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An integrated approach to identifying and characterising resilient urban food systems to promote population health in a changing climate

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Abstract

Objective: To determine key points of intervention in urban food systems to improve the climate resilience, equity and healthfulness of the whole system.
Design: The paper brings together evidence from a 3-year, Australia-based mixed-methods research project focused on climate change adaptation, cities, food systems and health. In an integrated analysis of the three research domains – encompassing the production, distribution and consumption sectors of the food chain – the paper examines the efficacy of various food subsystems (industrial, alternative commercial and civic) in achieving climate resilience and good nutrition.
Setting: Greater Western Sydney, Australia.
Subjects: Primary producers, retailers and consumers in Western Sydney.
Results: This overarching analysis of the tripartite study found that: (i) industrial food production systems can be more environmentally sustainable than alternative systems, indicating the importance of multiple food subsystems for food security; (ii) a variety of food distributors stocking healthy and sustainable items is required to ensure that these items are accessible, affordable and available to all; and (iii) it is not enough that healthy and sustainable foods are produced or sold, consumers must also want to consume them. In summary, a resilient urban food system requires that healthy and sustainable food items are produced, that consumers can attain them and that they actually wish to purchase them.
Conclusions: This capstone paper found that the interconnected nature of the different sectors in the food system means that to improve environmental sustainability, equity and population health outcomes, action should focus on the system as a whole and not just on any one sector.

Keywords
Climate change
Ecological footprint
Food systems
Food security
Population health
Health inequity
Urban settlements

Changing climatic and environmental conditions, and their strong bidirectional association with the food system[1], necessitates both the creation of climate-resilient food systems and ensuring food systems mitigate further environmental degradation. There are various sectors and subsystems that constitute the food system as a whole. Each stage of the food system – from production through manufacturing and processing, to retail and consumption – has the potential to be affected by and contribute towards environmental degradation[2]. Food systems also, generally, comprise three subsystems which are associated with different scales of operation: highly industrial globalised supply chains (anchored by transnational and national food commodity producers, supermarket chains, food-service sector) sit alongside 'alternative commercial' national and localised food chains (producer co-ops, community supported agriculture, artisanal farms), as well as civic agriculture chains based on household and community gardens[3]. Each of these subsystems draws differently on ecosystem services (water, soil, energy) and human capacities, generating potentially wide variability in their environmental and human health consequences[4].

Urban food security in the context of environmental change is gaining prominence internationally as an important health and health equity concern. Issues of availability, accessibility, affordability and acceptability of food within cities appear to be being intensified by environmental change, compounding existing pressures arising from ongoing urbanisation, including the movements of people into cities, as well as population increases. This increase of urban populations necessitates larger urban food supplies, and urban sprawl and its progressive depletion of local agricultural lands

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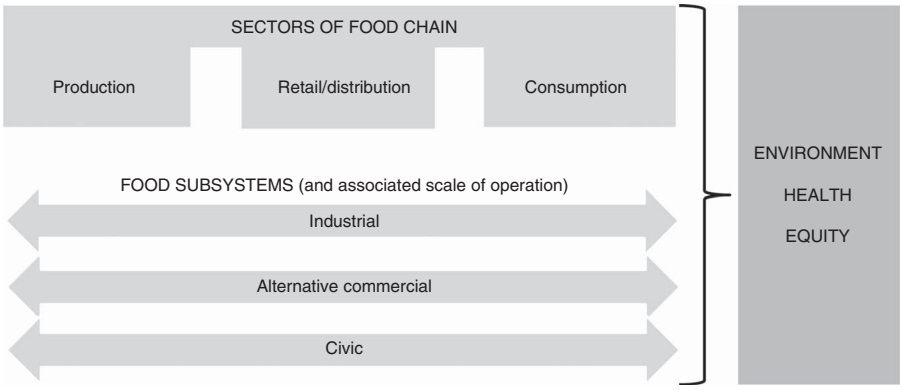

Fig. 1 A whole-of-system approach to understanding the interrelationship between food sectors, subsystems, environmental change, health and equity

is leading to the need to bring food into the city from other areas[5–8]. With more than half of the world's population now living in urban and suburban locations[9] and urban growth rates expected to climb in the coming decades, there are significant implications for urban food demand, population health and the environment[6]. This urban phenomenon creates an opportunity, and an urgency, to consider the environmental as well as the health and equity aspects of urban food supplies and food systems more broadly.

To do this arguably requires understanding and acting on the whole food system. To date, however, the lack of research that takes a whole-of-system perspective means that there is not an empirical basis on which to ascertain how best to intervene in an integrated manner. To help address this evidence gap, the present paper takes a whole-of-food-system perspective, investigating the food supply chain from production to distribution and consumption and through the various food subsystems (industrial, alternative commercial and civic) to determine their efficacy in achieving improved environmental, health and equity outcomes in an urban setting (summarised in Fig. 1).

The paper begins by briefly examining the contemporary literature on food systems, climate change and human health. This review illustrates the siloed nature of current empirical research and the privileging of particular food subsystems and their associated scales of operation in current agendas for change. We then present an overview of empirical evidence generated through a 3-year, Australia-based research project concerned with climate change adaptation, cities, food systems and health[10].* To incorporate the often disparate themes of food and sustainability, food and health, and food and health equity, the project comprised three interconnected aims: (i) assess the environmental footprint of an urban food supply; (ii) identify the availability and affordability of nutritious and environmentally friendly foods; and (iii) assess the acceptability of environmentally friendly foods across a range of socio-economic groups. A key goal of the study was to provide an empirical evidence base on which to interrogate the prevailing conceptual and fragmented arguments for food system change. As the capstone to the research project, the present paper undertakes this meta-analysis, synthesising findings from the three domains of the research to provide an integrated overview of Sydney's urban food system. Drawing on this analysis, the final section of the paper discusses key entry points for action across the whole food system. This suite of measures is intended to assist national and local governments and city planners create urban food systems that are adaptive to climate pressures and help ensure nutritious food is available and accessible to all communities in ways that mitigate further environmental harm.

Beyond scales and sectors – an assessment of the literature

The lack of whole-of-systems perspectives in current food research can partly be attributed to the complexity of food systems[11]. This complexity in food systems is evident both horizontally, across sectors in the supply chain from production (producers and manufacturers) to distribution (retailers and food services) to consumption (consumers), and vertically, as these systems work across local, regional, national and global scales.

The multitude of factors operating within any food system means that creating environmentally resilient, equitable and healthy food systems requires the identification of strategic points at which intervention would be the most effective. To date, however, the small but growing body of work examining the need for whole-of-system change has been largely conceptual. Empirical research has focused predominantly on specific sectors (production, distribution and consumption) and/or scales of the food chain (local, regional, national and global)[12–18].

* Adaptation is defined as the modification of current policies and practice to cope with the unavoidable impacts of climate change. Climate change mitigation represents actions that reduce the causes of climate change. In the present paper both are positioned as operating along a continuum and interconnected.

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Sectors: the siloing of health and environmental food research

Environmental and health concerns have been the primary drivers of the renewed attention to food systems in the last decade. There is a substantial disconnect between these two research streams, however, as each has focused on different sectors of the food chain. This has contributed to a siloing of advocacy and policy in each area, with a lack of attention to the interrelated nature of health and environmental issues across the food system.

In the environmental sustainability literature, the emphasis has largely been on the production phase of the food chain[19–21]. Agricultural production accounts for an estimated 14 % of greenhouse gas emissions worldwide[22]. Certain aspects of production, such as the farming of ruminants (i.e. cows, goats and sheep) for meat, are considered particularly problematic due to their high greenhouse gas output[23,24]. The predicted drop in global agricultural production due to climate change and a parallel rise in world population have generated fears of future food insecurity and even, in the view of some, 'a coming famine'[25]. Other predicted changes, including a decline in fossil fuels needed for the global trade of foodstuffs and a rise of food-borne diseases, have exacerbated these concerns[26].

Conversely, health-related food research, which incorporates equity concerns on issues such as food availability, accessibility, affordability and acceptability, has largely focused on the distribution and consumption sectors of the food chain[27–29]. This research is often concerned with the dietary options available to urban populations, especially lower-income populations, through the industrial food system[30].

To create resilient urban food systems for population health in a changing climate, however, it is necessary to move beyond this traditional siloed approach. Research instead needs to focus on the interconnections between health and environmental issues across the food system as a whole.

Scale: globalised industrial food subsystem through to localised civic subsystems

One common thread between environmental- and health-related food research and advocacy is that both areas have focused on the localisation of food production and distribution as a means to address the perceived problems of the prevailing industrial food subsystem[31,32].

The industrial food subsystem, with its focus on transnational food commodity producers, supermarket chains and the food-service sector, is the dominant system in most developed countries[33]. Few would question the efficiencies introduced by this type of food system due to the scale and technological sophistication of the supply chain of producers, processors and logistics enterprises[4]. However, the industrial model is associated with widespread land degradation and pollution, and stresses the ecosystem services that society is reliant upon for sustaining production for future generations[34,35]. Industrial food systems have also increasingly produced large volumes of highly processed foods. When overconsumed, these foods are associated with adverse health and environmental impacts due to their typically energy-dense and nutrient-poor compositions and the additional environmental resources (water and energy) required for production[36]. Due to these traits the industrial system is viewed by many as the least resilient of the three food subsystems, being most vulnerable to economic and social disruptions and potentially to environmental disruptions caused by climate change[37].

The ethical, social and environmental problems associated with the industrial food subsystem have led to a championing of local, alternative options such as urban agriculture as a solution to food system problems[32,38]. In these discourses, civic and alternative commercial subsystems are associated with local or regional scales and the industrial subsystem is associated with the global and sometimes national scale[39]. The underlying assumption within much of this literature that local and/or alternative food systems create better environmental, health and equity outcomes has, however, been challenged by recent research[40–42]. Furthermore, the apparent conflation of scale and subsystems is not necessarily accurate: industrial subsystems operate at the geographically local level and 'alternative' subsystems can operate at national and global levels.

These considerations bring into question whether focusing on localised alternative subsystems is the most effective approach for creating resilient urban food systems. The lack of empirical research examining the relative efficacy of different subsystems in achieving environmental, health and equity outcomes within a whole-food-system framework, however, means that it is difficult to ascertain how best to intervene[43].

Methods

The present paper addresses the identified evidence gap of whole-of-system perspectives by drawing together empirical research generated through a 3-year, Australia-based mixed-methods research project (led by one of the authors of this paper, S.F.) focused on climate change adaptation, cities, food systems and health[10]. The aims of the project were to scope the existence of urban food subsystems in a location in Australia; examine their relationship with population health, equity and environmental health; and describe possible policy options to ensure climate-resilient urban food systems that protect human and environmental health. An overarching goal of the project was to provide an empirical evidence base on which to interrogate the prevailing conceptual and

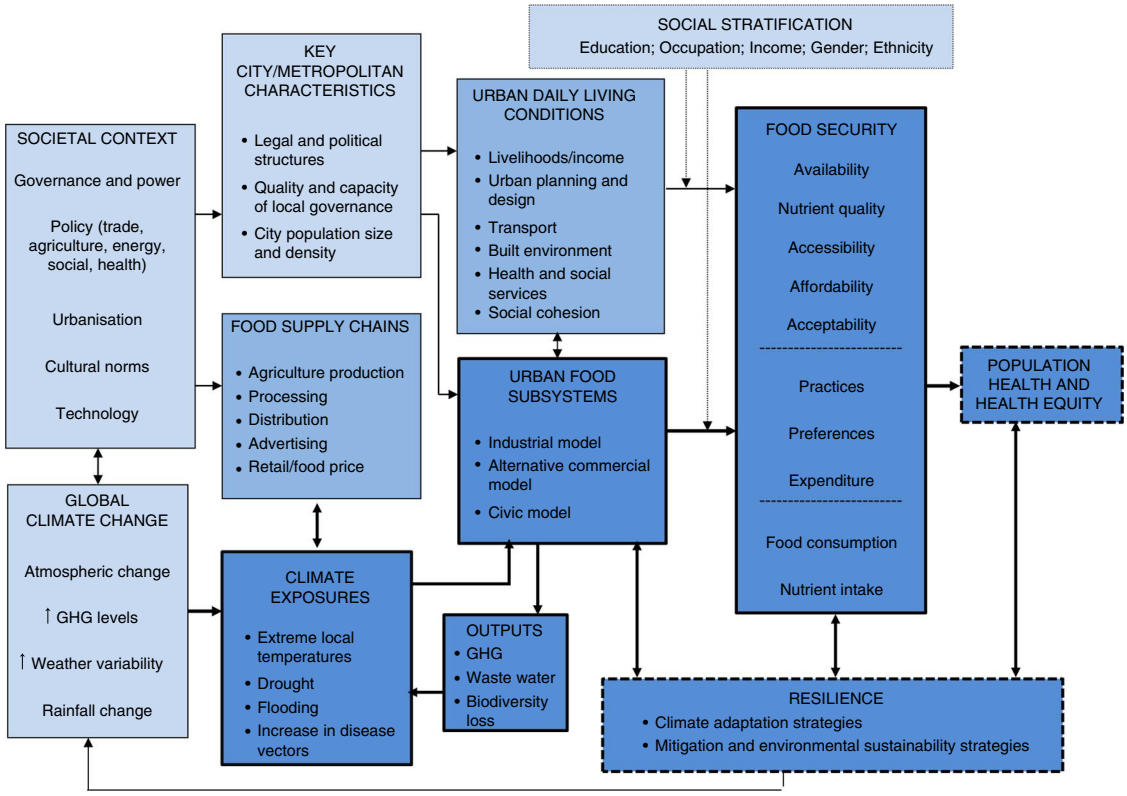

Fig. 2 (colour online) Interplay between climate change, cities, food security and population health (GHG, greenhouse gas)

fragmented arguments for food system change. To achieve this goal, the project comprised three interconnected but distinct domains of research on Sydney's food chain encompassing production, distribution and consumption, and focused on the following research questions.

1. Domain 1: Environmental footprint of food subsystems: how do they differ?
2. Domain 2: Sustainable and healthy food consumption: issues of availability, affordability and access from urban food subsystems.
3. Domain 3: Creating a demand for sustainable and health food consumption: citizens' views, practices, and access to healthy and sustainable foods.

Figure 2 provides a diagrammatic representation of the intersections between climate change, cities, food systems and population health and provides the context for these three domains.

The key research findings from these three domains form the foundation for the present paper. As the capstone to this research, the paper aims to synthesise these key findings and present a whole-of-systems perspective on Sydney's food system. The paper uses the higher-order results from the three research domains to provide the empirical evidence base for this whole-of-systems analysis. In illustrating the interconnected and interdependent nature of the food system, this whole-of-systems perspective allows our research to move beyond the siloed nature of previous research in the food, environment and health area. This is critical in enabling the identification of key points for intervention across the system as a whole identified in our discussion.

Location of study

The study was located in Greater Western Sydney (GWS) in the state of New South Wales, Australia. This region was selected as the primary geographic area of reference as it defines a political, social and economic area that demonstrates many issues regarding the problems of sourcing a healthy and sustainable diet for a large and growing urban population in a developed nation[3]. New South Wales has the largest proportion of urban dwellers in Australia, with more than 60 % of the 7 million urbanites living in Sydney, the State capital. GWS is characterised by high levels of social disadvantage[44]. Despite the fact that the Sydney Basin has fertile soils, agricultural land in the region has been declining steadily for years and GWS is heavily reliant on food produced elsewhere[45]. Currently, only four out of forty-one Local Government Areas in the region consider food production in local council legislation[46]. GWS is also likely to be adversely impacted over the long term by climatic changes that will produce conditions that are warmer and drier, with associated increases in evaporation and heat waves, further threatening regional food production[47].

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Main findings from the research project domains

The following sections presents the headline results from the three domains of the research project. These findings provide the empirical basis for the subsequent integrated analysis and discussion of Sydney's food system as a whole.

Domain 1: Environmental footprint of food subsystems: how do they differ?

The environmental impact of production is a key focus of current international research concerned with identifying ways to reduce greenhouse gas emissions and supporting adaptive capacity to address food security concerns[48]. Domain 1 of the project examined the environmental footprints of a selection of foods from different urban food production systems. Assessing the vulnerability and opportunities for mitigation in food subsystems can be done using life-cycle analysis (LCA)[49]. In the present study, LCA was performed on two food commodities (chicken meat and lettuce) produced from two food subsystems (industrial and civic).

For a detailed description of the study design and results, see Hall *et al.*[50]. In brief, the two food commodities chosen were important in dietary terms regarding quantity consumed and nutritional value, as well as significant production in Sydney by different food systems. The LCA undertaken were: (i) compare the environmental health impact of the production of 1 kg of chicken meat in the industrial subsystem and the civic system; and (ii) compare the environmental health impact of the production of 1 kg of lettuce in the industrial system and the civic system.

In both the chicken and lettuce LCA, the most environmentally influential stages of the supply chain were found to be the production and processing stages, with retail and food preparation/cooking having relatively little environmental impact.

Chicken

From the LCA it appears that industrial chicken is less CO_2 intensive than civic production, due to lower land use per chicken, shorter life spans (which means less feed is required per chicken compared with civic system) and less feed per chicken (feed is the key component of CO_2 emissions for chicken production).

Lettuce

The results of the LCA identified that civic production of lettuce is less environmentally intensive than industrial lettuce, with the main influence on carbon efficiency being the use of commercial fertiliser, cow manure and industrially produced seed.

Domain 2: Sustainable and healthy food consumption: issues of availability, affordability and access from urban food subsystems

The importance of integrating environmental considerations into people's food choices is now recognised as a significant component of both adaptation and mitigation policy responses concerned with sustainability, food security and health[51–60]. Adoption of sustainable diets among urban populations has at least two important benefits: (i) stresses on ecosystem services may be reduced, which in turn helps reduce food-related climate change impacts; and (ii) such a mantra helps foster the consumption of healthy and nutritious foods, which in turn fosters a reduction in chronic disease. There are, however, gaps in the evidence base concerning which type of food subsystem (industrial, alternative commercial and civic) best provides consumers with a healthy and sustainable diet (hereafter 'H&S diet') and the cost of the H&S diet from different food subsystems relative to a typical diet.

In Domain 2 of the project we first outlined what an H&S diet might contain based on three principles: (i) reducing overconsumption; (ii) reducing consumption of discretionary foods; and (iii) eating less animal-derived foods and more plant-based foods. Second, we assessed the availability, affordability and accessibility of an H&S diet across different food subsystems in GWS in five different socio-economic neighbourhoods, surveying eighty-two food provisioning outlets. For a detailed description of the study design and results, see Friel *et al.* and Barosh *et al.*[61,62].

Retail outlets and issues of availability and accessibility of a healthy and sustainable diet

The survey found the total number of food provisioning subsystems was higher in the more socio-economically disadvantaged study sites. However, availability of alternative food systems compared with industrialised outlets increased with the socio-economic status of the neighbourhood. There was a large discrepancy in the availability of food items between the food provisioning subsystems: overall, the availability of the typical and H&S diet food items was very limited in alternative and civic food provisioning systems. In each study site, the travel distance to each food outlet via a road network was outside the ideal, a maximum walking distance (500 m)[63]. Given the lack of walkability to food outlets in the study sites, accessibility by distance and car ownership were found to favour advantaged areas[64,65].

Affordability of a healthy and sustainable diet

The cost of the H&S diet was greater than the typical basket in all five socio-economic neighbourhoods, with the most disadvantaged neighbourhood having to spend relatively more (30 %) to purchase the healthy and sustainable basket. When analysed according to household income, households in the lowest income quintile would have to spend up to 48 % of their weekly income to purchase the healthy and sustainable basket, while households in the highest income quintile would have to spend significantly less of their weekly income (9 %).

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Domain 3: Creating a demand for sustainable and health food consumption: citizens' views, practices, and access to healthy and sustainable foods

Consumers are increasingly encouraged to become ecological citizens and much literature exists on alternative communities' transition to sustainable living[66]. Mainstream consumers are less understood in this regard, particularly the experience of people in socio-economically disadvantaged urban areas. The creation of climate-resilient urban food systems requires an H&S diet not to be considered only 'yuppie chow'[67]; rather it must be adopted by the mainstream population. In Domain 3 of the study, we undertook qualitative research in three different socio-economic areas of Sydney, with the aim of uncovering mainstream consumers' views towards sustainable and healthy diets. For a detailed description of the study design and results, see Dixon and Isaacs[68]. In brief, interviews were undertaken with households in a low, middle and high socio-economic status area in Western Sydney to investigate the food provisioning practices. Many participants indicated a discrepancy between the food practices they wished to practise, such as buying more Australian produce, and the reality of what actually occurred. This discrepancy was attributed at least in part to cost. Even in terms of the practices people would like to implement, however, the environment did not rate highly in the concerns of the majority and a low priority was accorded to the purchase of sustainably credentialed foods. How mainstream consumers construe nutritious (as fresh food, preserving family ties, entertainment and pleasure, rather than nutritionally recommended food groups) and local foods (Australian made) appears to be at odds with the definitions set out in official public health guidelines, by council food planners and the local food movement[68].

A whole-food-system approach to climate adaptation, resilient food systems and urban population health

Moving along the food chain, from production to distribution to consumption, the findings from this three-domain research project created a cumulative picture of the points of pressure and possibility to improve climate resilience equity and population health within the urban food chain. The key findings were as follows: (i) While it has been the focus of much work around the environmental sustainability of the food system, addressing the production sector alone will not create a more resilient urban food system. The results of our study affirm the significance of the production sector in terms of greenhouse gas output and therefore for reducing environmental impact. They do not indicate, however, that localised, alternative subsystems are necessarily more sustainable than the industrial production. Illustrating that there is not a particular mode or subsystem of production that is always more sustainable, our findings suggest it is not only how food is produced but also what types of food are produced, and in what volume, that needs to be considered for environmental sustainability. LCA also, critically, does not incorporate health or equity concerns and so cannot be relied upon as primary indicator of the resilience of urban food systems when incorporating these concerns. Such an objective requires a more comprehensive view of the food chain that includes the distribution and consumption sectors. (ii) It is important then to determine a diet that is both healthy and sustainable. It is also necessary for the consumer to be able to attain it. In this regard, the study findings illustrate the need to improve access, affordability and availability of H&S diet options in urban areas. This is a complex process, requiring an increase in the diversity of retail outlets across neighbourhoods, greater diversity of sustainable food items available within the outlets and consideration of the real cost of healthy and sustainable living. (iii) Finally, our research indicates that it is not enough to simply have healthy and sustainable options available to urban consumers in order to ensure healthy and sustainable consumption. The consumer desire and ability to take up the options in the context of other daily activities and needs are critical. It is therefore necessary to identify from a consumer perspective the key barriers to, and opportunities for, consumption of an H&S diet.

Our analysis of the GWS food system illustrates that issues of urban population health and sustainability cannot be addressed with a focus on just one sector or scale of the food system. The interrelationship and interconnectedness of the various sectors and subsystems indicates that they must all be engaged to improve outcomes across the food chain. In summary, the requirements for achieving a climate-resilient food system for population and environmental healthy are (at least) threefold: there must be healthy and environmentally sustainable food options produced, consumers must be able to easily attain these goods and they must also want to buy them.

In terms of the transferability of the study results, Sydney is a 'global' city. It has a similar food system to many other large industrialised countries such as North America or the UK. It is characterised by a dominant industrial subsystem with a concentration of food retail in supermarket chain stores served by long, global supply chains. It also features growing alternative food systems including civic and commercial alternatives. In this regard the conceptual framework on which our analysis is based (Figs 1 and 2), as well as the implications of our research findings, are transferable to other industrialised cities. Furthermore, the transferability of our findings is evidenced by the fact that the findings from each of the research domains are complementary and comparable to international evidence. In terms of the cost of an H&S diet as studied in Domain 2, for example, the capacity to afford

healthy and sustainable food products was tested across all social gradients. Such social gradients occur in other developed countries across the world[69,70], therefore our findings in this regard are transferrable and comparable for other similar cities.

Based on our analysis of the food system at different scales and in different sectors, the following actions, we believe, are necessary to achieve these goals and improve the resilience of urban food systems for population and environmental health.

1. Develop multiple food subsystems: beyond local v. *industrial*

There has been much emphasis on localisation of food production to increase resilience of urban food systems[12,71]. This has been supplemented by a view of the industrial system as problematic environmentally, ethically and health-wise[72]. Our study has found that the industrial system is efficient at producing two core dietary items (chicken and lettuce) and at least in the case of chicken, in a way that is less environmentally damaging than civic production. In terms of retail/distribution, the conventional outlets of large supermarket chains provided the greatest number of healthy and sustainable options, operating often in a vacuum of alternative retail outlet options.

Climate change is, however, likely to challenge many of the current efficiencies of the industrial system. Predictions suggest that as temperatures increase so will the requirement for inputs such as fertilisers, water and fuel to sustain production[73]. In distribution, there may be an even greater emphasis on energy-intensive cold chains and highly processed foods with a long shelf-life for food safety[74], with flow-on implications for food prices and the types of foods stocked by retailers and food vendors[74]. A critical step for climate adaptation is to increase resilience and reduce vulnerability by incorporating diversity and flexibility within systems[26]. Adaptive capacity combined with ongoing mitigation provides major protection against vulnerability. Development of multiple sustainable food subsystems is therefore a strategic mechanism to increase resilience.

Our findings suggest that the different food subsystems should be seen as complementary, rather than conflicting, in creating resilient urban food systems. While alternative and local food subsystems may have the capacity to provide new and potentially more environmentally sustainable options across all sectors of the food chain, our research illustrates that this potential has not yet been realised. To contribute to a more resilient urban food system, alternative systems of production, distribution and consumption need to be strengthened and improved in a number of ways (see Table 1).

2. Improve health, equity and environmental sustainability across all sectors of the food system

Our findings also indicate that production itself is not the only, or even the most, important sector in the food chain in creating a more environmentally resilient and healthy food system. All sectors of the food system must be addressed, and improved, to reach this goal, specific strategies for which are detailed in Table 1. In addition to addressing production, the retail, distribution and consumption aspects of the food chain must be improved as they are the conduit through which consumers can access what has been identified as a H&S diet. Equity is a key concern here, with the need to ensure that healthy and sustainable food items are not only available but also accessible and affordable across the different geographic and socio-economic communities that comprise the urban population.

In addition to reducing structural barriers, consumers themselves have a critical role to play in the transformation of the urban food system. The small but expanding body of literature on H&S diets focuses primarily on the impact of particular dietary items and the need to change consumption habits in relation to these food items[75,76]. The emphasis, therefore, is principally on individual consumer choices. The findings of our consumer research in Domain 3 support this conclusion to the extent that it affirmed the importance of consumer choice in moving towards an H&S diet. It is clear that unless consumers think it is sufficiently important to change their current shopping habits they will not move to an H&S diet.

Addressing the barriers identified by consumers to consumption of an H&S diet, such as equity concerns around cost and accessibility, cannot be left purely to the marketplace. Taking locally produced fresh food as an example, when left to market demand farmers' markets often struggle to survive in lower-income neighbourhoods[77,78]. People in higher socio-economic neighbourhoods have more discretionary income and so can more easily afford healthy and sustainable items such as farm fresh fruit and vegetables. In addition, among many people in middle to high income groups, purchasing local food has become a social more[79]. To shift the perception of healthy and sustainable food as the domain of wealthy, middle-class consumers and encourage greater consumption across the urban population requires addressing the systemic barriers around access, affordability and availability. This requires a comprehensive approach encompassing all sectors of government.

3. Whole-of-government approach

In Australia there is no government department for food. Instead responsibilities for different aspects of the food system sit with a wide range of departments[80]. Creating comprehensive food system change and encouraging the consumption of an H&S diet would require the engagement of departments as diverse as agriculture, health, the environment, climate change, trade, regional development, and community and family services. It would also require integrated action across the different levels of government in Australia – local, state and federal – as they all have responsibility for different aspects of the food system[81].

Table 1 Summary of key action areas and policy directions for a whole-of-food-system approach to creating climate-resilient urban food systems improving sustainability, equity and population health

Research domain	Action areas/strategies	Anticipated outcome
Environmental footprint of food subsystems	Support and strengthen multiple food production subsystems to maximise sustainability and security of the food system as a whole. Achieving this goal requires a range of actions from both policy makers and industry Policy makers: **1.** Continue supporting industrial chicken production as it is currently the most ecologically efficient mode of production **2.** Support the emergence of backyard chicken farming to increase the variety of food supply systems to urban inhabitants, with an emphasis on 'closed-loop operations' such as use of household food scraps and use of manure, and consideration of slaughtering at an earlier age so as to reduce demand for feed per kg of chicken meat, thereby reducing the environmental impact of production **3.** Facilitate the emergence of civic urban agriculture for lettuce due to its low ecological footprint **4.** Continue to support industrial lettuce production so as to maintain variety in the food subsystems available to people, and to support the access to vegetables of people with limited land access to grow their own **5.** Foster a transition to renewable energy to halt the continuation of electricity- and fossil fuel-oriented GHG emissions, thereby significantly reducing the greenhouse impact of operations in both systems Industry: **6.** Explore opportunities for transitioning to renewable energy to potentially reduce up to two-thirds of energy footprint **7.** Use cow manure and collect own seed in both settings in order to reduce the ecological impact **8.** Lobby for the transition to renewable energy to significantly reduce the ecological footprint, with the potential benefit of significant annual cost saving	Improved resilience of urban food systems through development and strengthening of multiple food subsystems Achieving environmentally best-practice production across all food subsystems, increasing environmental sustainability and strengthening food security Potential to reduce carbon footprint of vegetable production by two-thirds and producer electricity bill
Sustainable and healthy food consumption: issues of availability, affordability and access from urban food subsystems	Improve the affordability, accessibility and availability of H&S diet items across all geographic areas and SES. A range of specific strategies and actions by policy makers is required to achieve this goal: **1.** Policy makers concerned with health, nutrition and environmental sustainability are encouraged to use the H&S diet framework to support cross-sectoral food and health policy discussion and action in Australia **2.** Make sustainable food options more affordable. Subsidies could be provided to producers to ensure the cost of sustainable foods is not greater than non-sustainable options. Tax incentives are need to bring alternative commercial and civic production into low-income areas. The real cost of healthy and sustainable food consumption needs to be reflected in welfare levels and wages **3.** Ensure H&S diets are more readily available from the industrial food subsystem. Given the need to create diversity in food systems in order to lower the environmental impact, urban planning is needed that ensures the range of subsystems is available in all neighbourhoods regardless of SES **4.** If the presence of alternative outlets is to have an impact on food choices, the quality and quantity of foods available at those outlets needs to be improved **5.** Provide public and active transport options in lower SES areas that facilitate better access to healthy and sustainable foods	Achieve policy coherence across all levels and sectors of government to achieve desired goals Make the healthy and sustainable choice the easier choice by: **1.** Ensuring social equity in the process of adapting to climate change by providing healthy and sustainable food as an affordable option to all social groups **2.** Ensuring that a variety of food subsystems is available to all social groups **3.** Ensuring that healthy and sustainable food is accessible to all, and that car ownership does not dictate accessibility Reduced public health costs through improved population health Ensure that the future location and variety of food provisioning outlets is based on principles of equity and sustainability, in addition to the traditional economic goals

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Table 1 *Continued*

Research domain	Action areas/strategies	Anticipated outcome
	6. Support local communities, especially those of low SES, to build civic and alternative food subsystems **7.** As many items of the H&S diet were not found in existing specialty stores, especially in the lowest SES areas, policy makers are advised to include some degree of vendor education relating to healthy and sustainable dietary guidance, to support the sales of relevant foods beyond just the supermarket in existing outlets **8.** Support food production across all subsystems including urban agriculture and peri-urban commercial farms in national and state-level food and nutrition policies, in addition to industrial agriculture **9.** Policy makers and local authorities are encouraged to use the geospatial analysis developed in the present study as a visual to assist decisions on the planning of the location and type of food provisioning outlets	
Creating a demand for sustainable and health food consumption: citizens' views, practices and access to healthy and sustainable food	Encourage consumption of an H&S diet across all sectors of the urban community. Specific strategies for policy makers to adopt in achieving this goal include: **1.** Recognition of environmental sustainability as a key issue in national and state-level food and nutrition policies **2.** Increase awareness of healthy and sustainable food behaviours across the urban population through education campaigns and tools. This could include food labelling indicating environmental footprints of food items **3.** Identify key barriers to healthy and sustainable consumption at a national level, and develop policies to address these barriers and facilitate healthy and sustainable consumption	Increased understanding of what constitutes healthy and sustainable food consumption across the population Development of policies that support all households, particularly those of low and middle SES, to engage in healthy and sustainable food consumption

GHG, greenhouse gas; H&S diet, healthy and sustainable diet; SES, socio-economic status.

Rather than rely on one measure to create change, a whole-of-government approach would require a range of policy actions working together to achieve a common goal–policy coherence[80]. This suite of policies could include regulatory, information and/or market based options, as outlined in Table 1.

Conclusion

The present research has illustrated the need to move beyond a scales-and-sectors approach to one that embraces the whole food system, if climate-resilient and healthy urban food systems are to be achieved. While there are specific actions that can be undertaken in each sector of the food chain and at difference scales in the system, these need to be undertaken as part of a comprehensive agenda to address the food system as a whole.

In asserting the need for a whole-of-systems perspective, these findings bring into question the assumption that going 'local' and rejecting the industrial food system addresses many of the current environmental and health problems of the urban food system. In contrast, our research indicates that all food subsystems have benefits and limitations in achieving better food-related environmental and health outcomes for our cities.

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