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COMMENTS

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Urban agriculture as nature-based solutions: Three key strategies to tackle emerging issues on food security in Chinese cities under climatic and non-climatic challenges

1 Introduction

Achieving food and water security, according to the United Nations Sustainable Development Goals (SDGs), only requires a minimal environmental cost (Batalini de Macedo et al., 2022). However, in terms of agriculture, blindly devoting efforts to offset low-productivity farming or production techniques and industries, without systematic water, fertiliser, farm residue, tillage, and fallow management, will eventually interrupt the carbon sink under the soil and escalate greenhouse gas emissions, which is not helpful to meeting global climate targets. Thus, science-based land management practices are essential to decouple agricultural productivity from greenhouse gas emissions (Buscardo et al., 2021).

China, the world's most populous country and a traditional agricultural country, is already grappling with decreasing agricultural productivity and food security challenges from climatic (flood, drought, and increasing temperature) and non-climatic drivers (urbanisation, land use changes, farmland and cropland removals, and devegetation). Tremendous efforts are required to increase food production; however, over 40% of China's arable land continues to undergo widespread degradation by factual phenomena such as land use change, soil erosion, overgrazing, pollution, and nutrient mining (Delang, 2018). Climatic impacts on the natural environment including soil, water, and biodiversity are the most challenging risks to human societies. The demand for population growth and socioeconomic development has driven the rapid urbanisation and land use changes in China, which has dramatically concentrated the population and land in China from the primary industry to the secondary or tertiary industry and may accelerate the deterioration of future environmental and food security. In this situation, to achieve food security for the rapidly growing urban population considering the global climate target and SDGs, farmers and agricultural producers in semi-urban and peri-rural areas of China, where urbanisation is happening and land use is shifting, have to carry the climatic and non-climatic burdens.

Nature-based solution (NBS) is a science-based land management practice that aims to maximise the ability of nature to provide ecosystem services that restore the natural capital in the urban environment and can deliver multiple benefits to maximise the co-benefits. The Sponge City

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Program (SCP), the Chinese version of NBS, was established in 2014 to resolve climate change, biodiversity, and social challenges in China. The major function of SCP is to adopt the urban blue–green infrastructure and enlarge urban greening for tackling urban stormwater problems, and that has addressed the urban stormwater protection standard seeking up to 1-in-30 years return period that aligns with major Asian cities such as Singapore, Hong Kong, and Tokyo. The SCP delivers multiple benefits, not only increasing blue–green spaces but also helping reduce urban runoff by restoring the blue–green spaces and incrementing the water intake by soil and vegetation (Chan et al., 2018).

Nevertheless, NBS is not a panacea for all these climatic and non-climatic challenges. Severe consequences, such as degradation, biodiversity loss, and adverse effects on the local community, may occur if NBS is not precisely designed for the local environment and the voice of residents is not heard. Introducing non-native species (e.g., agroforestry) can serve as a transition toward forest restoration and be beneficial for the conservation of local biodiversity, but it might turn into an invasion of alien species. Moreover, designing NBS without considering indigenous peoples and local communities cuts off the bridge between the ecosystem and the local communities, and may end up with green grabbing — the appropriation of natural resources in the name of the environment (Seddon et al., 2021).

Still, the emerging trade-offs on the current Sponge City (or NBS) development are realistically growing. For example, an urban shelterbelt in China protects city dwellers from dust storms, but the northwest local communities settled downstream suffer from heavy irrigation practices (Missall et al., 2018). Furthermore, the over-focus on tree planting in the Grain for Green Program implied that tree-planting schemes must be carefully designed; otherwise, they can do more harm than good such as planting on high-carbon soils that cause trade-offs among ecosystem services (Xian et al., 2020).

The future urban food security issue is currently neglected. An important question remains to be answered under the shadow of climate change and rapid urban growth, and seemingly, the future pathway toward NBS–urban agriculture will be the sustainable way forward. However, mixed crossroads of emerging challenges arise for the Chinese NBS (SCP) to tackle the broader urban challenges of climate and non-climatic factors. From this perspective, three major solutions are provided here.

2 Three solutions to tackle future Chinese urban food security

2.1 Recognise the role of urban agriculture on NBS

The transition of Chinese economy has rapidly changed from primary (agriculture and aquaculture driven) to tertiary (finance, services, and technologies driven) industries in Chinese cities. That development is reflected in the increasing rate of urbanisation over the last decades. In this context, the urban communities have gradually disconnected from future food security because of the change of living style (improvement of wealth, change of job natures, and the transformation of urban living style — living in apartments without gardens) and confronted high living pressure (Liao et al., 2022).

Urban agriculture is broadly defined as the production (including processing and marketing) of food, flowers, fibre, feed, and herbs on land (and water), dispersed throughout urban and peri-urban areas (Food Tank, 2016). Growing evidence highlights the important role of urban agriculture in enhancing climate change mitigation/adaptation and ecosystem services, and improving food security, well-being, and social cohesion. The social, environmental, and health benefits of urban agriculture make it a "visible" NBS and an effective sustainable intervention that has currently been proposed by scholars (Kingsley et al., 2021).

Urban agriculture as NBS serves not only as a source of food supply for cities but also as biomes that support social and ecosystem services. Most urban communities are keen on improving their living conditions for a greener living environment, for example, the promotion of green roofs, green façades, and roadside swales around the estates, because green spaces can improve the level of physical exercise engagement, support local businesses, and enhance residents' life quality (Li et al., 2019). The NBS can tick boxes that not only sustain the future SCP developments but also encompass a range of future practices that promote "conservation agriculture". If managed well, that could bring incentives with integrating healthy (non-invasive species) flora and vegetation (e.g., vegetables and fruits) and restoring habitats to improve the living environment for the water, soil, and air quality. A similar study in London successfully improved the urban habitats (via the green walls and green roofs in E London) and raised public awareness and engagement (e.g., volunteering teams for maintenance of green infrastructure — weed removal) (Francis and Hoggart, 2009).

Delivering the NBS–urban agriculture can lead to more co-benefits such as reducing greenhouse gas emissions, increasing carbon storage (e.g., via land restoration or crop planting), and improving carbon offsets (e.g., reducing crop logistics and carbon emission transportation). For example, the emission for the logistics (i.e., road transportation) of 1 t of the crop from Victoria state (outside Melbourne) to Melbourne market (in the Central area) is about 34 kg of CO_2-e per year. Annually, 60000 t of potato consumption in the city might be reduced by up to 2000 t of CO_2-e. In this case, the fixed price of 1 t of CO_2-e in Australia is AUD $25. The promotion of

NBS–urban agriculture could not only reduce carbon offsets by AUD $50000 per year, which illustrates the multiple co-benefits of delivering food, but also reduce food mileage and expand urban green spaces for cities (Moglia, 2014).

2.2 Providing incentives on NBS–urban agriculture means for the communities

With more than half of arable lands currently used for agricultural production worldwide, farmers and other food producers are positioned to take on important stewardship before taking care of lands, soil, and water resources. However, the urban communities are not farmers because they normally do not have such knowledge and motives in agriculture. Transitioning to nature-positive production practices requires large demand for essential workers and investors working together. A success story is the Dutch greenhouse smart agricultural system, which adheres to the philosophy of co-innovation to encourage the joint work of the municipality government, industry/social enterprises, and research institutions on agricultural innovation (Hoste et al., 2017). The Dutch government adopts a "Top sector policy" strategy that focuses on the nine most relevant industries for the Dutch economy, namely, horticulture and propagation, agriculture and food, water, life sciences and health, chemicals, high technology, energy, logistics, and creative industries. The government innovation funding is mainly concentrated in these sectors. Within the strategy, local governments, companies, and research institutions are working together to improve the knowledge, innovation, and economic status of the involved parties and sectors further.

Another major concern by urban communities on food security issues arises owing not only to the dosage and supply but also to the quality of the food product such as the level of harmful substances (i.e., the residues of pesticides or relevant chemicals) that stay on the food products in the traditional agricultural production. The NBS–urban agriculture connection also provides a long-term sustainable solution by guiding the communities and farmers to decide on the application (dosage) of synthetic chemical pesticides (e.g., Glyphosate, Acephate, DDT, and Malathion) and soil fertilizers (e.g., nitrogen, phosphorus, and potassium) (Qian et al., 2020). The Qiandao Water Fund program suggested that farmers follow a "Three 'No' Principle", which proposed that no herbicides, pesticides, and fertilizers should be applied on their own. In turn, the application of these chemicals was supervised and monitored by the cooperative following best management practices (e.g., mulching and burying fertiliser). With such practices, the losses of total nitrogen, total phosphorus, ammonia nitrogen, and nitrate nitrogen were reduced by 36.6%, 38.1%, 48.7%, and 61.6%, respectively, while the average income of participating farmers rose by 30%–40% (Iseman and Miralles-Wilhelm, 2021).

In return, NBS–urban agriculture is a nature-positive food system because the operation size is limited and marginalised compared with the traditional industrial and agricultural sectors. They normally over-relied on intensified chemical inputs to boost unsustainable yields, damaged soils, drastically reduced the diversity of plant and animal species, and caused negative effects on animal health and toxic effects on human health.

2.3 Coproduction of the NBS–urban agriculture system through the "One Health" approach

Facing the rapid population growth in China and elsewhere across the world, promoting the NBS–urban agriculture system is the way forward. The interconnectedness of agricultural practices and the health of vegetation (crops and plants) and animals (at all levels including microorganisms) call for the "One Health" approach to achieve food and nutrition security and promote sustainable agriculture.

This ("One Health") approach encourages ecological practices that optimise limited urban spaces and minimise synthetic inputs that particularly merge with the suggested NBS–urban agriculture remit and require coproduction from local stakeholders, communities, and local farmers. Examples include the success story in Paris that owned the global largest soil-free rooftop farm that cultivates cash crops (e.g., strawberries) in vertical plastic columns without soil and some lettuces, tomatoes, and aubergines in horizontal trays packed with coconut fibre. Such practice, namely, "Maraîchage Sol Vivant (Living Soil Vegetable Gardening)", has illustrated the success of feeding 100 people with fresh vegetables grown only in a relatively limited space of less than 5000 m^2 (Henley, 2020). The Ferme Abattoir farm on the roof of a food market in Belgium, is an agriculture–aquaculture system with an area of only 2000 m^2 but still produces 35 t of striped bass per year along with herbs, tomatoes, and other horticultural vegetables (Horn and Proksch, 2020), as shown in Fig. 1.

"One Health" calls for a collaborative way to achieve optimal health for people, animals, and the environment. Sustainable approaches that implement human and animal waste for soil remediation and management were applied, such as using construction waste (e.g., limestone) and biochar produced from organic biomass (e.g., agricultural residue and municipal waste) as amendments for soil, also promoting the pesticides- and synthetic chemicals-free approaches altogether. Reusing or recycling the constructed wasted limestone (liming) by applying calcium carbonate in the topsoil effectively neutralises acidic soil against urban soil acidification and can alleviate global warming potential and improve crop yield. Such an idea is essentially important in Chinese and eastern

Fig. 1 Maraîchage Sol Vivant: Permaculture gardening for NBS–urban agriculture (source: Pixabay).

Asian cities with a condensed population density that is using very minute space (less than 10% land use area) to produce many crop products to feed the megalopolis districts.

Indeed, the benefits of the "One Health" approach also emphasize crop diversity through farming with locally adapted crops to avoid the adverse effects of invasive species competition in ecology and use inputs utilized by a single local crop. It also encourages probiotics and postbiotics to manage viral diseases in animals and humans such as linkage to the interactions with viruses and the production of inhibitory substances (e.g., bacteriocins, enzymes, and peptides or the stimulation of the host immune system), and large reduction of pesticides and related chemical pollutants for enhancing urban soil conservation, which has multiple benefits and functions on our communities. The key to achieving these practices is necessarily coproducing and working together with stakeholders across academics, government, private institutions, and local communities to transform the existing food production system that integrates with the NBS–urban agriculture with such approaches (Fig. 2). The technical support from the Food and Agricultural Organization's framework for the urban food agenda 2030 explicitly provided a multisector, multistakeholder, and multilevel approach to provide a more explicit pathway for countries to enhance co-partnerships across actors.

Coordination is also the core of the "One Health" approach. Coordination is to account for regional differences between the involved sectors and stakeholders by integrating the various components and synchronising the functions of the various departments (Fu et al., 2020).

3 Recommendations: Reaching a "Climate-Resilient" NBS–urban agriculture

Conceptual theory-oriented research that needs to address some core issues related to climatic (climate change) and non-climatic factors is currently lacking. NBS can co-produce with urban agriculture and can enhance multiple benefits, but that may cause trade-offs between ecological values and social inclusiveness. NBS can bring green and blue–green spaces to absorb excessive solar radiation, trap heat, and reduce greenhouse gas emissions to reduce heat island effect (HIE). Food production is seriously affected by extreme weather, which has been more frequent and severe due to climate change and directly affects food security issues with growing risks (i.e., drought and flood). China still has about one-fifth global population (about 1.4 billion) but only owns about 8% of the world's arable lands, and climate extremes via temperature extremes and intensive rainstorms exacerbate food security (Lu et al., 2018).

Under the climate crisis, China has gone through a persistent heat wave with record-breaking high temperatures from July to August, 2022, and areas such as Shanghai and Ningbo (located on the eastern coast of China) and those across southwest China (Sichuan province and Chongqing municipality) and midpart of China (Hubei, Hunan, and Jiangxi provinces) have recorded a temperature over 40°C for the red alert of high temperature. High temperature affects major crops, and the China Meteorological Administration expected the high temperature might exceed 62 days (China Daily,

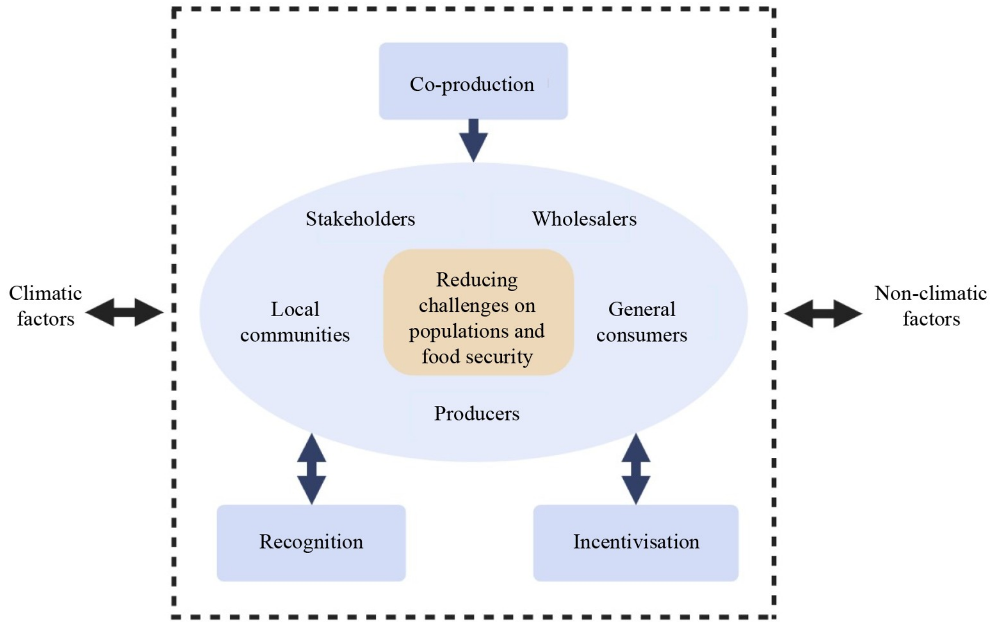

Fig. 2 Coproduction mechanism among all actors in NBS–urban agriculture and the "One Health" system.

2022). The heatwave has affected crops and caused major grain losses by drought under high temperatures. Urban water demand will grow to reach 80% by the 2050s, and the Intergovernmental Panel on Climate Change's Fifth Assessment scenarios (via the WaterGAP3 model) project an urban surface water deficit ranging from 1386 million m^3 to 6764 million m^3 (Flörke et al., 2018). Thus, the conflict between urban water consumption and demands will exceed water availability. This issue seriously brings water scarcity and affects food security for uncertain irrigation resources, particularly reflected in the drought or under a lengthy period of high temperatures such as in the summer of 2022 in most parts of China and across the world (e.g., the UK; Southern, Central, and Eastern Europe; and southwest of the US) (Gye, 2022).

The authors encourage China to turn these challenges into opportunities that are crucial to reach a consensus on delivering a successful practice with compliance and guideline for potentially delivering a "Climate-Resilient" NBS–urban agriculture system in China and extending it worldwide. For example, an improved urban agriculture water-use efficient system that could free up enough water for urban use (including residential and commercial practices) and avoid the growing conflict on urban water demand should be implemented. This promotion could focus on the Chinese cities with frequent intensive rainstorms (i.e., east and south Chinese coast) and the semi-arid and arid areas for water scarcity and storage issues (i.e., central and northwestern Chinese cities). That system not only benefits urban water storage in return for reducing flood risk and well-utilized water uses in eastern and southern Chinese coastal cities but also reduces the potential risk of droughts (e.g., irrigations) in the central and northwestern Chinese cities. That approach is necessary considering a wide range of habitats and the effects of interventions in one habitat and ensuring the participatory design and implementation using different forms of knowledge.

To promote good trade-offs and conflicts across natural landscapes and societies, which build up the climate-resilience agricultural urban ecosystem with NBS, China must reduce pesticide use and promote green pesticide control technologies that connect with better protection of urban agricultural biodiversity. Investing in nature to preserve and restore the ecosystem and encouraging these practices are proposed. An action plan on urban green spaces and farmland protection will be an important linkage with legislation and annotation. For example, the Chinese government may take further actions, such as implementing the Chinese National Urban Agricultural Directive and National Adaptation Strategy to conserve urban green spaces and soil (i.e., soil organic matter) and reduce water scarcity. These practices provide the right direction to interlink climate change and biodiversity crises that bring positive effects on addressing urban food security and livelihood for future Chinese cities.

Competing Interests The authors declare that they have no competing interests.

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