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Urban and Peri-Urban Agriculture: A Pathway to Sustainable Cities

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Highlights

- By 2050, urbanisation will drive a 35-56% rise in food demand, with food systems contributing to one-third of global greenhouse gas emissions.
- Urban and peri-urban agriculture paves the way for sustainable cities, but measures are needed to reduce its carbon footprint, especially regarding energy use.
- Embedding Resource Nexus thinking into urban and peri-urban agriculture fosters synergies between food, waste, energy, and water systems.
- Strengthening research and continuous monitoring helps us understand the effects of changing climate patterns on the carbon emissions and sequestration of urban and peri-urban agriculture.

New Challenges

As global urbanisation rises, the urban population is projected to increase to 68% by 2050 (United Nations, Department of Economic and Social Affairs, 2019), and the accompanying food demand is also expected to grow by 35-56%, which already contributes to one-third of the total anthropogenic greenhouse gases emissions (Costa et al., 2022). Cities face increasing demands for sustainable food systems to support urban populations. Traditional food supply chains are often long and complex, contributing significantly to greenhouse gas emissions.

Recent events, including the COVID-19 pandemic, have exposed vulnerabilities in the global food supply chains and highlighted the need for resilient urban food policies. Urban and peri-urban agriculture – the practice of cultivating crops and raising livestock for consumption, within cities and their surrounding fringes – has gained increasing interest from citizens and policymakers over time and more so after the pandemic (Thilmany et al., 2021). Agriculture in urban and peri-urban areas increases the resilience of cities by increasing food security, increasing distribution efficiencies, improving social cohesion and socioeconomic conditions, and increasing the adoption of innovative technologies (FAO

et al., 2022).
Additionally, Urban and peri-urban agriculture also provides cities with substantial environmental benefits and ecosystem services that can help in mitigating and adapting to climate change, such as sequestering carbon, increasing biodiversity, reducing stormwater runoff, reducing urban heat islands, and improving air and soil quality (Goldstein et al., 2016). However, urban and peri-urban agriculture can also contribute to climate change through greenhouse gases emissions, soil pollution, resource use, and other negative environmental impacts. This policy brief outlines recommendations to enhance sustainable and resilient cities through urban and peri-urban agriculture as an innovative agri-food system.

> By 2050, more than two-thirds of the global population will live in urban areas (United Nations, Department of Economic and Social Affairs, 2019), and urban food demand is expected to grow by 35-56% (Costa et al., 2022).

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Adopting and Adapting Innovative Tech

Through adopting new technologies, urban and peri-urban agriculture can play a vital role in creating sustainable and climate-resilient cities, particularly in rapidly urbanising regions in the Global South. Low-cost and climate-resilient solutions, such as hydroponics and aquaponics, can be optimised for local urban contexts, particularly where space and water are limited. Depending on the degree of climate control (e.g., indoor or outdoor), these systems may also enable year-round food production and reduce reliance on distant supply chains. In Singapore, growing leafy vegetables in soil-based greenhouses or vertical farming with sunlight has a smaller carbon footprint than that incurred from food miles via imports (Song et al., 2022). Implementing circular systems that recycle water and nutrients within urban and peri-urban agriculture can create self-sustaining models. For instance, closed-loop systems that use organic waste from fish rearing as fertiliser for irrigation in aquaponics contribute to resource efficiency

Increasing biodiversity through urban and peri-urban agriculture, such as using agroforestry or green roofs, can enhance urban habitats, reduce urban heat, and support local ecosystems, contributing to urban resilience against climate impacts. Productive green infrastructure can reduce air pollution and enhance carbon sequestration (CS), reducing CO_2 concentration by around 6% (Anderson and Gough, 2021). Urban and peri-urban agriculture can provide a habitat for beneficial insects and wildflowers for nectar and pollen, which can, in turn, support food production (Orsini et al., 2014).

Policies supporting equitable urban and peri-urban agriculture access for marginalised urban communities would facilitate affordable technologies and technical support. In the Global South, urban and peri-urban agriculture often serves as a critical mechanism for income generation and food security, addressing the immediate needs of vulnerable populations. Conversely, in the Global North, agriculture in urban and peri-urban areas is frequently leveraged for its social benefits, such as fostering community engagement, improving mental health, and enhancing urban green spaces. Recognising these regional distinctions can help tailor policies that maximise the specific benefits urban and peri-urban agriculture offers in different contexts, ensuring its role as a transformative pathway to sustainable cities.

Clean Energy in Urban and Peri-urban Agriculture

Urban and peri-urban agriculture has the potential to reduce the environmental impacts of food supply chains compared to conventional agriculture. However, the environmental impacts of an urban and peri-urban agriculture system still depend on the means of production, especially concerning energy consumption.

For instance, producing lettuce with indoor farming using the current energy mix in the United Kingdom generates higher emissions than conventional supply chains (Sandison et al., 2023). The energy used for lettuce production by vertical farming in the Netherlands has driven a higher carbon footprint than other forms of production (Blom et al., 2022). In Sydney, Australia, commercial production in peri-urban farms has fewer emissions than the interstate supply chain due to post-harvest and on-market operations (Rothwell et al., 2016). These variations in the performance of urban and peri-urban agriculture compared to conventional systems indicate that urban and peri-urban agriculture is not always the optimal solution, and measures are needed to reduce the carbon footprint of urban and peri-urban agriculture to be a sustainable and resilient food system, especially regarding energy use.

Improvement in urban and peri-urban agriculture systems – particularly their energy efficiency – must be increased to make it a sustainable option for urban food production. Optimising the growing conditions for indoor farming can reduce emissions while maximising yields. Renewable energies – while paying attention to other resource synergies and tradeoffs – could power innovative indoor and rooftop farming (Blom et al., 2022; Sandison et al., 2023). For instance, coupling photovoltaics with rooftop farming can produce synergies and maximise the use of rooftops (Corcelli et al., 2019). Policies should incentivise renewable energy (e.g., solar, wind) for urban and peri-urban agriculture operations to reduce greenhouse gases emissions.

Integrating the Resource Nexus in Urban and Peri-urban Agriculture

Urban and peri-urban agriculture plays a pivotal role in advancing the Resource Nexus by linking water, energy, waste, and food systems through circular economy principles. Integrating urban and peri-urban agriculture with waste management in the city helps address organic waste disposal, nutrient recovery, and resource inefficiencies while aligning with climate goals. Repurposing urban organic waste and agricultural residues into compost or biochar enhances soil health, increases CS, and reduces reliance on synthetic fertilisers.

The energy-water-food-waste nexus is further reinforced through material efficiency. Transitioning to recycled, biodegradable, or reusable materials in farming infrastructure significantly reduces the carbon footprint of high-tech systems like vertical farming. Life-cycle assessments highlight the potential of waste-to-energy technologies, such as biogas from organic waste, to improve urban energy resilience.

Embedding Resource Nexus thinking into urban and peri-urban agriculture fosters synergies between food, waste, energy, and water systems. This holistic approach reduces environmental impacts, optimises resource flows, and creates sustainable urban food systems that enhance climate resilience and resource security.

Case studies: Resource Nexus in Urban and Peri-urban Agriculture

Singapore: Rooftop and indoor farming systems utilise renewable energy, recycle nutrients, and reuse water, creating efficient and sustainable urban agriculture models (Song et al., 2022).

France: Rooftop agriculture in Paris leverages biochar to integrate waste management, energy recovery, and food production, reducing greenhouse gas emissions and boosting resource efficiency (Dorr et al., 2017).

Spain: Community gardens irrigated with treated wastewater demonstrate how urban farming can conserve freshwater and address urban waste challenges (Pérez-Neira and Grollmus-Venegas, 2018).

Urban Planning

Integrating urban and peri-urban agriculture into urban and regional planning is crucial for building sustainable food systems. This requires adopting sustainable agricultural practices and innovative technologies within urban food policies. Such policies should aim to enhance food security and sustainability by reducing greenhouse gas emissions, boosting biodiversity, and promoting social and economic cohesion. FAO describes a city region as encompassing not only megacities and their surrounding rural and agricultural areas but also small and medium-sized towns that connect remote small-scale producers and their agricultural value chains to urban centres and markets (FAO, 2023). This comprehensive view of the city region allows for a more holistic analysis of urban food systems. Policymakers and urban planners are encouraged to identify these regions through participatory approaches, such as those outlined by the FAO. Prioritising allocating spaces in urban areas for agricultural activities is essential in land-use planning, with policies adapted to various urban contexts and stakeholders.

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Urban planning can enhance the sustainability of urban and peri-urban agriculture through measures such as strengthening local food markets and facilitating resource exchanges between cities and agriculture. These initiatives create synergies that benefit both urban and peri-urban agriculture and urban environments. By strategically selecting crops and implementing effective management practices, urban and peri-urban agriculture can contribute to resilient, low-carbon local food systems.

Spatiotemporal analysis supports decision-making by helping planners visualize urban changes, assess policy impacts, and simulate growth scenarios for sustainable development. Integrating these tools into urban planning supports incorporating urban and peri-urban agriculture into frameworks, aligning agricultural practices with urban development goals (Ahmed and Raihan, 2024).

Strengthening Data Collection and Research Efforts

Reliable, context-specific data is vital to measure and maximise the climate benefits of urban and peri-urban agriculture. Currently, data on urban and peri-urban agriculture's CS and emissions vary greatly due to inconsistent methodologies and limited regional research. Continuous monitoring throughout different seasons and crop cycles is required to understand the effects of changing climate patterns on urban and peri-urban agriculture emissions and CS potential. Strengthening field data collection and monitoring is essential for a better understanding of the role of urban and peri-urban agriculture in climate change mitigation and impacts. Field data can also enhance the reliability of modelling approaches which offer a better understanding of spatiotemporal dynamics within urban and peri-urban agriculture systems on a broader scale. Spatiotemporal analysis and process-based modelling are needed to estimate greenhouse gases emissions and CS of urban and

Resource Nexus Perspective

Integrating a Resource Nexus perspective, which connects **water, energy, food**, and **waste**, promotes a circular economy, optimizes resource utilization, and minimizes waste, offering a more sustainable approach compared to the isolated management of each resource. This integrated strategy enhances the urban system resilience, improves the efficiency of urban and peri-urban agriculture, and contributes to the advancement of climate resilience and resource security.

peri-urban agriculture.

Current research shows that environmental impact studies of urban and peri-urban agriculture often neglect the social and economic benefits of urban and peri-urban agriculture. Research efforts should integrate other benefits into ES assessment frameworks. Research funding should encourage the integration of social aspects within the sustainability assessments of urban and peri-urban agriculture projects, as urban and peri-urban agriculture often has essential social functions other than productivity and economic benefits (Dorr et al., 2021; Al-Qubati et al., 2024).

Conclusion

Urban and peri-urban agriculture offers a transformative opportunity to address urban challenges, including food security, climate resilience, and environmental sustainability. By integrating the Resource Nexus into urban and peri-urban agriculture, cities can optimise water, energy, waste, and food systems through circular economy principles. Case studies further demonstrate the practical benefits of these integrated approaches, including reduced greenhouse gas emissions, enhanced resource efficiency, and improved urban sustainability.

To maximise urban and peri-urban agriculture's potential, policymakers must prioritise data-driven approaches, adopt and adapt innovative technologies, and integrate urban and peri-urban agriculture into urban planning frameworks. Focus should be placed on renewable energy, resource recovery, and equitable access to ensure sustainable and resilient urban food systems.

Future research and policy efforts should address data collection gaps and methodological standardisation for evaluating urban and peri-urban agriculture's environmental, social, and economic impacts. Expanding spatiotemporal studies will provide insights into resource use, CS, and emissions in diverse urban contexts. To ensure equitable access to sustainable food systems, there is also a need to explore scalable, low-cost technologies and practices, especially for rapidly urbanising regions in the Global South. Additionally, embedding urban and peri-urban agriculture into broader urban planning frameworks focusing on renewable energy, biodiversity, and community engagement will be crucial for maximising its long-term benefits.

Key Recommendations

To enhance sustainable and resilient cities, policies should seek to:

1. **Promote urban and peri-urban agriculture technological innovation:** Support technology transfer and local adaptations, especially for the Global South.
2. **Encourage clean energy adoption:** Provide incentives for renewable energy integration into urban and peri-urban agriculture systems while optimising growing conditions.
3. **Enhance waste management:** Implement policies promoting circular systems that recycle organic waste and reduce materials' carbon footprint.
4. **Integrate urban and peri-urban agriculture into urban planning:** Allocate spaces for urban and peri-urban agriculture and prioritise its integration into urban food policies.
5. **Strengthen data collection:** Invest in standardised methods to measure and monitor urban and peri-urban agriculture's carbon sequestration and emissions.

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