

Improving ecosystem services through urban agriculture and greening initiatives

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Abstract

With the increase of urbanization, environmental degradation, and climate change, urban agriculture and urban green space initiatives have gained increasing attention for their roles in improving urban ecosystem services. This literature review discusses the role of urban agriculture in mitigating challenges associated with urbanization, while highlighting its role as an ecosystem service provider. Literature was selected and synthesized using keyword searches in academic search engines and grey literature. This review defines the four dimensions of ecosystem services, explores the environmental, cultural, and socioeconomic impacts of urban agriculture, and highlights the contributions of ecosystem services to ecological health, food security, and urban development. Additionally, the emerging trends in urban agriculture and urban green space research are highlighted, while noting the research gaps and barriers in adoption. Because this review contains several aspects of urban ecosystem services, it may limit the exploration of all service functions and benefits. It is important to recognize the multifunctional roles that urban vegetation plays in creating more resilient, sustainable cities.

Table of Contents^[OBJ]

List of Figures	v
List of Tables	vi
Introduction.....	1
Methodology	3
Glossary	5
Urban Ecosystem Services.....	7
Introduction.....	7
Provisioning Services	8
Regulating Services	10
Cultural Services	11
Supporting Services	13
Enhancing Ecosystem Services Through Urban Agriculture and Greening Initiatives.....	14
Environmental Benefits	15
Provisioning Services.....	15
Regulating Services	18
Supporting Services	20
Socioeconomic Benefits	22
Cultural Services	22
Economic Opportunities	24
Overcoming Barriers.....	27
Emerging Trends, Research Gaps and Conclusions	33
References	39

List of Figures

Figure 1: The classification scheme of ecosystem services and the associated forms of well-being. Millennium Ecosystem Assessment, 2005.....	8
Figure 2: Mean crop yields per growing cycle of urban agriculture for disaggregated crop categories (Payne, 2022).	16
Figure 3: Prevalence of food insecurity, average for 2021-2023 (USDA, Economic Research Service, 2023).	30
Figure 4: Projected vertical farming market worldwide from 2022-2032 (in billion USD) (Kabir, 2023).	34

List of Tables

Table 1: Types of regulating ecosystem services enhanced by UA and urban greening.....	20
Table 2: Types of cultural and socioeconomic benefits enhanced by UA and greening.....	27
Table 3: Common sources of soil contamination (EPA).	28

Introduction

Rapid urbanization is transforming urban and peri-urban environments across the globe. The global urban population is projected to increase to 70% by 2050, up from 56% in 2024 (United Nations Department of Economic and Social Affairs, 2018). While urban expansion drives economic, technological, and cultural growth, cities are simultaneously facing heightened threats of climate change, environmental degradation, pollution, and food insecurity. Additionally, urban areas are exposed to increased flooding, urban heat islands, soil degradation, and a lack of urban green spaces (UGS), to name a few. The impacts of urbanization stretch beyond the physical boundaries of urban spaces (Deelstra & Girardet, 2000; Zheng & Chou, 2023).

The compounding challenges of urbanization, climate change and environmental degradation is causing stress on urban ecosystem services (UES), the benefits that humans obtain from natural ecosystems (MEA, 2005). In response to these challenges, cities are adopting sustainable initiatives, like urban agriculture (UA) and urban green spaces (UGS). UA and UGS play complementary roles in supporting ecosystem service (ES) provisioning and urban and ecological well-being (MEA, 2005; Qui, 2023). Despite UA's long history, modern UA yields nutritional, economic, cultural, and ecological services to cities and their residents (Tornaghi, 2020). The goal of this review is to synthesize academic and grey literature in order to discuss the role of UA and UGS in supporting and improving ES.

Today, UA is taking shape through community gardens, vacant lot restoration, rooftop gardens, vertical farms, commercial farms, and educational gardens; and plays a critical role in preserving natural resources and UES (Deelstra & Girardet, 2000). Likewise, UGS include methods of adding vegetation that may not involve food production, such as green roofs, parks,

or bioswales. Understanding the relationships between ES, UA, UGSs and human well-being is crucial for creating sustainable, resilient urban ecosystems (Corstange, 1997; Harris, 2021).

This review discusses UA and UGS' role in mitigating the challenges associated with urbanization, while discussing its role as an ES provider to urban residents and communities. ES, comprised of regulating, supporting, cultural, and provisioning services, will be discussed in this paper, highlighting the environmental and socioeconomic benefits UA and UGS provide to cities. This review synthesizes UA, UGS, and UES research, reviews, and reports in an effort to:

1. Define the four ecosystem services categories,
2. Examine the environmental and socioeconomic benefits and barriers of urban agriculture and urban green spaces,
3. Discuss how urban residents and stakeholders can preserve and enhance ecosystem services, and
4. Identify emerging trends and research gaps associated with urban agriculture and ecosystem services.

Methodology

Academic search engines, including ResearchGate, Google Scholar, and ScienceDirect, were used to collect peer-reviewed literature, as well as grey literature such as fact sheets, guides, and informational reports from university websites and federal agencies. Governmental publications from the United States Department of Agriculture (USDA), the Environmental Protection Agency (EPA), the Food and Drug Organization (FAO), the National Park Service, and the World Health Organization (WHO) provide data on current and future projections of urban agriculture and ES. Findings were synthesized from approximately 95-115 sources, including review articles, empirical research, government reports, and university publications.

To provide a more recent analysis of UES, most of the sources that were used in this review were published between 2015-2025. Inclusion criteria consisted of peer-reviewed articles and grey literature focused on urban contexts and written in English. Exclusion criteria consisted of non-English sources, studies focused on rural or animal agriculture, or any opinionated-based sources. Key words involved in the search process included, but were not limited to, *urban agriculture, ecosystem services, provisioning services, regulating services, supporting services, cultural services, urban sustainability, green infrastructure, urban greening, urban green space, urbanization, climate change, socioeconomic benefits of urban agriculture, sustainable developments, vertical farming, rooftop garden, green gentrification, controlled environment agriculture*.

The literature was selected and categorized into thematic groups including: foundational information of UES, UA, and UGSs, the four ecosystem service types (provisioning, regulating, cultural, and supporting), and emerging trends and challenges and barriers associated with UA and UGS. The discussion below highlights the interconnected relationship between ES, UA, and UGS. Because the focus of this review is broad and covers many topics, it may be limited in the

exploration of all service functions or benefits. Additionally, research on UA, UGS, and UES is often conducted in the Global North. The location bias is evident in this review, as approximately 35 peer-reviewed articles were focused on the Global North, while a smaller portion of peer-reviewed articles (~12) explored the Global South.

Glossary

Urban Agriculture (UA) – The cultivation, processing, and distribution of agricultural products (food or non-food) in urban and suburban areas (USDA).

Ecosystem Services (ES) – The benefits people obtain from ecosystems. These services include provisioning, regulating, supporting, and cultural services (Millennium Ecosystem Assessment, 2005).

Provisioning Ecosystem Services (PES) – The tangible products that are obtained from ecosystems, including food, water, fuel, wood, medicinal resources, etc. (Millennium Ecosystem Assessment, 2005).

Regulating Ecosystem Services (RES) – The benefits obtained from the regulation of ecosystem processes, including climate regulation, flood, disease, and erosion control, etc. (Millennium Ecosystem Assessment, 2005).

Cultural Ecosystem Services (CES) – The non-material benefits that people obtain from ecosystems through recreation, tourism, aesthetic appreciation, spiritual enhancement, etc. (Millennium Ecosystem Assessment, 2005).

Supporting Ecosystem Services (SES) – Services that maintain fundamental ecosystem processes, such as the maintenance of genetic and biological diversity, photosynthesis, habitat for plants and wildlife, etc. (Millennium Ecosystem Assessment, 2005).

Food Security – When all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO).

Food Insecurity – The situation when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life (FAO).

Green Infrastructure (GI) – A network of natural areas, conservation lands, and productive landscapes that support native species, maintain natural processes, sustain air and water resources, and contribute to the health and quality of life for communities and people (USDA).

Food Desert – Areas that are separated from food venues where residents experience physical and economic barriers to accessing healthy food (USDA).

Environmental/Green Gentrification – When urban greening projects or environmental improvements raise surrounding property values, resulting in gentrification that displaces lower-income residents (Anguelovski, 2019).

Urban Resilience – The ability of an urban system and all its constituent socio-ecological and socio-technical networks to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to transform systems that limit current or future adaptive capacity (Feinberg, 2020).

Urban Ecosystem Services

Introduction

In urban environments, urban ecosystem services (UES) face heightened and distinct pressures due to population and infrastructure densities, impervious surfaces, or a lack of green spaces. Yet, UES are crucial for ecological and human well-being and resilience. The concept of ecosystem services (ES) was initiated and later published in 2005 by the Millennium Ecosystem Assessment (MEA, 2005). This assessment, involving 1,360 experts and 95 countries, provides a framework for classifying ES and the interconnected relationship between humans and the environment.

The MEA defines ES as the benefits that humans obtain from ecosystems. These benefits are categorized into four service types: provisioning ecosystem services (PES), such as food, fiber, and fuel; regulating ecosystem services (RES), the climate, flood, and disease control; supporting ecosystem services (SES), such as soil formation and photosynthesis; and lastly, cultural ecosystem services (CES), the recreational, aesthetic or spiritual aspects of ecosystems (MEA, 2005).

The collaborative effort of the United Nations assessed the connection between ecosystems and human well-being, noting the consequences of ecosystem change, and establishing a call-to-action model for conserving ecosystems and their service delivery. This framework continues to guide research and ecosystem assessments, like the Socio-Ecological Systems Framework (SESF) or the Economics of Ecosystems and Biodiversity (TEEB). Like the MEA, the SESF focuses on the linkages and feedback mechanisms between social and environmental systems across various levels and scales. The SESF notes how “actors”, like urban farmers, urban dwellers, or policy makers, interact with ecological components, like water

systems, soil systems, or wildlife (Partelow, 2018, and Salimi, 2021). For example, city planners and developers (the actors) installing urban green roofs contribute to reducing air pollution, energy use, or enhancing stormwater management (ecological components) (EPA, 2025). Overall, frameworks such as the MEA and SESF can help us understand how ecosystem functions are distinct in urban areas and highlight the importance of preserving and advocating for these functions.

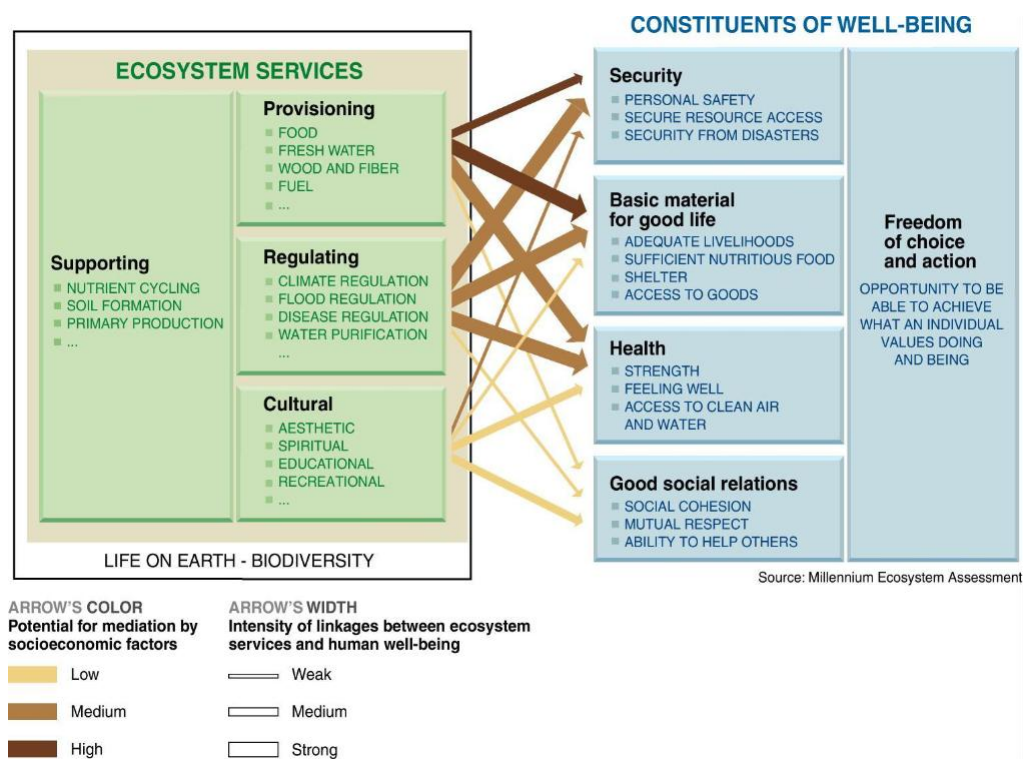


Figure 1: The classification scheme of ecosystem services and the associated forms of well-being. Millennium Ecosystem Assessment, 2005.

Provisioning Services

Provisioning services (PES) refer to the material or energy outputs directly derived from ecosystems, like food, water, fuel, and timber (Qiu and Zhao, 2023). Among these, food production is one of the most notable outputs. However, several studies highlight that global

urbanization is posing a challenge to food availability, production, and distribution (Szabo, 2016). In the United States, 13.5% of households are facing food insecurity. Worldwide, this figure increases to 111.1 million people (Fernandez-Casal, 2025). Of this, urban areas and residents have increased pressures of food insecurity and injustice (USDA, Economic Research Service, 2023).

As food insecurity and injustices become increasingly concerning, adaptive food systems and movements, such as UA, may enhance food provisioning services by increasing local production, shortening supply chains, or improving access in underserved areas. UA and UGS initiatives may also contribute to food diversity, allowing for the cultivation of culturally relevant or specialty crops. In addition to fruit and vegetable production, medicinal or ornamental plants and animal products can be supported by, and produced through, UA and UGSs.

UA and UGS can also play a role in water provisioning. With urbanization, a lack of pervious surface cover, and more frequent and severe weather patterns, urban stormwater runoff, water pollution, and flash flooding are becoming more prevalent (Walsh, 2012). It was found that 4 billion people live under conditions of severe water scarcity for at least 1 month of the year (Mekonnen, 2016). Additionally, traditional agricultural systems account for 70% of the global freshwater supply (UNESCO, 2024). UA and UGS may contribute to water provisioning through green roofs, rain gardens, or bioswales, to name a few. According to the EPA, green roofs or rain gardens can reduce stormwater runoff by 40-80% annually (EPA, 2024). Similarly, bioswales may reduce 30% of runoff (Lu, 2024). Strengthening freshwater management and conservation strategies through approaches like UA or UGS can offer the potential for greater ecosystem health and freshwater availability (Freshwater Information Platform, EU, n.d.).

UA alone cannot feed an entire city, however, UA can complement the larger food system. There are limitations inhibiting UA and UGS adoption. These limitations may include contaminated soil, land access and cost constraints, land use regulations, or required technical skills and knowledge. Despite the limitations, these green initiatives could strengthen provisioning services, contributing to human development and urban well-being.

Regulating Services

Regulating ecosystem services (RES) include the benefits obtained through the moderation or control of ecosystem processes. The regulation of local climate, air, or soil quality, carbon sequestration, flood, disease, erosion control, and pollination are a few examples of RES (USDA). Urbanization and urban population growth are among the main reasons for increased pressure on urban ecosystems and their services (Stoycheva, 2023; Geneletti, 2023). UA and UGS can support multiple regulating services, including urban cooling, air filtration, or stormwater management.

Urban heat islands, for example, are a phenomenon where cities experience higher air temperatures than surrounding areas (MIT Climate portal, 2021). These “islands” of increased temperatures are caused by the abundance of buildings, roads, and other infrastructure that absorb and re-emit heat (EPA, 2025). According to the EPA, urban areas range from 1-7°F higher than surrounding areas during the daytime and 2-5°F higher at night (EPA, 2025). Compounding challenges such as impaired water quality, increased air pollutants, energy consumption, and threats to human health will become more notable with growing urbanization (Epa, 2017). Vegetation in urban farms, community gardens, or neighborhood parks can reduce

surface temperatures through shading and evapotranspiration. Similarly, incorporating vegetation into “gray cities” can improve air quality by sequestering carbon or removing airborne particles.

As mentioned previously, incorporating UA and UGS into urban networks, through green roofs, rain gardens, or bioswales, contributes to stormwater regulation and flooding control. These ES do not function in isolation. For example, these initiatives not only help stormwater management (regulating service) but also contribute to food production and material provisioning (provisioning services). This highlights how UA and UGS are multifunctional landscapes.

Like PES, there are challenges and limitations. For instance, UA and UGS can provide localized benefits; however, these initiatives cannot solve the climate, flood, or disease threats entirely. Additionally, like the other ES, not all categories of benefits are assessed. Villamagna (2013) notes how regulating ecosystem services, like air quality maintenance or pest and disease regulation, are “process-driven” and harder to measure at larger scales. Researchers suggest that the lack of data is a drawback in environmental advocacy and integration. Despite the research gaps, RES are crucial for cities' ability to moderate and adapt to threats of climate change and urbanization.

Cultural Services

Several studies have shown that urban vegetation has quantifiable benefits to human wellbeing (Dickinson and Hobbs, 2017) through the delivery of cultural ecosystem services (CES). CES are simply described as the non-material benefits that humans obtain from ecosystems (MEA, 2005). The Millennium Assessment categorizes types of CES as: recreation and ecotourism, aesthetic values, sense of place, inspiration, social relations, knowledge systems,

and cultural diversity (MEA, 2005; Yang, 2022; Cao, 2022). However, with global urbanization, climate change, or population shifts, there is an ongoing loss of CES (Cardinale, 2012). As UGSs decline, city residents are less exposed to biodiversity, opportunities for community engagement, or recreation, to name a few.

The integration of UA and UGS is vital for mental and physical well-being, whether that be through recreation, cultural expression, or community interaction. Community gardens, for example, provide a shared space where neighbors can interact, exchange knowledge, and even grow culturally diverse plants. Greiner (2004) highlighted the positive correlation between social participation in UA and mental health. Other studies note the association of UGSs and boosted mental and physical health (McMahan and Estes, 2015; Pasanen, 2023). Exposure to green spaces can improve mental health by stabilizing emotions and releasing stress and anxiety (WHO, 2013) or improve physical health through exercise, physical fitness, or access to healthy food options (Zutter, 2023). Additionally, UA and UGS can offer educational opportunities through school gardens, urban farms, or other learning initiatives.

Similar to PES, CES availability is often faced with injustice, and vulnerable populations may not have equal access to CES. Discussions on low-income, indigenous, elderly, or disabled communities' relationship with UGS are often mentioned in CES literature. Kosanac (2020) noted that there is a need for further research on CES role in human well-being and how the impacts of environmental and climate change will affect more vulnerable communities (Kosanac and Petzold, 2020). Moreover, the decline of CES in cities, especially within marginalized communities, can directly impact residents' mental and physical well-being or weaken community ties (Kosanac, 2020).

Many studies highlight that CES are site-specific and culturally diverse (Otero-Rozas, 2013, and McElwee, 2022). One study acknowledged that CES research has a geographical bias toward Europe and North America (McElwee, 2022). This is resulting in knowledge gaps on how the increasing challenges of urbanization, climate change, and population growth will affect different cultures and communities. Despite the research gaps and location biases, CES can contribute to human well-being, development, and social equity.

Supporting Services

Many underlying natural ecosystem processes are often overlooked. These processes, known as the supporting ecosystem services (SES), maintain fundamental ecosystem processes (MEA, 2005). Biodiversity support, nutrient cycling, genetic diversity, or soil formation are key SES that affect ecosystem health, adaptation, and resilience (National Wildlife Federation).

Among these, urban soils play a substantial role (and directly affect) other ES as a whole (Tian, 2019). Urban soil is affected by anthropogenic, or human-driven, activities. These include soil degradation, contamination, and changes to land use. These threats result in increased pressures on soil fauna, plant growth and survival, carbon sequestration, and more (Tian, 2019). UA and UGSs, like community gardens or bioswales, can help restore soil structure, reduce compaction, and increase organic matter through composting and other regenerative activities. Likewise, urban development has predominantly negative effects on pollinator habitats (Fenoglio, 2020; Millard, 2021). UA and UGS can incorporate native plants, crops, or other habitats for pollinators, improving pollinator population and supporting synergies between other ES.

The impact on soil, for example, directly affects other ES such as food production (provisioning services) or climate regulation (regulating services). The interconnected relationship calls attention to the need for ecosystem conservation and sustainability at all levels. UA and UGS support SES, which in turn supports all ES provisioning. These initiatives deliver tangible and non-tangible benefits within and beyond urban boundaries (Qiu and Zhao, 2023). From improving equitable access to food to moderating the environment, UA and UGS, when used with ecological intent, can enhance ES availability and delivery. Overall, improving ES provisioning contributes to urban resilience, healthy ecosystems, and human well-being.

Enhancing Ecosystem Services Through Urban Agriculture and Greening Initiatives

UA, as defined by the United States Department of Agriculture (USDA), is the cultivation, processing, and distribution of agricultural products in urban and suburban areas. The multifunctionality of UA and UGS promotes urban sustainability and human well-being through environmental and socio-economic factors. This section synthesizes past UA and ES literature to highlight how provisioning, regulating, supporting, and cultural ecosystem services are enhanced by UA and UGS. This section also draws on case studies to explore the benefits and barriers that inhibit the adoption, maintenance, or research and development of these initiatives.

Environmental Benefits

Provisioning Services

PES refers to the material or energy outputs directly derived from ecosystems, like food, water, fuel, and timber (Qiu and Zhao, 2023). Many studies suggest that food production is the most notable output; however, other studies highlight how PES include any benefit that people can extract from nature. This includes the provisioning of wood, fuel, drinking water, oils, medicinal plants, or plants that can be made into other products (National Wildlife Federation). UA and greening play an important role in not only the food system, but also in global urban sustainability.

Our current food system is facing pressing challenges to reduce its ecological footprint. It is estimated that between 21-37% of total anthropogenic greenhouse gas emissions are linked to the global food system (Payen, 2022). Urban food growing has been recognized as a multifunctional strategy that can help reduce these pressures and support resource conservation. It was estimated that between 15-20% of food is produced in urban areas globally (Abdulkadir, 2012, and Payen, 2022). Across the US, UA in cities like Detroit supplies 30% of seasonal vegetable demand, or in Southern Minnesota, 100% of dietary requirements (Gunapala, 2025). Additionally, UA is more prevalent in East Asia, South Asia, and in developed countries (Thebo, 2014; Nicholls, 2020). In a study of 15 developing countries, results found that 10-70% of urban households engaged in urban food production (Zezza and Tasciotti, 2008; Nicholls, 2020). Engagement in urban food production can reduce the ecological footprint by shortening supply chains, reusing land and water resources, and promoting biodiversity (Ghahremani, 2024; Gunapala, 2025).

To test the productivity of UA compared to conventional agriculture, Ferre (2022) compared average crop yields per square meter per crop cycle in urban and conventional agricultural settings. Compared to large-scale field production sites, this study found that crops grown in smaller-scale vertical farms, rooftops, or community gardens resulted in higher yields per crop cycle. In Figure 2, you can note that cucumber yields were 4.4 times higher than conventional yields, while tomatoes and peppers ranged from 2.4 to 3.1 times higher (Ferre 2022 and Payen, 2022). From utilizing controlled environments, optimized growing systems, or short-growing crops, these results suggest that UA can contribute not only to food sovereignty but also to reducing the ecological footprint required for food production (reduced water use, fertilizer needs, or land use).

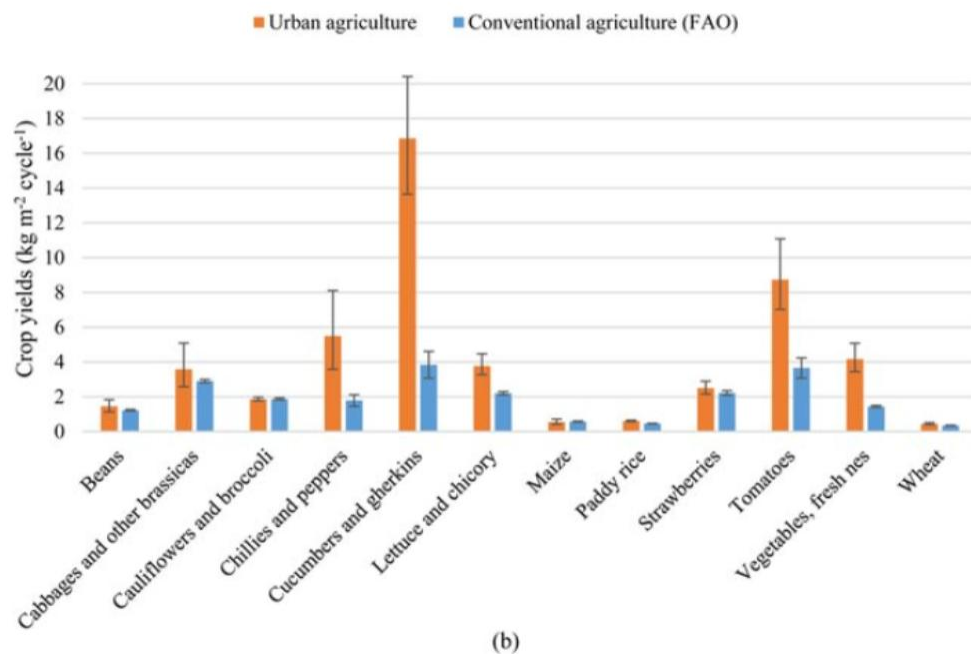


Figure 2: Mean crop yields per growing cycle of urban agriculture for disaggregated crop categories (Payne, 2022).

Beyond food production, other provisioning services, like medicinal plant cultivation, are becoming more prevalent in urban areas. In developing countries, over 4 billion people depend on plant products as their primary source of healthcare (Asigbaase, 2023). Of the 50,000-80,000 plant species that are used for medicinal purposes, 15,000 are threatened with extinction due to population growth, overharvesting, and habitat destruction (Ladha, 2025, and Asigbaase, 2023). Medicinal plants can be incorporated into UA and UGS initiatives to improve human well-being, pharmacology, and ecosystem health (Ladha, 2025).

Additionally, UA and UGS can contribute to water provisioning through collection and reuse. Beyond agriculture, residential irrigation accounts for the highest water usage in urban areas (Li, 2025). By collecting, storing, or treating rainwater, it can be used for irrigation and other non-drinking purposes. Steffen (2012) notes that rainwater harvesting systems increase the water self-sufficiency of cities, which can help delay the construction of water supply infrastructure or alleviate local freshwater stress (Steffan, 2012; Li, 2025). Other studies suggest that rainwater harvesting, when used with infiltration-based systems, can reduce runoff, recharge groundwater, and improve urban microclimates by increasing evapotranspiration and helping mitigate heat islands (Dillion, 2005; Hamel, 2012).

Other material items, like fiber plants or hemp, are also outputs brought by UA and UGS. Although less common in UA, hemp can be used for food, fiber, fuel, and medicine, and construction materials. A Pennsylvania-based urban brownfields redevelopment project notes that the global market for hemp includes more than 25,000 products. Hemp parts can be used in fabrics and textiles, paper, construction and packaging materials, animal bedding, body-care items, and more. Integrating hemp plants into UA and UGS provides a multitude of PES. Hemp can also be grown to help the remediation of urban soil. The plants' ability to absorb heavy

metals (such as lead, nickel, cadmium, zinc, and chromium), and their long root system may make them useful for phytoremediation (Urban Brownfields Redevelopment and Ahmad, 2016).

These examples show how PES are interlinked, and food production, for example, supports synergies between other ES. A technological innovation that highlights this synergy includes agrivoltaics. Agrivoltaics combines harnessing solar energy with crop cultivation. Crops are grown beneath or between the rows of photovoltaic panels (Jing, 2023; PennState Extension). This multifunctionality supports the provisioning of food production and renewable energy generation. UA and UGS can be designed and integrated into urban environments to maximize and support material provisioning.

Regulating Services

RES, and their processes, work to make ecosystems resilient to change. Some of the benefits of RES can include climate regulation, water purification, carbon sequestration, as well as flood, disease, and erosion control (MEA, 2005). Forms of urban vegetation, including green roofs, community gardens, or green infrastructure, all contribute to RES and can improve air quality, reduce urban heat islands, enhance water quality, and more (EPA, 2025).

Urbanization significantly contributes to airborne pollution and particulate matter (PM) concentrations. Researchers suggest that integrating urban vegetation into planning can help mitigate PM emissions and improve air quality in urban areas. In London, a study comparing PM concentrations across proximity to emission source types (industrial, roadside, and park sites) suggested that PM concentrations were higher in industrial areas (36.25 $\mu\text{g}/\text{m}^3$), compared to roadside (25.73 $\mu\text{g}/\text{m}^3$) and parks (20.17 $\mu\text{g}/\text{m}^3$) (Islam, 2024). This case study demonstrates

that prioritizing vegetation through UA and UGS in higher PM-concentrated areas may provide a larger impact in improving air quality and ES provision.

Cities also face rising temperatures due to the urban heat island effect. UA and UGS can contribute to cooling through evapotranspiration or shading. In Chicago, an EPA-based green roof installation project is ongoing at the city hall. This 20,300sqft green roof contains 20,000 herbaceous plants and vegetables, 112 shrubs, 2 trees, and an area dedicated to rainwater collection. It was found that the planted area of the green roof registers 7 degrees cooler and saves \$5,000 annually on utility bills (City of Chicago, Nicholas Institute for Energy, Environment & Sustainability, and the National Park Service).

Water quality is another regulatory service impacted by UA and UGS. In Hangzhou, China, the local government implemented a water quality improvement plan to restore the Grand Canal. The restoration processes included limiting wastewater discharge and planting vegetation buffers along the canal banks. Studies suggest that vegetation buffers can filter contaminants, reduce flooding and erosion, and improve aquatic life (USDA). In 1998, only 25% of the secondary protected areas in the canal were suitable for human consumption and use. By 2021, compliance reached 100%, demonstrating that urban vegetation can improve water quality in the long term.

Additionally, UA and UGS can provide general noise reduction. Urban development has brought higher noise levels and noise pollution, particularly through traffic noise. Urban vegetation, from UA and UGS, can absorb and reduce noise, which may result in positive impacts for urban residents' mental health, sleep, and community interaction (Feng, 2024). In Singapore, researchers explored urban vegetations impact on traffic noise levels. This study examined how minimal, moderate, and dense plantings affected noise levels. It was found that

traffic noise was reduced by 50% when vegetation was enhanced from minimal to moderate, suggesting that urban vegetation, when planted in higher densities near roadsides, can reduce urban noise pollution (Ow, 2017). Overall, such initiatives that support RES can positively impact ecosystems and their ability to adapt and provide ES. The table below highlights types of RES improved by UA and UGS and their impacts.

Table 1: Types of regulating ecosystem services enhanced by UA and urban greening.

Data was compiled from USDA, EPA, Nicholas Institute, and Feng, 2024.

Regulating Service	UA/Greening Initiative	Impact
Air quality regulation	Urban farms, orchards, rooftop gardens, tree planting, etc.	Filter air pollutants, sequester carbon
Stormwater management & enhanced water quality	Rainwater harvesting, rain gardens, green roofs, etc.	Reduce flooding and erosion, stabilize soil, improve aquatic life, filter nutrients and toxins
Urban heat island mitigation	Green roofs, vertical farming, tree planting, etc.	Reduce surface and air temperatures, energy cost savings
Carbon sequestration	Urban trees, orchards, soil amending, urban farming, etc.	Vegetation absorb CO ₂
Noise reduction	Urban trees, parks, vegetation	Absorb and reduce traffic noise pollution

Supporting Services

Although less visible, SES plays a crucial role in maintaining fundamental ecosystem processes (MEA, 2005). These underlying processes include nutrient cycling, soil formation, habitat, and biodiversity support. These services contribute to the long-term sustainability and health of urban and rural ecosystems and are necessary for the provision of all other ES. Through direct and indirect strategies, UA and UGS contribute to and enhance SES.

In combination with climate change, biodiversity loss is directly and indirectly affecting human populations (Dura, 2023). Pollution, habitat loss, invasive species, and natural disasters are all factors intensifying the loss of biodiversity. Scholars note that biodiversity conservation

must extend to urban areas. Dura (2023) observed that green roofs may be of “far greater ecological importance than initially imagined”. In Valencia, Spain, researchers compared arthropod biodiversity on green roofs to adjacent conventional roofs and ground-level gardens. The results confirmed that green roofs significantly increased arthropod abundance and contained exclusive species than those found at ground level (Dura, 2023).

In Zurich, Switzerland, researchers investigated the impact of gardening activities on soil health and biodiversity across 85 allotment and domestic garden sites. Soil multifunctionality was highest in organic garden settings, where soil was rich in organic matter, bacterial content, and microbial carbon. Results also showed that berry and flower-producing plants increased plant diversity and soil multifunctionality, and indirectly- increased soil fauna diversity and biomass. Additionally, high-intensity practices, like tilling, reduced both plant and fauna diversity (Tresch, 2025).

UA and UGS also contribute to nutrient cycling through reducing synthetic fertilizer use, composting organic wastes, and reusing runoff nutrients. In contrast to conventional agricultural systems, UA typically relies less on synthetic nutrient applications. However, many urban farmers couple compost and synthetic fertilizers to meet their crop needs, as compost may be missing vital nutrients. Overall, integrating organic nutrients like compost into UGSs improves soil health, biological activity, and fertility while reducing nutrient runoff. Additionally, rain gardens or other UGSs can act as buffers that absorb residue before it reaches water systems (Polo, 2024).

Lastly, in the Central Western Ghats of India, traditional agro-biodiversity strategies are merging with current strategies. Urban farmers are conserving genetically diverse landraces for their farming systems. A landrace is defined as ‘dynamic population(s) of a cultivated plant that

has historical origin, distinct identity and lacks formal crop improvement' (Casanas, 2017). These landraces are locally adapted to water or temperature stressors and contribute to food system resilience and genetic diversity. Overall, UA and UGS strategies such as organic farming, compost use, soil amending, or habitat restoration contribute to the long-term health and sustainability of SES. Strengthening the foundations that make up SES will ultimately improve the provisioning of other ES (Puneeth, 2024).

Socioeconomic Benefits

Cultural Services

Globally, UA and greening initiatives have been shown to enhance city life, not only through environmental benefits, but also by supporting physical and mental health, creating recreational and educational opportunities, community engagement, spiritual enhancement, and contributing to local economies (Ilieva, 2022). UA and UGS initiatives are driven by several motives, including the desire for high-quality food, environmental benefits, mental and physical health, and economic motives (Cano-Verdugo, 2024).

UA-based educational programs have become an emerging subject in urban communities. In the past, most agricultural education programs were in rural areas, creating a barrier in reaching diverse student populations (Martin, 2024). However, in recent years, there has been a shift in agricultural education programs, with urban participation increasing. Incorporating UA into school and university curricula bridges a rural-to-urban gap, teaches practical skills and knowledge in food production, and fosters community engagement (Martin, 2024). Additionally, researchers suggest that UA programs can help prepare youth for future civic engagement by enhancing their understanding of social justice (Russ, 2021).

Beyond education, UA and UGS have been associated with increased psychological well-being. In Southeast England, the city of Brighton and Hove launched a Food Partnership in 2006 to support the local food system and address residents' mental and physical health. This project focused on 75 communal growing spaces, and participants were encouraged to help maintain, grow, and harvest produce. At the end of this 3-year community gardening project, participants completed surveys of their experiences and outcomes. Of the 2000 participants, an independent assessment conducted by the University of Essex found that 97% reported increases in mental well-being by feeling a sense of purpose, emotional relaxation, and an opportunity for positive social interaction while gardening. Likewise, 89% reported that attending the garden sessions increased their physical fitness and health through increased movement and healthy eating (Nicholls, 2020 & Rogerson, 2017).

Many scholars highlight how recreation and urban farming contribute to positive physical health benefits. According to the National Recreation and Park Association (NRPA), children who live within two-thirds of a mile from a park or green space are 5 times more likely to be at a healthy weight. Likewise, in a systematic review of urban farming's impact on physical health before and after engaging in urban farming, 82.7% of people reported improved physical health (Cano-Verdugo, 2024). Likewise, urban farming and gardening can contribute to positive nutritional outcomes and have benefits for diet quality, health, and improved food perceptions (Mead, 2024; Hume, 2022). In Denver, Colorado, a population-based survey evaluating the relationship between UA activities and fruit and vegetable consumption found that community gardeners consumed fruits and vegetables 5.7 times per day compared to non-gardeners at 3.9 times per day (Litt, 2011).

UA and UGS have been associated with psychosocial benefits for individuals living in marginalized and/or chronically ill communities. In a St. Louis-based study aimed to reduce depressive symptoms among individuals, participants were asked to work on an urban farm over 8 weeks. The findings highlight that there was a decrease in depression and anxiety symptoms among participants. Respondents described that urban farming contributed positively to their mood, reduced feelings of isolation, and increased community bonding (Shacham, 2013).

In Philadelphia, researchers are exploring the effects of the uneven distribution of green spaces on the mental health of community members. Another CES, aesthetic value through UA and UGS, also impacts urban well-being. The Southeastern Pennsylvania Household Health Survey found that higher levels of residential tree cover, particularly in lower-income neighborhoods, were associated with better mental health, reduced physiological stress, and improved mood (U.S. Forest Service, 2024).

This study, as well as the one in St. Louis (Shacham, 2013), demonstrates the need for urban vegetation in underserved and marginalized communities to not only tackle environmental and social challenges but also to enhance neighborhood aesthetics, physical and psychosocial well-being. However, incorporating UGS into marginalized communities may contribute to green gentrification and the displacement of lower-income residents. These green spaces must be intentionally designed to avoid exacerbating social injustices.

Economic Opportunities

As UA and UGSs become more prevalent in urban areas, researchers are reporting that agriculture is becoming a driver of economic development. The economic impact of urban vegetation is multifaceted; scholars highlight UA and UGS contributions to employment

opportunities, local food systems, and property values. UA and UGS can offset food or energy costs, contribute to small businesses and job training, and raise property values.

Across the food chain, UA can generate employment opportunities from farming, food processing, distribution, and marketing. The increasing market demand for locally produced foods is encouraging the growth of UA and UGS businesses. Between 2020 and 2025, employment opportunities for U.S. college graduates interested in food, agriculture, renewable natural resources, and the environment are projected to grow 2.6% (Purdue University). Beyond employment opportunities, UA initiatives like community gardens are being used as job training centers. Salt Lake City's Wasatch Community Gardens provides adult education and on-site job training for homeless women. This job training program provides participants with a paid position, educational workshops, and further community resources. Through these job opportunities and training programs, UA is also creating demand for agricultural inputs (seeds, compost, irrigation systems, raised bed materials) and supporting local UA businesses through farmers' markets or farm-to-table restaurants (Getta University, 2024).

Produce grown through UA can also diversify the products sold at local food businesses and/or reduce home food costs. Many UA initiatives focus on growing specialty crops or culturally relevant crops, which can introduce food products that may not be produced in conventional agricultural settings. Additionally, as food costs rise globally, homeowners are becoming increasingly interested in growing their own food. University of California's Cooperative Extension conducted a survey on 85 community gardens and 500 home gardeners in low-income neighborhoods in San Jose. By growing their own food, home gardeners saved an average of \$92 per month, and community gardeners saved \$84 per month. UC Extension also

noted that participants doubled their vegetable intake throughout this study (University of California, 2016).

Beyond urban farming, UGSs contribute to reducing energy costs. The topic of green roofs is often noted in literature for its energy-saving benefits. According to the EPA, green roof temperatures can be 30-40 °F lower than conventional roofs, reducing citywide ambient temperatures by 5 degrees (EPA, n.d., and Besir, 2018). Likewise, from a modelling study of 40 buildings with green roofs in Dubai, it was found that incorporating green infrastructure into cities can cut building cooling demands by up to 13.9% (Mohammad, 2023). Simultaneously, at the city-wide level, incorporating green roofs into infrastructure may help provide relief to stormwater and municipal systems.

Other studies looked at the economic value of UGSs and recreation. According to the National Recreation and Park Association, in 2019, local park and recreation agencies in the United States generated nearly \$218 billion in economic activity (McCosh, 2024). These recreational sites, as well as other green spaces, enhance property values and business opportunities. However, several scholars suggest that UA and UGS can contribute to gentrification and the displacement of low-income residents (Gould, 2017; Anguelovski, 2020; Creasy, 2024). Overall, UA and greening provide multifunctional benefits to urban spaces that not only contribute to environmental and cultural well-being but also to local economies.

Addressing anti-gentrification strategies should be a main concern in UA and UGS planning. The table below describes various types of cultural and socioeconomic benefits that are improved by UA and UGS.

Table 2: Types of cultural and socioeconomic benefits enhanced by UA and greening.

Data was compiled by the EPA, Getta and Purdue University, UC Extension, McCosh (2024), and Mohammad (2024).

Cultural and Socioeconomic Service	UA/Greening Initiative
Physical health enhancement	Recreation, parks, urban farms and community gardens, etc.
Mental and spiritual enhancement	Therapeutic gardening, connection to nature, grounding spaces, repetitive movements and meditation, etc.
Social cohesion	Shared community gardens and farms, community workshops, etc.
Education	Urban farm training programs, community workshops, K-12 based educational programs, etc.
Food affordability	Home gardens, urban or community farms reducing expenditures.
Job opportunities	Employment opportunities throughout food value chain: farming, processing, distribution, marketing, etc.
Enhanced property value	Urban green spaces, parks, community farms, etc.
Reduced energy costs	Green roofs, vertical farms, tree cover, etc.

Overcoming Barriers

UA and its affiliated green spaces provide many opportunities for environmental and socio-economic growth; however, they do not come without challenges. UA and ES literature identify several barriers that inhibit UA adoption, research, and development. These barriers directly impact the well-being of urban ecosystems, humans, and the environment. On an environmental scale, availability of soil that is free of contamination and/or suitable for crop production is a notable barrier. From a socio-economic perspective, funding and policy support, zoning restrictions, and gentrification are all highly recognized challenges.

Urban development results in several risks to urban ecosystems, particularly urban soils. The extensive use of construction materials, machinery, pesticides, and vehicle use is contributing to pollution and soil degradation. The topic of soil contamination is frequently discussed in UA literature as researchers investigate how anthropogenic activities impact soil contamination, ecosystems and their services, and community well-being. It is important to note

that soil properties are affected by past and current land use (Turner, 2009). Table 3 lists general sources and contaminations found at various sites.

Table 3: Common sources of soil contamination (EPA).

(Turner, 2009)

General Source	Specific Example of Previous Site Use	Specific Contaminants
Paint (before 1978)	Old residential buildings; mining; landfill operations	Lead
High traffic areas	Next to heavily traffic roadways or highways	Lead, zinc, polycyclic aromatic hydrocarbons (PAHs)
Treated lumber	Lumber treatment facilities	Arsenic, chromium, copper
Burning wastes	Landfill operations	PAHS, dioxins
Contaminated manure	Copper and zinc salts added to animal feed	Copper, zinc
Coal ash	Coal-fired power plants; landfill operations	Molybdenum, sulfur
Petroleum spills	Gas stations; residential/commercial/industrial uses	Cadmium, copper, zinc, lead, persistent bio accumulative toxins (PBTs)
Pesticides	Widespread pesticide use; pesticide formulation, packaging and shipping	Lead, arsenic, mercury, chlordane
Commercial/industrial site use		PAHs, petroleum products, lead, and other heavy metals (arsenic, cadmium, chromium, lead, mercury, zinc)

Overcoming soil contamination is a crucial step in supporting ecosystem health and ES delivery. However, with a lack of funding or support, remediation is not always accessible. Several studies have examined remediation strategies. Factors to consider in the remediation process include cost, accessibility, location, effectiveness for intended use, and timeframe (Turner, 2009). Remediation strategies from soil washing, excavation, and phytoremediation are all commonly used methods (Turner, 2009; Trojanowska, 2023). Raised beds, containers, or soil-less farming options are also strategies being used in urban settings where remediation is not feasible (Joshi, 2022; Miernicki, 2018).

At a social level, UA and UGS initiatives have led to or exacerbated social challenges like gentrification. Growing literature on green gentrification discusses how UGSs can contribute to gentrification. This is creating inequalities in access to, or the benefits provided by, UGSs (Anguelovski, 2020). In more recent studies, scholars have argued that UGSs are also contributing to increased property values, housing prices, and the displacement of residents (Gould, 2017; Anguelovski, 2020). Race, ethnicity, and poverty correlate with this access, which reinforces historical patterns of injustices in urban development and our food system (Anguelovski, 2018).

Oftentimes, injustices that exist may impact access to ES in marginalized communities. Residents living in low-income neighborhoods may have less access to recreational or UA opportunities. The lack of UGS can restrict ES delivery, like climate adaptation through tree canopy cover or restricted access to food (Shokry, 2020). Food deserts are the result of restricted access to food and reflect how social, economic, and physical barriers and injustices undermine PES in urban areas (Spears, Powell, and Kim, 2024). Food deserts contribute to social disparities in diet and diet-related health outcomes (Beaulac, 2009). With increasing concern about food insecurity and inequities in urban communities, sustainable solutions and alternative food networks, like UA, can contribute to creating resilient urban food systems.

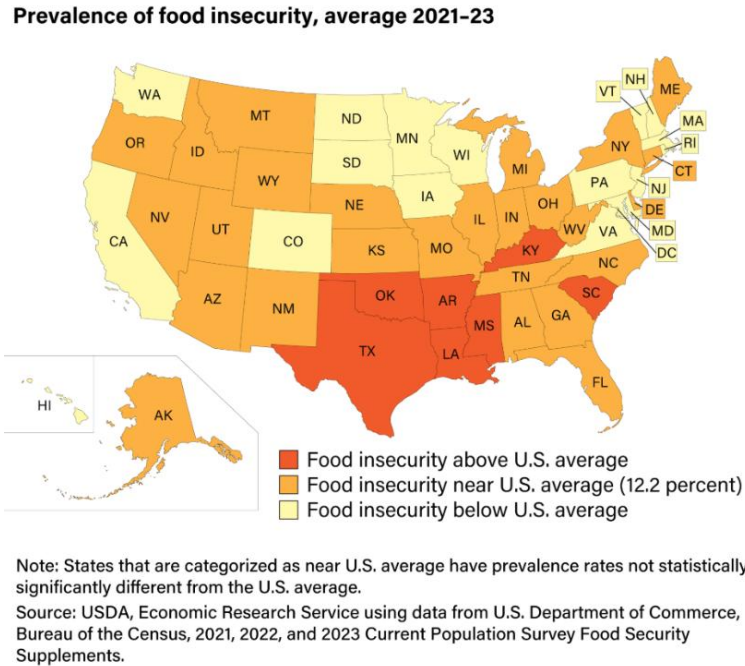


Figure 3: Prevalence of food insecurity, average for 2021-2023 (USDA, Economic Research Service, 2023).

To help overcome these challenges, Creasy and Maxwell (2024) suggest that local authorities and planners must (1) engage with current residents through consultation and assessment, (2) take on holistic approaches to development and zoning, such as anti-displacement measures, (3) retain neighborhood identity, and (4) understand the impact and dynamic between local authority, developers and residents (Creasy, 2024). Likewise, Horst, McClintock, and Hoey (2024) urge urban planners to confront UGS’s contribution to injustices. Overall, planners can play a significant role in overcoming injustices by considering whether their efforts truly benefit disadvantaged communities (Horst, 2024).

In addition to gentrification, policy and zoning concerns are barriers that restrict green space growth and ES delivery. A key challenge is land tenure, as UA is often viewed as a temporary use of land and oftentimes competes with commercial or industrial developments (Horst, 2024; Neuner, 2011). This perception of UA being a short-term land use limits ES

provisioning and urban sustainability. Though environmental and food system planning has evolved to support sustainable initiatives, the lack of zoning support, alongside short-term funding, often puts UA in competition with other urban developments that are economically favored (Horst, 2024; Neuner, 2011).

Cities across the U.S. are overcoming these challenges and adopting plans that support urban sustainability by creating available land inventories, reducing permitting fees, and advocating for green space education (Horst, 2024). For example, the city of San Jose, California, established the Urban Agriculture Incentive Zone (UAIZ), a contract between the city and property owners of vacant properties. Property owners who maintain a UA site on their vacant property for 5 years will receive property tax benefits (City of San Jose). Similarly, the City of Baltimore, Maryland, tracks available land inventories, allowing for UA sites on unused lots (City of Baltimore). Additionally, other strategies to overcome these barriers include funding mechanisms through grants or public-private partnerships, policy implementation for land access, community engagement, and education and awareness.

Funding mechanisms, like grants offered by federal agencies or grants from state departments of agriculture, provide support to UA and UGS initiatives. As of 2025, the USDA is awarding \$14.1 million to support UA and innovation production. The USDA's Office of Urban Agriculture and Innovation Production (OUAIP) is providing \$2.5 million for Urban Agriculture and Innovation Production (UAIP) grants, building on the \$53.7 million invested since 2020. Additionally, in an interagency agreement, the National Institute of Food and Agriculture (NIFA) and the Natural Resources Conservation Service (NRCS) are providing \$11.9 million in funding. Lastly, other programs such as the Local Agriculture Market Program (LAMP) supplied \$26 million to strengthen UA and local food systems (USDA).

Likewise, public-private partnerships and private foundations are also offering solutions. NYC's GreenThumb Program supports over 550 urban farms, a majority of which are in transformed abandoned lots. This partnership project works with NYC Parks and Recreation, non-profits, and other sponsors to provide fresh produce to local NYC neighborhoods. Similarly, private foundations, like the Surdna Foundation, have provided more than \$14 million to organizations supporting equitable food systems and UA programs.

To ensure long-term land access, various UA and UGS policies, including land trusts or right-to-grow ordinances, are protecting these green spaces. UA land trusts offer secure access to land for urban farmers. Similarly, right-to-grow ordinances permit the growth and sale of produce and other products in urban settings. In Kansas City, Missouri, a right-to-grow policy allows gardens, beekeeping, and small animals husbandry for the purpose of selling the subsequent products in urban areas since 2010 (City of Kansas City). Policies that remove zoning barriers ultimately support local food systems and encourage urban residents to grow food for themselves and their surrounding communities.

Lastly, community engagement is a vital solution for addressing UA and UGS barriers and promoting its long-term urban sustainability. Engaging with and allowing residents to participate in such initiatives is a crucial solution to gentrification and social cohesion. UA, UGS, and ES literature addresses the fact that gentrification, zoning, policy, and funding barriers all impact the well-being of urban ecosystems, humans, and the environment. Finding holistic measures that work to overcome these barriers will result in equitable access to all ES.

Emerging Trends, Research Gaps and Conclusions

UA is a form of modern agriculture that aids in food security, maintains ES provision, and improves urban well-being (Yan, 2022). Several academic studies focus on how UA contributes to urban food production. However, in a study evaluating the developments in knowledge of UA, it was commonly mentioned that UA-related sustainability is an emerging international topic (Yan, 2022). With the pressures of growing populations and urbanization, UA continues to evolve through agricultural research, technological and social innovations, and within policy and planning. All these advancements contribute to ES provisioning.

The transdisciplinary collaboration between urban planners, ecologists, social scientists, and local communities is an emerging subject that is vital for holistically addressing key barriers, research gaps, and ensuring that UA and UGS initiatives are more integrated and sustainable. Technological innovations open new opportunities for UA and ES, especially by bringing attention to the importance of these services for human well-being (Schirpke, 2023). Advanced technologies being used in UA include waste management strategies, space-saving production systems, molecular breeding technologies, agrivoltaics, and technologies that assist policy makers in assessing UA and ES data (Fei, 2025).

Regarding waste management strategies, UA can help support circular economies in urban areas. Circular economies involve recycling and alternatively reusing materials, fostering resource efficiency and reducing disposal costs. In UA and UGS contexts, reusing wastewater for irrigation or utilizing urban waste as compost can contribute to this closed-loop approach. Researchers suggest that integrating resource-efficient systems into UA and UGS contributes to long-term urban sustainability (Jesus, 2024).

Other resource-efficient systems like vertical farming utilize hydroponics, aquaponics, or aeroponics to grow crops in controlled, indoor environments (Chattergee, 2020). With a lack of arable land and water, these systems utilize limited space, produce crops year-round, and reduce urban food miles (Mir, 2022). This alternative to traditional agriculture can yield 10 times higher than traditionally grown field crops and save 70-95% of water (Mir, 2022). Globally, vertical farming systems are gaining momentum in Europe, Asia, and North America. In 2022, the global vertical farming market, including the technology, equipment, and crop production, reached \$5.6 billion and is estimated to grow to \$35 billion by 2032 (Kabir, 2023).

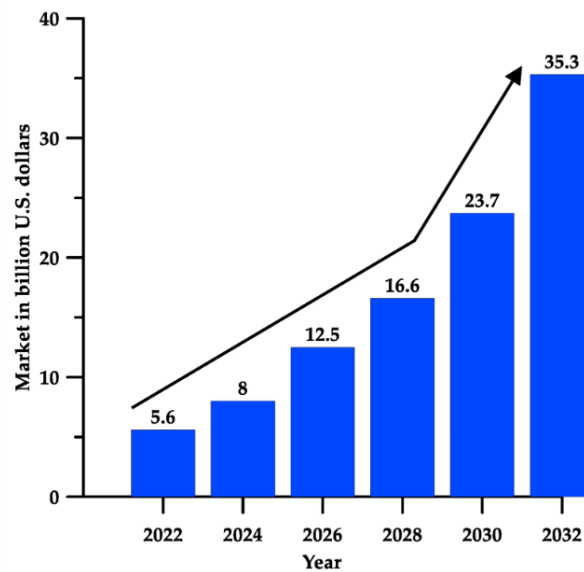


Figure 4: Projected vertical farming market worldwide from 2022-2032 (in billion USD) (Kabir, 2023).

Other precision management tools, like the Internet of Things (IoT), are being used to increase crop quality and production. These systems help reduce energy and water consumption, as well as labor costs (He, 2022). The IoT is a technology that monitors and controls crop growth and environmental conditions like temperature, humidity, soil moisture, and pH (Madushanki,

2019). Additionally, on an ES level, mapping and monitoring green infrastructure and urban green spaces (UGS) have become more prevalent as climate change and urbanization threats increase.

Remote sensing tools like Geographic Information Systems (GIS) are being used by researchers and city planners to assess, identify, and enhance ES. GIS's spatial visualization of urban spaces can pinpoint where UGS is located and where UGS could be better utilized for ES delivery. Likewise, citizen science initiatives are a growing trend that focuses on technological and social interactions to empower citizens. These initiatives focus on ES data collection and help communities monitor urban biodiversity, air quality, and food production.

Over the past decade, a trend in urban development and planning has been the implementation of green infrastructure (Evans, 2022). Several articles noted the multifunctionality of green infrastructure. The USDA defines green infrastructure as networks of natural areas, conservation lands, and landscapes that support native species, maintain natural processes, sustain air and water resources, and contribute to the health and well-being of communities and individuals (USDA Forest Service). Wang and Banzahaf (2018) synthesized ES assessments and highlighted 28 types of services green infrastructure provides to urban areas. Of these services, RES, like climate and temperature regulation, or CES, like recreational opportunities, were highlighted. More recently, edible growing spaces are becoming more intertwined in green infrastructure and UGS, though it brings a new set of challenges, including maintenance and/or concerns of soil contamination.

Beyond technological and urban planning advancements, social innovations like farm-to-fork educational programs are becoming more widespread in urban spaces. These food movements aim to increase food accessibility and education, provide an income among growers,

and promote the importance of environmental stewardship (Patel 2021). This social, economic, and environmental synergy is gaining traction in policy, society, and research settings (Egli, 2023). As UA becomes more active in cities, local governments are increasingly contributing to local food systems. Food policy councils, for example, are collaborative efforts between stakeholders (local governments, nonprofits, community members, etc.) that improve food systems, and in this case, advocate for UA (Schiff, 2023). In San Francisco, the San Francisco Food Policy Council provides educational and technical support to urban farmers while developing regulations for local farmers' markets (City of San Francisco) to make food access more equitable.

Despite the leading research and development, there are research gaps impacting ES provisioning. Many studies assess ES on an uneven scale. Most of these studies are carried out in North America, Europe, and parts of Asia (Boerema, 2016). When mapping the inequality in human exposure to greenspace between cities of the Global North and the Global South, Chem (2013) found that there are strong differences in greenspace exposure and inequality between cities in the Global North and the Global South. With the lack of data in the Global South, it is less clear how ES affects different communities, especially as urbanization and climate challenges increase.

Additionally, some services are often overlooked in policymaking or environmental decision-making processes. For example, RES or SES can be overlooked due to their less tangible benefits. Villamagna (2013) notes how RES, like air quality maintenance, is “process-driven” and harder to measure at larger scales. The lack of larger-scale data undervalues RES (Mengist, 2020). Likewise, aspects of CES are also under-researched. The less tangible benefits,

like mental health or spiritual experience, are often overlooked as its harder to measure its economic impact.

Kosanic (2020) highlights how this lack of data and analysis, plus difficulties assigning monetary value, makes ES difficult to consider in policymaking processes. Without robust data, it becomes difficult to advocate for UA and UGS initiatives or otherwise justify public investment or intervention. Because of this, long-term monitoring programs and data collection tools are crucial for understanding the benefits and trade-offs of UA and UGS; a more standardized assessment of this will allow for a better valuation of UES (Sparrow, 2020).

Understanding that urban ES vary between location, cultural identity, individual and institutional perceptions (Leuderitz, 2015) is crucial for urban development and well-being. Additionally, evaluating all dimensions of ES will allow for a deeper understanding of how urban ecosystems can help sustain human well-being, and how we can sustain our ecosystems. As UA and UGS become more prevalent in urban areas globally, addressing the gaps in research will create more resilient and productive cities and ecosystems.

UA and UGS can be used as multifunctional strategies to help improve ecological functioning and human well-being in urban areas. These strategies amplify the availability and delivery of UES. Despite UA and UGSs notable benefits, there are several research gaps and barriers, including zoning restrictions, inadequate policy support, gentrification, and uneven distribution of research, all of which limit their adoption. However, the multifunctionality of UA and UGS systems can help overcome these barriers. Each ES, including the provisioning, regulating, supporting, and cultural services, plays a crucial role in urban areas. Interdisciplinary collaboration between stakeholders is vital for the long-term sustainability of urban ecosystems. To work towards these goals, researchers should prioritize filling in data gaps

and utilizing long-term monitoring systems. Urban planners can contribute by incorporating and advocating for green spaces into city zoning. Policymakers have the power to enact supportive legislation, and lastly, community members are integral for promoting and supporting green cities. As the challenges of climate change, urbanization, and food insecurity increase, strengthening UES through these actions can play a key role in supporting ecosystem health and the well-being of current and future generations.

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