make to transition toward a smart, sustainable, and healthy urban future. To achieve the full potential of smart cities, discussions must move beyond data to envision cities as multisectoral, multiscalar, social-ecological-infrastructural systems with diverse actors, priorities, and solutions.

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PERSPECTIVE

Hidden linkages between urbanization and food systems

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Global societies are becoming increasingly urban. This shift toward urban living is changing our relationship with food, including how we shop and what we buy, as well as ideas about sanitation and freshness. Achieving food security in an era of rapid urbanization will require considerably more understanding about how urban and food systems are intertwined. Here we discuss some potential understudied linkages that are ripe for further examination.

The rise of urbanization is transforming food systems in many areas, including production on the farm, processing and packaging, distribution and retail, and consumption at the table. Cities concentrate people who live and work in close proximity and facilitate social interaction, which results in a greater variety of available food choices and creates new habits and tastes. Though a few links between urbanization and food systems are attracting increased attention from researchers, we discuss many poorly understood linkages that require further study if we are to achieve food security in an urban era.

Urbanization is a complex phenomenon that involves change in multiple dimensions, including a growing percentage of people who live in urban areas; the expansion of built environments; and changing norms, cultures, and ways of living. Most of what we know about how urbanization affects food systems is focused on two issues: the physical expansion of urban areas (food supply side) and changes in diet (food demand side). A widely expressed concern about urbanization is that expanding cities will result in widespread loss of croplands. Between 1970 and 2000, our global urban footprint expanded by 58,000 km^2 (*1*). By 2030, built-up areas are forecasted to nearly triple in size over the 2000 area, an increase of 1.2 million km^2 (*2*). However, croplands, which account for 12% of the world's ice-free land cover, exceed urban areas, which take up less than 3% (*3*). Though this difference in total area suggests that expansion of urban areas will have a minimal effect on Earth's total cropland, two qualifications are important.

First, because built-up areas are growing faster than urban populations in most parts of the world (*1*, *4*), cropland loss is likely to be acute in countries where urban population growth rates are high and the economy is largely agrarian. Thus, the loss of cropland due to urban expansion is likely to be more of a regional problem than global one. For the affected regions in particular, strategies are needed to manage urban expansion in ways that reduce pressure on farmland, inefficient land-use patterns, and leapfrog development. Toward these goals, the United Nations Human Settlements Programme (UN-Habitat) is supporting efforts to minimize urban sprawl by encouraging densification and more compact cities in countries such as Brazil, Ecuador, and Egypt. An alternate strategy is to safeguard agricultural land from development. The Canadian province of British Columbia established the Agricultural Land Reserve, a land-use zone intended to protect fertile agricultural land from development.

Second, given that cities historically developed in fertile agricultural areas, future expansion of built-up areas will probably encroach on productive agricultural land. This has already occurred in India, Vietnam, China, Turkey, and the United States, where urban expansion has resulted in the loss of prime agricultural land. Loss of the most productive agricultural land leads to decreased average cropland productivity (*5*), which is not a promising trend at a time when closing yield gaps is considered important (*6*, *7*). Furthermore, the loss of agricultural land may result in the need to expand crop production into marginal and fragile lands, as well as other ecosystems. In the tropics, deforestation due to agricultural land expansion is estimated at 12 million ha per year (*8*). Notwithstanding these qualifications, the effect of urban expansion on farmland loss is unlikely to be the most important influence of urbanization on food systems.

On the demand side, it is well documented that the diets of urban and higher-income societies require costly expenditures of land, water, and energy (*9*, *10*). With few exceptions, highly urbanized countries consume more animal protein—in the form of pork, poultry, beef, and dairy products—than the world average. Globally, the average meat consumption per capita is 36.9 kg per year, but there is huge variation between countries, with higher-income countries consuming 81.8 kg per year per capita compared with 17.2 kg per year in lower-income countries (*9*). In the United States, where 81% of the population lives in urban areas, per-capita meat consumption is 89.7 kg per year. In China, per-capita

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meat consumption quadrupled between 1970 and 2015, a period when the urban population increased from 17.4 to 55.6%. Other countries experiencing high rates of urbanization are undergoing similar dietary transitions (*11*, *12*). It is important to point out that changes in diet are not limited to increased meat consumption but also include more nuanced shifts in quality, composition, and sources of caloric intake. In general, changes in diet can be characterized as a shift from complex carbohydrates, grains, vegetables, and fruits to a higher proportion of animal proteins, refined fats, refined sugars, alcohols, and oils (*13*).

The exact mechanisms that undergird these dietary shifts are not well understood, and many studies conflate urbanization, rises in income, and westernization. More affluent households can afford higher-quality diets with greater variety, the means to physically reach grocery stores that have better selection, and nutritional knowledge. Disentangling the income or economic development effect from the urban effect on diets will require substantially more research that goes beyond comparison of urban diets to rural ones. Given that urbanization is a major global trend, we need research that helps us isolate the urban effects on diet. For example, how does urban spatial form affect food demand? How are our food choices shaped by where we live and work, their relative locations, and our travel behavior? How does living in large mega-urban regions affect our exposure and access to foods, as well as our food preferences and choices? How does urban living influence our exposure to "foodstyles," such as veganism, organic, and local foods, as well as our purchasing habits and diets? We need to move beyond understanding urbanization's direct effects on diet and toward examining its indirect effects on resource use and the environment, such as embodied energy for food production, transport, packaging, cold storage, and the rest of the entire chain from farm to fork.

> ***"We need to move beyond understanding urbanization's direct effects on diet and toward examining its indirect effects on resource use and the environment, such as embodied energy for food production, transport, packaging, cold storage, and the rest of the entire chain from farm to fork."***

Urbanization could drive profound changes in food systems in ways unrelated to rises in income, such as through shifts in norms and attitudes about food; increasing opportunity cost of time and the necessity of convenience; growing availability and access to modern energy; and changes in the structure of the economy, household dynamics, the workforce, and urban form and infrastructure (Fig. 1). The pace of life in cities is fast, and with the onset of the 24-hour workday and more women joining the workforce, there is a growing need to reduce meal cooking time. This creates a demand for time-saving food preparation, from prepackaged items to reduced shopping time; meals away from home; and convenience foods on the go (*14*, *15*). Around the world, more urbanized societies eat more meals away from home (Fig. 2). Urban and food systems coevolve: Increased convenience allows people to work longer, furthering the demand for convenient foods. Although these foods reduce meal preparation time, they also increase the need for preprocessing, packaging, and refrigeration. In 2005, food container and packaging waste accounted for nearly one-third of total municipal solid waste in the United States (*16*).

In addition to packaging waste, food losses and waste place enormous burdens on the environment by contributing to greenhouse gas emissions, eutrophication, and the waste of resources used to produce food that is not eaten

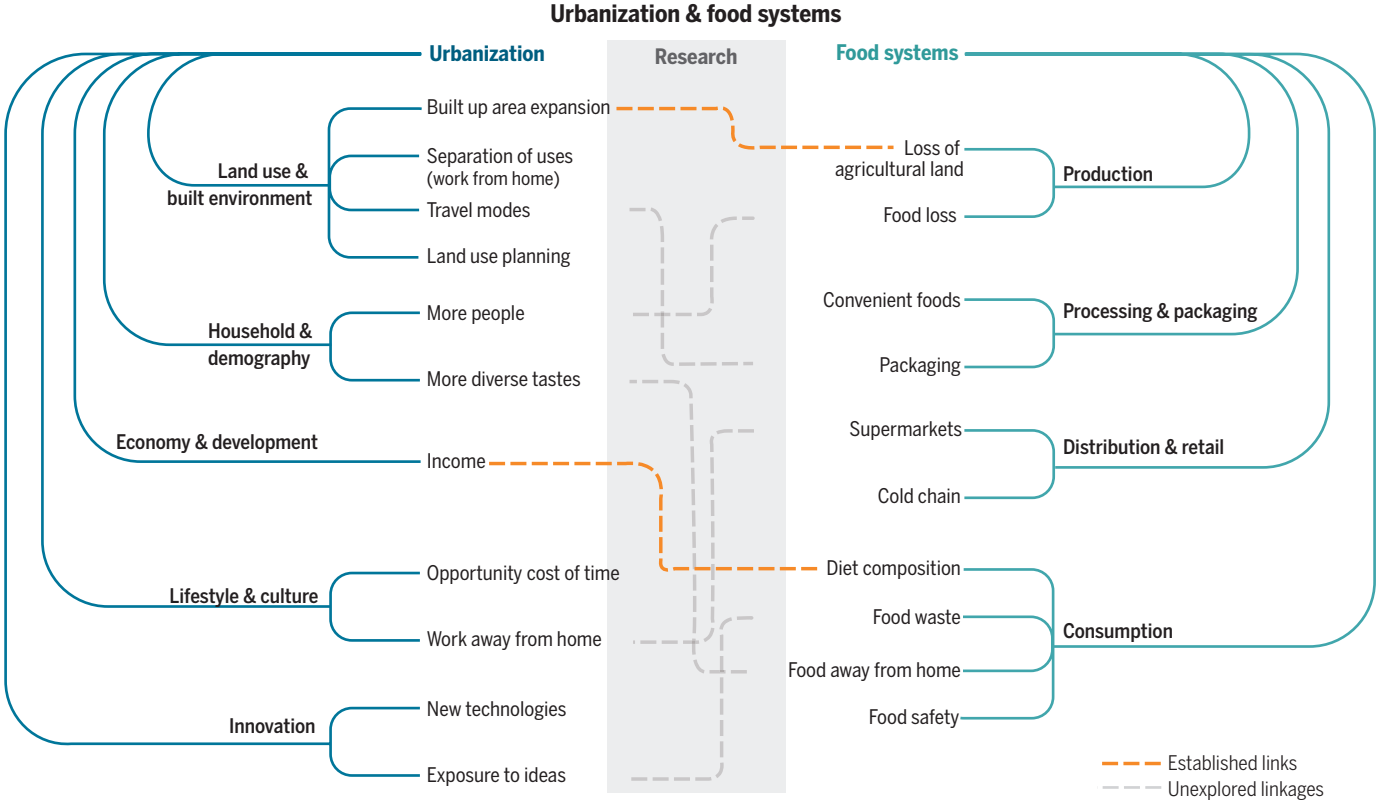

Fig. 1. Established and underexplored linkages between urbanization and food systems. The underexplored linkages are illustrative and not exhaustive.

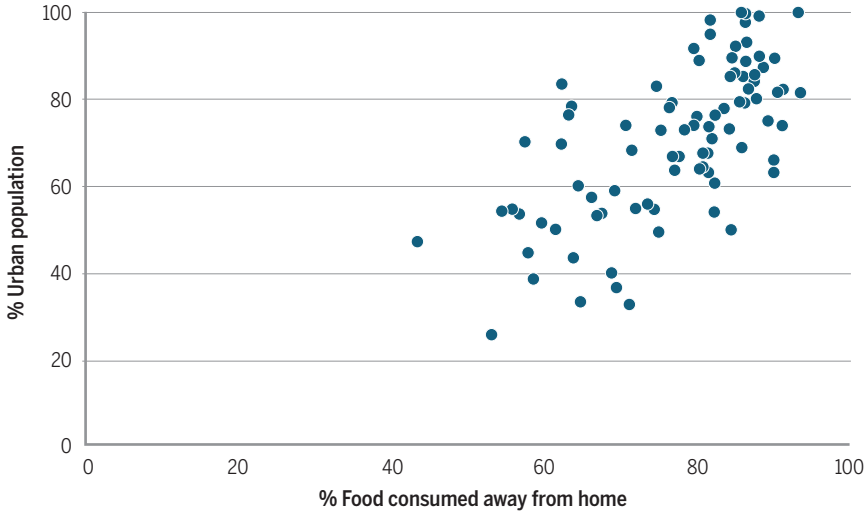

Fig. 2. Percentage of the national population living in urban areas versus percentage of consumer expenditures on food consumed away from home for 86 countries in 2014. Urban population estimates are from the World Bank; estimates for shares of food consumed at home are from the Economic Research Service of the U.S. Department of Agriculture (we inferred the percentage of food consumed away from home to be 100% minus the percentage of food consumed at home).

(*17*). Food loss and waste within the food system depend on many factors, but the level of economic development is a strong predictor: Preconsumer food losses within the supply chain are more prevalent in developing countries, whereas postconsumer food waste is a bigger issue in high-income countries (*18*). Urbanization may actually be beneficial for reducing food losses through improvements in technology, such as cold storage and transportation. There are many reasons why people in the developed world waste so much food: We overbuy and then overprepare and discard excess food. This is overwhelmingly a problem of the affluent, where food is a small percentage of the total household budget, thus reducing the cost of discarding food. Again, as with diets, disentangling the income effect from the urban effect on food loss and waste will require far more research. For example, how much does food consumed away from home, which is strongly associated with urban living, influence food waste? How do mixed-use urban forms, with close access to grocery stores, allow people to purchase food when they need it and reduce household food waste?

With greater numbers of people and activities, urban areas also require more institutions to maintain law and order, sanitation, and public hygiene. More rules and changes in attitudes come together to create new norms and regulations about food safety. Though some of these regulations (such as cold-storage requirements) may appear benign, together they constitute a substantial shift in where and how food is stored, packaged, and sold. In many Asian cities, wet markets are giving way to more sanitized farmers markets and multinational supermarkets, partly due to concerns about the avian flu but also because of changing attitudes around freshness and modernity.

Where they exist, urban planning and land-use zoning regulations greatly affect food retail diversity and accessibility. Transport planning, modes of mobility, street connectivity, and land-use mix affect how often people shop for food, what they buy, and where they eat. In cities where street connectivity is high—characterized by smaller blocks, shorter distances, and many intersections—there is a positive correlation with walking and, thus, more convenience, higher accessibility, and lower energy costs of food procurement. Land-use regulations are central to creating retail "foodscapes" that are diverse by either enabling small-scale, independent food shops and restaurants or limiting food commerce to stores or chains that can afford higher rents and fill large retail spaces.

Urban areas are also hubs of innovation, where new technologies and ideas about food systems emerge, such as vertical farming, entomophagy, the slow food movement, farmers markets, and community-supported agriculture. Urban dwellers are increasingly disconnected from the agricultural land base but are finding creative ways to remain connected to the food system. Changes in urban consumer preferences can have far-reaching consequences. For example, European preferences for non–genetically modified foods have contributed to the rapid expansion of South American farming and the development of entirely new supply chains (*19*). The rapid growth of organic farming is driven by increasing demand from urban consumers in North America and Europe, whereas the majority of organic farmers are located in developing countries (*20*).

Of all the myriad ways in which urbanization affects different parts of the food system, the effects on the people who produce food are perhaps some of the least studied. There are an estimated 500 million smallholder farms in developing countries providing livelihoods for almost 2 billion people (*21*). Urban expansion may displace these farmers into marginal lands, and the increase in land value may encourage them to sell their farms and seek alternate means of livelihood, possibly in urban areas, leading to even greater rural-to-urban migration. Further, as cities grow larger, the food retail market becomes increasingly dominated by large supermarket chains, and this has secondary effects on traditional retailers, small-scale producers, traditional food brokers, and the entire supply chain (*22*).

Most discussions of food security focus on how to sustainably provide for a world of 9 to 10 billion people in 2050. Much less attention has been paid to the fact that ~6.5 billion of these people will live in urban areas and that the transformation toward a more urbanized society will have many consequences for food systems. The overwhelming effects will be indirect. To achieve food security in the urban century, we urgently need more research that unravels how these two systems are linked.

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