Urban Agriculture and Food Security in Development Planning

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ABSTRACT

With the world population anticipated to reach over nine billion in 2050, and the majority of whom will live in cities, feeding a predominantly urban population will pose additional challenges to a predominantly rural-based agrifood system. Further, with the focus of economic activity being centered in cities, a development question is whether agriculture in cities should be an integral part of national planning. This is particularly when food insecurity is expected to challenge the poor in cities much more than in the countryside. Urban and peri-urban agriculture has been practiced in many parts of the world through activities ranging from community gardens to commercial farms of varying sizes. A major change, accelerated by supply chain disruptions and the COVID-19 pandemic in the early 2020s, has been the rapid development of technologies (digital, physical, biotechnological) that increases food production capabilities in urban areas and provide economic opportunity for entrepreneurship. Additionally, sizable investments from private equity have seen sophisticated food production facilities, such as indoor vertical vegetable and fish farms and precision fermentation factories, produce novel food such as alternative proteins in city spaces. Apart from the economic and food security benefits arising from urban agriculture, environmental and social benefits have also been demonstrated in cities that have adopted a clear mandate to become "green" and reduce their carbon footprints. This paper provides a background on urban farming, its justification as a worthwhile activity, and the rationale for explicitly including urban agriculture in national planning.

Keywords: urban agriculture, economic planning, development planning, technological innovations, food security
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INTRODUCTION

Feeding a world population of more than nine billion people in 2050 would require agriculture to raise overall food production by some 70 percent between 2005 to 2007 and 2050 (FAO 2009a). Production in the developing countries would need to almost double. At the same time, most of the world population will have moved away from the countryside to live in cities, consequently reducing the number of farmers to produce food on less arable land and with less water resources. In Asia, it is likely that the locus of poverty will also shift from the countryside to cities (Teng, Escaler, and Caballero-Anthony 2011), making the urban ecosystem an important consideration for many Asian governments when planning economic development. Urban agriculture (UA) can be part of the solution to urban food security, and thereof contribute to overall food security as a pillar in economic development (Escaler and Teng 2014).

Agricultural development literature is strongly immersed with transformation of the rural sector as historically, agriculture has originated in the countryside (Teng and Montesclaros 2023). In fact, much of the theory behind agricultural transformation has been based on changes in rural areas and the interlinks in capital redeployment between rural and urban sectors (Timmer 2017). In the current millennia, economic development and agricultural transformation further have to occur in a landscape characterized by dynamic and volatile changes in demographics, physical environment, sociopolitical relationships and global "mega" concerns such as sustainability and net-zero carbon. The continuing series of climate summits (the latest being COP28[1]) have resulted in a global common dedication to reducing greenhouse gas (GHG) emissions due to a common concern about rising ambient temperatures and challenged development paradigms of increasing productivity. With increasing acknowledgment that the UN Sustainable Development Goals (i.e., SDGs) are unlikely to be met,[2] attention is refocusing on what constitutes sustainable development.

Agriculture has been postulated in development literature as an enabler and precipitator of economic restructuring by serving as a source of capital for establishing the industrial sector (Teng and Montesclaros 2023). Many countries are known to have followed the development path of evolving from predominantly agrarian economies to urban industrialized economies using the Timmer model of transformation (Timmer 2017). This development path has been a major influence on strategies for economic development, and deviations have been noted for small island developing states (Teng and Montesclaros 2023) in which capital accumulation in urban areas have enabled the agriculture sector to develop. As an addendum to the thinking, this paper postulates that UA should be integrated in development planning to maximize the benefits of having food produced where it is most consumed. Sonnino (2014) postulated that there is a growing food localization phenomenon among governments to deal with the increase of rural-urban interlinks. FAO's global survey (FAO 2020) revealed that many cities have identified the importance of promoting local food production and improving access to locally produced food—e.g., newly created initiatives that have responded to the pandemic or the expansion of existing programs to ensure continued food supply and to protect the most vulnerable residents. This paper aims to provide the evidence for this postulate.

First, the urbanization of society and its implications are reviewed to provide a context for UA. Then the practice of UA is explicated relative to the economic development imperatives of livelihood, employment, and social benefits. Technological innovations with potential to augment economies are then discussed. The paper ends with insights into the positive expectations of including UA in development.

1 The UN Climate Change Conference held in Dubai, United Arab Emirates, from 30 November until 12 December 2023.

2 https://www.unep.org/news-and-stories/press-release/climate-change-undermines-nearly-all-sustainable-development-goals

THE URBANIZATION PHENOMENON AND ITS IMPLICATIONS

The world has seen increasing urbanization since 2008, with more people now living in cities than at any other time in history. Concomitant with this has been the reduction in arable land due to other human needs such as housing, infrastructure, manufacturing, and recreation. Additionally, land and water degradation from anthropogenic activities has resulted in decreased productive farmland. The traditional rural-urban links, especially with respect to rural areas as the assured source of food security, were further frayed by the COVID pandemics (Fan et al. 2021) from movement restrictions introduced by many countries to reduce spread of the virus. The pandemic and supply chain disruptions caused by the Russia-Ukraine conflict further degraded trust in the capabilities to move food and people from the countryside to urban areas, a phenomenon noted by Carolyn Steel (2013) in "Hungry City." Steel had postulated that the growth of cities depended on their access to food from the immediate countryside and the era of the 2020s has served to reinforce this.

Urban Demographics in Population Growth

Population growth is one of the main drivers of increasing food demand. Unfortunately, population growth continues to overtake food availability in many countries.

The UN Population Division estimates that global population is projected to grow to 9.2 billion in 2050 (Teng and Escaler 2010a). Though population growth rates will slow down considerably compared to the preceding 50 years, the absolute increase will still be significant: 2.3 billion more humans by midcentury. Nearly all of this population increase will take place in developing countries, particularly in Asia, accompanied by increased urbanity.

According to the United Nations Human Settlements Programme (UN-Habitat), this century will be the century of cities (Tibaijuka 2008). In Asia, 45 percent of the population already lived in cities in 2010; by 2050, this figure will climb to 64 percent. Between 2012 and 2050, the world population is expected to increase by 2.4 billion, from 6.9 billion to 9.3 billion, with Asia capturing the lion's share. At the same time, the population living in urban areas is projected to gain 2.9 billion, passing from 3.6 billion in 2011 to 6.3 billion in 2050 with most growth concentrated in the cities and towns of the less developed regions (UN 2012).

The Asian Development Bank estimates that half of the population of Asia lived in urban areas as of 2020 (ADB 2023). Strong economic growth is a contributing factor to this rapid urbanization phenomenon, and this is not likely to change, looking to the future.

Urbanization and Food Preferences

Urbanization combined with rising incomes will not only increase food demand but also accelerate the diversification of diets. As incomes rise, diets will eventually include more resource-intensive food products, such as meat, dairy, eggs, fruits, and vegetables (Teng and Escaler 2010a). Since the early 1960s, in Asian developing countries, meat consumption more than tripled and egg consumption increased by a factor of five. This has translated into a considerable growth in global per capita intake of energy derived from livestock products albeit with significant regional differences. All regions, except sub-Saharan Africa, experienced increased consumption with the greatest increases occurring in East and Southeast Asia, particularly in the Democratic People's Republic of Korea, Malaysia, and Vietnam (FAO 2009b).

Supplying urban inhabitants with sufficient and, more importantly, affordable food will put an enormous strain on the food supply and distribution chains. With more and more Asians living in cities, urban food security will play an increasingly important role in maintaining peace and stability. As the world witnessed in 2007–08, the sharp increase in food prices resulted in food riots in 43 countries across the world (Escaler and Teng 2014). Similarly, higher food prices played a

role in fomenting demonstrations and protests in Tunisia in 2011, the forerunner of the Arab Spring.

The urbanization trend, in which geographic regions such as Asia are predicted to become mainly urban with "mega-cities" (ADB 2023) is accompanied by demographic changes such as increasing numbers of middle-class households with higher GDP per household and distinctive diet preferences such as more animal protein and diet diversity. The income disparity between urban and rural parts of the same country has come under scrutiny in economic planning (Wong et al. 2024) and is another noteworthy consideration in the new landscape of development.

Fish consumption has also undergone major changes in the past four decades (Deb and Dey 2024). Similar trends have been observed in the consumption of fruits and vegetables. Between 1970 and 2000, the average worldwide consumption of vegetables increased from 60 kg to over 100 kg per person, but trends vary among countries and regions (Wopereis et al. 2024). A low consumption of fruits and vegetables is a persistent phenomenon in many regions of the developing world, especially in Africa.

The urban environment presents unique challenges, which potentially render its residents more vulnerable to disruptions in the global food supply chain and to price fluctuations.

Migration of Poverty to Urban Areas

Urban poverty is one predictable outcome of the mass migrations to cities, and it is strongly linked with poverty and hunger (Sonnino 2014; Teng, Escaler, and Caballero-Anthony 2011). While most of the world's poor still currently live in rural areas, the numbers of the urban poor are significant and continue to increase at an alarming rate. According to UN- Habitat, most of the current population growth in cities is already being absorbed in life-threatening slums. In 1993, 1.3 billion people were living in extreme poverty (i.e. on less than USD 1 per day), of which 19 percent, or 236 million people, lived in urban areas (Ravallion, Chen, and Sangraula 2007). By 2002, though the population in extreme poverty declined to 1.2 billion people, the urban share increased to 25 percent, and the number of poor urban residents had increased to 283 million. The "absolute number" of slum dwellers actually increased from 776.7 million in 2000 to some 827.6 million in 2010, with Asia accounting for more than half of the world's total slum population (UN-Habitat 2010). For the majority of the urban poor, a large proportion, as much as 50 to 70 percent, of their household budget is spent on food. Thus, rising food prices may mean having less meals a day, or worse, having no food at all. Another feature of the urban environment, which renders them more vulnerable to food price increases, is the fact that jobs of the urban poor are casual, transient, low-paying, and vulnerable to outside forces (Teng, Escaler, and Caballero-Anthony 2011).

The urban poor are often forced to live in environmentally unsafe areas, including steep hillsides and flood plains, or near garbage dumps, open drains and sewers. Further, there is evidence that the urban poor and those living around cities are also exposed to a "double health burden," being subject both to the communicable diseases typical of rural areas and the noncommunicable "lifestyle" diseases typical of the urban health transition (Prain 2006). With greater exposure to advertising and easier access to supermarkets, urban dwellers, and particularly children, tend to consume more processed and fast food, which tend to be of poorer nutritive value. In addition, because urban areas are centers of economic opportunity, there are more women working outside. As a result, women in those areas have less time to prepare meals and to provide care for their children.

Increased Vulnerability Due to Climate Change

The challenges posed by climate change on rising urban poverty and food security are increasingly being recognized by the international community. As highlighted by UN-Habitat (2010), "cities are a major part of the cause and are suffering the most impacts and therefore play a primary role in finding the appropriate solution." According to the World Bank (2010), urban areas

accounted for over 67 percent of energy-related global GHGs, which is expected to rise to 74 percent by 2030.

Climate change can also disrupt critical food supplies within cities. Not only can it lower agricultural production in the surrounding countryside, but it may also disrupt the transport of food to urban areas (Steel 2014). Both instances can lead to higher food prices and food shortages. The urban poor, who live in slums and informal settlements, are affected disproportionately by the above impacts of climate change.

The Nature of Food Security in Urban Areas

Food security in urban environments has distinctive differences from the rural (Teng and Escaler 2010), foremost of which are the lack of access to the means of producing food and a dependence on supply chains to transport food from outside cities. As the urban-rural disconnect widens, and as more people live in cities, imports will be key to ensuring food supply to consumers. When events precipitate sudden disruptions in food availability, then governments commonly resort to their stockpiles. A number of forces can affect food availability (Teng 2024), including how farmers perform in response to market conditions.

Physical access to food (Escaler and Teng 2014) is an aspect of urban food security that is threatened by war, civil strife, poor infrastructure, inadequate logistics for food distribution, and market imperfections. For urban populations, market supply chains, whether local or global, are the main distribution channel for food; hence, in cities, raising the efficiency of market supply chains to deliver food to consumers is a primary concern. This efficiency can be particularly affected by losses and wastage, which occur during distribution of food; in developing countries, the lack of cold chain management logistics often results in losses of fresh fruits and vegetables (Rolle 2024). Efficient food distribution, however, incurs costs and according to Reardon (2010), 50 to 70 percent of consumers' cost of food is formed in post-farmgate segments of supply chains, e.g., wholesale, logistics, processing, and retail. Availability and physical access are strongly influenced by the state of science and technology in a country. Countries with more advanced science and technology generally incur lower losses in food production and distribution.

Economic access to food or the ability of a household to purchase the food it requires is a challenge for both developed as well as less developed countries. This dimension weighs in more heavily in an urban setting where poor consumers spend a significant proportion of their household budget on food. During the last five years, poor urban consumers have been the hardest hit by food price increases and volatility (Donnellon-May and Teng 2023). Factors that influence this include employment and income security, macroeconomic policies and of course, food availability through its impact on supplies in the market, and therefore, on market prices. Managing the economic access dimension is important to assure equitable access to affordable food since any small increase in price drives more people below the "hunger line" and becomes a catalyst for civil disobedience. This dimension is noted as a critical component of food security due to the increasing disparity in income levels among urban subpopulations, a phenomenon increasingly recognized by urban planners (Wong et al. 2024).

Another aspect of food security is food utilization. A household may be able to purchase all the food it needs but it may not always utilize that capacity to the fullest (Teng and Escaler 2010b). Food utilization is typically reflected in the nutritional status of an individual; and therefore, factors that can influence this dimension include the quantity and quality of food, general childcare and feeding practices, food preparation, food storage, and an individual's health status. Food safety is another aspect of this dimension. With the growing distance between consumers and the source of food in urban areas, there is a greater need to preserve the "freshness" in foods as it is transported over longer distances. Therein is a strong argument to have UA.

Food security is particularly challenging because it is the result of the interplay of a range of interconnected factors operating at different

levels. Not only is a broad perspective needed but interconnected policymaking is just as critical. According to the UK Foresight Report on Food and Farming Futures (Foresight 2011), there is an "urgent need to link food and agriculture policy to wider global governance agendas such as climate change mitigation, biodiversity, and international development. Without this link, a decision in one area could compromise important objectives in another."

Why are UA and Food Security Important?

The urban environment therefore presents challenges that differentiate it from the countryside. Urban residents have to purchase almost all of their food as well as other goods and services, including housing, transportation, healthcare, and education (Teng and Escaler 2010a). Therefore, food security in cities depends to a large extent on individual household circumstances as it operates within this purchasing environment. Studies by the International Food Policy Research Institute (i.e., IFPRI) and others show the extent of the vulnerability of the urban poor—the budget share devoted to food in poor urban households ranged from 48 percent in Guatemala to 74 percent in Tajikistan; in 18 of the 20 countries, households allocated more than half their budgets to food (Ahmed et al. 2007). Similarly, Redwood (2009) found that poor residents in Bangkok, Thailand, spent 60 percent.

In contrast, because of increased incomes, urban areas see a higher consumption of more expensive sources of nutrients such as meat, fruits and vegetables, and a lower consumption of staples such as cereals. Urban areas typically offer residents a wider choice of foods including produce from foreign cultures than do rural areas. Some argue that as countries become more developed, and given the trend toward globalization, their dietary structure tends to become increasingly similar across similarly developed countries (Regmi and Dyck 2001).

Urban areas are centers of economic opportunity, so more women are working outside the home (Regmi and Dyck 2001). The increased opportunity cost of women's time raises the demand for processed and fast food in many countries as such food requires less time to prepare. Reardon (2010) estimated that two-thirds to three-quarters of the food market in developing countries today is in urban areas, and what happens in these urban food markets determines the markets farmers face.

Traditionally, agriculture has been considered a rural phenomenon. With more people now living in cities, UA can help cities achieve some level of self-sufficiency in at least some of the key food products that its inhabitants consume (Escaler and Teng 2014).

SCOPE OF URBAN AND PERI-URBAN AGRICULTURE

An estimated 800 million people are involved in agriculture in urban and peri-urban areas and contribute to feeding urban residents. Of these, 200 million produce for the market and 150 million work full-time (Ludher 2024).

Urban Agriculture and Peri-Urban Agriculture

A has been considered as "the practices that yield food and other outputs from agricultural production and related processes (among others transformation, distribution, marketing, recycling), taking place on land and other spaces within cities and surrounding regions, involving urban and peri-urban actors, communities, methods, places, policies, institutions, systems, ecologies and economies, largely using and regenerating local resources to meet changing needs of local populations while serving multiple goals and functions" (FAO, Rikolto, and RUAF 2022). In short: "The production of food and other outputs and related processes, taking place on land and other spaces within cities and surrounding regions" (Ludher 2024).

The literature shows that it is common to consider UA as a part of urban and peri-urban agriculture (UPA). UPA has been defined by the Resource Centers on Urban Agriculture and Food

Security (RUAF[3]) as the growing of plants and the raising of animals within (urban) and around (peri-urban) cities.

Its striking feature is that it is embedded in—and interacts with—the urban ecosystem. It uses urban residents as laborers and urban resources, organic waste for compost and urban wastewater for irrigation, as inputs. It has direct links with urban consumers—links that many rural food producers have lost—and direct impacts (positive and negative) on urban ecology. It competes for land with other urban functions and is influenced by urban policies and plans. The success of UPA in cities such as Hanoi, Shanghai, Beijing, Mexico City, Dakar, and Accra have shown how urban farming can contribute to poverty reduction, food security, improvements in nutrition, environmental protection, and increased awareness of the importance of agriculture. In Singapore, the practice of UPA involves technologies such as aeroponics—the growing of plants without soil and water—aquaculture, city gardens, and agrotech parks (Teng 2020).

UA systems include horticulture, floriculture, forestry, aquaculture, and livestock production (Escaler and Teng 2014). Some examples of UA include formal and informal community gardens; home gardens; institutional gardens (e.g. managed by schools, hospitals, nurseries; rooftop gardens; or cultivation in cellars or barns (e.g., mushrooms, earthworms).The intra-urban agricultural activities tend to be smaller in scale and more subsistence-oriented than peri-urban agriculture. Peri-urban agriculture takes place on the fringe of a town or city and farm activities are, on average, larger than those in the city centers and more strongly market oriented. However, land available for peri-urban agriculture may be vulnerable to changes over a given period such as land use competition, rising population density, and the influx of people from both rural and urban areas. One important feature of the UPA that distinguishes it from rural agriculture is that it is an integral part of the urban economic, social, and ecological system. UPA uses urban resources such as land, labor, inputs, public services, and even organic wastes and in turn, supplies material resources, products, and services largely to the residents in that area (Teng and Escaler 2010b).

It is estimated that 15–20 percent of the world's food is from UPA with majority of urban farmers located in Asian cities (Mougeot 2000). Most countries in Asia have long recognized the role UPA can play in urban food security, poverty reduction, and environmental management. However, their experiences in its application are varied (Escaler and Teng 2014). Developing countries like the Philippines, Malaysia, and Vietnam have applied UPA, primarily to help increase food production and improve income in highly urbanized areas. In more developed Asian countries, such as Korea and Taiwan, the UPA has gone beyond its traditional purpose of food production and has evolved into a practice that connects urban residents with the environment, agro-tourism, and leisure farming, thus providing them a richer experience and, at the same time, enhancing the quality of life of the countryside. The experience of China in UPA over the last 20 years is worthy of recognition. It has demonstrated the importance of government support in transforming UPA into a mainstream activity within cities. Because of supportive policies and investments by the government, the UPA has been legitimized as playing a vital role in enhancing life in some Chinese cities (Natrajan 2021).

Types of UPA

Based on the UPA sourcebook, UA can be broadly grouped into the types summarized below (FAO, Rikolto, and RUAF 2022; Ludher 2024).

Home-based farming. This is the most common form of UA. Outputs are vegetables, herbs, fish, or livestock. Production may be in front- or backyards, balconies, windowsills, rooftops, or indoor spaces. With small-scale "growlight" and hydroponic technologies increasingly available, home-based farms are no longer only grown in ground, pots, or containers. Fish may also be grown in ponds or

3 https://ruaf.org

containers. Small-scale livestock farms of chicken, guinea pigs, goats, or others, may also contribute to household food security. Livestock could also be confined to the home or allowed to roam. Food produced is mostly for self-consumption.

Community-focused farming. These are often outdoor farms, which could be situated in residential, recreational, educational, industrial, or commercial spaces in a city. Many urban farms are established due to their considerable community benefits. Farms can range from one or two square meters to hundreds. Spaces could be farmed collectively or in allotments. Participation is often open to the public, or could be run by a formal group, a cooperative, or a loose group of farmers. Similarly, the produce may be for individual use, for the community, or welfare. Some farms may prefer more organic, regenerative, or traditional farming methods, others may include irrigation or hydroponic systems, or be combined with livestock farming.

Commercial farms. These can be outdoor or indoor farms within the confines of the urban or metropolitan region. It can be for horticulture, fish, livestock or fungi farming. They can be grown on soil or land, in greenhouses, or indoors. Technologies adopted include hydroponics (or its derivatives aeroponics or aquaponics), recirculating aquaculture systems (RAS), among others.

Commercial farms have always been part of cities. Indeed, the historical growth of cities, especially in Europe, has been strongly influenced by the proximity to food sources (Steel 2013). With urbanization, commercial farms have often been pushed to peri-urban areas, but with the rise of technology and the ability to farm more intensively in small spaces, commercial farms have been established in city centers, including on rooftops, underground, industrial spaces, or even shop lots (Teng 2020).

Institutional farms. These are food growing facilities within institutions—schools, universities, prisons, hospitals, etc.—that cater to its community. Its purpose is typically for social benefits—health, education, interaction, etc.

Beyond food, UA could also contribute to livestock feed, ornamental planting (such as flowers), or for enhancing biodiversity and providing ecological services (through pollination, habitat creation, ecological bridges, or other benefits).

TECHNOLOGICAL INNOVATIONS SPURRING UPA

UPA has ridden the wave of technical innovations starting in the early 2020s, fueled by the increased amount of private equity (Hulme 2024), coincident with a global food supply crisis caused by the COVID pandemic and the Ukraine-Russia war (Teng and Donnellon-May 2021). Urban centers are commonly the hubs for innovation. And in this context, technological innovations in UPA serve as catalysts for entrepreneurship, and as in the case of Singapore, spur the formation of a new economic subsector in national development.

During 2020-21, momentum built up among financial institutions, such as venture capital companies, to invest in startup companies that produce technological innovations to address the shortcomings in food production and food supply chains. Many of these innovations fit as a "disruptive technology" (i.e., DT), one that displaces an established technology and shakes up the industry or a groundbreaking product that creates a completely new industry (Christensen, Raynor, and Mcdonald 2015).

The UN Climate Summit COP26 further spurred activity before and after it was held, to focus on farming with reduced carbon footprints, reduced GHG emissions and valorization of food waste, all aimed at promoting more sustainable and circular food systems.

The pandemic and general supply chain disruptions have highlighted the need to produce more food locally and to use techniques that both minimize the use of labor and avoid a high carbon footprint. Governments have responded to some of these through policies and action. The private sector has responded even quicker, having detected investment opportunities to support solutions to

these problems. Venture capital funds like Funder and Yield Lab have set up their Asian bases in Singapore to support initiatives throughout the Asia-Pacific (Hulme 2024).

A set of technological innovations that are impacting UPA and spurring urban economic activity is discussed in the following sections.

Urban Agtech

Urban agricultural technology (agtech), an emerging subset of alternative farming in cities, leverages new technologies that use a fraction of land and water of traditional farming. Case studies reveal that its proximity to cities can yield many benefits, such as employing the urban poor and reducing food miles and a lower measure of the amount of energy and fuel required to transport food from one location to another.

An illustrative urban agtech are the plant factories with artificial light (PFALs), which are essentially enclosed, environment-controlled greenhouses in which vegetables are grown in tiered trays. These plants grown indoors generally have no need to use insecticides and can produce many times more per unit area using light emitting diode (i.e., LED) lights. In Asia, over 450 PFALs were reported as of 2016, and the number is growing in countries like China, Japan, Singapore, South Korea, and Taiwan (Liu and Teng 2017). These will increase the FAO estimate of 20 percent of food produced in urban areas. However, PFALs require large financial resources to set up and their produce is costlier than outdoor vegetables. The expectation, though, is that efficiency will improve, and produce will become cheaper as the technology is scaled up. Plant factories are promising alternative farming production systems that can help countries secure their food supply in places that are vulnerable to major temperature changes or disasters (Liu and Teng 2017). Implementing new indoor urban vertical farming operations like PFALs is one way to combat climate change from an ecological and social perspective (Avgoustaki and Xydis 2020).

Urban Aquatech

World fish production, consumption, and trade are expected to increase, with total fish production (aquaculture plus wild capture) expected to grow to 201 million tonnes in 2030. Aquaculture production is projected to reach 109 million tonnes in 2030, an increase of 32 percent (26 million tonnes) over 2018. Asia will continue to dominate the aquaculture sector and will be responsible for more than 89 percent of the increase in production by 2030 (Deb and Dey 2024).

The systems and technology used in aquaculture have developed rapidly in the past 50 years. They vary from very simple facilities (e.g., mud ponds for domestic consumption) to high technology systems (e.g., intensive closed systems for export production). A greater understanding of complex interactions among water, microbiome, and cultured organisms, together with advances in hydrodynamics applied to pond and tank design, have enabled the development of closed culture systems, such as RAS. RAS has the advantage of isolating the aquaculture systems from natural aquatic systems, thus minimizing the risk of disease or genetic impacts on the external systems. Aquaculture technologies, such as robotics, sensors, internet of things (i.e., IoT), and artificial intelligence (i.e., AI), have further advanced significantly in recent decades, supporting the growing scale of production and reducing costs and risks (Lee, Padmanabhan, and Chan 2024).

Intensification in urban aquaculture can provide opportunities to develop low-cost, energy-efficient, and intensive RAS that can benefit small-scale farmers, especially in Asia where most farms are relatively small. The use of modern technology can also help farmers make better decisions and improve practices that can eliminate waste, improve animal health, and boost economic productivity, while also supporting sustainable and responsible practices that can help ensure the long-term success of the industry. Overall, intensification and the adoption of modern technologies and best practices in aquaculture can open the gate for success and prosperity for farmers, while also

helping to produce enough protein for a growing population (Lee, Padmanabhan, and Chan 2024).

Urban Waste Valorization

The global percentage of food lost after harvesting at the farm, transporting, storing, wholesaling, and processing was estimated at 13.3 percent in 2020. Thus, prioritizing the reduction of food loss and waste is critical to transforming the Asian region's agrifood systems to make them more efficient, sustainable, inclusive, and resilient, diminishing their impact on the natural resource base and the environment, while ensuring their contribution to improving food security and nutrition across the region (Rolle 2024).

Food loss percentages across the Asian region are high, with Eastern Asia registering the highest percentages in 2020 at 15.3 percent, followed by Southeast Asia (14.7%), West Asia (14.1%), South Asia (13.9%), Australia and New Zealand (13.6 %), and Central Asia registering at (9.9%). High levels of losses in Southeast Asia are largely due to high levels of losses in value chains for fruits and vegetables, when compared with Central and Southern Asia (13.6%) and Australia and New Zealand (13.6%) (FAO 2022).

Major underlying causes of food losses in the region include the lack or inadequacy of technology and infrastructure in the traditional chains that supply the bulk of food requirements to low-income consumers and the relatively weak knowledge base of smallholders who operate in these chains.

Because of the extent of food waste and its potential for utilization, initiatives have been developed to make use of such waste and generate economic value from them. Upcycling provides a good economic case for the reduction of food loss and waste with the generation of financial gains through value creation. An interesting example from the region is the production of non-alcoholic beverages from fruit and vegetable waste and loss such as fruit peels, seeds, and rinds for local and export markets (Taylor 2022). Traditional food fermentation processes applied across Asia, such as the production of fish sauces and vinegars, are excellent examples of the upcycling of by-products that contribute significantly to diets across the region. Upgrading these processes with technological innovations to improve the efficiency of their operations, with attention to assuring the environmental sustainability of their practices, will also contribute significantly to food systems transformation.

The upcycling of food waste through treatment with the black soldier fly (BSFL), *Hermetia illucens*, has many benefits, such as reducing GHG emissions and the generation of harmful substances associated with existing disposal methods (including landfills and incineration). The BSFL larvae convert organic waste into high-quality nutrients for pet foods, fish, and poultry feeds as well as residue fertilizer for soil amendment, using technologies of various levels and scales of operation. Cultivating the BSFL in Asian countries with adequate light and a mild climate offers small businesses the opportunity to generate high returns without high levels of investment. The BSFL can thrive on many biogenic sidestreams, such as food waste, and this contributes to a circular economy concept. To valorize a broader range of waste, insect-microbe symbiosis poses a promising and presumably adjustable system (Hermansen et al. 2024).

The circular economy offers potential to increase efficiency and profitability, and to reduce cost, drive innovations, and create more sustainable business models.

Novel Food Technology

Novel foods—a category of food or food formats that hitherto has not been consumed by the mainstream population—is a potential (partial) solution to the increasing demand for the world's food supply. Novel foods and their associated production systems contribute to food and nutrition resilience as most are located in urban areas. Novel foods generally comprise three main categories: plant-based, microbial-based, and cultivated meat (Wong 2024).

Whilst Asia has long produced and consumed plant-based protein foods such as tofu, tempeh,

and seitan, they did not closely resemble the characteristics of animal-based foods. Next-generation (novel) plant-based products aim to imitate the characteristics of their animal-based counterparts.

Plant-based products today are typically made of soybean or other legumes. Other crops such as pea and potato have become more popular as ingredients in plant-based meats.

Microbial proteins are produced using fermentation as a basic process and Asia's use of fermentation dates back centuries. Modern precision fermentation uses microbial hosts as "cell factories" to produce specific functional ingredients such as lipids, vitamins, flavoring, and colorants to improve sensory and functional aspects of finished food products. Microbial protein production can be more efficient than conventional production. As long as inputs can be obtained, high risk or non-agricultural areas like cities can generate high-quality proteins for both food and feed, which could ultimately contribute to food security in Asia.

Cultured or cultivated meat is meat derived by growing animal cells in biosecured containers with the requisite nutrient solution. This has been gaining the attention of governments, scientists, investors, and entrepreneurs alike (Hulme 2024). However, much innovation is required to overcome challenges in costs and scalability, safety, consumer acceptance, and nutrition (Wong 2024).

INCLUDING UPA IN DEVELOPMENT PLANNING

For many of the reasons discussed in preceding paragraphs, UPA can confer benefits to urban regions, specifically, but also contribute to general food security in a country. Including UPA in development planning, therefore, is an important value addition. Furthermore, UPA has the potential to increase the number of new entrants into farming, especially through the attraction of high technology "controlled environment agriculture" with strong appeal to younger people (Teng 2024).

Tapping the Benefits of UA

The benefits of UA can be grouped into four areas: food and nutritional security, environment and ecosystem services, economic benefits, and social benefits (Figure 3 of Ludher 2024).

UA provides food and nutrition security as fresh produce retains nutrition for longer. By harvesting on demand, yield over time may be higher, with less waste. Where farming uses organic and regenerative principles, produce may also be a better source of vitamins, micronutrients, and proteins compared to conventionally farmed foods. Urban farms often also offer a variety of species to enrich diets; this diversity also increases resilience against disease.

UA also supports environmental quality and ecosystem services by enhancing greenery in urban spaces—rooftops, balconies, road verges, and vertical spaces (Escaler and Teng 2014). They may not only slow rainwater runoff, act as groundwater sinks and retain habitats for fauna, but may also alleviate urban heat island effect. Where farming utilizes regenerative techniques such as companion cropping, no-till farming, or organic composting, farms may also protect and enrich soils and sequester carbon. Participating in food growing often enhances environmental and ecological awareness. Urban and peri-urban forestry also improves air quality, mitigates urban warming, reduces erosion, and maintains biodiversity.

Economically, UA allows income savings and moderates the effects of price volatility; thus, is an effective poverty alleviation tool. It provides opportunities for social and economic integration of women, youth, and urban newcomers, as intensive horticulture units can provide between 10 and 40 jobs per hectare (FAO 2011). Beyond low-income communities, UA also benefits the wider public. Having short supply chains means food retailers may be less inclined to overstock as foods are more accessible. UA has also created more livable environments; urban farms have been known to improve property values. Urban farms have become an attractive urban design feature. Recognizing this, a skyscraper in the middle of the central business district (i.e., CBD) in Singapore incorporated a public urban farm on its rooftop (Ludher 2024).

Finally, UA contributes numerous social benefits, such as community cohesion, mental health improvement, and active lifestyles that improve physical fitness. A study in Singapore showed that those who are involved in community gardens reported higher levels of resilience and optimism than nongardening control groups (Koay and Dillon 2020). Furthermore, those involved in community gardening have higher levels of social empowerment and sense of belonging to the community.

UPA as Climate Change Adaptation

UPA, with its technological innovations has become increasingly "climate-smart farming:" as most of it is controlled environment agriculture (i.e., CEA).

Climate change, on balance, will do more harm than good to agriculture and forestry systems, particularly in developing countries. Although the countries in the south are not the main culprits of climate change, they may suffer the greatest share of the damage in the form of declining agricultural yields and greater frequency of extreme weather patterns (e.g., droughts and floods). In Asia, climate change could disrupt normal monsoon patterns, possibly resulting in decreased agricultural productivity (Norbert-Munns, Damen, and Baccudo 2024). Determining the exact impact of climate change on agricultural systems has proven to be a challenge due to highly complex probability models and the fact that agriculture itself (which releases high levels of methane and nitrous oxide) contributes about 14 percent of GHG emissions (6.8 gigatonnes [Gt] of CO_2). But it also has the potential to mitigate between 5.5–6 Gt of CO_2 per year, mainly through soil carbon sequestration.

Dealing with the Fragility of Agroecosystems as Food Production Systems

Many of the world's rural agroecosystems being used as food production systems are already showing worrying signs of degradation. According to the Millennium Ecosystem Assessment (2005), 60 percent or 15 out of 24 ecosystem services examined are already being degraded or used unsustainably. The use of two of these systems, capture fisheries and freshwater, is now well beyond levels that can be sustained even at current demand, much less future ones. For example, because actions to increase food production typically involve the increased use of water and fertilizers or expansion of the area of cultivated land, these same actions often degrade other ecosystems, including reducing the availability of water for other uses, degrading water quality, reducing biodiversity, and decreasing forest cover (which in turn may lead to the loss of forest products and the release of GHG).

Currently, land resources available for food production are under stress. More than 20 percent of all cultivated areas, 30 percent of forests, and 10 percent of grasslands are degrading (Escaler and Teng 2014). As soil is a fundamental component of land, soil degradation is a fundamental component of land degradation. Soil degradation includes loss of topsoil through erosion by water or wind, depletion of soil nutrients, loss of soil organic matter, compaction, waterlogging, salinization, and acidification. One study has further affirmed that arable land in Asia is declining at about three percent per year (d'Amour et al. 2017). The area of arable land per person in Asia has further been estimated to decline by five percent by 2030 (PwC, Rabobank, and Temasek 2019).

Replacing the Declining Number of Rural Farmers

The rapid increase in urbanization and the migration of people from rural to urban areas have highlighted another key concern regarding the future of global food security. Will there be enough farmers to farm the land to feed the people in the cities in the next 10, 20, 30 or more years? The last five decades have seen a significant shift from the countryside to the cities. With this massive migration, the world has seen the number of people working in agriculture decline over the years, including in Asia (ADB 2023; Teng 2024). In North America, Europe, and some parts of Latin America, this has been a result of increased farm efficiency and the mechanization of agriculture,

but the declining number of farmers in other parts of the world has been due to more lucrative and attractive jobs offered by the city compared to the drudgery of rural farm life.

A more worrying trend is the fact that the farmers left to tend the world's agricultural land are also growing older (Rigg et al. 2019). The proportion of farmers over age 65 in Japan and in South Korea is much higher than the proportion of the total population over 65 years of age. In addition, the average age of full-time farmers in those countries is much higher than that of the labor force in general. It is worth noting that Japan is a high-income country with an "old" population, while South Korea is a middle-income country in transition from having a "young" population to having an "old" population.

In Japan, the average age of the country's self-employed farmers is over 65 (Yoshikawa 2022). In China, the average age of working farmers is 40 but in worse situations, the average age is above 50 (He 2007). In Korea, people over 65 years old make up 30 percent of the rural population, an aging rate more than three times that of the national average. In a decade, it is likely that the average age of China's population of working farmers will be over 50, or even 60. These are worrying trends especially in light of the current food crisis (Doczi, Calow, and d'Alançon 2014).

UA as a sector has potential to increase the overall number of younger farmers due to its high use of technology appealing to a younger demographic.

FUTURE

Urbanization, climate change, and population growth will continue to disrupt our current food systems and their contribution to economic development. Business as usual will result in increasingly frequent episodes of food shortages and empty shelves and disrupt social networks and cohesion. UA, in concert with rural agriculture, can contribute to alleviating these. But UA on its own represents an under-exploited sector that can potentially add value to development planning.

While UA in the form of home-based, community, commercial, and institutional agriculture is already present in many cities, it plays a relatively minor role in the global food supply. UA needs to contribute more than its current 5-20 percent if it is to have a role toward a food secure future.

Many challenges still exist for UPA to reach its full potential in Asia. Increasing urbanization is putting pressure on land currently being used for UPA activities. Gardens are being converted into housing, industrial development, and highways. Agricultural land in and around cities cannot compete with the economic return of other types of urban land use. With the exception of China, UPA is still not recognized by many cities in Asia as a legitimate land use category and, therefore, is not given priority in urban development. There is also a general lack of public appreciation and awareness of agriculture among Asia's city dwellers with many still believing that farming and food production should remain a rural phenomenon.

Beyond contributing to food, UA creates a greener, more biodiverse city. Where residents are involved, it promotes social cohesion, mental and physical health, and economic opportunity. However, UA needs to be integrated into city masterplans to harness its benefits in the long term. Those cities that do not have the foresight to integrate food into plans now risk unintentionally adopting policies that exclude agriculture, resulting in needless setbacks and missed opportunities and, ultimately, a more food insecure and vulnerable future (Ludher 2024).

Facilitating UA requires national, state, and local governments to put in place governance structures and policies, which include updating land, zoning, and lease policies to conserve and promote urban farms. Food security is an important foundation for economic development. The COVID-19 and the Russia-Ukraine war have given a glimpse of how food insecurity could challenge society in an increasingly volatile future. The action today will determine how urban centers can become an integral part of a sustainable, circular economy.

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