

# The future for urban agriculture

## Is it time to rewrite the rules of agriculture?

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### Key messages

- Urban agriculture has the potential to improve local food security and reduce greenhouse gas emissions. However, there is an urgent need for better information about who practices it, where it takes place and levels of productivity.
- In the Global North, high-tech Controlled Environment Agriculture (CEA) is attracting major investment and further expansion of the sector seems assured.
- In the Global South, urban agriculture often takes place in informal settlements and receives little in the way of state funding or encouragement. This needs to change.
- Policies for urban agriculture need to be context specific. There is a strong argument to be made for redirecting perverse subsidies which cause environmental damage to activities which can increase food security and help to tackle climate change. Urban agriculture is a prime candidate.

## Time for change

The way we produce, process and distribute food will have to change dramatically if we are to provide the human population with adequate nutrition in the coming decades. It is not just the quantity of food that matters, but the way it is grown and reared. Agriculture already takes up 40% of the land surface and accounts for 70% of the freshwater we consume. It is directly responsible for up to 8.5% of all greenhouse gas emissions, with a further 14.5% coming from land use change, much of which involves the destruction of forests to make way for crops and livestock.<sup>1</sup>

Total global food demand is expected to increase by between 35% and 56% from 2010 and 2050 to satisfy the world's projected population of 9.8 billion.<sup>2</sup> That means producing more food in the next 50 years than we have in the past 400, at the same time as addressing a whole host of additional constraints, including limits on available land. If we were to persist with current agricultural practices, an estimated 2.1 billion acres of additional land – an area the size of Brazil – would be required to cope with the increase in demand.<sup>3</sup> This simply cannot happen, hence the need to produce more food on land which is already in production, and develop and promote new technologies such as indoor vertical farming.

The concentration and consolidation in the production, distribution and retailing of food in the Global North has led to a relatively small number of companies dominating the food system.<sup>4</sup> In the US, four companies are now responsible for 42% of food sales. Much of the food travels huge distances between field and fork, making a significant contribution to greenhouse gas emissions. The system often discriminates against small producers and encourages practices which cause soil erosion, water pollution

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**70%**

**of fresh water consumption is linked to agriculture**

and biodiversity loss. The globalisation of the food system and economies of scale have reduced prices for consumers in the wealthiest parts of the world, but it has made the food system more vulnerable to shocks such as extreme weather events and pandemics.

There is a compelling case to be made for establishing local systems of production which provide access to healthy, affordable, sustainably produced food. Growing more crops and rearing more livestock in and around urban centres must be part of the solution, not least because two-thirds of the world's population will live in towns and cities by 2050.<sup>5</sup>

During recent years, billions of dollars have been invested in companies practising high-tech production systems suited to urban areas. But urban agriculture, defined by FAO as "plant cultivation and animal rearing (including aquaculture) within cities and towns and in their immediate surroundings", has many manifestations. According to UNDP, by the mid- 1990s some 200 million people were employed in urban agriculture and related enterprises, contributing to the food supply of 800 million people.<sup>6</sup> The vast majority of urban farmers are in the Global South; most use traditional methods of production, often on a modest scale. Helping them to become more efficient and productive will be as important as expanding urban food production using the latest advances in technology.

## The diverse world of urban agriculture

Growing crops and rearing livestock in urban settlements has an ancient history. For most of the past 10,000 years, fields, homes and workshops were jumbled together, with locally produced food providing the fuel for increasingly sophisticated societies. Cities established by the Mayans in South America and the Khmer in Cambodia were fine examples of agrarian-based, low-density urbanisation.<sup>7</sup> The Romans developed sophisticated food production systems within their cities; in the Middle Ages, many cities grew crops and reared livestock behind their defensive walls.<sup>8</sup> In European cities livestock production had

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a significant presence until relatively recently. In 1864, for example, there were over 18,000 dairy cows in 1,361 herds in London.<sup>9</sup>

The rearing of livestock remains a significant activity in the Global South.<sup>10</sup> About 40% of urban households in Africa are thought to engage in some kind of farming practice, although there is a serious lack of reliable data about its scale and importance in developing countries.<sup>11</sup> Nevertheless, it is clearly a significant activity in many cities. For example, livestock numbers in Nairobi increased rapidly between 2008 and 2011, with the population of broiler chickens doubling, the population of laying hens increasing by 34% and that of pigs by 56%.<sup>12</sup> In 2017, there were an estimated 1.3 million livestock in Nairobi, whose farmers supplied an estimated 25% of the milk and 20% of eggs consumed in the city. A study of 2,687 households in urban areas with populations of less than 200,000 people in Zambia and Kenya found that 33% were engaged in urban agriculture.<sup>13</sup>

Urban agriculture also makes a significant contribution to food security in many parts of Asia. Approximately a third of the sewage produced by the citizens of Kolkata, India, seeps into the East Kolkata Marshes and provides nutrition for both fish and vegetables.<sup>14</sup> Every year, 10,000 tons of fish are harvested in the marshland ponds and the vegetables grown on organic waste supply 40-50% of the city's needs. That is why Kolkata has the cheapest food in the country. Backyard poultry keeping is another significant urban farming activity, benefiting an estimated 30 million farmers in India alone.<sup>15</sup> Backyard poultry keepers currently provide 30-35% of India's national egg supply. In China, too, urban food production is of paramount importance. In some cities 85% of the vegetables consumed are grown within municipal boundaries and up to a million migrants from rural areas are involved in food production in the area immediately surrounding Beijing.

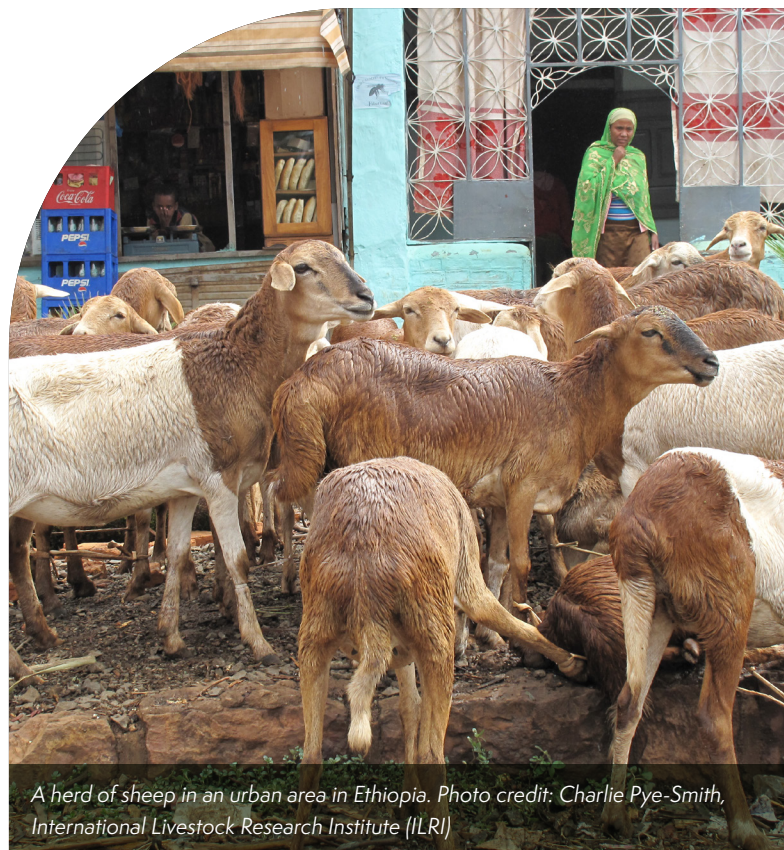
Urban agriculture in developing countries poses some significant challenges for policy makers. Controlling livestock keepers is difficult for a number of reasons: the inaccessibility of informal settlements, lack of trust in government authorities and the belief among livestock keepers that they are treated as outlaws. Backyard slaughtering and the sale of dead or sick animals on the

black market poses a significant health risk to consumers and proximity to urban livestock may increase the risk of urban dwellers catching zoonotic diseases.

## The potential of high-tech urban agriculture

A recent review of urban agriculture in the Global North identified five main types: allotments; extensive peri-urban farms; urban community gardens; rooftop farms where crops are grown in greenhouses; and vertical farms. While local governments and communities focus on encouraging, or producing, food from green spaces, financial institutions are pouring money into new technologies associated with controlled environment agriculture (CEA).<sup>16</sup>

According to a recent study based on a nationwide analysis of 26 cities and towns in the UK, there is a massive untapped potential to increase the production of fruit and vegetables on urban green spaces.<sup>17</sup> The fact that UK food self-sufficiency is steadily declining makes this all the more important. Between 1996 and 2015, the UK's fruit and vegetable imports doubled and the country is now just 75% self-sufficient in foods that can be grown in a temperate climate. The study calculated that if developed to the upper limit, urban green spaces have the capacity to grow a quantity of fruit and vegetables equivalent to 38% of current domestic production and imports combined.



A herd of sheep in an urban area in Ethiopia. Photo credit: Charlie Pye-Smith, International Livestock Research Institute (ILRI)

Of course, this assumes that homeowners will be happy to replace roses with rhubarb and peonies with parsnips. But leaving private gardens aside, there is a considerable area of urban green space that could be developed for food production. This is already happening in many towns and cities, encouraged by a range of programmes. Networks like C40 Good Food Cities are committed to developing sustainable, equitable and low-emission food systems. They explicitly recognise the social and health benefits, as well as the environmental and economic advantages, of local communities growing their own food.

There are many old, infant and new technologies – most notably those around CEA – which have the potential to increase food production in urban areas. One of the leading proponents of vertical farming, Dickson Despommier, argued that by growing food in city skyscrapers, using drip irrigation, hydroponics and aeroponics, we could dramatically increase global food supplies. His futuristic vision no longer seems as far-fetched as it did when he wrote *The Vertical Farm* in 2009.<sup>18</sup> Over the last 10 years there has been a rapid increase in food production systems using hydroponics and other cutting-edge technologies in greenhouses, old shipping containers, underground bunkers, abandoned industrial sites and purpose-built vertical farms.

According to a 2017 survey by the AgTech company Agrilyst, 49% of indoor farms in North America were using hydroponics, 24% were soil-based, 15% were

producing fish and vegetables using aquaponics, and 6% were using aeroponics.<sup>19</sup> By far the most economically important growing system was hydroponics, yielding revenues of US\$848 million in 2017. The lion's share was generated by a small number of companies – two major players in the south-west were responsible for over 50% – operating large-scale greenhouses. Nevertheless, hydroponics is also important for many indoor farming ventures in urban areas.

Hydroponics involves growing plants without soil in water enriched with nutrients. The plant roots may be entirely exposed to the liquid solution or they can be physically supported by an inert medium such as perlite or coir. Aeroponics requires no substrate and involves saturating the air around the crop roots with a mist of nutrient solution. Many of the enterprises which practice hydroponics in urban areas use artificial light provided by light-emitting diodes (LEDs). Yields for hydroponic lettuces grown in greenhouses were about 12.6 times greater than those of conventionally grown lettuces, according to the Agrilyst survey of 2017. Yields per unit area can be even greater in vertical farming systems although the productivity figures provided by companies – some are quite staggering – have frequently not been corroborated by independent sources.

Aquaculture and aquaponics are both well suited to small spaces in urban areas. The former is solely concerned with fish production; the latter combines fish with vegetable production. Recirculating aquaculture



*A combined aquaponics and aquaculture system*

systems are said to use 90% less water than conventional aquaculture techniques such as flow-through raceways and ponds.<sup>20</sup> Aquaponics involves using the water which has been fertilised by waste products from the fish as a nutrient solution which is delivered hydroponically to vegetables. Tilapia, catfish, trout and bass are particularly well suited to these systems, and the vegetables grown are much the same as those which are popular with indoor vertical farms, such as basil, salads, herbs, lettuce and kale.

It says much about the nature of indoor food production that many companies talk about their facilities, rather than their farms. In recent years, the sector has expanded rapidly, and will continue to do so. The 2020 State of Indoor Farming report for North America found that 73% of companies which responded had plans to expand within the next five years. Mid-tech, glass/poly greenhouses were expected to double their acreage compared to high-tech glass greenhouses and indoor vertical farms. But the latter, which are particularly well suited to small spaces in urban areas, are also on a rapid upward trajectory.

## Vertical farms

One of the largest enterprises practising vertical farming in the US is Aerofarms. Its vertical 70,000 square-foot facility in New Jersey was supplying over 200 grocery stores with 2 million lbs of food per month – bok choy, spinach, micro broccoli, micro kale – by 2021. Crops are grown aeroponically – nutrients for the crops are supplied in the mist – and Aerofarms uses no artificial fertilisers or pesticides. It claims that it has cut water use by 95% compared to conventional growing methods and that its yields, per unit area, are over 300 times greater than those of conventional farms. It is in the process of establishing a new facility at Danville, Virginia, which will provide 100 jobs in an economically depressed area. It has recently launched a new company to develop the world's largest indoor vertical facility in Abu Dhabi, UAE, and has plans to establish 16 more vertical facilities in the US.

Two other leading names in US vertical agriculture are Plenty, whose flagship farm is in California, and Bowery, whose first vertical farming enterprise was established in industrial warehouses in Kearney, New Jersey. The fact that Walmart has bought a significant stake in Plenty suggests that its impressive production claims are credible. According to the company, it uses 5% of the water and a tiny fraction of the land required to produce

the same amount of crops by conventional methods. Decades of research and development led to a sudden surge in yields, which increased by a factor of seven in just two years in its leafy green growing rooms. Plants are grown on tall towers with a modular setup, providing a yield 150–350 times greater than conventional farms. Robots are used to plant, feed and harvest crops. “Plenty,” claims the company, “is rewriting the rules of agriculture.”

Bowery is not averse to marketing hype either with its talk about growing “post-organic” produce. Like most vertical farms it doesn't use any agrochemicals. It claims to have yields 100 times greater than those of conventional farms and to use 95% less water. By 2021, the company's produce was available in 850 stores. In the same year, it raised US\$300 million of finance – bringing the total raised to US\$472 million – and announced that it was establishing two more large indoor facilities, one in Georgia and the other in Texas. The company has attracted investment not just from financial institutions, but celebrities like the singer Justin Timberlake and Formula One driver Lewis Hamilton. The two new facilities in the southern states will both employ 100 workers and rely on 100% renewable sources of energy.

Japan has taken a keen interest in setting up and supporting vertical farming enterprises. According to an article in the Financial Times, many companies have attempted to set up vertical farms using empty or abandoned factory space, often without success.<sup>21</sup> Indeed, one estimate suggests that over 60% of the vertical farming operations in Japan are only profitable because of government subsidies. Several enterprises, however, buck this trend, one being the Keihanna Facility near Nara, which produces robotically planted and harvested lettuce. Established in 2007 by the company Spread, the Keihanna facility first began making a profit in 2013, automation being a major factor as it reduced labour costs.

A major constraint on indoor vertical farming, apart from the high capital/start-up costs, is the cost of energy, most of which goes on providing artificial light with LEDs. Some companies have opted to make use of sunlight in their vertical farms as an alternative. In England, for example, Shockingly Fresh established its hydroponic vertical farming system in 3 acres of greenhouse in 2021. Unlike facilities using LEDs, production is influenced by the seasons and the availability of natural light. However, yields are still four times greater than those of conventional farms. The company now plans to build 40 more farms, including one which will cover some 30 acres in southern Scotland.

Singapore has a population of 5 million people in an area of 710 km<sup>2</sup>, which includes just 250 acres of farmland. As a result, 90% of food is currently imported, making the country vulnerable to vagaries in food supply from other parts of the world. The government's "30 by 30" strategy, whose aim is to increase food self-efficiency to 30% by 2030, means more space will be devoted to urban agriculture and increasing productivity through the adoption of vertical farming and other technologies.<sup>22</sup> One company, Sky Greens, has developed a soil-based vertical farming system which takes advantage of sunlight to produce one tonne of leafy greens every two days. Crops are sown in growing troughs stacked vertically on 9 m A-shaped aluminium towers which slowly rotate to give the plants equal access to sunlight. A hydraulic system – just 0.5 L of water will rotate a 1.7 t structure – also provides irrigation for the plants. The facility is not only highly productive, but very efficient in terms of its low use of energy.

## From rooftops to bomb shelters

It is estimated that half of all the lettuces consumed in the US will be grown in greenhouses by 2030. While some greenhouses will be close to major urban centres, many will be situated far from consumers, in the countryside or near small towns. This means their produce will often carry a heavy burden of food miles and carbon emissions. One way of establishing greenhouses which produce food for local consumption is by making use of rooftops. In places like Singapore, where land is at a premium, rooftop greenhouse farms have a promising future. Abyfarm's 3,200 square-foot rooftop greenhouse on a city car park is using all the latest technology, including solar-powered sensors which track temperature, rainfall, humidity and sunlight, to produce leafy greens.

One of the best-known rooftop greenhouse companies in the US is Gotham Greens, which was established in 2009 with the mission of producing food and revitalising urban areas. Its first commercial rooftop greenhouse covered 15,000 ft<sup>2</sup> in Brooklyn, New York City. Since then it has established greenhouses – all based on the hydroponic system – in Brooklyn, Chicago, Maryland, Rhode Island and Colorado. It claims that its greenhouses are 30 times more productive than conventional farming systems.

LUFA Farms was established in the Canadian city of Montréal in 2009 with the aim of growing food sustainably close to where people live. Three rooftop greenhouses covering 138,000 ft<sup>2</sup> provide local consumers with 20,000 baskets of vegetables per week. In 2020, the company built the world's largest rooftop greenhouse – 164,000 ft<sup>2</sup> – where it grows tomatoes and eggplants hydroponically in a coconut fibre substrate. It uses biological systems of pest control rather than pesticides. Eventually, its greenhouses should be capable of feeding 10,000 families year round.

Rooftops can be used to produce fish as well as leafy greens and vegetables. Brussels Aquaponic Farm was established in 2018 above a food hall in the city centre. The nutrient-rich water from the fish farm, which is situated in a greenhouse, is recycled in a hydroponic system to grow herbs, vegetables and tomatoes in 2000 m<sup>2</sup> of greenhouse and a similar area of outdoor gardens. Supplementary LED is used in the greenhouse.

Equally impressive in terms of productivity is Growing Underground's farm in London. This occupies a World War II air raid shelter 100 feet below Clapham High Street. The company specialises in micro-greens which take just two weeks to grow, including pea shoots, basil, coriander, parsley and rocket. These, they claim, contain



*A vertical hydroponic vegetable farm*

90% more nutrients than their fully grown counterparts. The company's partnership with scientists at Cambridge University has helped it to significantly improve its crop yields. The underground farm produces 12 times more per unit area than traditional greenhouses, although it consumes four times more energy. An estimated 95% of the electricity used in the underground farm goes on powering extraction fans and LEDs.

The success of this and other similar ventures encouraged the president of the World Society of Sustainable Energy Technology, Prof Saffa Riffat, to suggest that abandoned coal mine shafts and tunnels could be the perfect environment in which to grow vegetables and herbs, and a cheap alternative to vertical farming in greenhouses. He estimates that one 7 m<sup>2</sup> reconditioned mine shaft could produce 80 tonnes of food per year.

## Key challenges

Although vertical farming operations are rapidly increasing in number, particularly in the Global North – one estimate suggests they will generate US\$3 billion of revenue by 2024 – their environmental impact is a curate's egg: good in parts, not so good elsewhere. A life cycle analysis conducted by the Markets Institute of WWF and published in 2021 compared lettuce grown conventionally in fields in California and shipped to St Louis with lettuce grown in a range of CEA facilities in St Louis. As far as climate change was concerned, the Californian lettuce had a much lower impact than the St Louis lettuce, despite making a journey of almost 2000 miles.<sup>23</sup>

The study modelled lettuce from five systems – conventional, greenhouse hydroponic, greenhouse aquaculture, vertical hydroponic and vertical aquaculture – evaluating their impact on human health, ecosystems, resources, energy demand, climate change and water use. In terms of impact, conventional lettuce scored best,

**“The environmental impact of vertical farming is a curate's egg: good in parts, not so good elsewhere.”**

followed by greenhouse hydroponic lettuce. The vertical systems fared worse, especially in terms of their energy demand and impact on climate change.

The authors of the report suggested that three things were needed to improve the environmental impact of vertical facilities. Ideally, they should make use of renewable energy sources such as solar if they are not using natural sunlight. If renewable energy sources are not available, vertical facilities should consider co-locating next to enterprises which can provide a free or cheap source of waste heat and power. Finally, improvements in the efficiency of LEDs would make a big difference to the calculation. Over the last five years their efficiency has improved by 40%. If that continues it could significantly reduce vertical facilities' carbon footprint.

The relative costs of production of different farming systems is just as important as their yields. At present, crops in vertical farms are far more expensive to produce than crops in open field systems. By analysing the figures provided by various enterprises in North America, agricultural consultant Peter Tasgal was able to calculate the cost to grow and deliver greens in different systems. On conventional outdoor farms the cost was around \$0.65/lb, compared to \$2.33/lb in a hydroponic greenhouse, \$3.07/lb in a vertical farm and \$7.14/lb in a container farm.<sup>24</sup> In other words, it is 3 to 5 times more expensive to produce crops in greenhouses and vertical farms than on conventional outdoor farms. However, Tasgal is optimistic about the future of greenhouse and vertical farming, asserting that with today's technology it is possible to deliver locally grown greens to the mass market at a price that is competitive with other similar offerings throughout the year. Furthermore, advances in technology should bring costs down in future.

A somewhat gloomier analysis was provided by scientists at Cornell University. They looked at the environmental and social impact of 10 urban farms in New York City, six on roofs which use sunlight and supplementary light and four in buildings or shipping containers. In total, the facilities covered just over 3 acres.<sup>25, 26</sup> They found that farms using sunlight – one example was Gotham Greens – performed well from an environmental point of view, but those reliant on LEDs had a negative climate change impact. The authors also criticised the fact that most of the food produced was of low nutritional value and was sold at a premium to relatively wealthy members of the public, rather than at an affordable price to the poor.

While conceding that CEA farms use less water, pesticides and fertiliser than conventional farms, they

were of the opinion that there was “little evidence that citing CEA farms in New York City is necessary, especially as rural and peri-urban ones can accomplish the same more efficiently.” The authors concluded that CEA makes most sense in regions with favourable climates where less supplementary heat and light is needed. They also suggested that it would be better if they grew more nutritious crops like spinach and kale that the poor could afford. In the end, they suggested CEA is most beneficial when carried out by institutions and community farms that have demonstrated efficacy with soil-based production and focus on nutrient-rich produce.

## **Policies for urban agriculture**

Urban agriculture encompasses a vast range of activities, from keeping a few chickens in the backyard to intensive pig and poultry units and high-tech vertical farms. This means that there can be no one-size-fits-all policies for urban agriculture. At present, few countries – one exception is Singapore – have developed comprehensive policies for urban agriculture. Some cities in the Global North are beginning to do so. As far as the Global South is concerned, urban agriculture seldom features in policy-making.

There is enough evidence to suggest that urban agriculture could make a significant contribution to improving food security and nutrition. However, there is a serious lack of data about urban agriculture. How significant is it in terms of food production? Who are the people who are practising urban agriculture? Can it improve food security and reduce our carbon footprint? Where tradition survey methods are impractical or too expensive, national and local authorities should make use of big data – derived from satellite surveys and the like – to gain a better picture about the prevalence and importance of urban agriculture.

It has sometimes been claimed that urban agriculture could dramatically increase food production – particularly through controlled environment agriculture (CEA) such as vertical farming – and as a result reduce pressures which are leading to deforestation and the conversion of peatlands, especially in the tropics. This seems a dubious proposition, not least because forests are generally cleared to make way for livestock and cash crops such as soya and cocoa, not the sort of crops which are grown in high-tech greenhouses and vertical farms.

However, urban agriculture could be one of a suite of activities which help to increase food production

and take pressure off natural habitats. Other activities which could play an important role in the future include cellular agriculture, still in its early stages but providing promising evidence that meat grown from cells in vitro, or from vegetable matter, will soon provide a significant alternative to livestock raised on grasslands.

It is currently estimated that subsidies amounting to some US\$750 billion a year will be needed to reduce deforestation and the conversion of peatlands. This sounds like an astronomical figure, but it should be seen in the context of the amount currently allocated to environmentally destructive subsidies. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) calculates that subsidies to the fossil fuel industry amount to around US\$345 billion a year.<sup>27</sup> If externalities that are not included in the price of fuel are factored in, such as pollution and environmental destruction, the cost comes to over US\$5 trillion. Reorienting perverse subsidies to promote activities which have the potential not only to improve food security but mitigate climate change should be a priority. Urban agriculture is a prime candidate for targeted support.

At the local level, whether in the North or the South, the authorities could introduce policies which encourage and promote urban agriculture. These could include providing secure tenure, especially in informal settlements, making vacant lots and brownfield sites available for food production, providing grants and low-interest loans to encourage urban farming, and ensuring that organic waste is made into fertiliser rather than sent to landfill sites. National and local authorities could also provide training programmes for people who wish to grow food in the urban environment.

**“Urban agriculture could be one of a suite of activities which help to increase food production and take pressure off natural habitats.”**

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"Urban agriculture could make a significant contribution to improving food security and nutrition."

