Essay

Enhancing Food Resilience in the Age of Geoeconomics by Applying Biomimetic Principles in Urban Agriculture

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Enhancing Food Resilience in the Age of Geoeconomics by Applying Biomimetic Principles in Urban Agriculture

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Abstract: Biomimicry, though still emerging within the social sciences, offers promising insights for improving food security by drawing analogies from natural ecosystems and re-exploring traditional ecological knowledge. This paper argues that adopting nature-inspired strategies in urban agriculture can significantly enhance resilience against geoeconomic pressures, logistical disruptions, and disasters. As geopolitical tensions intensify, exacerbated by climate change, pandemics, and urbanization, the strategic use of food power is likely to become increasingly relevant, particularly impacting urban areas due to their high dependence on external food supplies. Urban agroecology, which inherently embodies biomimetic principles, is presented as a viable pillar for building more resilient and self-sustaining food systems. The paper explores how an urban agriculture approach grounded in biomimicry can serve as a critical mechanism for food security, especially in urbanized regions vulnerable to potential food power dynamics. Additionally, it examines current methods by which states and cities prepare for food supply challenges and highlights the untapped potential of urban food production as a strategic response to these vulnerabilities.

Keywords: geoeconomics; economic resilience; food power; food security; urban agriculture; sustainability; biomimicry; agroecology

1. Introduction

In recent years, the global economy has recovered faster than anticipated in many countries, however, supply chain bottlenecks have begun to affect all markets, resulting in significant disruptions that reach all the way to the end consumers. Consequently, food security has also been challenged numerous times all over the globe through demand-side price inflation, geopolitical tensions and devastating natural phenomena [1]. The whole world could observe that how much damage some deliberated or just consequential geoeconomic measures such as international retaliations, protectionist policies or maritime blockages caused to the global food ecosystem, of which effects reached national security levels in several countries [2–4].

The previous decades provided many examples of political instabilities and social unrests provoked by food insecurity [5]. Additionally, in long-term the situation could become more devastating without even any geopolitical intensions. A notable surge in food costs, and potential shortages, may occur due to compounding factors like failures in industrial farming, heightened energy expenses, demographic pressures, and the growing dominance of multinational corporations over the food system [6].

These uncertainties urged many food security experts to revisit the importance of preferably the most 'localized' food sourcing methods in order to strengthen geoeconomic resilience [7]. In the upcoming decades reduced supply chains and proximity to consumers are certainly becoming more and more crucial parts of food strategies. These features could be considered more essential in a dynamically urbanizing world, especially in the most populous continent - Asia. By 2030, it is

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estimated that 60% of the world's population will live in urban areas, with 56% of the world's impoverished and 20% of those who suffer from malnourishment also residing in cities [8]. Cutting off supply right from these citizens could induce direct ripple effects in most of the political communities [5].

'Onshoring' possibly the most of the necessary food production capacities came up as suggestions, not only in land and resource scarce countries [7]. The most effective way to accomplish the above-mentioned goals would be to introduce urban agriculture techniques, particularly in the densely populated areas where the high number of long-haul logistics could be replaced by local production activities like vertical farming, aquaculture or floating gardens. Presently, cities with a population of 10 million or more must import more than 6,000 tons of food daily, with an average distance travelled of 1,500 kilometres [9]. In the conventional food supply chain, farming, packaging and transport phases are responsible for the largest amount of food waste, thereby emission as well [10]. Thus a localized ecosystem like urban agriculture not only further ensures food security, but by its closeness and convenient delivery it

constitutes a far more sustainable method of food production [11]. Moreover, it is going to be less and less exposed to contamination and exhausted gases in the cities thanks to the electric revolution across industries [12].

However, as emerging agricultural techniques, functioning of conventional urban agriculture is facing limits like resource scarcity and many methods are not flawless yet [13]. Their operations could cause overloads in local networks, deforestation or drainage of water reservoirs [14]. By analysing the current urban agriculture segment from nature-based sustainability perspective, this localized food production system could be adjusted so to function as a more reliable and significant source of food supply. A more advanced urban agriculture seems to be more indispensable than ever in a world experiencing frequent geopolitical instabilities, food supply disruptions together with ambitious decarbonization on the back of global fight against climate change and continuous population growth followed by record rate of urbanization.

Relevant actors should look at the whole urban agroecosystem to assess how this food production process is aligned with nature's rule on circularity and sustainability, represented by the nine basic principles of biomimicry [15]. To enhance harmony with the principles, which have been perfected over 3.8 billion years and the ones natural processes tend to follow, several systematic and specific techniques could be analysed. Besides optimizing water usage and running on renewable energy, noteworthy agroecological methods could include traditional indigenous practices [16].

As biomimicry has been applied in designing, manufacturing and construction, its principles could act just as practically in the field of geoeconomics with special focus on food supply and security. In this sub-field, this more holistic and systematic approach does not seem to have been solidified its place in national strategies yet.

This paper aims to draw attention to an emerging approach in designing food ecosystems to enhance food supply resilience by providing evidence that nature's basic principles can serve as a valuable additional framework. By exploring how a nature-inspired urban agricultural approach could contribute to more resilient food security, this study seeks to demonstrate the potential for more robust development and decision-making processes, ultimately leading to more effective mitigation of potential foreign political influence through economic means.

2. Food Power

As countries seek to maintain and expand their influence in an interconnected and interdependent world, geoeconomics has become increasingly important in the global arena [17]. It is often seen as a complement to traditional geopolitical strategies, which focus on military and diplomatic power. The term is used to describe the intersection of economics and geopolitics in which economic tools, such as trade, investment, and financial policy, are applied to achieve geopolitical goals and advance a country's strategic interests [18]. In other words, it is the use of economic power as a tool of statecraft. The direct restriction of food supply reflects the use of food power as a form of

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retaliation against another country [19]. In this case a country imposes a food embargo in response to perceived unfair trade practices or other grievances.

To be able to apply food power, the given countries must possess a high degree of food self-sufficiency and export capacity to use their surplus food production to exert influence on other countries or regions that are dependent on food imports [20]. For a major exporting country to use food as a tool to advance its diplomatic or security objectives against other nations, certain conditions must be satisfied simultaneously. Specifically, four conditions must be met [21].

The primary prerequisite for food power is the scarcity of food, and another essential condition is the concentration of food supply. If food production is controlled by a small group of producers, it becomes possible to form a food cartel, and in extreme cases, they could establish a monopoly over the food supply [21]. In addition to the above conditions, food power effectiveness also relies on the dispersion of food demand and action independence. When several food importers are competing for limited food supplies, a dominant food exporting country can leverage this situation to its advantage by playing the importers against each other, increasing prices, or imposing conditional agreements [21]. It is evident that meeting all four of these conditions is exceedingly challenging, if not outright impossible. Not mentioning, due to the perishable nature of food, storage becomes complicated and expensive once it is removed from the market, and if it is stored for an extended period, it will spoil [17].

In the post-Cold War period, a neoliberal food regime emerged which has been characterized by market liberalization, privatization, and deregulation [22]. This system emphasizes trade liberalization, the removal of government intervention in markets, and the promotion of large-scale agribusiness over small-scale farming. States have gradually lost footholds in commodity trading thus in applying direct control over food exports [23].

3. Not Applicable Anymore?

Enforcing food power can be challenging because unlike technology, food, particularly grain, can be easily substituted. For instance, rice can be used as a replacement for wheat, and if the embargo is not global, imports can be obtained from other nations. A similar scenario occurred during the US embargo against the former Soviet Union in 1980-81 [24]. Nevertheless, food is a vulnerable target for embargoes, as food items are typically bulky and difficult to conceal during transport [25]. Moreover, food is expensive and tricky to store for extended periods, particularly perishable foods including meat, fruits, and vegetables [26].

In regions with cold climates, the seasonal production of food can delay the replacement of imports with domestic production for up to a year while crops grow. Consequently, the short-term supply of domestic food tends to be inflexible. Demand for food is typically less elastic compared to non-food products, which means that any food-related embargoes can result in significant price increases due to the inelastic supply response in the short run [27]. Although food stocks can alleviate the immediate pressure on prices, it may not be possible to avoid price increases in the long run [28].

Climate changes and natural disasters (Pakistan in 2022 and Texas in 2021) [29,30] may be resulting more and more food scarcities as well as food supply concentrations in the future. Observing the location of countries characterized by high food dependency and those being the most vulnerable to climate change, this scenario does not seem impossible from time to time in the future [31]. These markets would also be harshly impacted by food supply chain disruptions via any accidental or military blockades (Suez Canal 2021 and Black Sea 2022) [2,3] or another logistic shutdown because of an upcoming global pandemic [32]. These phenomena would considerably increase the number of potential buyers entering the global commodity market which further expand the food demand dispersion, favouring for taking advantage of food power. Besides food, transport of basic agricultural input materials could suffer heavy delays regardless of their recipients [27].

Despite the interconnected nature of the globalized world, where conditions for fully leveraging food power may be lacking, recent history provided again a spectacular taste of that setup when some countries could easily play with food power, even if partially [33]. The reliance on global supply chains could cause severe shortages whenever export countries implement export bans, even if for

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just couple of months to ensure domestic supply as it happened after the Russo-Ukrainian War sin 2022 [34].

4. Cities in the Crosshairs

Urbanized areas are more vulnerable to international food supply disruptions because they tend to rely heavily on imported food to meet their needs [35]. In many cases, urban areas have limited agricultural land and water resources, making it difficult to produce enough food to sustain their populations. If there is a disruption in the international food supply chain, like an embargo or trade war, urban areas may face food shortages or price spikes, which can lead to social and political instability [5]. Since urban populations are typically more concentrated and reliant on food markets and supermarkets, any disruption in the food supply chain can have a greater impact on them compared to rural areas where people may have more access to alternative food sources [36].

Local human negligence could further aggravate the already serious supply issues like in Beirut, Lebanon in 2020 [37]. Food supply disruptions due to a combination of factors, such as economic crisis and COVID-19 pandemic, got worsen by an explosion in the port of Beirut. The explosion destroyed the city's main port, which was responsible for most of the country's food imports. Besides civil wars like the ones in Syria or Libya, COVID-19 pandemic did disrupt food supply chains in many cities, especially in India [38]. Lockdowns and restrictions on movement made it difficult to transport food, and many urban areas faced shortages of essential items namely fruits, vegetables, and dairy products. Food shocks and their ripple effects then turned into food riots in Nigeria or Kenya over the course of 2020 [39], and later post-covid price inflation evolved into national social unrests in Peru, Chile or Sri Lanka in the 2022-23 period [40].

Properly timed food power projection could easily provoke such social responses and further weaken political stability in the targeted nations. To act in favour of the huge urban population, accounting for the majority of electorate in most of the countries, governments may satisfactorily implement the necessary moves to resolve the food scarcity [41].

It is projected that by 2050, over 1,600 cities will have 2.5 billion residents living in states where at least one major crop is expected to decrease [41]. In the future cities that tend to have better resilience to food supply issues are those that have diverse and decentralized food systems, strong local food production and processing capacity, and efficient distribution networks [42]. Cities that prioritize sustainable and equitable food policies and programs may be better equipped to address food supply issues [43].

5. A Promising Solution within the Gates

Despite occupying only 2% of the world's land surface, cities utilize more than 75% of the world's material resources due to the intense concentration of various activities within their boundaries [44]. Furthermore, with projections indicating that approximately 80% of the global population will live in cities by 2050—up from 55% in 2022—urban agriculture emerges as a promising component of a comprehensive strategy to ensure food supply for these densely populated areas [45]. Urban agriculture has demonstrated significant potential for food production, and studies have shown that urban areas can be equally, if not more, productive than rural areas [46]. The average crop yields from urban agriculture are comparable to or higher than those achieved through conventional agricultural methods. Urban agriculture presently contributes between 5% to 10% of the global legumes, vegetables, and tubers production [47]. In the future, by harnessing the food production capacity of peri-urban regions, it is anticipated that it could provide sustenance to around 30% of the urban population, although this may vary in different regions of the world [48]. Urban unused land, rooftops, parks, and other urban spaces could potentially produce up to 180 million tonnes of food each year [47]. This amount would account for roughly 10 percent of the worldwide production of legumes, roots, tubers, and vegetables. In some cities, such as Havana, Cuba, urban agriculture already provides a significant portion of the city's food supply, with up to 60% of fresh produce coming from urban farms and gardens [49].

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However, there are currently a number of challenges that urban agriculture as cultivation method is facing and why it cannot maximize its full potential [50]. Conventional urban agriculture techniques agriculture may not be resilient for several reasons. Conventional agriculture requires large amounts of land and resources, which are often limited in urban areas. Such extensive form of cultivation can lead to soil degradation, water scarcity, and other environmental issues. In many urban areas, fresh water is scarce, and conventional agriculture may compete with other uses such as drinking water and sanitation [51]. Concerning natural water resources, reliance heavily on chemical fertilizers, pesticides, and herbicides is common feature to maintain crop yields [13]. Overuse of these inputs can lead to soil contamination and water pollution. Monoculture farming is the most usual farming type, which can likely result a loss of biodiversity and increase vulnerability to pests and diseases [52].

Soilless urban agriculture, which includes hydroponics, aeroponics, and aquaponics, has gained popularity as a means to produce food in urban settings with limited space. While it offers various benefits such as increased crop yields, reduced water usage, and year-round production, this method also poses several challenges and considerations, particularly concerning nutritional content, biodiversity, ecology, CO_2 sequestration, and regeneration [53].

6. Nature as Mentor: Urban Agroecology

Biomimicry has been present in traditional agricultural processes for thousands of years [54,55]. By observing and understanding how natural ecosystems function and the strategies that living organisms use to thrive, biomimicry can inform the design and implementation of more sustainable and efficient agricultural methods [56]. By studying the way that plants interact with their environment and communicate with each other, farmers developed agroecological practices that mimic natural systems and increase biodiversity, soil health, and productivity [57,58]. However, the modern movement of biomimicry started in the 1990s, when biologist Janine Benyus introduced the term in her 1997 book "Biomimicry: Innovation Inspired by Nature" with highlighting nine basic principles nature is organized by [15].

Biomimicry is a problem-solving and innovation methodology that draws inspiration from nature's designs, patterns, and strategies. The approach involves examining biological systems and processes to create new technologies, materials, and systems that imitate or take inspiration from nature's billions of years of evolution [59].

The most resilient urban agriculture techniques are those that are designed to be sustainable and adaptable to changing conditions [60]. Agroecological movements were exactly established with these ideas in mind. This approach focuses on creating self-sustaining ecosystems that mimic natural systems, using techniques namely agroforestry, composting, and soil regeneration. Agroecologically cultivated systems can be highly resilient to external factors such as drought, pest invasion, flooding, and soil degradation, but requires careful planning and management [60]. This holistic view of agriculture regards natural process as sole inputs in its system [61]. This is why, this urbanized version of this agricultural system also represents the most authentically the principles of biomimicry.

Urban agroecology could also be regarded as the most resilient way of urban agriculture to food crises due to several reasons. It is designed to create a self-sustaining and diverse ecosystem that is less dependent on external inputs and resources, such as fertilizers and pesticides, which could be disrupted or become unavailable during food crises [62]. In this framework it is essential to be adaptable and flexible, allowing for changes in growing conditions and environmental stressors, which could arise during food crises. Another unique aspect is that urban agroecology promotes the use of perennial crops, which have deeper roots and are more drought-resistant, and the practice of water harvesting and conservation, which can maintain food production during periods of water scarcity [63].

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7. Self-Sufficiency with Higher Yield

Agroecological practices are essential strategies in sustainable agriculture that enhance soil quality, increase crop yields, and improve pest management through various innovative approaches [58]. One such practice involves the addition of organic matter, such as distributing fava beans and peas as green manure [64]. This method serves as a cost-effective way to enhance nitrogen provision for crops. The inclusion of green manure often results in increased levels of key nutrients such as phosphorus and potassium, alongside improvements in soil pH, organic matter content, and the presence of micronutrients [65]. Furthermore, these practices help retain soil nutrients, immobilize contaminants, and stabilize pH levels. An added benefit is the improvement in soil structure, facilitated by increased biomass and earthworm activity, which contributes to a positive yield response in most crops when compost is used [66,67].

Water conservation and efficient use are also critical components of enhancing soil quality [63]. By sourcing water from various sources, such as wastewater, greywater, or harvested rainwater, and applying it through irrigation, crops can be better supported. Additionally, using straw or grass mulch to reduce evaporation can further aid in maintaining soil moisture [68]. Notably, even a 1% increase in soil organic material can lead to a significant increase in the soil's water storage capacity, estimated at 1.5 liters per square meter [69]. This method also supports the positive effects of arbuscular mycorrhizal colonization, which is beneficial for fruit yield [70]. Crop diversification is another core principle in agroecology, aimed at enhancing agroecosystem sustainability. Temporal diversity through crop rotations involves rotating plant families to reduce soil-borne diseases and soil-dwelling insects that are specific to certain crops. This practice not only helps in disease management but also promotes overall soil health [71].

Intercropping, which involves planting mixtures of annual crops simultaneously in the same plot, is another effective crop diversification strategy [72]. It enhances resilience to climatic variability, improves nutrient cycling, boosts soil fertility, and aids in pest control. Over-yielding, a related concept, involves combining two contrasting species as a mixture to utilize resources more efficiently than in separate monocultures [73]. Polyculture, for instance, can require up to 50% less area for the same production of crops like lettuce, mizuna, kale, and arugula [60]. Mixed cropping systems typically yield higher outputs compared to monoculture practices and are more efficient at removing nitrogen from the soil [74].

The diversification of urban gardens, particularly through the planting of trap crops, plays a significant role in insect pest regulation [75]. Implementing intercropping methods in these gardens has shown positive outcomes in pest management, including enhancements in the activity of natural enemies, reductions in pest populations, and decreased crop damage [76]. Such polyculture systems, characterized by their diversity, also experience significantly lower rates of pest immigration compared to monocultures. Additionally, these systems favour the presence of natural pest enemies, and having a greater diversity and abundance of these enemies early in the growing season can prevent pest populations from escalating [77].

8. Rethinking Food Resilience through Biomimicry

Food security, a cornerstone of global sustainability, faces unprecedented challenges due to factors such as climate change, population growth, and resource depletion. As traditional methods struggle to keep up, a novel perspective rooted in biomimicry could offer a transformative framework to reshape the concept of food security. By drawing inspiration from nature's adaptive strategies, this emerging approach seeks to create a sustainable and inclusive global food system that mirrors the resilience, diversity, and balance observed in ecosystems.

Natural ecosystems have evolved mechanisms that enable them to withstand shocks and stressors, providing valuable insights for creating adaptable food systems. Just as diverse ecosystems exhibit increased resilience, the integration of diversified crop varieties and agricultural practices can enhance the resilience of food systems against various disturbances. By embracing this concept, such food systems could be designed that are better equipped to withstand unforeseen challenges. One of the lessons humans can glean from nature is the self-sufficiency exhibited by localized ecosystems.

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Through the establishment of decentralized food production hubs, communities could be empowered to take charge of their food security. These hubs, akin to natural ecosystems, should reduce dependency on centralized distribution systems, while simultaneously bolstering local food security and enhancing community resilience.

Nature's blueprint for resilience lies in its biodiversity and regenerative practices. By emulating these principles, urban agriculture can transition to regenerative agricultural practices that enrich soil health, sequester carbon, and enhance ecosystem services. This shift not only contributes to long-term food security but also aligns with nature's intrinsic ability to restore balance. Observing interconnected ecosystems, it is possible to adjust global supply chains to prioritize cooperation over competition. By forging symbiotic relationships among nations, regions, or communities the food system should ensure mutual support during periods of scarcity or disruption. This collaborative approach reflects the balance found in ecosystems, paving the way for a more robust global food network.

Natural closed-loop systems offer a compelling model for reducing waste and resource depletion. Through the creation of circular food economies, the transformation of organic waste into valuable resources becomes a cornerstone. This approach aligns with the principles of biomimicry by ensuring that resources are utilized efficiently, mirroring the resource cycles seen in nature. Ecosystems thrive on balanced consumption patterns. Reflecting this, a holistic approach to nutrition can be adopted. Encouraging diets that incorporate a diverse range of nutrient sources reduces the strain on specific crops and enhances overall nutritional resilience, promoting a sustainable food security paradigm. Raising awareness about the impact of consumption habits on food security and empowering individuals to make informed decisions fosters a more resilient and interconnected food system.

Biomimicry presents an opportunity to redefine food security as a symbiotic interaction between humans and the environment. By embracing the principles of resilience, diversity, interdependence, and balance inherent in natural ecosystems, it is more likely to transition towards a more sustainable, equitable, and resilient global food system. This promising paradigm has the potential to guarantee access to nourishing food for all while cultivating a profound sense of interconnectedness with the natural world, ultimately paving the way for a secure and prosperous future.

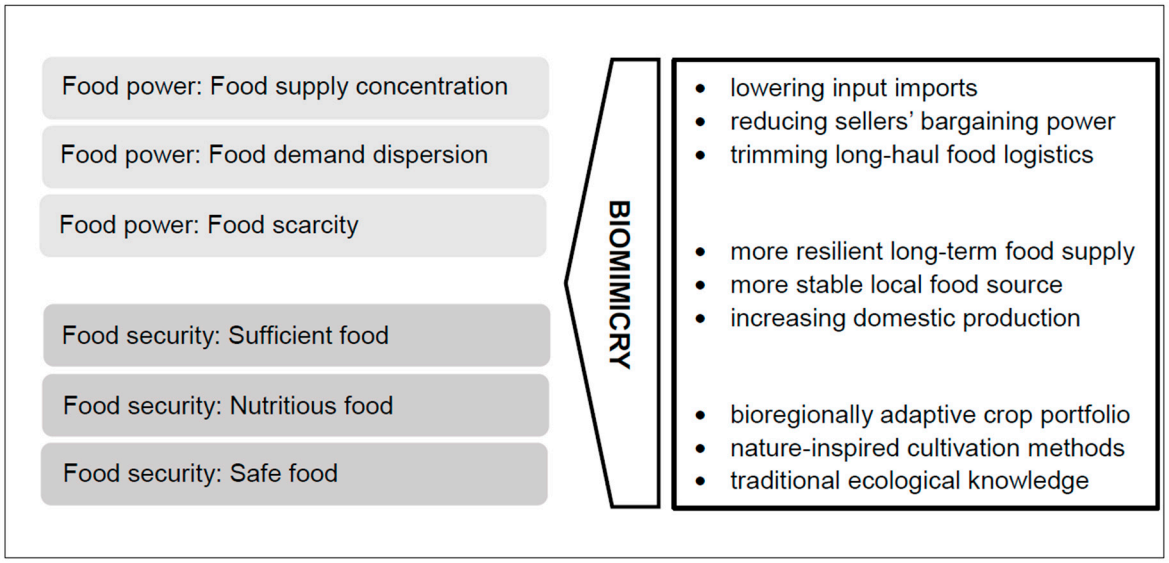

Figure 1. Potential reshaping effects of biomimicry on global food security (The author).

9. Conclusions

Urban agroecology presents a promising approach to enhancing local food security amid growing uncertainties in the global food supply chain and complex geopolitical arena. By promoting localized food production, urban agroecology can reduce dependence on imported goods that are

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often subject to price volatility and geopolitical tensions. This reduction in reliance on external sources may contribute to greater stability in local food prices, even during periods of international market fluctuations. Additionally, the emphasis on diversity and resilience could provide a buffer against price spikes and shortages, thereby strengthening resilience against external economic pressures and food power projections.

Agroecology, embodying the principles of biomimicry, further enhances the sustainability and resilience of local food systems through practices that closely mimic natural processes. The incorporation of organic matter, such as green manure from crops like fava beans and peas, improves soil fertility by increasing essential nutrients and enhancing soil structure. Water conservation techniques, including the use of mulch and harvested rainwater, help retain soil moisture and support crop health. Additionally, crop diversification strategies like intercropping and crop rotations foster a balanced ecosystem that enhances nutrient cycling, improves pest control, and boosts overall crop resilience. These low-input, nature-inspired methods not only optimize resource use but also strengthen the capacity of urban food systems to withstand environmental stresses and disruptions, making local food production more sustainable and resilient over the long term.

This paper uniquely contributes by illustrating how urban agroecology can be applied within the context of geoeconomics to mitigate the risks posed by food power dynamics and geopolitical tensions. While urban agroecology shows promise, further research is needed to fully understand its potential and limitations in different contexts. Its capacity to enhance food security and economic resilience, particularly in the face of severe global disruptions and geoeconomic measures, remains an area for ongoing study. Additionally, the scalability of these practices, especially in densely populated urban areas, requires careful consideration.

The current global food system faces multifaceted challenges including climate change, pandemics, geopolitical conflicts, and logistical disruptions, all of which exacerbate food insecurity concerns. Traditional strategies such as increasing domestic production, diversifying imports, and investing in overseas agriculture, while beneficial, may not fully address the compounded effects of these issues, especially when coupled with economic retaliations. In this context, urban agroecology offers a complementary approach that fosters self-sufficiency and reduces vulnerability to external shocks.

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