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Kitchen Gardening: A Dual Solution for Urban Heat Islands and Nutritional Security in India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Urbanization has led to significant environmental and societal challenges, including the Urban Heat Island (UHI) effect and nutritional insecurity. Kitchen gardening, also known as urban horticulture, emerges as a promising solution to these pressing issues. By cultivating food in urban settings, individuals and families contribute to a more sustainable and resilient ecosystem. The practice of kitchen gardening plays a pivotal role in managing the UHI effect. Vegetation in urban areas helps moderate temperature extremes, reducing the heat retained by concrete and asphalt. This cooling effect contributes to lower energy consumption for air conditioning, mitigating urban pollution and reducing greenhouse gas emissions. Additionally, the proximity of urban gardens to residential areas decreases the need for transportation of produce, further cutting down on pollution and energy usage associated with food distribution. From a nutritional standpoint, kitchen gardening ensures food security by providing a direct source of fresh, healthy produce. This practice aligns

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with several Sustainable Development Goals (SDGs), including zero hunger (SDG2), good health and well-being (SDG3), and responsible consumption and production (SDG12). Urban horticulture empowers individuals to take control of their food sources, promoting a balanced diet and reducing dependence on industrial-scale farming. Furthermore, it creates opportunities for community engagement and economic growth, supporting decent work and economic growth (SDG8) and sustainable cities and communities (SDG11). Kitchen gardening is a multifaceted approach that addresses both environmental and nutritional challenges. Its benefits extend beyond individual households, contributing to broader sustainability goals and fostering a more harmonious relationship between urban development and the environment.

Keywords: Resilient; UHI effect; vegetation; sustainable; SDGs; urban horticulture; pollution.

1. INTRODUCTION

Kitchen gardens, also known as home gardens, represent the cultivation of food in proximity to a residence for household consumption [1]. These gardens can take various forms, including mixed gardens, backyard plots, farmyard spaces, compound gardens, or homestead gardens. Historically, kitchen or home gardening has been identified as the earliest and most prevalent method of food production globally [2-3]. Essential food staples like vegetables and fruits do play a particularly crucial for growing populations of moving forward nations like India, Pakistan and Bangladesh. The production of vegetables and fruits within homesteads offers households direct availability to essential nutrients that may otherwise be inaccessible due to economic constraints [4]. Recognizing the vital role of vegetables in human nutrition, it becomes imperative to raise awareness among rural communities, aligning with Sustainable Development Goals 2 and 3, which address food security and health. Hence, kitchen gardens, also referred to as home-based garden plantations, can address the challenges like hunger and malnutrition in these nations. Evidence suggests that kitchen gardens have already emerged as a significant supplementary food source in countries like India and Sri Lanka [5]. Moreover, kitchen gardening has demonstrated its cost-effectiveness and sustainability in producing organic vegetables like as cauliflower, radish, and turnip [6]. According to Sharma [7], addressing the training needs related to household food security through kitchen gardening remains a key priority in rural Bulandshahr (Uttar Pradesh), necessitating consistent training efforts to bridge the knowledge gap.

Urbanization and food security have become major concerns in the modern world. In recent years, many rural and poor urban households have faced increased uncertainty regarding safe and regular access to food. This has raised significant concerns about food security in numerous developing countries. Millions of people globally cannot afford or access sufficient food for themselves and their families [8]. This critical situation underscores the need for safe food production and reliable food supply chains in low-income countries. It is imperative to explore all available methods for food production and distribution. Germany has pioneered innovative urban agriculture techniques, including Zero-Acreage Farming (ZFarming). This approach, which includes rooftop gardens, indoor farms, and other building-integrated farming methods, has made notable contributions to the food supply in urban areas [9,10]. These techniques offer sustainable solutions for urban environments where traditional agriculture is impractical, providing a promising path to improved food security. A hands-on learning environment built around a demonstration garden can effectively serve multiple purposes. Visitors can explore a diverse range of vegetables, including both traditional and hybrid varieties. In addition, the garden can be used to teach essential gardening skills such as composting, live fencing, using natural pest control methods, and achieving year-round harvests. Women are the driving force behind many kitchen gardening initiatives. Their involvement brings a multitude of benefits [11]. Firstly, it empowers them economically, leading to better management of household resources and improved caregiving practices. This economic empowerment directly tackles poverty, a key focus of UN Sustainable Development Goal 1. Beyond that, kitchen gardening contributes to broader socio-economic improvements by reducing healthcare costs, potentially lowering birth rates, and ultimately infant mortality rates and decreasing maternal.

By empowering women and enhancing their involvement in household affairs, home gardening programs play a crucial role in community development. It's worth noting that women are predominantly engaged in agricultural activities, particularly in rural areas where there is ample vacant land available for establishing kitchen gardens. These gardens not only contribute to addressing vitamin deficiencies in the population (SDG3) but also generate surplus produce for sale in the market, thereby increasing family income and promoting decent work opportunities, thus contributing to socio-economic development (SDG8). The contemporary era is marked by pressing issues such as increasing urbanization and food security (FAO, 2010-11) [12,13]. Over the past few years, reliable availability of food has become uncertain for many rural and impoverished urban households, raising concerns about food security in numerous growing nations. Millions of individuals worldwide struggle to afford or obtain adequate access to a reliable and sufficient supply of nutritious food to ensure the well-being of their households [14]. The lack of access to diverse food items among the needy is a primary contributor to malnutrition, exacerbated by factors like limited purchasing power, lack of knowledge, large family sizes, inadequate sanitation and hygiene, and poor nutrient absorption in the body. The intake of essential diets including pulses, vegetables, milk, and fruits provide some essential nutrients, but they may not be enough to prevent nutritional deficiencies [15].

A report by the Hunger and Malnutrition Organization reveals a critical situation of malnutrition in Indian children [16]. According to the report, a significant proportion of children suffer from malnutrition, with 42.3% being underweight, 58.8% stunted, and a concerning 11% wasted [17]. Given these challenges, guaranteeing the production and delivery of healthy, uncontaminated food is imperative for resource-constrained countries, necessitating the exploration of all available techniques for food supply and distribution management [18,19]. In Germany, innovative approaches to urban agriculture, such as ZeroAcreage Farming (ZFarming), have emerged. ZFarming, which includes rooftop gardens, indoor farms, and other building-integrated forms, has significantly contributed to food availability and promoted food access by breaking down barriers that prevent people from obtaining nutritious food, such as poverty, geographic location, or lack of infrastructure while offering various environmental, social benefits and, economic [20].

1.1 The objective of the Activity is to

- Reduce spending on vegetable purchases by members.
- Ensure the availability of fresh, organic vegetables.
- Provide convenient doorstep access to vegetables.
- Encourage self-consumption among families and their neighbourhoods.

2. KITCHEN GARDEN VS. URBAN HEAT ISLAND EFFECT

This occurrence is primarily a result of human activities and the development of structures such as buildings, roads, and other infrastructure that absorb and retain heat. Additionally, the decrease in vegetation and natural land cover in urban settings contributes to this phenomenon [21]. The built environment and human activities cause cities multiple degrees warmer than developed and underdeveloped areas, an occurrence known as the urban heat island (UHI) effect. This disparity arises from variations in heat temperature regulation between sustainable building components and earthy textures [16,22-23]. Concrete materials, with their large thermal inertia and dark surfaces, are particularly prone to absorbing and storing solar radiation [14,24]. This solar absorption predominantly results in sensible heat rather than latent heat due to the lack of evaporative cooling on impervious pavements [25,26,15] causing the release of sensible heat into the urban environment and contributing to the UHI effect. Since pavements typically cover 20–40% of a typical city [5]; Hashem A et al. [27], the concept of employing cool pavements to combat the UHI effect has obtained attention.

There are several ways to create cool pavements. These include altering existing materials or pavement layouts or incorporating entirely new materials into traditional pavements (Santamouris M, [28,29,30]. Cool pavements are distinguished by their ability to reflect sunlight, a property known as solar reflectance. They also promote water evaporation from their surface and minimize the transfer of heat to the surrounding urban environment, a phenomenon termed sensible heat release [23]. This three-

pronged approach helps to mitigate the urban heat island effect, a well-documented challenge in many cities. Cool pavements come in various forms, each strategically designed to combat urban heat [19]. Reflective pavements, for example, boast a higher albedo compared to traditional surfaces. This translates to a greater ability to reflect sunlight, resulting in cooler pavement temperatures and less heat radiating back into the environment (sensible heat release).

In essence, reflective pavements act like mirrors for sunlight, bouncing it back into the atmosphere and preventing the pavement from absorbing excessive heat. This can significantly reduce the urban heat island effect, a phenomenon where cities experience higher temperatures than surrounding rural areas due to the abundance of heat-absorbing surfaces. [9,29,30] and [31]. Evaporative pavements employ a clever strategy to achieve a cooler surface temperature. They function by storing water within their surface or lower layers. This retained water acts like a natural coolant, facilitating a process called evaporative cooling. As the sun heats the pavement, the stored water begins to evaporate. During this phase change from liquid to gas, the water molecules absorb heat from the pavement surface, effectively carrying away thermal energy. This heat absorption process significantly lowers the pavement temperature, creating a more comfortable and sustainable urban environment [32,33,34].

Heat-harvesting pavements take a proactive approach. They capture the sun's thermal energy and convert it into a valuable resource – renewable energy. This captured heat can then be used for various purposes, effectively lowering surface temperatures while providing a sustainable energy source [35,36,37]. Cool pavements are no longer viewed solely through the lens of surface temperature reduction. Their role has expanded to encompass a broader understanding of their impact on urban climates. Researchers are now comprehensively evaluating cool pavements, considering not just the benefits like mitigating urban heat islands, but also potential drawbacks, life-cycle costs, and the policy landscape for wider adoption [5,11], and [21].

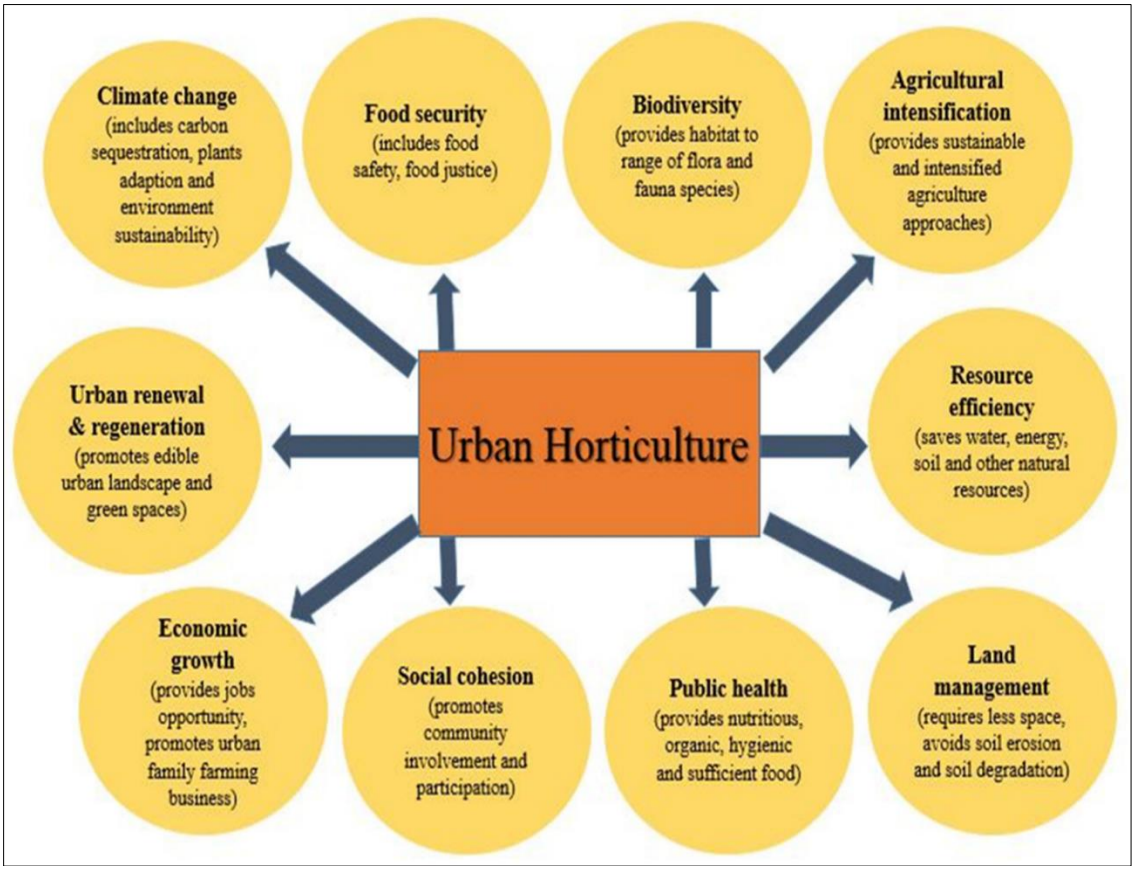

Fig. 1. Urban horticulture for food secure cities and its different aspects [6]

3. KITCHEN GARDENING ALLEVIATING URBAN HEAT ISLAND EFFECTS

Kitchen gardening, or urban or home gardening, involves cultivating plants, herbs, and vegetables in urban areas, often within constrained spaces like balconies, rooftops, and backyard gardens. It presents numerous advantages, including its potential to mitigate the impacts of urban heat islands. Here's how kitchen gardening can contribute to alleviating urban heat island effects:

1. **Enhanced Vegetative Cover:** Urban areas typically comprise concrete, asphalt, and structures that absorb and retain heat, leading to elevated temperatures. By introducing vegetation through kitchen gardening, urban greenery can be enhanced. Plants absorb sunlight and convert it into energy through photosynthesis, thereby reducing heat absorption by surfaces and the surrounding air.
2. **Shade and Cooling:** Plants in kitchen gardens offer shade to surfaces such as rooftops, walls, and pavements, thereby reducing direct exposure to sunlight. Transpiration, the process by which plants release water vapour, cools the environment, resulting in lower temperatures in the immediate vicinity.
3. **Evapotranspiration:** Plant transpiration aids in cooling the surrounding air, effectively counteracting the higher temperatures caused by heat-absorbing urban surfaces, thus mitigating urban heat island effects.
4. **Thermal Insulation:** Plants serve as natural insulators, creating a barrier between buildings and the external environment, thereby reducing heat transfer into buildings during hot weather. This can lead to a decrease in the need for air conditioning, consequently lowering overall energy consumption.
5. **Microclimate Modification:** Kitchen gardens can create microclimates that differ from the surrounding urban environment, providing cooler and more comfortable conditions. Increased adoption of kitchen gardening practices can result in noticeable improvements in local microclimates.
6. **Community Engagement:** Encouraging kitchen gardening fosters community involvement in sustainability initiatives. Collaborative gardening activities promote social connections and a sense of ownership over the environment, thereby participating to the lowering of urban heat island effects.
7. **Air Quality Enhancement:** Many plants absorb pollutants from the air, thereby improving overall air quality. This contributes to a more pleasant urban environment and aids in diminution the urban heat island effect.
8. **Education and Awareness:** Highlighting kitchen gardening as a way to mitigate the urban heat island effect in cities raises awareness about the environmental challenges posed by excessive urban heat. Educating individuals about the benefits of green spaces and plants in cooling urban areas can lead to more informed and sustainable urban planning and development strategies.

Nutrition awareness initiatives stress the importance of incorporating regionally available fruits and vegetables, such as mango, papaya, guava, and salad greens, into regular diets. Therefore, every family or individual must transform their surrounding vacant land into a productive kitchen garden, growing seasonally appropriate fruits and vegetables. The primary motive of a kitchen garden is to supply the household with fresh food, and nutrient-heavy vegetables daily. A properly designed nutrition garden can fulfil the entire family's fruit and vegetable requirements year-round [38]. Encouraging the cultivation of regionally grown plants is an effective approach to enhance vegetable usage in a specific area, as numerous reginally plants contain beneficial compounds with antioxidative, anti-mutagenic, and anti-inflammatory properties [39]. While fruits and vegetables are commonly purchased from markets, it may not be feasible for small and marginal families to include them in their daily diets. If you're considering a vegetarian diet, [40] research suggests incorporating specific quantities from various food groups like leafy vegetables, root vegetables, and fruits for optimal nutrition [24,41,36].

4. NUTRITIONAL VALUE OF KITCHEN GARDEN

Nutrition awareness initiatives stress the importance of incorporating locally available fruits and vegetables, such as papaya, mango, guava, and leafy greens, into daily diets. Therefore, every family or individual must transform their

surrounding vacant land into a productive kitchen garden, growing seasonally appropriate fruits and vegetables. The primary aim of a nutrition garden is to supply the family with fresh, nutrient-rich vegetables daily [42,43]. A properly designed nutrition garden can fulfil the entire family's fruit and vegetable requirements throughout the year [38]. Encouraging the cultivation of local plants is an effective strategy to increase vegetable consumption in a specific area, as many local plants contain beneficial compounds with antioxidative, anti-mutagenic, and anti-inflammatory properties [39].

While fruits and vegetables are commonly purchased from markets, it may not be feasible for small and marginal families to include them in their daily diets. According to [40], a healthy vegetarian diet should include specific quantities of leafy vegetables, root vegetables, other vegetables, fruits, grains, and pulses. Establishing and maintaining a nutrition garden on a small plot of land at home, recognised as a nutrition garden, is essential, especially in an underdeveloped place where access to markets is limited and incomes are constrained [44]. Location-specific initiatives like the promotion of nutrition gardens can significantly contribute to addressing malnutrition issues. The idea of a nutrition garden targets to ensure a steady stream of homegrown vegetables to keep your family nourished throughout the year, utilising available space and household waste through organic practices, along with water management [16]. According to Shukla et al. [45], the development and maintenance of a nutrition garden require the collaborative effort of family members, usually overseen by a woman or housewife.

5. FOOD PRODUCTION BY HOME GARDENING AND URBAN AGRICULTURE

Urban agriculture (UA) encompasses a broad range of agricultural activities, from food production to non-food cultivation, taking place within or on the outskirts of cities. This form of agriculture has gained significant attention for its role in enhancing various ecosystem services and offering tangible benefits to urban communities [31]. UA can improve human health by providing fresh and local produce, thus contributing to better nutrition and food security. It also facilitates greater food access for local communities, generating income and job opportunities, and promoting economic prospects for urban residents [46,37].

Beyond its economic and health benefits, urban agriculture adds to the aesthetic value of urban landscapes, bringing greenery and natural beauty into city environments. It also plays a role in education, offering opportunities for city dwellers to learn about farming practices, sustainability, and food systems. Additionally, urban agriculture fosters community resilience by creating spaces for communal engagement, social interaction, and shared responsibilities [6]. UA can take various forms, including traditional ground-based outdoor gardens and farms, as well as innovative approaches like hydroponic or aquaponic indoor production, rooftop gardens, and landscaping businesses. Skyfarming, which involves cultivating crops in high-rise buildings, is another emerging form of urban agriculture. Moreover, UA can include urban livestock farming, adding diversity to the agricultural practices within cities.

Community gardens are a specific type of urban agriculture where members of a community collectively manage a shared agricultural space within city limits [22]. These gardens may be used to grow vegetables, fruits, and even raise livestock. They can be collectively owned by the community or subdivided into individual allotments for personal cultivation [7]. Community gardens offer a unique blend of agriculture and social cohesion, enabling urban residents to connect with nature and each other while contributing to food production in their neighborhoods. Urban agriculture, with its versatility and community-oriented approach, has the potential to transform urban spaces, making them more sustainable, inclusive, and vibrant. By embracing various forms of UA, cities can address challenges related to food security, urbanization, and climate change, creating healthier and more resilient communities in the process (Fig. 2).

6. FUTURE ASPECTS OF KITCHEN GARDENING IN INDIA

Kitchen gardening is gaining momentum in urban India, presenting a solution to multiple contemporary challenges. As urbanization continues to increase, exacerbating the Urban Heat Island (UHI) effect and impacting food security, the role of kitchen gardening will become even more critical. Looking ahead, the

following future aspects highlight the potential of kitchen gardening in mitigating these issues:

1. **Expansion of Green Infrastructure:** Kitchen gardening could play a pivotal role in expanding urban green infrastructure. As cities grow, integrating rooftop gardens, community gardens, and vertical farming into urban planning can significantly reduce the UHI effect. These practices can also enhance biodiversity in urban environments, supporting pollinators and other beneficial species.
2. **Strengthening Community Engagement:** Future kitchen gardening initiatives can focus on fostering stronger community bonds. Community gardens and shared spaces for urban horticulture offer opportunities for social interaction, knowledge sharing, and collective problem-solving. This can contribute to building resilient urban communities that prioritize sustainability and food security.
3. **Addressing Food Security and Nutrition:** Kitchen gardening can directly contribute to urban food security by providing fresh, locally grown produce. Looking ahead, integrating kitchen gardening into educational programs and public health campaigns can promote healthy eating habits and reduce dependence on industrially produced food. This could help combat malnutrition and lifestyle-related health issues.
4. **Technological Innovations**: The future of kitchen gardening may involve greater use of technology, such as smart gardening systems and hydroponics. These innovations can increase efficiency, enabling year-round cultivation and higher yields in limited spaces. The incorporation of technology can also make kitchen gardening more accessible to a wider audience, encouraging greater participation.
5. **Policy Support and Incentives:** To fully realize the potential of kitchen gardening, future efforts should focus on policy support and government incentives. Local governments can encourage urban horticulture through tax incentives, grants, and zoning regulations that promote green spaces. National policies could also support urban agriculture as part of broader sustainability and climate action goals.
6. **Integration with Sustainability Goals:** Kitchen gardening aligns with several Sustainable Development Goals (SDGs), including climate action, zero hunger, and sustainable cities. Future efforts can focus on integrating kitchen gardening into national and local sustainability plans, reinforcing its role as a critical component of sustainable urban development.

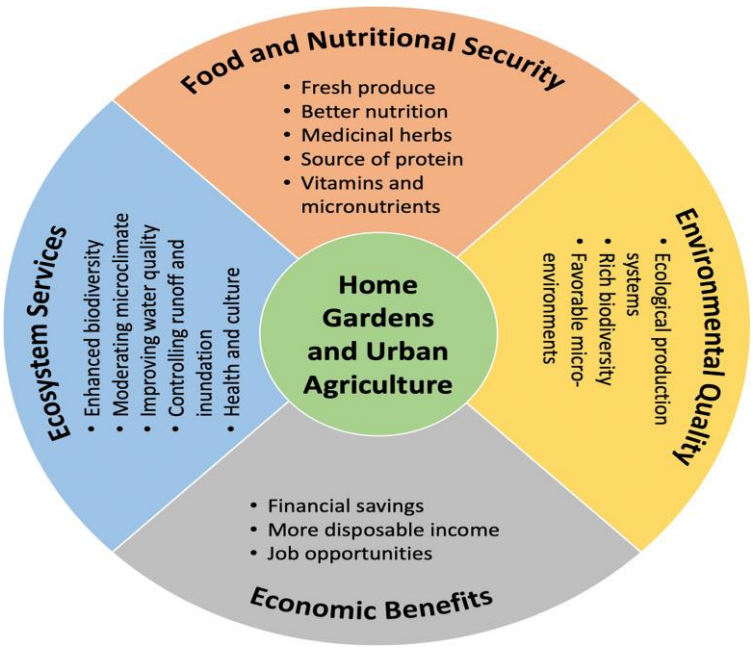

Fig. 2. Food, environmental, economic, and ecosystem service benefits of home gardens and urban agriculture [8]

By addressing these future aspects, kitchen gardening can emerge as a robust solution to the dual challenges of urban heat islands and nutritional security in India. This approach holds the potential to transform urban landscapes, create healthier communities, and contribute to a more sustainable future.

7. CONCLUSION

The establishment of kitchen gardens holds significant importance in addressing malnutrition and micronutrient deficiencies in both urban and rural settings. One of the simplest and most cost-effective approaches to maintaining good health is to increase the consumption of fruits and vegetables. Backyard kitchen gardens offer direct availability to fresh produce which can be harvested, cooked, and eaten daily, thus enhancing home food security. Even individuals facing extreme poverty or landlessness can cultivate their food in small spaces, containers, or alternative locations. Kitchen gardens also provide women with opportunities for employment, income generation, and efficient utilisation of space and water resources. Therefore, promoting and implementing kitchen gardening nationwide is essential for enhancing family food security. Moreover, kitchen gardening plays a multifaceted role in mitigating the impacts of urban heat islands by increasing greenery, offering shade and cooling, facilitating evapotranspiration, enhancing air quality, and fostering community engagement. As urbanization continues to expand, incorporating more green spaces like kitchen gardens can be a valuable strategy for creating healthier and more resilient cities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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