Urban Agriculture and Smart Cities: The Integration of Controlled Environment Agriculture, Community Gardens, and Public Health Policies

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Abstract: Urban agriculture has emerged as a key strategy for building smart cities, fostering synergies between environmental sustainability, technological innovation, social inclusion, and food security. This article aims to analyze the integration of Controlled Environment Agriculture (CEA), community gardens, and public health policies, emphasizing their contributions to urban resilience and sustainability. The study adopts a qualitative methodology, based on literature review, analysis of official documents, and case studies from Brazilian cities such as Salvador, Recife, São Paulo, and Rio de Janeiro. Results indicate that CEA enhances productivity in small spaces with reduced water and input consumption, community gardens strengthen social cohesion, mental health, and local food supply, while public policies link these initiatives to school feeding programs, health promotion, and income generation. Despite significant progress, challenges remain regarding high implementation costs, regulatory gaps, and lack of institutional support. The findings reinforce the need to incorporate urban agriculture into master plans and legal frameworks, promoting research, training, and public-private partnerships. By combining food production, innovation, and policy integration, urban agriculture positions itself as a structural axis for more resilient, sustainable, and equitable cities.

Keywords: Urban Agriculture. Smart Cities. Community Gardens. Public Health. Controlled Environment Agriculture (CEA).

1. Introduction

Urban agriculture has been consolidated as a strategic dimension in the context of smart cities, articulating sustainability, food security, and technological innovation. By integrating technologies such as Controlled Environment Agriculture (CEA), sensors, Internet of Things (IoT), and renewable energy solutions, it offers responses to growing urbanization, climate change, and food insecurity.

In developing countries, about 30 to 40% of vegetable production is lost during post-harvest, processing, and distribution stages, representing a waste of the resources used in production (land, water, energy, and inputs) [1]. Vertical farming – which requires only 5% of the water used in open-field or traditional cultivation – is one of the sustainable methods of growing vegetables and small fruits such as strawberries, for example. Conscious consumers value local producers, the consumption of fresher foods, and demand that production be closer to the point of sale to avoid such waste.

2. Urban Agriculture in Smart Cities

Smart cities are defined by the articulation between urban infrastructure, digital data, citizen participation, and sustainability. In this context, urban agriculture is understood as essential green infrastructure that offers: I) Reduction of emissions and waste by avoiding long food transport distances; II) Resource optimization through intelligent monitoring systems; III) Requalification of underutilized urban spaces; IV) Integration with urban, environmental, and health policies.

The presence of growing spaces within the urban fabric significantly contributes to urban sustainability, by acting on: Ecosystem services: microclimate regulation, rainwater retention, increased urban biodiversity; Urban efficiency: integration with water collection systems, solar energy, organic waste recycling; Digital and social inclusion: promoting access to technology, use of open data, formation of collaborative networks; Food resilience infrastructure: decentralization of production, reduced dependence on long logistics chains, and prioritization of family farming.

Food production in urban areas can be seen as a potential strategy to meet part of the food demands in urban areas [2].

Modern architects envision opportunities for requalifying degraded urban areas and enhancing public and collective spaces through urban agriculture. Productive green roofs and walls, vertical cultivation, CEA in greenhouses, vertical farms, smart agricultural containers, gardens in ecological corridors or abandoned subway stations (as in Paris and London) demonstrate how integration can occur even in dense cities. This type of agriculture not only optimizes underused urban spaces but also functions as green havens, contributing to improved air quality and community well-being. Cultivation in greenhouses and/or controlled environments can ensure year-round production of locally grown and consumed crops regardless of climatic conditions, significantly reducing the use of natural inputs such as water and soil.

Added to this is the possibility of being integrated into urban digital platforms. In this way, urban agriculture can dialogue with real-time data on energy consumption, food production, air quality, and population well-being, becoming part of evidence-based decision systems. Supporting local public policy decision-makers. “The bridge between smart cities and urban agriculture is not just a connection; it is a path to a more sustainable and vibrant future” [3].

Therefore, within the smart city ecosystem, urban agriculture operates as a cross-structuring axis, with positive impacts on housing, transportation, environment, education, and health policies.

In May 2019, the ISO 37122:2019 standard, last revised version: 2024 ("Sustainable cities and communities — Guidance on the use of ISO 37120, ISO 37122, and ISO 37123 standards") on performance measurement in smart cities was published, which specifies and establishes definitions and methodologies for a set of indicators for smart cities (ISO, 2019). The Brazilian version translated by the Brazilian Association of Technical Standards (ABNT), ABNT NBR ISO 37122:2020 Corrected Version: 2021 – Sustainable cities and communities – Indicators for smart cities [4], includes 19 themes: economy, education, energy, environment and climate change, finance, governance, health, housing, population and social conditions, recreation, safety, solid waste, sports and culture, telecommunications, transportation, local/urban agriculture and food security, urban planning, sewage, and water.

According to the 2023 Connect Smart Cities Ranking, Salvador became the first Brazilian capital certified by ABNT – Brazilian Association of Technical Standards in international indicators of urban service quality, quality of life, and smart city standards established by ABNT NBR ISO 37120:2021 and NBR ISO 37122:2020.

Figure 1 – Connected Smart Cities Ranking 2023 edition

POSIÇÃO	MUNICÍPIO - UF	NOTA
1º	Florianópolis - SC	36,762
2º	Curitiba - PR	35,789
3º	São Paulo - SP	35,604
4º	Belo Horizonte - MG	35,540
5º	Niterói - RJ	35,492
6º	Barueri - SP	35,477
7º	Vitória - ES	35,468
8º	Santos - SP	35,429
9º	Salvador - BA	34,308
10º	Rio de Janeiro - RJ	34,307

Source: Connected Smart Cities Ranking (2023) [5]

Figure 2 – Connected Smart Cities Ranking 2024 edition

POSIÇÃO	MUNICÍPIO - UF	NOTA
1º	Florianópolis - SC	37,525
2º	Vitória - ES	37,513
3º	São Paulo - SP	36,828
4º	Curitiba - PR	36,808
5º	Niterói - RJ	36,765
6º	Balneário Camboriú - SC	36,699
7º	São Caetano do Sul - SP	36,164
8º	Belo Horizonte - MG	35,705
9º	Barueri - SP	35,579
10º	Salvador - BA	35,364

Source: Connected Smart Cities Ranking (2024) [6]

In the general Connected Smart Cities ranking, the capital of Bahia ranked 9th (Figure 1), 1st among cities in the Northeast, and reached 11th place in the Urbanism axis. In 2024, it remained the best-ranked city in the Northeast but dropped to 10th in the general Connected Smart Cities ranking (Figure 2), and ranked 7th in technology and innovation.

The Salvador City Hall presents in its 2022 Smart City Technology Master Plan, 50 challenges aligned with the Smart City Objectives (OCI's). This is a framework that adopts the United Nations Sustainable Development Goals (SDGs) as foundations for urban transformation, guided by sustainability purposes that support the adoption of innovation and technology in local public service. In its Objective 32 – Urban Agriculture, aligned with SDGs 2 – Zero hunger, 11 – Sustainable cities and communities, and 12 – Responsible consumption and production, the city's 2021-2024 strategic plan is cited with the Urban Gardens program, which aims to: "Stimulate local food production, reduce costs, and increase the population's access to healthy and affordable food. Among the expected results are the strengthening and expansion of urban agriculture and income generation for vulnerable communities." [7]

2.1 Controlled Environment Agriculture (CEA) and Technological Innovation

Indoor and vertical urban production, supported by CEA, represents a systemic technological approach: sensors, controls, automation, LED, AI/ML, and computer vision form an ecosystem capable of producing food with high resource efficiency. Energy, financial (high initial investment), skills and knowledge gaps, and regulatory challenges still need to be overcome.

According to food security expert Dr. Dickson Despommier from Columbia University [8], foods grown in controlled urban environments (such as microgreens, for example) represent na important step toward food resil climate change and accelerated urbanization. Benefits include reducing the need for long distance transportation and waste while – Sustainable cities – Responsible sumption 2021- results are the s atory resilience in times of longdistance transportation and waste while increasing efficiency and regularity in production, regardless of regional climate. Indoor growing, home growing, and controlled environment cultivation are various terms for the same practice. Controlled environment production involves more sophisticated techniques than field cultivation [9]. This type of farming is characterized by using a closed environment with artificial lighting, automated irrigation, and controlled temperature and humidity suitable for the specific crop being cultivated.

A microclimate must be simulated for controlled environment production, consisting of the ideal combination of air temperature, relative humidity, and light, assuming that other factors such as CO_2, soil pH, and nutrients are not limiting [10]. This control aims to provide plants with the ideal conditions for germination and/or growth, mimicking outdoor conditions without the unpredictability of weather and seasonality, bringing harvest predictability. Because the environment is enclosed/controlled, the incidence of pests is greatly reduced.

These characteristics promote higher yields, demonstrating efficiency and excellence production. Cultivation can be done in small spaces using trays and shelves, also known as vertical farming or vertical gardens.

According to Gould and Caplow [11], implementing agriculture within urban centers has great potential to significantly reduc fuel consumption, improve urban ecology, ensure food security, enhance public health, and conserve building energy. Still little known and developed in most countries, vertical farming or urban farms – presents itself as a solution to improve urban populations' access to higher quality food.

Table 1 – Brazil x World Comparison Urban Indoor Cultivation

Aspect	Brazil	World
Development Stage	Emerging: growing number of urban gardens and hydroponic systems	Established: presence of large networks and consolidated indoor farming startups
Market Scale	Country still in the initial phase, no consolidated USD data	Global indoor farming market estimated at ~US$ 42 billion (2024), projected to reach ~US$ 88 billion by 2030 (CAGR ~13.5%)
Key Technologies	Hydroponics, CEA, community gardens and local startups	Hydroponics, aquaponics, vertical farms automated with AI and LED lighting
Resource Use	Up to 90% water savings via hydroponics; energy depends on source	Globally, indoor farms use up to 95% less water, but high energy consumption
Main Challenges	High initial cost; lack of institutional support and regulation	High CAPEX and operational costs (energy, infrastructure); legal frameworks in progress
Growth Prospects	Likely expansion with support for technologies and urban sustainability (early stage)	Global market projects continued growth: indoor farming ~US$ 88B by 2030; vertical farms worth ~US$ 35B by 2032

Source: Author based on [12] (2018)

"In Brazil, however, the practice of urban agriculture has encountered numerous challenges, such as insufficient financial support, limited technical assistance, lack of legal land ownership, and the absence of a legal framework or legislation to promote i strengthening, which leads to the slow development of the activity" [13]. Controlled agriculture systems are gaining momentum but lack consolidated statistics and strong government support. According to (table 1), the global market is already more mature and rapidly growing, with expectations of widespread adoption of AI, automation, and water efficiency.

2.2. Community Gardens and Social Cohesion

Community gardens go far beyond food production: they function as social infrastructures, promoting social i engagement, strengthening cohesion, solidarity, mental health, and cultural identity. They create learning and socializing spaces, contribute to food security, and support the democratic use of urban space. Benefits are particularly evident vulnerable neighborhoods, with a direct impact on collective well-being, inclusion, and urban resilience.

According to the 2022 Smart City Technology Master Plan, the Salvador City Hall presents in its Objective 32 (Urban Agriculture) the "Urban Gardens" program with the following action lines: a) Mapping non-building areas suitable for urban agriculture; b) Providing training for sustainable urban agriculture aimed at commercialization; c) Drafting an Urban Agriculture Law Project; d) Implementing community urban gardens aimed at subsistence and income generation in vulnerable communities; e) Encouraging residential gardens through the Home Garden program.

The Salvador City Hall, through the Secretariat for Sustainability, Resilience, Well Animal Protection (Secis), is implementing agroecological commercial gardens. These examples demonstrate a path for the development of urban agriculture and its contribution to smart cities and public well being.

2.3. Integration with Public Health Policies

The articulation between SUS and urban agriculture initiatives can foster the creation of public policies that encourage the production of healthy and sustainable food in cities. Urban agriculture is directly related to health: improving the population's n preventing chronic diseases (diabetes, hypertension); promoting mental well physical activity; combating food insecurity.

Cities such as Belo Horizonte, Medellín, and Vancouver have established programs integrating gardens wit school meals.

Studies conducted by the School of Public Health, University of São Paulo [13], on the effects of Urban and Periurban Agriculture (UPA) practices in Basic Health Units (BHUs) as a health promotion activity, and the extent to which their therapeutic dimension aligns with integrative and complementary practices, in the municipality of Embu das Artes in São Paulo, concluded that community garden cultivation activities serve as health-promoting practices that integrate key elements of integrative and complementary practices (PIC).

2.4. Urban Planning and Governance

Data from the 2022 Demographic Census by the Brazilian Institute of Geography and Statistics (IBGE) [14] indicate that 87% of Brazil's population lives in urban are urbanization rate at 84.4% compared to the previous 2010 census. The highest percentages of urban population were observed in the Southeast (94.44%) and Centerregions, followed by the South (88.24%), North (78.47%), and Northeast (77.64%).

Sustainable urban development planning must address challenges that, in addition to ensuring adequate environmental conditions, must consider the population's food and nutritional security.

To ensure urban agriculture is sustainable and integrated, the following are necessary: favorable land use policies; incentives, training, and financial support for vertical cultivation in controlled environments; technical and community support and training for family farmers; and the inclusion of urban agriculture in master plans and planning instruments.

The National Urban and Periurban Agriculture Program (PNAUP) [15] is a Brazilian government policy aimed at promoting sustainable agriculture development in urban and periurban areas. The program seeks to enhance food security, generate income, promote environmental education and agroecological production, and encourage organic waste management. Instituted by Decree No. 11.700/2023, PNAUP focuses on food, medicinal, aromatic and ornamental plants, herbal medicines, and inputs. The program covers all stages, from production to commercialization, including organic waste management.

2.5. Challenges and Recommendations

The potential benefits of implementing urban agriculture are still underexplored and overlooked by municipal governments. Given the country's size and vast agricultural potential, Brazil is doing far less than the global standard in this area. International trends, climate emergencies, sustainable water and soil use, and the increasing and aging global population call for stronger and more concrete actions.

Recommendations include incorporating urban agriculture into public health, education, and socio-economic well-being policies; public funding and public-private partnerships;cooperation with universities and research institutes; training community-based multipliers; utilizing idle and underused public spaces; and strengthening family farming.

3. Conclusions

Increasing urbanization and the challenges related to food security, climate change, and social inequality have driven the search for innovative solutions in cities. In this context, the integration between urban agriculture, technology, and public policies has emerged as a synergistic and essential strategy to promote more sustainable, resilient, and inclusive cities.

Urban agriculture – which includes community gardens, vertical farming, hydroponic systems, and farms in controlled environments – contributes directly to local food supply, income generation, the strengthening of community bonds, and the requalification of idle spaces. Additionally, by reducing the dependence on long logistics chains and minimizing the carbon footprint of food transport, it aligns with the principles of urban sustainability.

The use of digital technologies and controlled environment agriculture (CEA) systems further enhances these benefits. Solutions such as IoT sensors, automation, artificial intelligence, and optimized spectrum LED lighting allow maximizing productivity and reducing the consumption of resources such as water and energy. These advances are especially relevant in dense urban areas, where space is scarce, and environmental challenges are more intense.

However, for these practices to be viable on a large and equitable scale, the active role of the public sector is essential. Well-designed public policies are fundamental to ensure access to urban land, technical and financial support, specific land use regulations, and integration with intersectoral agendas such as health, education, and environment. Cities like Belo Horizonte, São Paulo, and Recife already implement local policies that incorporate urban agriculture into their sustainable development strategies, often associated with public health and food security programs.

The synergy between urban agriculture, technology, and public policies not only expands the efficiency and scale of these practices but also strengthens community protagonism, promotes social innovation, and transforms the way cities produce, consume, and organize themselves. By integrating these dimensions, it is possible to build a new urban paradigm based on resilience, socio-environmental justice, and food sovereignty.

References

[1] GUSTAVSSON, J.; CEDERBERG, C.; SONESSON, U.; OTTERDIJK, R.; MEYBECK, A. *Global food losses and food waste: extent, causes and prevention*. Rome: Food and Agriculture Organization of the United Nations, 2011, pp. 1–38.

[2] NICHOLLS, E. et al. *The contribution of small-scale food production in urban areas to the sustainable development goals: a review and case study*. Sustainability Science, Tokyo, v. 15, p. 1585–1599, 2020.

[3] SIMOS, N. *Bridging the gap between smart cities and urban agriculture*. 2024. Available at: https://www.agritecture.com/blog/bridging-the-gap-between-smart-cities-and-urban-agriculture. Accessed: June 27, 2025.SIMOS, N. Reduzindo a distância entre cidades inteligentes e agricultura urbana. 2024. Disponível em: < https://www.agritecture.com/blog/bridging-the-gap-between-smart-cities-and-urban-agriculture>. Acesso em 27 jun. 2025.

[4] ABNT – Brazilian Association of Technical Standards. *NBR ISO 37122 – Corrected Version - 2021: Sustainable cities and communities – Indicators for smart cities*. Rio de Janeiro: ABNT, 2021.

[5] Connect Smart Cities. *CONNECTED SMART CITIES RANKING 2023*. Available at: https://web.nectainova.com.br/ranking-csc_2023/. Accessed: June 27, 2025.

[6] Connect Smart Cities. *CONNECTED SMART CITIES RANKING 2024*. Available at: https://web.nectainova.com.br/rcsc_ranking-csc_2024/. Accessed: June 27, 2025.

[7] Prefeitura Municipal de Salvador. *Smart City Master Plan 2022*. Available at: https://semit.salvador.ba.gov.br/plano-diretor-de-cidades-inteligentes/. Accessed: June 27, 2025.

[8] DESPOMMIER, Dickson. *The Vertical Farm: Feeding the World in the 21st Century*. Macmillan, 2010.

[9] SAHA, M. K. *Automated farming using microcontroller and sensors*. International Journal of Scientific Research and Management Studies, v. 2, n. 1, p. 21–30, 2017.

[10] NIU, G.; SUN, Y.; MASABNI, J. G. *Impact of low and moderate salinity water on plant performance of*

leafy vegetables in a recirculating NFT system. Horticulturae, v. 4, n. 6, 2018.

[11] GOULD, D.; CAPLOW, T. *Building-integrated agriculture: A new approach to food production*. In: *Metropolitan Sustainability*. Woodhead Publishing, 2012. p. 147–170.

[12] FARIAS, A. et al. *Sustainable cities and communities: contributions from Embrapa*. 2018. Available at: https://www.researchgate.net/publication/359169993_Desafios_para_uma_urbanizacao_sustentavel. Accessed: June 30, 2025.

[13] CUNHA, M.; CARDOSO, R. *Urban gardens in promoting food and nutrition security and sustainable development in Salvador, Bahia*. 2022. Available at: https://www.scielo.br/j/asoc/a/JnfmVX3jJYxjYFN53ZngbpM/?format=pdf&lang=pt. Accessed: June 30, 2025.

[14] BRAZIL. Ministry of Health. Department of Primary Care. *National Policy on Integrative and Complementary Practices in SUS*. Brasília: MS, 2006.

[15] IBGE – Brazilian Institute of Geography and Statistics. *2022 Census: 87% of the Brazilian population lives in urban areas*. 2025. Available at: https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/41901-censo-2022-87-da-populacao-brasileira-vive-em-areas-urbanas. Accessed: June 30, 2025.

[16] BRAZIL. *Decree No. 11.700, September 12, 2023*. Establishes the National Urban and Periurban Agriculture Program and its Working Group. Brasília, 2023.