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RESEARCH ARTICLE

Key catalysts and constraints of urban agriculture for sustainable food systems: A case study of Thiruvananthapuram, India

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Abstract

Urban agriculture (UA) has emerged as a key response to the challenges associated with urbanization, addressing urban poverty, food insecurity, livelihood vulnerability and environmental stress. This study examines key catalysts and constraints influencing UA in the Thiruvananthapuram corporation, Kerala, India. Using mixed-methods research design, data were collected from 124 urban farmers across 20 purposively selected wards through pre-tested questionnaires and focus group discussions during 2024. The identified catalysts were categorized into three groups: socio-economic benefits, ecosystem services and fitness and well-being. Analysis revealed significant differences among these three categories, with fitness and well-being emerging as the most influential catalysts, followed by socio-economic benefits and ecosystem services. Psychological well-being and reduction of lifestyle disorders were the primary catalysts, indicating the role of UA in mental and physical health. Socio-economic benefits included improved access to fresh food, income generation and preservation of cultural practices, while ecosystem services contributed to sustainable development, biodiversity and improved environmental quality. The constraints were grouped into institutional and socio-economic categories, with the lack of timely information, extension services and agricultural inputs identified as the major institutional barriers. Socio-economic challenges included poor soil fertility and high costs of specialized inputs and labour. The findings collectively elucidate the key catalytic factors and constraints shaping the adoption and practice of UA.

Keywords: constraints of urban agriculture; ecosystem services; health and well-being; key catalysts; socio-economic benefits; urban agriculture

Introduction

In 2008, urban dwellers outnumbered rural residents globally for the first time. Projections suggest that by 2050, the world's population will reach 9.2 billion, with 70 % expected to live in urban areas (1). In numerous developing nations, urbanization coincides with a rise in urban poverty and environmental degradation. These factors exacerbate food insecurity and malnutrition, particularly among vulnerable groups, such as children, pregnant women and lactating mothers. Urban agriculture (UA) has emerged as a promising approach for addressing these challenges, offering opportunities to enhance food availability, improve health outcomes, stimulate local economies, foster social cohesion and promote environmental sustainability. UA is a widespread phenomenon, existing in various forms across the globe, with approximately 25–30 % of urban residents worldwide participating in agro-food activities (2).

Urban agriculture generally refers to gardening, farming and related activities conducted on small parcels of land within or near cities. While the conventional definition emphasizes horticulture and agriculture, some interpretations encompass animal rearing (3, 4). As of 2018, more than half of the world's population lived in urban areas, which produce over 80 % of the global gross domestic product and UA, encompassing a range of farming methods, is widely practiced across urban settings (5–7). These activities may involve ground-based cultivation or integration into building structures, with or without environmental control systems (8). The significance of urban and peri-UA lies in its multifaceted ability to provide social, economic and environmental benefits, as well as ecosystem services (9).

Urban agriculture is primarily motivated by its ability to facilitate food production close to urban populations (10). The integration of vegetables into diets is essential for maintaining an optimal nutritional balance, however, global vegetable consumption remains below the recommended levels in many regions (11, 12). UA has emerged as a potential solution to address this shortfall, contributing 5–10 % to the global production of legumes, tubers and vegetables (12, 13). The increasing market demand for locally sourced, safe and sustainably produced food has led to a significant rise in investments in UA in numerous developed cities (14). Investments in backyard and vegetable gardening in urban areas are seen as essential elements for enhancing livability, positively impacting emotional, psychological and physical well-being (15, 16).

As per capita arable land decreases and urban migration increase due to aspirations for better opportunities, the integration of UA into urban planning has emerged as a feasible concept. The key aspect of urban planning is repurposing abandoned urban land (17). These underutilized spaces are an important avenue for urban green infrastructure. It also provides valuable ecosystem services, which are increasingly recognized in cities worldwide (18). Green infrastructure, including urban wastelands, plays a critical role in improving air and water quality, managing stormwater, regulating microclimate and promoting human health and recreation (19). Several European city regions have implemented green infrastructure initiatives to foster sustainable spatial planning through the ecosystem service framework (20). These initiatives aid climate mitigation and adaptation by reducing urban heat island effect, managing runoff during extreme rainfall events, promoting urban circularity and conserving urban biodiversity (13, 21–23).

Urban agriculture also contributes to household income, reduces food-related expenses, generates employment opportunities and fosters social cohesion and public engagement (22, 24). By enhancing food security, public health, social capital and sustainable economies, UA can strengthen resilience against diverse stressors and shocks. Despite these recognized benefits across social, ecological, environmental and economic dimensions, significant knowledge gap remains regarding how these impacts vary across different urban contexts and the mechanisms driving these outcomes, highlighting the need for further research (25).

Although UA offers a range of opportunities, it also faces several obstacles. These include social and ecological vulnerabilities in urban settings and among their inhabitants. Such vulnerabilities manifest as food shortages under evolving conditions, such as global climate change, pandemics such as Covid-19 and the growing future demand for food (26). Additional negative social and environmental externalities associated with agricultural production and supply chains, such as urban land teleconnections are overlooked. Environmental degradation, including deforestation, can occur due to increased spatial needs, while increased fertilizer demand is linked to distant monoculture established on previously non-arable land (27). The misinterpretation of UA multifunctionality remains a barrier to its effective integration into urban planning (28, 29).

The objective of this study was to identify the key catalysts driving the growth of UA, defined as the specific and influential factors that significantly promote the initiation, development and sustained practice of agriculture in urban environments. Additionally, the study examines the institutional and socio-economic constraints that impede the success of urban agricultural in urban settings.

Materials and Methods

Identification of key catalysts of urban agriculture

The research team initially identified 43 sub-catalytic factors, which were divided into three dimensions: socio-economic, ecosystem, fitness and well-being. These items were generated through a desk review of relevant literature, consultations with subject-matter experts and the prior research experience of the study team. The categorization of sub-catalytic factors into socio-economic benefits, ecosystem services and fitness and well-being was conceptually grounded and reflects the multi-functional role of urban food systems, while clearly distinguishing economic, ecological and health-related outcomes.

An expert panel of judges comprising university faculty, extension personnel and practitioners with extensive experience in UA reviewed the initial list of 43 sub-catalytic factors through a relevancy rating procedure. Forty-five judges were invited to assess each item on a five-point Likert scale ranging from 'most relevant' to 'least relevant'. Of these, 30 judges responded, enabling the calculation of a relevancy index for each item. To ensure content validity and focus, only those items with a relevancy index above 0.80 were retained for inclusion in the final survey questionnaire. This selection process resulted in 30 statements, evenly distributed with ten items under each of the three dimensions, thereby maintaining balanced representation across socio-economic, ecosystem and fitness and well-being aspects.

The questionnaire was subsequently pre-tested, during which the research team refined and modified specific items to address ambiguities that arose during translation into Malayalam, the regional language of the study area, thereby ensuring clarity, linguistic accuracy and contextual appropriateness.

Locale of the study

Thiruvananthapuram, the capital city of Kerala, India, is located on the southwestern coast of the Indian peninsula along the Arabian Sea at approximately 8.5241° N and 76.9366° E longitude. It covers a geographical area of 2192 km^2 and is bordered by the Arabian Sea to the west, Tamil Nadu to the east and Kollam district to the north. The city was selected for this study because of its rapid urban growth, distinctive socioeconomic and environmental conditions and active engagement in UA (30). The city faces unique challenges related to urbanization, including limited arable land, rising food demands and socio-environmental vulnerabilities, making it a pertinent site for exploring the multifaceted role of UA in promoting urban resilience and sustainable development (31, 32). The Thiruvananthapuram city corporation, the primary local governing body, grapples with specific challenges, such as swift urbanization, limited land availability and waste management problems. Investigating how UA responds to these challenges and capitalizes on the available opportunities yields valuable insights for other urban locales facing similar challenges.

Selection of respondents

This study employed an *ex post facto* research design, a systematic empirical inquiry where the researcher does not have direct control over independent variables, since their manifestations have already occurred or are inherently non-manipulable. The research was conducted in the twenty selected wards of Thiruvananthapuram corporation, Kerala, India. Wards are the basic administrative units of local self-government (LSG) in Kerala. The research team selected twenty wards of Thiruvananthapuram corporation with prominent vegetable cultivation, through purposive sampling in consultation with officials from the Department of Agriculture Development and Farmers' Welfare and allied line departments, Government of Kerala. The research team further selected ten urban farmers from the selected wards, who involved in various forms of gardening as home gardens, kitchen gardens, terrace gardens or combined terrace–

kitchen gardens through purposive sampling with the assistance of elected members from the respective LSG wards, yielding a total sample of 200 respondents.

The questionnaire was developed and pre-tested in non-sample areas before administration. Following pretesting, the questionnaires were distributed primarily through email to all respondents; for those whose emails were undeliverable, postal mail was employed as an alternative. Additionally, data collection was incorporated into face-to-face interactions to maximize response rates. Ultimately, 124 complete responses were obtained, comprising 30 via email, 25 by postal mail and 69 through in-person interviews.

Data collection

The questionnaire comprised two major sections: catalytic factors promoting the initiation and continuation of UA and constraints impeding its effective practice in the city. Subsequently, the team collected data from the respondents on a five-point Likert scale ranging from strongly agreeing to strongly disagreeing, corresponding to numerical scores from 5 to 1. Data collection was conducted from September to December 2024 using a mixed-mode approach (online and direct) to ensure comprehensive representation of respondents from all selected wards.

Constraints faced by urban farmers

Based on review of the literature, preliminary field interactions and consultations with subject-matter experts, the research team identified the constraints experienced by urban farmers in Thiruvananthapuram corporation and classified them into two broad categories: institutional and socio-economic constraints. The team adopted this categorization to distinguish barriers arising from governance, policy and service delivery systems from those linked to household-level resources, labour and economic conditions and assessed each constraints using a three-point continuum: to a larger extent [3], to some extent [2] and to a lesser extent [1]. The use of a three-point scale was intentional, as it enabled respondents to clearly indicate the intensity of constraints without introducing the response of ambiguity. This approach is widely used in applied agricultural and extension research, where the objective is to prioritize limiting factors rather than measure attitudinal gradation.

Data analysis

Both descriptive statistics (frequency, percentage, mean score and rank) and inferential statistical analyses were used to analyze data. One-way ANOVA was used to assess differences among the three catalytic domains, followed by Tukey's HSD test for pairwise comparisons of the results. This approach enabled robust identification of statistically significant differences among domain means.

Analysis of variance (ANOVA)

The F-statistic for one-way ANOVA (Eqn. 1) was computed to test the null hypothesis of equal group means. Significant F-values ($p \leq 0.05$) warranted post-hoc analysis using Tukey's HSD (Eqn. 2) to identify specific group differences.

$$F = \frac{MS_{Between}}{MS_{Within}} \qquad \text{(Eqn. 1)}$$

where,

$$MS_{Between} = \frac{SS_{Between}}{df_{Between}}, MS_{Within} = \frac{SS_{Within}}{df_{Within}}$$

and

$$SS_{Between} = \sum_{j=1}^{k} n_j(\bar{X}_j - \bar{X})^2, SS_{Within} = \sum_{j=1}^{k} \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2$$

with

$$df_{Between} = k - 1 \quad df_{Within} = N - k,$$

$\bar{X}_j$ = mean of group j

$\bar{X}$ = overall mean

n_j = number of observations in group j

X_{ij} = individual observation

A significant *F*-value ($p \leq 0.05$) indicated that at least one group mean differed significantly.

Tukey's (HSD) test

When ANOVA showed significant results, Tukey's HSD was employed to identify the specific group means that differed. The formula used was:

$$HSD = q_{\alpha,k,df_{Within}} \times \sqrt{\frac{MS_{Within}}{n}} \qquad \text{(Eqn. 2)}$$

where,

$q_{\alpha,k,df_{Within}}$ = studentized range value at significance level α, for k groups and df degrees of freedom

MS_{Within} = mean square within groups (from ANOVA)

n = sample size per group (or harmonic mean for unequal n).

If

$$|\bar{X}_i - \bar{X}_j| > HSD,$$

then $\bar{X}_i$ the $\bar{X}_j$ difference between the two means and was considered statistically significant at the chosen level of probability.

Results and Discussion

Key catalysts driving growth and development of urban agriculture

The total mean scores of the key catalysts under the three dimensions are listed in Table 1. ANOVA revealed significant differences among the three categories of UA catalysts ($p < 0.05$). Fitness and well-being recorded the highest mean score (41.40), followed by socio-economic benefits (38.04) and ecosystem services (36.90), indicating that individual-level psychological and lifestyle-related motivations were the strongest drivers of UA adoption

Fitness and well-being

Psychological well-being (S1) emerged as the strongest catalyst within the fitness and well-being dimension, highlighting UA as an effective pathway for stress reduction, mental restoration and social reconnection in urban settings (Table 2; Fig. 1). This finding reinforces the role of urban food production as a nature-linked intervention that boosts mental health and quality of life, consistent with earlier studies reporting personal, social and emotional benefits of

Table 1. Mean scores of items under three catalytic factors of urban agriculture

Statement no.	Fitness and well-being		Socio-economic benefits		Ecosystem services	
	Mean score	Rank	Mean score	Rank	Mean score	Rank
S1	4.41	1	4.27	1	3.63	5
S2	4.27	2	4.05	5	3.51	8
S3	4.12	5	4.1	4	3.71	4
S4	4.06	7	2.8	9	3.49	9
S5	4.18	3	2.63	10	3.86	2
S6	4.18	3	3.86	8	3.93	1
S7	4.15	4	4.02	6	3.60	6
S8	4.10	6	4.12	3	3.86	2
S9	4.05	8	3.95	7	3.77	3
S10	3.90	9	4.25	2	3.52	7
Total	41.40		38.04		36.90	
Range	38 to 49		33 to 45		31 to 46	
SD	2.486		2.947		3.373	

ANOVA statistics

Statistic	Value
F value	78.598
p value	0.00001*
Mean square deviation (MSD)	0.266
Coefficient of variation (CV %)	7.625

Socio-economic benefits:

S1: I am aware that UA increases access to fresh and healthy food at households.

S2: I agree that UA helps in food production for my domestic consumption.

S3: I feel UA enhances intimate relations as well as social networks and interactions with different people and institutions, including the officials and elected representatives.

S4: I feel UA can influence local planning and policies that govern tenure security and shape people's ability to control and manage land.

S5: I can improve my social contact and integration through UA.

S6: I often feel that UA improves dietary diversity.

S7: I believe UA increases subjective well-being.

S8: I trust UA helps in the maintenance of cultural heritage.

S9: I feel urban agriculture augments my income through better access to jobs and livelihood opportunities, or another asset

S10: I like to share farming experience with other farmers.

Ecosystem services:

S1: I feel UA helps in increased species diversity and improved nutrient cycling.

S2: I feel UA provide nature-based solutions through green infrastructure.

S3: I think UA improves air quality.

S4: I feel UA improves soil fertility.

S5: I feel UA leads to soil and water pollution due to the overuse of chemical fertilisers.

S6: UA, through its green infrastructure solutions, is often identified as a vehicle to achieve the triple goals of sustainable development, human well-being and climate action.

S7: UA enhances pollination.

S8: UA maintained biodiversity and regulated microclimate and protected flora and fauna.

S9: I believe UA promotes a clean and sustainable environment.

S10: UA aids in reduction of energy use and greenhouse gas emissions.

Fitness and well-being:

S1: I think UA improves psychological well-being through the de-alienation process with community, nature etc

S2: I agree UA reduces lifestyle disorders.

S3: I think being involved in UA employs entertainment and leisure.

S4: It strengthens exercise and physical recreation.

S5: I think UA reduces the sense of boredom.

S6: I feel UA helps in improving healthy eating habits.

S7: I believe UA nurtures a soul with pleasure.

S8: I feel that practising UA is helpful for relaxation and stress reduction

S9: I agree UA gives personal satisfaction.

S10: I think the returns on urban agriculture is less substantive.

Table 2. Summary of primary, secondary and tertiary catalysts identified in each domain

Category	Primary catalyst	Secondary catalyst	Tertiary catalyst
Socio-economic	Access to fresh food (4.27)	Share farming experience (4.25)	Cultural heritage (4.12)
Ecosystem services	Sustainable development goals (3.93)	Biodiversity and pollution concern (3.86)	Clean environment (3.77)
Fitness and well-being	Psychological well-being (4.41)	Reduces lifestyle disorders (4.27)	Healthy eating and reduces boredom (4.18)

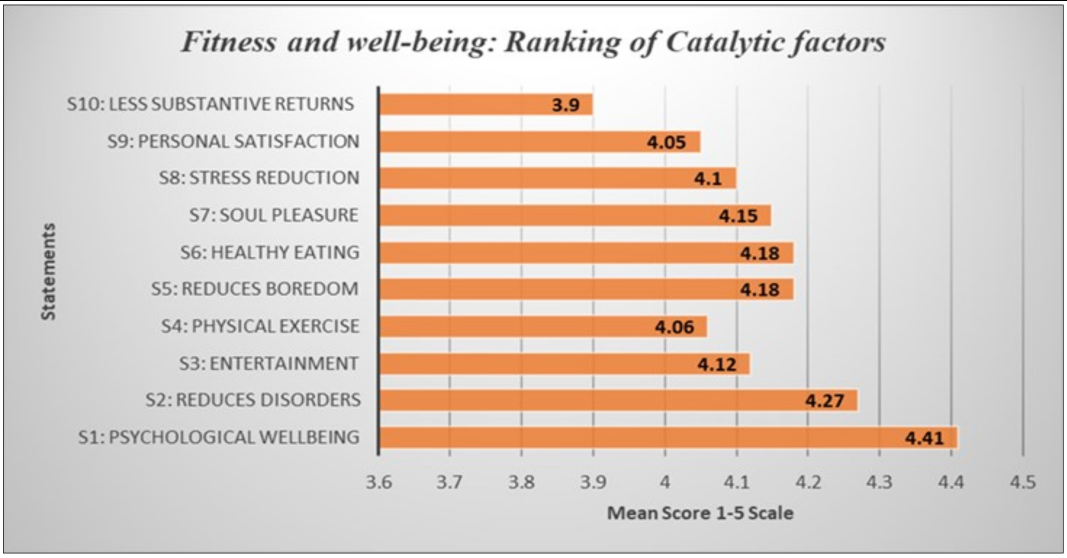

Fig. 1. Fitness and well-being: ranking of catalytic factors.

engaging in cultivation and green spaces (33, 34).The present findings are also consistent with those of, who emphasized the contribution of UA to well-being through the promotion of meaningful relationships, community belonging and a sense of fulfillment derived from productive engagement with the environment (35).

The secondary catalyst, reduction of lifestyle-related disorders (S2), along with high scores for tertiary catalysts, reduction of boredom (S5) and promotion of healthy eating habits (S6), underscores UA's preventive health potential. These results position UA not only as a food production activity but also as a low-cost, accessible public health co-benefit, particularly relevant in urban Kerala, where sedentary lifestyles and non-communicable diseases are increasing.

From a policy perspective, these findings support the inclusion of UA within health and wellness initiatives and its promotion through community-based programmes such as "Kudumbashree" neighborhood groups and Integrated Child Development Scheme (ICDS), which could integrate UA with their nutrition awareness and lifestyle improvement efforts. UA contributes directly to multiple aspects of human well-being, including food and nutritional security, livelihood enhancement, public health and social cohesion (36). The cultivation of both food and medicinal plants has further broadened their role in sustaining community health and resilience.

In contrast, personal satisfaction (S9) and perceived lower economic returns (S10) recorded comparatively lower mean scores. The lower ranking of S9 suggests that respondents may not consciously associate their farming activities with emotional fulfilment, even though the physical and psychological benefits were evident in practice (Fig. 1). The lowest score for S10 suggests that respondents largely perceived UA as offering limited direct economic returns, reinforcing its role in policy orientation towards food security, health, environment and well-being rather than income generation.

Socio-economic benefits of urban agriculture

The primary catalyst within the socioeconomic benefits dimension was attributed to the statement access to fresh food (S1), followed by the secondary and tertiary catalysts share experience (S10) and cultural heritage (S8) (Table 2; Fig. 2). Access to fresh food (S1) is ranked as the primary socio-economic catalyst, underscoring the role of UA in enhancing household food security. Statements related to sharing farming experiences (S10) and preserving cultural heritage (S8) formed secondary and tertiary catalysts, revealing a strong social dimension in community-based cultivation practices. The tertiary catalyst emphasized the cultural dimension of urban farming, where traditional practices and local heritage were valued and preserved through continued engagement in cultivation. Together, these three drivers demonstrate that UA is not only an economic activity, but also a social and cultural enterprise that reinforces household well-being, community resilience and collective identity (37).

The lowest mean scores within the socio-economic benefits dimension were recorded for influence policy (S4), indicating that respondents perceived limited opportunities to impact urban planning and governance (Fig. 2). This highlights the disconnect between grassroots practices and formal policy mechanisms in the city. Strengthening social integration through local cooperatives, farmer networks and inclusive urban food councils could enhance the visibility and agency of urban farmers, thereby transforming UA into a more equitable and policy-supported component of sustainable city development.

Ecosystem services of urban agriculture

The highest score for sustainable development (S6) reflects the perceived role of UA as a nature-based solution that contributes to sustainability goals including environmental protection, climate action and resource efficiency (Table 2; Fig. 3). This strong positive orientation coexisted with contrasting secondary perceptions,

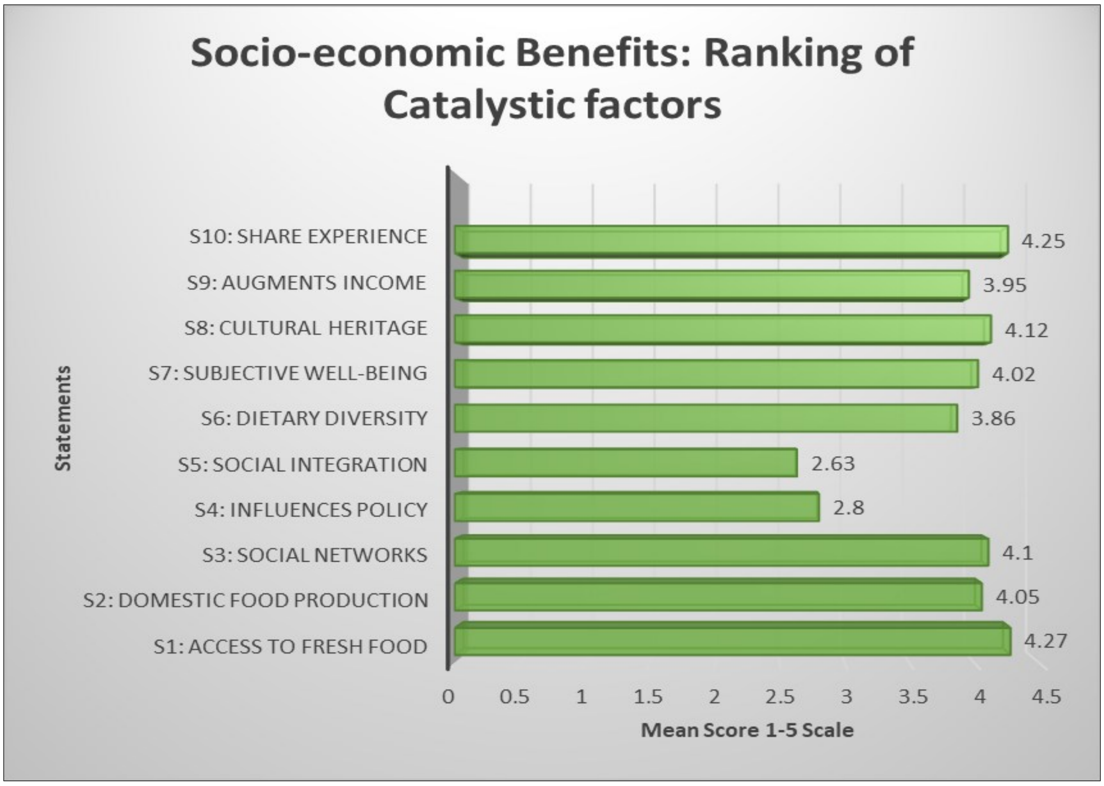

Fig. 2. Socio-economic benefits: ranking of catalytic factors.

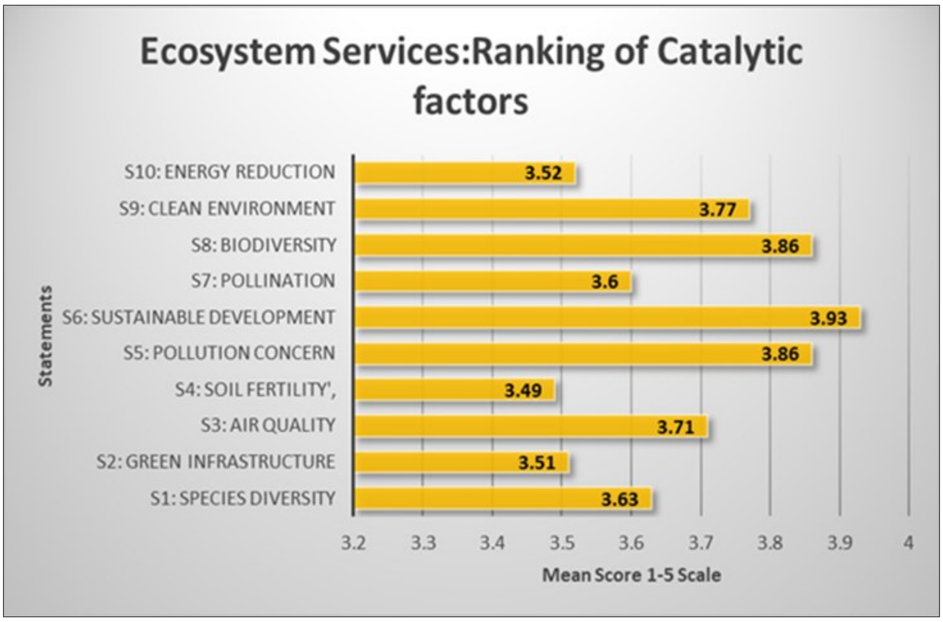

Fig. 3. Ecosystem services: ranking of catalytic factors.

represented by biodiversity enhancement (S8) and concerns over soil and water pollution due to chemical fertilizer use (S5). The high ranking of S8 indicates that respondents clearly recognized UA's role in supporting urban biodiversity**,** particularly through the creation of green spaces such as home gardens, terrace gardens and mixed cropping systems, attracting pollinators and beneficial insects and contributing to habitat connectivity within urban landscapes.

Although UA is often associated with improved soil fertility through its circularity, the relatively high score for the negatively framed statement on soil and water pollution due to chemical fertilizer use (S5) reflects context-specific concerns rather than a rejection of soil-related benefits**.** In dense urban settings such as Thiruvananthapuram, urban farming frequently occurs in space-constrained systems including rooftop gardens, grow bags and containers, where nutrient application tends to be more intensive and less buffered than in open-field agriculture. Under such conditions, respondents may perceive a higher risk of nutrient leaching, runoff, or salt accumulation**,** which also points towards a less stable extension of advisory service.

The tertiary catalyst, promotion of a clean environment (S9)**,** further reinforces UA's perceived contribution to improved urban environmental quality. Taken together, these findings highlight the importance of urban-specific ecological management frameworks that balance biodiversity enhancement with environmentally safe nutrient management. Strengthening collaboration among urban local bodies, agricultural extension services and research institutions can support integrated nutrient management, soil health monitoring and biodiversity-oriented UA programmes**,** thereby translating the ecological potential of UA into measurable and sustainable urban environmental outcomes (38).

Constraints faced by urban farmers

The constraints faced by urban farmers in Thiruvananthapuram corporation were categorized into two categories: institutional constraints and socio-economic constraints. Each constraint was ranked from highest to lowest based on the total score and the results are shown in Table 3.

Institutional constraints

Among the institutional factors, lack of timely information facilities ranked first (score 276), followed by lack of extension services (score 272) and shortage of agricultural inputs and equipment (score 268). These three constraints collectively indicated that urban farmers faced systemic barriers in accessing the technical, informational and infrastructural support essential for effective farming.

Timely access to information on weather forecasts, market trends, technological innovations and optimal agricultural practices is crucial for farmers to make informed decisions and adapt to changing conditions (39). However, the absence of structured information channels in urban areas limited their ability to respond proactively to market and climatic variability. Similarly, the lack of dedicated extension services tailored to the urban context has left farmers without essential technical guidance on soil health, irrigation, pest management and urban farming technologies (40).

Furthermore, shortages of inputs and equipment reflected the challenges of supply chain fragmentation and resource competition within cities. Urban farmers often find it difficult to procure affordable and high-quality inputs because of limited distribution networks and higher transportation and storage costs (41). Collectively, these institutional gaps hinder the scalability, efficiency and sustainability of urban farming initiatives. Limited extension services particularly highlight the absence of urban-specific advisory mechanisms, which are essential for guiding farmers on soil management, cultivation technologies and pest control under constrained urban conditions.

Socio-economic constraints

Under socio-economic constraints, the lack of soil fertility emerged as the most significant challenge (score 296), followed by the high cost of specialized farming structures and inputs (score 280) and the high cost of labour (score 276). Declining soil fertility directly affects productivity and profitability, posing a serious threat to the long-term sustainability of urban agricultural systems. Improving soil health through testing, composting and the use of organic amendments can mitigate this constraint (42).

The high cost of specialized inputs and structures, such as vertical gardens, hydroponic systems and protective covers, places a substantial financial burden on urban farmers, particularly on small-scale producers with limited access to credit. This financial barrier may discourage new entrants and restrict the expansion and diversification of existing enterprises (43, 44). Similarly, high labour costs further pose challenges to profitability and competitiveness, especially in cities where wage levels and opportunity costs are high. Although mechanization and automation could potentially offset labour dependency, adoption was constrained by high initial investment and technical complexity (45–47).

Lower-ranked constraints, such as crop damage, theft and limited credit facilities though less critical, still influenced farmer's willingness to expand or diversify production (35, 48). Together, these findings demonstrate that UA in Thiruvananthapuram is primarily driven by motivations related to well-being and food access, while impeded by institutional inefficiencies and resource-related challenges. Addressing these constraints through targeted extension models, improved input distribution systems and greater policy integration could strengthen the sustainability of UA in the region.

Conclusion

This study demonstrates that UA in Thiruvananthapuram functions as a multidimensional, plant-based urban system, delivering integrated socio-economic benefits, ecosystem services and fitness and well-being outcomes, while simultaneously facing institutional and practice-related constraints. Among the identified catalysts, fitness and psychological well-being emerged as the strongest drivers, highlighting that motivations for urban farming extend beyond food production to include mental restoration, physical activity and quality of life enhancement.

Table 3. Constraints faced by urban farmers

	Particulars	Larger extent		Some extent		Lesser extent		Scores	Rank
A	**Institutional constraints**	**F**	**P**	**F**	**P**	**F**	**P**		
1.	Lack of vacant spaces and land area for farming	52	41.94	28	22.58	44	35.48	256	**IV**
2.	RRestrictive rules and ordinances	36	29.03	52	41.94	36	29.03	248	**V**
3.	Lack of extension services	40	32.26	68	54.84	16	12.90	272	**II**
4.	Lack of credit facilities	28	22.58	64	51.61	32	25.81	244	**VI**
5.	Shortage of agricultural inputs and equipments	40	32.26	64	51.61	20	16.13	268	**III**
6.	Lack of timely information facilities	56	45.16	40	32.26	28	22.58	276	**I**
B	**Socio-economic constraints**								
1	Vulnerability to theft	20	16.13	28	22.58	76	61.29	192	**VIII**
2.	Crop damaged by passing livestock	16	12.90	48	38.71	60	48.39	204	**VII**
3.	Crop loss due to pest and disease	44	35.48	48	38.71	32	25.81	260	**V**
4.	Lack of soil fertility	56	45.16	60	48.39	8	6.45	296	**I**
5.	High cost of labour	48	38.71	56	45.16	20	16.13	276	**III**
6.	High cost of specialized farming structure/inputs	60	48.39	36	29.03	28	22.58	280	**II**
8.	Difficulty in getting quality inputs	60	48.39	28	22.58	36	29.03	272	**IV**
9.	Lack of labour and time	28	22.58	68	54.84	28	22.58	248	**VI**

From a theoretical perspective, the findings advance UA research by empirically illustrating the interconnectedness of food security, ecological functions and human well-being in urban contexts. Practically, the results point toward scalable and institutionally grounded pathways for strengthening UA in rapidly urbanizing cities. In Kerala, where decentralization is at its peak, integrating UA within local self-government initiatives, community-based institutions such as "Kudumbashree" and other urban-focused green infrastructure providing services can enhance environmental safety and long-term sustainability. This study also underscores the importance of science-based nutrient management and appropriate technologies to mitigate environmental risks while maximizing ecological benefits.

In conclusion, the insights from Thiruvananthapuram offer scalable lessons for other medium-sized cities in India and similar regions, where UA can be positioned as a strategic component of sustainable urban planning, public health promotion and environmental resilience.

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Authors' contributions

The research work was conceptualized by GSS and SSP. The study design and data collection were carried out by SGS, RM and SJR. Data analysis and interpretation were performed collaboratively by SGS, SS, SSP, SK, AKR, CVS and GS. The manuscript was prepared by SGS, SS, RM, SSP, SK, AKR, CVS and GS, with contributions from all authors to the final version of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT for grammatic corrections. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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