by the following equation:

$$A = M^i(O_M^i - C_M^i) - Z^i(C_U^i - O_L^i) \quad (1)$$

When $A > 0$, indicating the presence of the gray area in Figure 1, it signifies that the assessment experts' opinions on the indicator converge, and the questionnaire data are deemed credible. Conversely, when $A < 0$ or $A = 0$, and the gray area in Figure 1 is absent, it suggests that the assessment experts do not share the same opinion on the indicator. In

such cases, a second round of questionnaire research is necessary, along with the feedback of the questionnaire analysis results from the first round to the experts. This process is repeated until all A values of the indicators exceed 0, signifying the convergence of all experts' opinions and the attainment of consensus.

(4) To calculate the expert consensus value G^i , the data for each indicator is tallied. In the schematic diagram of the double triangular fuzzy number, G^i is represented by the position of the intersection of two triangles projected on the horizontal axis. The calculation formula for G^i is as follows:

$$G^i = \frac{O_M^i \times C_U^i - O_L^i \times C_M^i}{O_M^i + C_U^i - O_L^i - C_M^i} \quad (2)$$

Based on the calculated expert consensus value for each indicator and supplemented by empirical judgment, a threshold judgment value S is determined. Indicators with $G^i > S$ are then selected, representing influential factors of UAGR with analytical significance following the judgment of the fuzzy Delphi method.

4.3. Interpretive Structural Modeling (ISM) Approach

Interpretive Structural Modeling (ISM) was first proposed by John N. Warfield in 1974, and now it has become one of the most commonly used analysis methods in modern system engineering. It is a structured technical model based on the subjective practical experience of people; with the help of matrix calculations, it establishes an intuitive multi-order structural model by quantifying the complex correlation relationship between many elements in the system, which clearly shows the structural hierarchy of the system as well as the interdependence of the elements and provides a basis for the decision-making of the managers [52]. Its specific establishment method is as follows.

(1) Judge the mutual influence relationship between factors and establish the adjacency matrix. The factors that need to be modeled are listed. The interrelationship between each factor is judged. This process uses Boolean algebra operations, i.e., there are only two cases in which factor A will affect factor B and factor A will not affect factor B. If there are n factors in the system, a matrix of order $n \times n$ can be created, and this matrix is called the adjacency matrix. In this matrix, it is specified that if the factors A_i will have a direct effect on factor A_j , the corresponding value in the matrix $a_{ij} = 1$. And if the factor A_i will not have a direct effect on the factor A_j , then the corresponding value in the matrix $a_{ij} = 0$. In mathematical expression, it is

$$a_{ij} = \begin{cases} 1 & \text{When } A_i \text{ will have a direct effect on } A_j, i \neq j \\ 0 & \text{When } A_i \text{ does not have a direct effect on } A_j, i \neq j \end{cases} \quad (3)$$

(2) Establish a reachability matrix based on the adjacency matrix. The reachability matrix, as the name suggests, is a matrix used to describe the path through which a connection can be made between any two elements in a system. If the factors in the system A_i through r passes, it will have an effect on factor A_j ; then, $B = b_{ij} = 1$, and vice versa is equal to 0. From this, we obtain

$$B = (A + I)^r \quad (4)$$

In the calculation equation, the unit matrix I should match the order of the adjacency matrix A . The value of r must satisfy the following equation:

$$A + I \neq (A + I)^2 \neq \dots \neq (A + I)^{r-1} \neq (A + I)^r = (A + I)^{r+1} \quad (5)$$

That is, after traversing through the r -steps, all relationships among elements within the system have been fully explored.

(3) Hierarchical decomposition of the reachability matrix involves dividing the factors within the system into several levels. This process is essential for structuring the model hierarchically and organizing the relevant elements effectively. To conduct hierarchical

decomposition using the reachability matrix, we need to determine the reachable set $M(A_i)$, the prior set $N(A_i)$, and their intersection $P(A_i)$ for each factor A_i in the system. The reachable set $M(A_i)$ comprises other factors in the system affected by factor A_i identified by the row in the reachability matrix where factor A_i has a value of 1. The prior set $N(A_i)$ consists of factors that influence factor A_i , recognized by the column in the reachability matrix where factor A_i has a value of 1. The intersection of the reachable set and the prior set $P(A_i)$ reflects mutual influence relationships between factors. By comparing these relationships, we derive the hierarchy of the reachability matrix.

(4) Plotting a recursive hierarchical directed graph. On the basis of decomposing the hierarchy based on intersection $P(A_i)$ factor, hierarchy relationships are plotted to derive an explanatory structural model.

4.4. Research Design

4.4.1. Fuzzy Delphi Method Questionnaire Design and Research Questionnaire Design

Firstly, a questionnaire is made according to the 25 influencing factors of UAGR; the elements are arranged according to the starting stage of the project, the regeneration and construction stage, and the operation and management stage. In accordance with the fuzzy Delphi method, the experts are asked to judge the degree of importance of each influencing factor, M , the smallest acceptable value; C ; and the largest acceptable value, O . Each value is a natural number from 1 to 10, and the larger the number, the higher the degree of importance. The larger the number, the higher the degree of importance. The same method was used in the subsequent questionnaires, with the results of the previous round of questionnaire analysis added to the questionnaires for the experts' reference.

Research Scope and Subject Selection

The accuracy of the fuzzy Delphi method depends heavily on the subjective opinions of experts. It is crucial to choose experts who are knowledgeable in the research field. Having a larger number of experts, ideally 8–10, enhances the accuracy of the results. However, once the number exceeds 30, the accuracy does not improve further.

The study focuses on urban agriculture, a broad interdisciplinary field. Experts from urban planning, landscaping, social governance, and practitioners engaged in urban agricultural activities were chosen for their diverse perspectives, with a team of approximately 10–15 members.

4.4.2. Interpretive Structural Modeling (ISM) Questionnaire Design and Research

After identifying the key factors, the next step is to analyze how they relate to each other. This helps create a decision-making model for UAGR, clarifying project priorities and implementation logic. To do this, the author uses Interpretive Structural Modeling (ISM) to build a structured model that shows how factors interact. This makes it easier to understand the complexities of urban regeneration projects and make informed decisions.

To ensure the scientific validity of determining the relationships between elements in the explanatory structural model, the study conducted expert questionnaire research. Experts in related fields were invited to assess the interrelationships among factors influencing UAGR. A total of eight expert questionnaires were collected, involving the same experts as those in the fuzzy Delphi method. Due to the nature of Boolean algebra operations, which only involve judgments of 0 and 1, calculating an average value was not feasible. Therefore, the study adopted the majority principle during statistical analysis. If more than 70% of the experts agreed that a certain factor impacted another factor, an influence relationship was established and assigned a value of 1; otherwise, it was assigned a value of 0.

Given the complexity of matrix operations in the explanatory structural model, manual processing is impractical. Thus, the study utilizes MATLAB 2018a to facilitate matrix operations and hierarchical decomposition calculations. MATLAB simplifies the intricate process, enhancing efficiency and accuracy in analyzing the explanatory structural model.

5. Analysis Results

5.1. Analysis Results of Factors Affecting UAGR Decision-Making Based on the Fuzzy Delphi Method

This study examines the entire process of UAGR and identifies a total of 25 influencing factors that could impact decision-making. However, the subjective nature of this judgment and variations in their importance necessitate a scientific and objective assessment. To achieve this, the author employs the fuzzy Delphi method to screen these factors, ensuring a rigorous and convincing evaluation of their importance.

5.1.1. Analysis of Initial Questionnaire Results

The first round of questionnaires was distributed by email and in person; 17 questionnaires were sent out, and 14 valid questionnaires were returned, with a recovery rate of 82%. The data obtained from the questionnaire were analyzed (Table 2).

Table 2. Statistical results for the first round of questionnaires.

Norm	Single Value M		Conservative Perceived Value C			Optimistic Perception O			Check Value A	Consensus Value G^i	Convergence or Not
	MIN	MAX	C_L^i	C_M^i	C_U^i	O_L^i	O_M^i	O_U^i			
A1 Local regulations	6	10	3	6.314	10	8	9.516	10	1.202	8.462	
A2 Government Regulation	5	10	2	5.694	10	7	8.801	10	0.107	8.071	
A3 Land tenure relations	6	9	3	5.318	8	8	8.813	10	3.495	7.500	
A4 Original environmental conditions of land	5	10	2	4.896	8	6	7.994	10	1.098	7.071	
A5 Land area	4	9	1	3.370	7	5	7.560	10	2.190	6.286	
A6 Contact with the local population	5	9	3	4.985	8	6	8.345	10	1.359	7.071	
A7 Connecting with local community organizations	3	9	2	4.172	7	4	7.108	10	−0.064	6.214	not
B1 Design incorporates residents' needs	6	10	3	6.605	10	7	9.259	10	−0.346	8.071	not
B2 Design incorporates original site	4	9	2	4.904	8	6	7.978	10	1.075	6.786	
B3 Designing for local context	4	9	3	5.220	8	6	8.055	10	0.835	6.857	
B4 Aesthetics of design	3	9	1	3.368	8	4	7.234	10	−0.134	5.714	not
B5 Site construction quality	4	9	2	4.282	8	5	7.406	10	0.124	6.357	
B6 Filled soil quality	3	10	2	4.520	8	5	7.744	10	0.223	6.714	
B7 Utility of agricultural tools	2	7	1	2.500	6	4	5.735	8	1.235	4.571	
B8 Utility of pollution treatment facilities	3	9	2	3.935	7	5	7.369	10	1.435	6.143	
B9 Sustainable facility utility	6	9	2	4.935	8	6	8.147	10	1.212	6.929	
C1 Managers' operational capacity	4	8	1	4.184	8	5	8.062	10	0.878	6.571	
C2 Resident Planting Participation	5	9	3	6.295	9	6	9.384	10	0.089	8.154	
C3 Environmental adaptation of planting crops	5	10	3	5.752	8	6	8.672	10	0.920	7.643	
C4 Crop Diversity	3	10	2	4.120	8	4	7.391	10	−0.729	6.286	not
C5 Agricultural marketing channels	3	8	1	3.467	8	5	6.654	10	0.187	5.692	
C6 Degree of implementation of agricultural skills training	4	10	2	4.950	8	5	7.639	10	−0.311	6.643	not
C7 Degree of popularization of science education for children	4	10	2	4.808	9	6	7.977	10	0.170	6.857	
C8 Degree of community cultural activities	4	7	2	3.817	6	5	7.277	10	2.460	5.615	
C9 External Communications Visibility	2	8	1	2.863	8	3	6.210	10	−1.653	5.000	not

As can be seen from Table 3, the six indicators including Connecting with local community organizations (A7), Design incorporates residents' needs (B1), Crop Diversity (C4), Aesthetics of design (B4), Degree of implementation of agricultural skills training (C6), and External Communications Visibility (C9) did not converge, that is, the experts did not reach a consensus, and a second round of questionnaire research is needed.

Table 3. Statistical results for the second round of questionnaires.

Norm	Single Value M		Conservative Perceived Value C			Optimistic Perception O			Check Value A	Consensus Value G^i	Convergence or Not
	MIN	MAX	C_L^i	C_M^i	C_U^i	O_L^i	O_M^i	O_U^i			
A1 Local regulations	8	10	4	5.96	9	9	9.74	10	3.782	9.000	
A2 Government Regulation	8	10	4	5.733	9	9	9.487	10	3.754	9.000	
A3 Land tenure relations	7	8	5	5.207	6	8	9.105	10	5.899	6.836	
A4 Original environmental conditions of land	5	8	3	3.797	5	7	8.332	10	6.535	5.949	
A5 Land area	6	9	3	3.853	5	8	8.841	10	7.988	6.731	
A6 Contact with the local population	6	8	4	4.515	6	8	8.712	10	6.196	7.352	
A7 Connecting with local community organizations	5	7	3	4.141	6	7	7.956	10	4.815	6.660	
B1 Design incorporates residents' needs	7	10	4	6.365	10	9	9.558	10	2.193	9.133	
B2 Design incorporates original site	4	8	3	4.733	7	6	8.404	10	2.671	6.515	
B3 Designing for local context	6	9	3	4.603	7	8	8.958	10	5.355	7.714	
B4 Design Aesthetics	3	6	2	3.219	5	6	7.430	9	5.211	5.555	
B5 Site construction quality	4	7	3	4.196	5	6	8.066	9	4.870	5.280	
B6 Soil quality	5	7	3	3.778	6	7	8.210	10	5.432	6.647	
B7 Utility of agricultural tools	3	6	2	2.671	4	6	6.341	8	5.670	5.592	
B8 Utility of pollution treatment facilities	5	9	4	4.681	6	7	8.455	10	4.774	6.475	
B9 Sustainable facility utility	7	9	4	5.089	6	8	9.091	10	6.002	6.910	
C1 Managers' operational capacity	7	9	4	5.508	7	8	9.105	10	4.597	7.575	
C2 Resident Planting Participation	8	9	6	6.831	8	9	9.613	10	3.782	8.656	
C3 Environmental adaptation of planting crops	6	9	5	6.318	8	8	9.348	10	3.030	8.000	
C4 Crop Diversity	5	8	3	4.292	6	6	7.449	9	3.157	6.000	
C5 Agricultural marketing channels	3	7	1	2.747	5	5	6.790	8	4.043	5.000	
C6 Degree of implementation of agricultural skills training	6	9	3	4.667	6	7	8.455	10	4.788	6.478	
C7 Degree of popularization of science education for children	5	8	3	4.027	6	6	8.038	10	4.011	6.000	
C8 Degree of community cultural activities	4	8	2	3.386	5	5	7.345	10	3.959	5.000	
C9 External Communications Visibility	3	6	3	3.562	5	6	6.590	8	4.028	5.709	

5.1.2. Analysis of the Results of the Second Round of Questionnaires

In the second round of questionnaires, distributed exclusively via email to the 14 experts who participated in the initial round, 8 valid responses were received. This represents a return rate of 57%. The results of this analysis are presented in Table 3, providing valuable insights into the evolving perspectives of the experts on urban agriculture.

Table 4 displays the results of the second round of questionnaire screening, revealing a convergence of expert opinions and indicators. These data serve as a valuable resource for future research endeavors, benefiting from the alignment achieved among experts.

Table 4. Screened impact factors for UAGR.

Primary Impact Factors	Secondary Impact Factors	Expert Consensus Value G^i
Project initiation A	Relevant local regulations A1	9.000
	Government regulator tolerance A2	9.000
	Clarity of land tenure relationships A3	6.836
	Land Location Advantages and Disadvantages A4	6.731
	Closeness of contact with the local population A5	7.352
Project construction B	Degree to which the design incorporates the needs of the population B1	9.133
	Degree of design integration with the local environment B2	7.714
	Sustainable facilities utility B3	6.910
Operations and management C	Managerial Operational Capability C1	7.575
	Resident Cultivation Participation C2	8.656
	Degree of environmental adaptation of planted crops C3	8.000

5.1.3. Identification of Influencing Factors and Analysis of Findings

Screening of Influencing Factors

Following the attainment of expert consensus, all indicators underwent importance screening, guided by the consensus value of experts G^i . Initially, the threshold (S) was established, set at 6.7 after a thorough review of the literature and empirical judgment by the researcher. This threshold determined the selection of indicators where $G^i > 6.7$, resulting in the screening of 11 influencing factors, as depicted in Table 4.

Discussion

This section utilized the fuzzy Delphi method to construct an index system of influencing factors and conducted expert questionnaire research. Through this process, 11 influencing factors affecting UAGR decision-making were identified, as depicted in Table 5.

Table 5. Relationship matrix of factors influencing UAGR.

	A1	A2	A3	A4	A5	B1	B2	B3	C1	C2
C3	O	O	O	O	O	O	E	O	O	M
C2	O	O	O	O	O	E	E	A	O	
C1	E	E	E	O	M	A	A	O		
B3	O	O	O	O	O	E	E			
B2	O	O	O	O	E	M				
B1	O	O	O	O	E					
A5	O	O	E	E						
A4	O	O	O							
A3	O	O								
A2	M									

Notably, the indicators with the highest expert consensus values were the degree of tolerance of local regulations and the degree of integration of design with residents' needs. This underscores the significant influence of government regulations on urban regeneration with agriculture in China, aligning with the country's actual landscape. Moreover, the success of such projects hinges largely on whether the site design meets the practical needs of local residents.

Secondary influences, such as design aesthetics, crop diversity, and external publicity visibility, were considered less critical. The screening process of the fuzzy Delphi method refined the indicator system, ensuring a streamlined and accurate selection. This prevents redundancy and ensures the identification of effective influencing factors, laying a solid foundation for subsequent studies in the field.

5.2. Results of Decision-Making Modeling in UAGR Based on Explanatory Structural Modeling Approach

5.2.1. Analysis and Modeling Results of Explanatory Structural Models

Creating an Adjacency Matrix

Initially, expert questionnaire data were analyzed, yielding a matrix of factor interrelationships based on predefined statistical principles. This matrix, as illustrated in Table 5, encapsulates the relationships among factors as determined by the experts' responses.

In the table, the character O indicates that there is no interrelationship between the two factors. E indicates that the A_i would have a direct effect on A_j but A_j does not have a direct effect on A_i . A means that A_j will have a direct effect on A_i but A_i does not have a

direct effect on A_j . M indicates that the two factors will have a direct effect on each other. According to this, an adjacency matrix A can be established according to Table 6.

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

Table 6. Factor hierarchical decomposition results.

Level r	Factor A_i
1	8
2	10, 11
3	6, 7
4	5, 9
5	1, 2, 3, 4

Computing Reachable Matrices Using MATLAB

This step calculates the reachable matrix B from the adjacency matrix A. The calculation is carried out through a MATLAB program. Enter the adjacency matrix in MATLAB and run to obtain, when $F = 3$, $A1 = A2$, at which point the condition is reached, the loop can be exited, and the reachable matrix obtained, as follows:

$$B = A1 = A2 = \begin{bmatrix} 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \end{bmatrix}$$

Using MATLAB to Delineate the Hierarchy and Model the Explanatory Structure

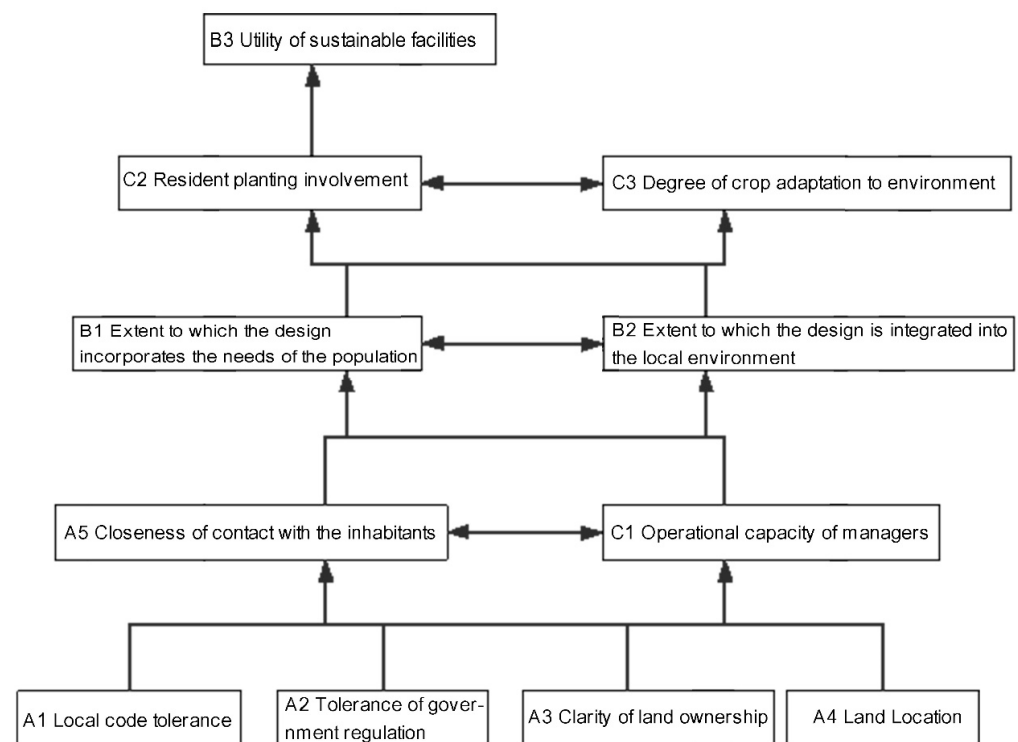
This step also performs the operation of hierarchical division in MATLAB. After inputting the reachability matrix B, the output is obtained, as shown in Table 6.

List the reachable sets for each factor according to the reachability matrix $BM(A_i)$, prior set $N(A_i)$, and intersection set $P(A_i)$. The results are shown in Table 7.

Table 7. Factor reachable set, prior set, and intersection statistics.

Considerations	Accessible Set $M(A_i)$	Precursor Series $N(A_i)$	Intersection Set $P(A_i)$
A1	1, 2, 5 to 11	1, 2	1, 2
A2	1, 2, 5 to 11	1, 2	1, 2
A3	3, 5 to 11	3	3
A4	4, 5 to 11	4	4
A5	5 to 11	1 to 5, 9	5, 9
B1	6, 7, 8, 10, 11	1 to 7, 9	6, 7
B2	6, 7, 8, 10, 11	1 to 7, 9	6, 7
B3	8	1 to 11	8
C1	5 to 11	1 to 5, 9	5, 9
C2	8, 10, 11	1 to 7, 9, 10, 11	10, 11
C3	8, 10, 11	1 to 7, 9, 10, 11	10, 11

The numbers in the table indicate the sequence of factors, i.e., from A1 to C3. Based on the hierarchical decomposition result table, the influencing factors are divided into levels, the factors of the same level are plotted on the same horizontal line, and the interrelationships between the factors are plotted according to the factor reachable set, prior set, and intersection statistics table. The explanatory structure model for the influencing factors of UAGR is finally obtained (Figure 2).

**Figure 2.** Schematic diagram of the explanatory structural model for the factors influencing Urban Agricultural Regeneration.

5.2.2. Analysis and Conclusions of the Decision-Making Model

The analysis of the explanatory structural model reveals a multilevel system with five levels of factors influencing UAGR. A structural directed graph visually represents the correlations among these factors, simplifying the understanding of their interrelationships.

Direct Impact Factors

In the explanatory structural model, the top layer signifies the first level, descending in sequential order. Among the first two layers of influencing factors, the most imme-

mediate determinants of effectiveness with UAGR are residents' participation in planting and the adaptability of crops to the environment, along with the utility of sustainable facilities. These factors reflect the community, agricultural, and environmental attributes of urban agriculture.

Residents play a pivotal role as the direct beneficiaries of urban agricultural spaces. The aim of renewing such spaces is to foster connections among community members and create harmonious communal environments. The degree of residents' participation in planting serves as a key indicator of achieving this objective. Active engagement of residents is essential for the success of urban agricultural spaces.

The adaptability of crops to the environment directly influences the success of agricultural activities within urban spaces. Unlike conventional green spaces, urban agricultural spaces are characterized by agricultural activities. The cultivation of high-quality crops with stable yields is vital for the sustainability and continued relevance of urban agricultural activities. Otherwise, these spaces risk being replaced by alternative types of green spaces.

Furthermore, urban agricultural spaces contribute to urban optimization by enhancing resource utilization and promoting sustainable development. As communal public spaces, their sustainable development fosters community-wide awareness of sustainable practices, thereby advancing city-wide development.

Thus, residents' participation in planting directly impacts the utility of sustainable facilities, while the effectiveness of these facilities reflects the success of environmental conservation and resource utilization in urban agricultural spaces.

Intermediate Layer Influencing Factors

In the middle layers of influencing factors, these elements impact the effectiveness of UAGR by influencing factors in the first two layers. The third layer includes the integration of design with residents' needs and the local environment. These factors influence the design phase of urban agricultural spaces, directly affecting residents' participation in planting and the adaptability of crops to the environment. This highlights the importance of thoughtful design in ensuring the success of subsequent operations.

Effective urban agricultural spaces must cater to the daily needs of local residents to attract their use and encourage participation in agricultural activities. Moreover, spaces aligned with residents' needs tend to have longer service lives and foster greater environmental consciousness among residents, thereby promoting crop growth.

Given the close relationship between agricultural activities and the natural environment, adherence to local environmental conditions is crucial for smooth agricultural operations. Urban agricultural space design must align with local climate and crop selection, directly impacting crop adaptability and residents' planting participation.

Ultimately, the degree of design integration with the local environment directly influences crop adaptability and residents' planting participation, underscoring the significance of harmonizing agricultural spaces with their surroundings for optimal effectiveness.

The fourth tier of factors influences the design of UAGR sites. These factors include the level of community engagement and the operational proficiency of the management team. The success of spatial design hinges on both the designer's operational capability and their adherence to user preferences. The former is influenced by the management team's business acumen, while the latter necessitates effective communication channels with local residents.

Establishing robust communication channels and incorporating resident feedback are essential for designing spaces that meet community needs. The management team plays a pivotal role in this process, as they are responsible for implementing resident suggestions. Effective communication with residents enhances the team's business acumen, creating a reciprocal relationship between communication and operational proficiency.

Underlying Influences

The fifth tier of factors is the most fundamental in determining the success of agricultural regeneration projects. These factors encompass local regulations, governmental oversight, clarity of land ownership, and land location. Established at the project's outset, these factors exert direct or indirect influence on all subsequent efforts.

In particular, the tolerance of local regulations and government supervision reflects China's current socio-political environment of strong government and big government, where only by complying with the relevant laws and regulations and obtaining the support of the government authorities can a project continue to be developed. This perception is deeply rooted in China and will influence whether the community supports urban regeneration and whether the relevant talent is involved in the project. If UAGR is not explicitly permitted by law or regulations, and if government departments do not support the project, local residents may choose not to participate in the project for fear of encountering problems, and the relevant talents may choose other career paths for their own development, thus affecting the development of UAGR activities.

The clarity of land ownership and land location reflect the social and spatial attributes of the space where the UAGR is to be carried out, respectively. Prior to the regeneration, the owners of all rights and interests in the land space must unanimously agree and reach an agreement before the project can be pushed forward. If the land tenure relationship is very complicated and belongs to many different interest subjects, the risk of each party arguing and shirking responsibilities for their own interests will be greatly increased, which will affect the next level and lead to the failure of the project. The advantages and disadvantages of land location will also have a direct impact on communication with residents and the ability of management personnel. If the land has poor accessibility to nearby residential areas, or if there are location problems such as neighborhood avoidance facilities or relevant supporting services that are not perfect, it will result in a decrease in the motivation of management personnel and a decrease in the communication with the residents, which will, in turn, have an impact on the UAGR Project.

Conclusion of the Interpretive Structural Modeling (ISM) Application

By employing Interpretive Structural Modeling (ISM), this study uncovers the intricate interactions among influencing factors of UAGR. It establishes a comprehensive five-level hierarchical structural relationship diagram, providing a visual representation of these interactions. The study elucidates the direct, intermediate, and fundamental influencing factors throughout the UAGR process, spanning pre-preparation, planning and design, implementation, and post-operation phases. It clarifies the logical relationships between various aspects of project implementation, offering valuable insights for decision-making in UAGR initiatives.

5.3. Case Study Results on Shanghai Chuangzhi Agricultural Park

5.3.1. Empirical Research Results from Hangzhou Cases

After establishing a decision-making framework for UAGR, this paper conducts empirical research on three cases in Hangzhou City, where multifunctional agricultural areas with mixed agriculture, commerce, scientific research, and residence are established by developing agricultural activities in and around abandoned commercial land. Three cases including plots in Binjiang District, plots in Zijinhang Campus of Zhejiang University, and a commercial farm in a shopping mall, are selected for a questionnaire survey. The survey results reveal tendencies among urban agriculture users and design decision-makers in the following aspects:

Policy-makers are cautious about urban agriculture construction. They prefer designing urban agriculture in combination with residential and commercial buildings and green space rather than using independent plots, favoring integrated design over incremental design. Due to tenure management complexity, policy-makers tend to adopt a multi-party cooperative operation and management approach. Both urban agricultural space users and

design decision-makers have a high degree of recognition of urban agriculture. However, significant differences exist between users and decision-makers regarding the advantages of urban agriculture, its actual operation, tenure, and social and environmental benefits.

Therefore, urban agriculture is not suitable for standalone land use; instead, it is most suitable to combine it with commercial space, green space, campus space, and urban gaps. Therefore, integrating urban agriculture into urban regeneration is highly appropriate. The costs of urban agriculture regeneration mainly involve site remediation, demolition of original structures, contamination treatment, and design costs. Operation costs primarily include management, agricultural product flow, and theft prevention.

Secondly, urban agriculture design should focus on the interest and diversity of agricultural space, incorporating the city's characteristics and enhancing the cityscape. In actual operation, attention should be paid to management efforts, site basic condition limitations, and optimizing space use. Ultimately, the successful development of urban agriculture depends on its legal legitimacy.

5.3.2. Case Study Results on Shanghai Chuangzhi Agricultural Park

This study utilizes the Shanghai Chuangzhi Agricultural Park project as a case study to analyze the application of the decision-making model for urban regeneration with agriculture. Situated in Chuangzhi Tiandi Park, Wujiaochang Street, Yangpu District, Shanghai, the farm spans 2200 square meters. Originally designated as G1 urban green space, the site evolved into temporary sheds and abandoned land due to the presence of important municipal pipelines and its triangular shape, characteristic of urban gap land, making commercial development challenging. In collaboration with Yangpu District Science and Technology Innovation Investment and Development Co., Ltd. and Hong Kong Shui On Group, Shanghai Cloverleaf Nature Experience Service Center spearheaded the secondary development of the park, transforming it into the first urban agricultural space within an open neighborhood in Shanghai. The park comprises three main sections: the public service area, agricultural activity area, and horticultural science popularization area. The public service area features an indoor public activity space crafted from repurposed containers, complemented by an outdoor plaza equipped with sustainable facilities. The agricultural activity area encompasses the Vegetable Garden, serving as an agricultural demonstration area, and the Public Agricultural Area, designated for neighborhood residents' planting activities. The Horticulture Popularization Area showcases gardening works and hosts community garden exhibitions to educate the public on horticultural science.

The daily operation and management of the Chuangzhi Farm are segmented into three primary components: community agricultural services, science education services, and community cultural services (Figure 3). Community agricultural services entail offering nearby residents access to urban agricultural land adoption and farming facilities, along with assistance in agricultural activities to ensure the smooth operation of the entire space. Science education services leverage the agricultural resources within the park to conduct natural science education programs for primary and secondary school students, supplemented by expert guidance from professional organizations to promote agricultural activities and disseminate natural knowledge. Community cultural services encompass agricultural product markets, community garden exhibitions, and similar activities designed to leverage the agricultural park's role as a communal public space, fostering resident engagement and participation (Figure 4).

According to the UAGR model, fundamental factors like local regulations, government supervision, land ownership, and land location play pivotal roles in determining the success of urban regeneration projects with agriculture. In the case of the Chuangzhi Farm, despite urban agriculture not being formally recognized in regulations, the project was developed as a "community garden," emphasizing its green space attributes, and received backing from the Yangpu District Government as part of the "Big Genesis Park" initiative. Ownership of the land was clearly established through negotiations, and its strategic location near the Wujiaochang business district, residential neighborhoods, and

educational institutions provided advantageous surroundings. Moreover, middle-level influencing factors such as design alignment with residents' needs, integration with the local environment, community connection, and managerial acumen further contributed to the project's success. Designed by the Shanghai Four Leaf Clover Nature Experience Service Center in collaboration with Tongji University, the farm's layout caters to residents' daily requirements while harmonizing with the local environment, evident in features like rainwater drainage systems and rain gardens tailored to Shanghai's subtropical monsoon climate. Direct impact factors, including high resident participation in planting, crop adaptability, and sustainable facility utilization, have also been commendable, indicating effective management and community engagement. Overall, the Chuangzhi Farm project has demonstrated favorable outcomes, underscoring the efficacy of urban regeneration strategies integrating agriculture.

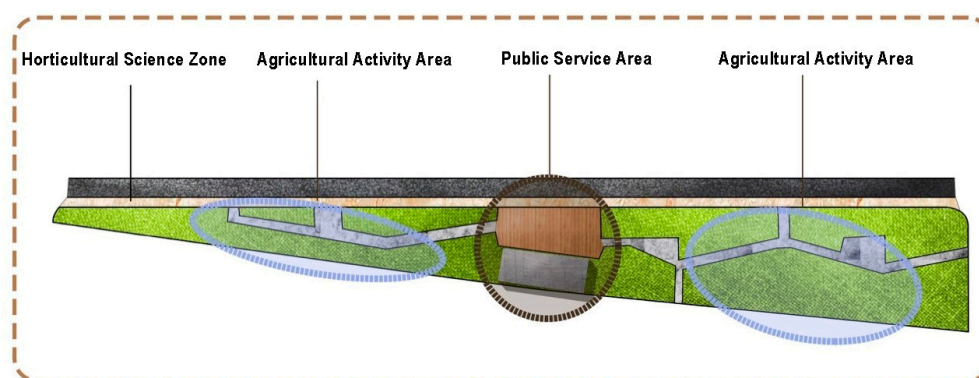


Figure 3. Schematic diagram of the functions in the farm (adapted from [54]).



Figure 4. Actual view of the farm (photo by the authors).

6. Discussion

6.1. Policy and Risk Perspectives

Urban and periurban agriculture (UPA) plays a vital role in modern agriculture, addressing food supply for urban residents, creating employment opportunities, and enhancing the urban ecosystem. However, without proper management and planning, UPA can also pose risks to the urban environment and public health. Zhou, D. provides a detailed analysis of the potential risks associated with urban agriculture and proposes preventive and control measures to mitigate these risks [55]. Moschitz, H. discussed the potential of urban agriculture to change agriculture and urban life and they argue that urban agriculture is a vehicle to deal with many urgent topics of societal transformation towards a sustainable future [56]. The analysis identifies opportunities for urban agriculture to help expand urban green spaces in cities, provided that policy mechanisms allow citizen organizations to maintain private or public spaces. However, such mechanisms may face resistance from public agencies due to uncertainties about the involvement and benefits of urban agriculture [57].

6.2. Lack of Existing Regulatory Basis for UAGR in Chinese Cities

Currently, China's urban planning regulations lack explicit provisions regarding the development of agriculture within cities. The 2012 edition of the Urban Land Use Classification and Planning Construction Land Use Standards (GB 50137-2011) [58] only mentions E2 medium class land use in the E class non-construction land use, encompassing cropland, garden land, forest land, pasture land, facility agricultural land, field cans, rural roads, etc. In the classification of urban construction land, the G class green land and square land use related to urban agriculture are designated for public access and primarily for recreational purposes. For instance, the G1 park land is intended for recreational purposes, with ecological, beautification, and disaster prevention functions, but there is no explicit mention of whether urban agriculture can be developed in these land categories.

The Urban Green Space Classification Standard (CJJ/T85-2017) [59] issued by the Ministry of Housing and Urban–Rural Development (MOHURD) in 2017 provides a detailed categorization of G land. It classifies G1 park land into G11 comprehensive parks, G12 community parks, G13 specialized parks, and G14 playgrounds (Table 8). Additionally, the standard introduces the code XG to indicate subsidiary green space, including green space attached to various types of urban construction land (except “green space and square land”). However, this standard does not explicitly address the development of urban agriculture within these land categories.

Table 8. Criteria for classification of land use class G1.

Middle Class	Subcategory	Element
G11 General Park	-	Green areas with rich contents, suitable for various outdoor activities, and with comprehensive recreational and supporting management and service facilities.
G12 Community Park	-	Green space with basic recreational and service facilities on separate sites, mainly serving the daily recreational activities of residents in the vicinity of a certain community area.
G13 Specialized parks	G131 Zoo	A green space with good facilities and interpretive signage system for the protection of wild animals in the area under artificial breeding conditions, for scientific research on animal breeding and propagation, and for popularization of science, viewing, and recreational activities.
	G132 Botanical Gardens	Green areas with good facilities and interpretive signage systems for plant scientific research, introduction and domestication, plant protection, and activities such as ornamental, recreational, and popularization of science.
	G133 Historic Gardens	Gardens that embody the representative gardening art of a certain historical period and require special protection.
	G134 Heritage Park	Green areas formed mainly by important sites and their background environments, which are of exemplary significance in terms of site protection and display and have cultural and recreational functions.
	G135 Amusement Park	Separate green space with large play equipment and good ecological environment.
	G139 Other specialized parks	In addition to the above specialized types of parks, green spaces with specific thematic content. They mainly include children's parks, sports and fitness parks, waterfront parks, memorial parks, sculpture parks and scenic parks, urban wetland parks, and forest parks located in urban construction sites.
G14 Garden Tour	-	In addition to the above parks and green spaces, there are also green spaces that are independent, small in size, or diverse in shape; convenient for residents to access in the vicinity; and have a certain degree of recreational function.

As can be seen, there is also no clear mention in the standard of whether urban agriculture can be developed on urban construction land. Therefore, at present, urban agriculture in China is still in a gray area at the regulatory level, without a clear basis for development.

6.3. The Exploration of Policies for UAGR in China

In exploring the regulatory basis for UAGR, it is argued that the development of urban agriculture in cities is both reasonable and necessary due to its multiple benefits, including enhancing the urban environment, enriching residents' lives, and providing locally grown agricultural products. However, given the current regulatory ambiguity surrounding urban agriculture in China, the author proposes ideas for its legalization. Drawing on international practices, such as those in Minneapolis and Chicago, where local zoning laws were amended to recognize urban agriculture as a distinct land use type, it is suggested that treating urban agriculture separately is feasible and aligns with global trends [60]. Moreover, within China, regulatory adjustments have been made over time, as evidenced by the inclusion of categories like G134 Relic Park in the Urban Green Space Classification Standard of 2017 [61], reflecting evolving societal priorities. Therefore, there is potential to add urban agriculture as a recognized land use type within existing norms. Based on these considerations and the community-oriented nature of urban agriculture, the author proposes adding a subcategory of urban agriculture parks to the G12 community parks classification in the Urban Green Space Classification Standard, thus paving the way for the legalization of urban agriculture. Additionally, reference is made to Site X in the 2018 Site Classification Standards (Discussion Draft) [62] for further insights.

7. Conclusions

7.1. Research Summary and Results

This study aims to systematically review current practices in urban agriculture and urban regeneration research and establish a rational decision-making model for urban regeneration with agriculture using the fuzzy Delphi method and the explanatory structural model. It applies this model to analyze real cases, focusing on the necessity and process of UAGR projects in China and identifying 25 influencing factors that could affect project effectiveness. Based on a literature review as well as data analysis, this study identifies multi-criteria objectives for UAGR across five aspects: Social and environmental benefits, including meeting people's needs for interaction and recreation, increasing community identity, improving air quality, reducing pollution, enhancing environmental efficiency, and improving food safety. Site planning and design, covering improvement of green space diversity, increase in natural open space, enhancement of public space interest, and coordination of design elements. Regeneration costs, encompassing demolition, pollution remediation, design, soil/fertilizer/seeds purchase, transportation, agricultural labor, and land prices. Management and operation, including operation mode (e.g., green space combination, residential building combination), operation ownership (e.g., multi-party cooperation, government unified management), and factors influencing actual operation (e.g., operation strength, space utilization advantages). User perceptions and feedback, involving factors such as laws and regulations improvement, operation maintenance, cityscape enhancement, and cost control. Additionally, the study explores the nature of existing land use (e.g., residential, commercial, industrial), renewed land use (e.g., urban green space, agricultural land), and operational aspects like irrigation, fertilization, and agricultural product processing and sales. It also considers the use of urban agricultural space for recreation, communication, planting, and maintenance, as well as potential improvements in agricultural practices such as odor control, landscape integration, and noise reduction. Employing the fuzzy Delphi method, experts scored and screened these factors across two rounds of questionnaires, resulting in the identification of 11 highly important factors. Relevant local regulations A1, Government regulator tolerance A2, Clarity of land tenure relationships A3, Land Location Advantages and Disadvantages A4, Closeness of contact with the local population A5, Degree to which the design incorporates the needs of the population B1, Degree of design integration with the local environment B2, Sustainable facilities utility B3, Managerial Operational Capability C1, Resident Cultivation Participation C2, Degree of environmental adaptation of planted crops C3. To analyze the correlations between these factors, the study employed the explanatory structural

model, distributing expert questionnaires to determine pairwise correlations. Matrix operations using MATLAB helped derive factor interactions, leading to the establishment of a decision-making model depicted through a recursive order structure in a directed graph. Finally, the study applied this UAGR Decision-Making Model to analyze the Shanghai Chuangzhi Agricultural Park project, elucidating its success and operational mechanisms. The establishment of a decision-making model for UAGR can offer practical guidance to practitioners, facilitating the development of urban agriculture and enhancing the urban environment.

7.2. Innovations

This paper constructs and optimizes the decision-making model for UAGR, which is the primary innovation. Developing a scientific and practical decision-making method and model for UAGR is the main innovation of the project. Traditional qualitative research methods may introduce subjectivity and ambiguity, lacking consideration for the interrelationships of factors or criteria. Thus, appropriate research methods are needed to reduce ambiguity and provide a systematic solution for criterion selection. This research refined the indicator system by simplifying the complexity, addressing the complexity of indicators, and the allocation of their weights is another innovation. Current methods struggle to simplify complex indicators, hindering the effective application of multi-criteria decision-making (MCDM) methods in evaluation models. Therefore, resolving the simplification issue and ensuring the scientific allocation of weights is crucial for enhancing the evaluation system's scientific nature.

7.3. Limitations of the Study

Due to the evolving nature of the research field, two of the three cases examined in this paper involve spontaneous urban agriculture, while the third and fourth cases are completed commercial projects. This resulted in insufficient data and information at the pre-project stage, limiting their utility as references for project selection. Consequently, the research program was adjusted to build upon existing case studies and conduct a questionnaire survey of policy-makers and users of urban agriculture. In the future, the project team plans to collaborate closely with relevant government departments to select urban regeneration cases with agriculture that offer more comprehensive data for verifying and enhancing the theoretical model.

7.4. Application Prospects of Research Results

Drawing on theoretical foundations in urban and rural planning, public management, and agronomy, this research investigates the development mechanism of urban regeneration in agricultural cities within the context of new urbanization. The findings offer theoretical insights and practical applications in planning practice, serving as valuable references for governmental decision-making departments, planning and design departments, peer experts, and scholars. Moving forward, the long-term goal is to further explore urban regeneration strategies with agriculture based on the decision-making method established in this study, thereby advancing research on optimizing urban land stock.

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