

## Review Article

# Preferred ecosystem characteristics: their food and health relevance to China's rapid urbanisation

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For most of its history, China has supported a growing population through food systems which have been mutually inclusive of people and their locality. This trajectory has required adequate ecosystem maintenance or humanised reformulation and a high degree of recyclable nutrient flow. The 'tipping point' in habitat sustainability has come with the size and demographic structure of China's population to one that is ageing, with modernisation of its infrastructure and increased expectations of better livelihoods, standards of living and health. In order to meet these expectations, China has embarked on rapid urbanisation for upwards of 300 million people over the next 15-20 years and to do so taking account of the environmental limitations. The process will radically change rural as well as urban China and the systems which connect them. Chief among these will be ecosystems in number and type along with the food and health systems integral to them. To minimise ecological damage and optimise the benefits to people and place, describing, monitoring and managing the process will be paramount. The present paper is a situational analysis of health as it may be ecologically favoured or disordered (Ecosystem Health Disorders) and of the food systems on which the environment and health depend. An effort is made to enumerate the current situation in China in a way that might enable the optimisation of humanised ecosystems.

**Key Words:** ecosystem health disorders, urbanisation, rural, natural environment, food systems

## CHINA'S RAPID URBANISATION: FOOD AND HEALTH SYSTEM RISKS

### *Early food systems*

China developed cities like Chang-an, now Xian, early in its history. Once the world's biggest city, its empire developed along the Yellow river, flowing from the Himalayan glaciers, north adjacent to the Silk road, and out into the Yellow sea (huáng hǎi) of the northern Pacific Ocean, trading food, tea, fabric and precious objects. China's food systems were and are still dominantly rural, and there were numerous cultural groups or indigenous people with unique food ways. While many have been lost or subsumed into the increasingly large and dominant Han civilisation, the indigenous food culture which remain have much to offer a rapidly urbanising country in terms of its future food security and health.<sup>1</sup> This prospect is supported by the United Nations Systems report in its International Fund for Agricultural Development program on indigenous food systems in regard to dietary diversity and resilience:<sup>2</sup>

"...indigenous peoples' can have a role in feeding the growing global population through their sustainable ways of preserving ecosystems and therefore conserving the world's biodiversity. However, they still need recognition of their rights, governments willing to work together with them in partnership, access to technologies, and a policy balance between the growing pressure of globalization

and the preservation of indigenous culture and food systems".

One of the most usual characteristics of indigenous food culture is its diversity. This is now known to confer more favourable health outcomes, well-being, functionality and longevity.<sup>3,4</sup> Although this may not have been so obvious when other factors compromised health, it is becoming more apparent that this association between food and health is at risk because of the rapid loss of food plant diversity.<sup>5</sup> For environmental and health reasons, therefore, this loss of diversity during the urbanisation process must somehow be minimised.

### *Urbanisation*

Urbanisation occurs when increasing numbers of people live in close proximity and share the resources required to support households, and adopt a common set of rules and

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Manuscript received 08 August 2015. Initial review completed 18 October 2015. Revision accepted 22 October 2015.

doi: 10.6133/apjcn.2015.24.4.29

beliefs which allow relatively harmonious dealings with each other. In so doing, the basic needs of life, including water and food, clothing, shelter, hygiene, social care in time of illness, education and transport have to be met in an identifiable geographical location, referred to as a village, community, town or city, depending on its relative size, population or power. The relationship between a settlement and the natural world usually changes, generally becoming more tenuous and replaced by more anthropocentric facilities. The link with the natural world becomes dependent on rural proximity, access routes by land or sea, and the extent to which that natural world can be replicated within the urban setting. If, as we understand, we are ecologically-dependent creatures, then our well-being and health are inevitably challenged,<sup>6</sup> and the question is how far this can go with advantage and without irretrievable impairment. Thus there is an imperative to identify and recognise ecosystem health disorders (EHDs) and their food system dependency at various stages of urbanisation, and to develop strategies to alleviate them.

With China proposing to integrate a further 70 percent of its rural population into urban areas by 2025,<sup>7-10</sup> direct and indirect ecosystem changes and livelihoods dependent on various phases of the food system will significantly alter people's food intake and health.<sup>11</sup> For example, displacement from food-producing lands, with resulting loss of agricultural self-sufficiency, may force urbanites to rely on a commercial food supply. As food demand increases, along with food prices, there may be greater reliance on cheap staple foods which cannot supply a nutritious diet.

We show in this report that health and well-being is intimately related to the ecosystems in which we live, recreate and work, so that their change and loss must be understood and compensated by no-less health-functional environs if health gains are not to be sacrificed. We argue that much is now known about ecosystem characteristics which confer health advantage. These can be captured by way of indices, measured at the beginning of rapid urbanisation and regularly monitored thereafter. Gibson et al have developed an urban food system index (U-FSI) which could influence food system outcomes and promote health and well-being.<sup>12</sup>

The rapid urbanisation initiative will not happen in isolation from a number of other dynamics. The first dynamic is that China is warming more rapidly than many other parts of the world, and there will be many concomitant consequences of this climate change. Marking the arrival of the World Meteorological Day on March 23, 2015, Zheng Guoguang from the Chinese Meteorological Administration spoke about "The scientific understanding of...climate security",<sup>13</sup> and warned that:

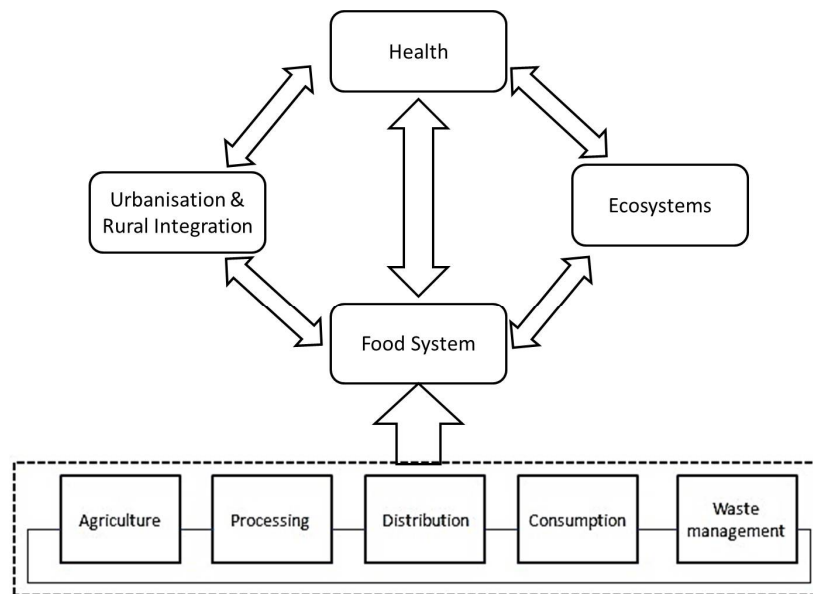
Climate change in China could increase the occurrence of extreme weather events, reduce atmospheric environmental capacity, reduce yields of wheat, corn and soybean, and increase soil erosion, ecological degradation and species migration. Higher than global average temperature rises also pose serious threats to major infrastructure projects, including the Qinghai-Tibet railway and the Three Gorges reservoir'.

The second dynamic is that the availability of arable land is diminishing as a consequence of residential and commercial development, construction of roads and railways, heavy metal and other industrial contamination, loss of soil fertility, conversion from food to biofuel production and reduced availability and quality of surface and ground water for irrigation.

A third dynamic is reduced availability of safe water needed for basic nutrition and hygiene. There is evidence that the Tibetan plateau is warming faster than expected due to the loss of reflectivity of snow and glaciers.<sup>14</sup> The precipitation required for water flows in the seven great rivers of Asia (Yellow river, Yangtze, Mekong, Indus, Brahmaputra, Ganges and Irrawaddy) is also beginning to fail and within the next few decades is expected to lead to major water shortages for some 3.2 billion Asians. At the same time, ground water is disappearing from Northern China. It is unlikely that alternative precipitation will compensate for the shortfalls, nor can the three massive water diversion projects in China fully address the incipient problem. Where there is no water, there is no food and policies to integrate urban agriculture into cities to increase food security have created resource competition between the urban and rural sectors, especially for water and nutrients.<sup>15</sup> It is critical that accelerated urbanisation does not compound this water problem and that the locations of new and growing cities are serviceable with the diminishing water reserves.

The fourth dynamic is lack of efficiency in the current food and water systems, both for inputs to consumption and outputs (waste). While consumerism is regarded by many economists as the logical next phase of China's development, there is an increased realisation that improved quality of life and health is not dependent on it, and may be compromised by it.<sup>16-19</sup> As a result, China is now encouraging frugality (节省 *jiéshěng*) as a national policy. As far as food is concerned, it is estimated that about 85 million people remain below the poverty line in China and often lack sufficient food, yet the amount of food wasted annually nationwide would be sufficient to feed 200 million people.<sup>20</sup> Food and other waste programs are increasingly in evidence in China, although there is much more that can be done. For example, concerted community-based programs linked to fertiliser and animal feed requirements in Taipei and its environs (operational waste management for about six million people) has reduced the need for incineration and landfill by more than 80% in just 10 years.<sup>21</sup> If this achievement could be replicated in the large mainland cities, the ecological benefits would be massive.

We should not necessarily be daunted by the prospect of relocating 300 million people from rural to urban settings (to join the existing 650 million or more already urbanised) in a relatively short period if it is accomplished methodically and with attention to ecological needs. In fact Thebo et al reported that, even now, some 60% of farm needs are met in urban settings.<sup>15</sup> However, it is not widely appreciated that family farming offers a history or opportunities for ecological integrity, production efficiency and livelihoods not equalled by agribusiness, to which deserted family farms may be subject in the name of increased efficiency.<sup>22</sup>



**Figure 1.** Ecosystem optimisation with urbanisation for food systems and health.

The science and technology of urbanisation must endeavour not only to drive and pace this human and planetary change, but to identify and manage its ecological (especially food system) and related health consequences.<sup>23</sup>

### FOOD SYSTEMS

A system is an assemblage of parts or things which form a unitary whole. These parts and their functioning, including all the required inputs and generated outputs such as “food” or “health”, can then influence one another within the whole and can provide both risks and benefits to consumers who depend on the system output. The term “food system”, which is frequently used in discussions about nutrition, food, health, community economic development and agriculture, includes all processes involved in feeding us: growing, harvesting, processing, packaging, transporting, marketing, consuming and disposing of food and food packages. Food systems comprise a significant part of ecosystems for the creatures in them. Here we are interested in how those ecosystems behave when people are part of them and, in particular, how they are additionally challenged through urbanisation (Figure 1).

Food systems should produce outcomes which underpin food security from which human health is partly determined. Food security, as defined by the World Health Organisation (WHO) as including both physical and economic access to food that meets people's dietary needs as well as their food preferences, is built on three pillars:

1. Food availability: affordable, adequate quantities of safe, quality and nutritious food available on a consistent basis.
2. Food access: having sufficient and sustainable resources to obtain appropriate foods for a nutritious diet; and
3. Food utilisation: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

This definition of food security is quite broad, so if these components of food security are not met it is very

likely that health problems will occur. However, food security discussions often fail to include the ecosystem element and health dimension which are both equally intrinsic to food security.<sup>6</sup> Food and human health are not just about eating food but also producing food. The way we produce our food can change ecosystems and climate and have characteristics which lead to ill health. Food production contributes to food availability by ensuring we have sufficient, safe, and healthy food, including food of acceptable nutritional quality.

### *Peri-urban and urban food systems*

All the way through food systems there are opportunities to favourably or unfavourably alter health. Today's food systems are diverse and complex, involving everything from subsistence farming to multinational food companies.<sup>24</sup> Peri-urban food systems overlap with rural and urban food systems, making it difficult to distinguish where rural areas end and urban areas begin. Food systems which started as individual rural systems have turned into urban environments as a continuum of food systems and proliferate as peri-urban environments on the surrounding boundaries of cities. In terms of access to food, the most significant difference between urban and rural areas is that people in rural areas can often produce their own food and rely on agriculture as their source of livelihood, while people in urban areas are more dependent on food purchases. However, although peri-urban producers have proximity to cities they do not necessarily have market access to sell their produce there. People do not see urban agriculture as integral to food systems, yet while rural agriculture grows staple food products, urban and peri-urban agriculture account for more fresh produce. Peri-urban and urban agricultural areas provide potential to recycle urban waste products, increase direct access to fresh vegetables, fruit and meat through a shorter food supply chain, increase consumption of fruits and vegetables and improve food safety.<sup>25</sup>

## HEALTH CONSEQUENCES OF RAPID URBANISATION

While the logistic, ecological (such as pollution control and provision of pollinator refuges for bees and insects) and food availability features of urban farming are generally advantageous, it brings about its own health related problems and risks. Table 1 sets out a typography of how human health may be ecologically favoured or disordered by EHD. The risk of food contamination from local industry and vehicular traffic was perhaps greater when gasoline was leaded, yet there remain problems with petrochemical particulates, plastic residues and other contaminants.<sup>26</sup> Chemical contaminants can become elevated in urban centres and peri-urban environments.<sup>27</sup> Water may contain endocrine disrupting chemicals, antibiotics, hormones and nutrients,<sup>28,29</sup> and soils and food stuffs can be elevated in heavy metals and nutrients from atmospheric deposition or irrigation with reclaimed water.<sup>30</sup>

The integration of farming in urban settlements may also increase the risk of inter-species transmissible disease (microbial and zoonotic) whether intermediate hosts are insects, rodents, avian species, mammals or livestock.<sup>31</sup> These risks may have quite intimate food and health system associations. For example, selenium (an essential trace element) may be limited geologically, and deficient in soil, poultry and humans; in this setting, more pathogenic viral transformation can occur, as with influenza.<sup>32</sup> This was a problem in Northeast China and Sichuan province until recognised and prevented in an ecological way. Other examples include Nipah virus, porcine and human encephalopathy in Malaysia, EBV virus and also nasopharyngeal cancer, commonly cause by fermented fish consumption in peoples who live in or come from the Pearl River delta in Guangdong province, China.<sup>33</sup> Table 2 develops insights into the environmental risks of urbanisation, providing situational analysis examples of EHDs that result from sub-optimal ecosystems, contributing to health outcomes.

The risks can be taken as difficulties, which may be minimised without precluding urban farming. Indeed, the increased biomass and diversity resulting from such farming may, in itself, make the contamination more tolerable, although this is not an argument for neglect. It typifies how nutritionally-related health problems may reflect widespread ecological disturbance, not fully remediable or preventable without ecologically-sensitive strategies. At the same time, this appreciation can inform how urbanisation might be inclusive of food systems.

Our health is profoundly environmentally-linked because we are ecological creatures. These linkages result from the indeterminate boundaries between ourselves and the environment, including our diurnal and seasonal rhythms, sensory connectedness, movement and perturbation of our surroundings, food and water needs, hormonal regulatory system, hygiene and excretory functions, communication methods and much more besides.<sup>34</sup>

## ECOSYSTEMS, ENVIRONMENT, HEALTH AND RELATED FOOD RISKS WITHIN URBAN CHINA

Most ecosystems are now inhabited by humans, and the few that are not are usually recognised as wilderness, sanctuaries or heritage areas of great value to global ecol-

ogy and sustainable living. Below we have set out a wide spectrum of interconnected information about the planet's ecosystems as inhabited by humans. These may perform not only to present human advantage, but also reflect the ecological characteristics required for sustainable health patterns. Part of the requirement to do so relates to the ecology of our food system for which examples are given in Table 3. With the asymptotic increase in human population size over the last hundred or so years, has come the pressure to settle and move into cities. Rapid urbanisation is now one of the major challenges to food security and human health, due to resulting environmental degradation. Tables 1-4 inform how we might record, evaluate, predict and remedy any problems defined.

### *Preferred inhabited ecosystem characteristics*

In order to develop a framework for evaluation of urban ecosystems and how they might alter health patterns and their food system contributors, we developed a matrix based on 14 ecosystem characteristics. These are:

1. Living and working where there are compatible geographical features
2. Non-extreme climate or its change and infrequent natural disasters
3. Extensive biodiversity
4. People able to function as ecological creatures
5. Adequate and safe food, water and air systems, including high levels of hygiene
6. Renewable and relevant energy systems
7. Intergenerational & life-course (conception to later life) compatibility
8. Gender socio-biology operative and equitable, non-discriminatory ecosystem access and service provision
9. Available and sustainable livelihoods as the primary economic platform
10. Recreational and socialisation options which are conservationist and healthy
11. Ecosystem resilience which allows for natural challenges, unexceptional human behaviour challenge and provides for population vulnerability
12. Accommodates practical and sustainable personal and collective transport
13. Assimilates interpersonal communication and discourse without undue ecosystem loss and which is conservationist
14. Involves governance directed towards ecological awareness and insight, participatory conduct and a culture of sustainability

### *Urban ecosystem health disorders*

In Table 1 we have set out a typography of how ecosystem health disorders may affect human health.

### *Situational analysis: examples of EHDs*

Table 2 categorises the environmental risks of urbanisation, providing situational analysis of some EHDs that result from sub-optimal ecosystems, contributing to health outcomes.

### *Food system dependency*

Table 3 details the related food system risks that confront rapid urbanisation in China.

**Table 1.** Urban ecosystem health circumstances and their disorders

<b>Living and working where there are compatible geographical features</b>	<b>Non-extreme climate or its change; infrequent natural disasters</b>	<b>Extensive biodiversity</b>
<ul style="list-style-type: none"> <li>• Sunlight deprivation</li> <li>• Culture-geographic dissonance;</li> <li>• Temperature intolerance; thirst failure &amp; dehydration;</li> <li>• Iodine deficiency disorders;</li> <li>• Fresh food deprivation;</li> <li>• Fossil fuel usage syndromes;</li> <li>• Defective occupational environs or food service problem</li> <li>• Sleep disturbance (duration &amp; quality)</li> <li>• Sound &amp; light contamination</li> </ul>	<ul style="list-style-type: none"> <li>• Atmospheric disturbance disorders</li> <li>• Terrestrial, landscape &amp; landholder rights difficulties with psychosocial and biomedical disorders</li> <li>• Sea, lakes, rivers, estuaries, aquifers and coastline access and sustainability problems</li> </ul>	<ul style="list-style-type: none"> <li>• Compromised biodiversity</li> <li>• Limited socialisation and ecological awareness</li> <li>• Environmental homeostatic failure</li> <li>• Ecosystem service compromise</li> </ul>
<b>People able to function as ecological creatures</b>	<b>Food, water and air systems which are adequate and safe; hygiene</b>	<b>Renewable and relevant energy systems</b>
<ul style="list-style-type: none"> <li>• Disturbed ecological activities and functions (e.g. environmental engagement by walking, time spent in natural surroundings, gardening)</li> <li>• Sensory deprivation - Less keen recognition or processing of sensory inputs (sight, sound, smell, touch)</li> <li>• Nutrition-dependent body defence including inflammatory and immune mechanisms challenged</li> <li>• Microbiomic integrity breached</li> </ul>	<ul style="list-style-type: none"> <li>• Limited access to safe and dependable water sources.</li> <li>• Food insecure with regard to availability, nutritional quality, safety or acceptability</li> <li>• Body defence mechanism weakened by ecological stressors (e.g. petrochemical pollution)</li> <li>• Microbiomic integrity breached</li> </ul>	<ul style="list-style-type: none"> <li>• Energy dysequilibrium manifest by increased risk of body compositional (obesity, sarcopenia), metabolic (e.g. diabetes), cardiovascular, neoplastic and neuro-degenerative disease</li> <li>• Dependence on non-renewable energy</li> <li>• Environments not conducive to physical activity</li> <li>• Inadequate appetite control</li> </ul>
<b>Intergenerational and life-course (conception to later life) compatibility</b>	<b>Gender socio-biology operative and equitable, non-discriminatory ecosystem access and service provision</b>	<b>Available and sustainable livelihoods as the primary economic platform</b>
<ul style="list-style-type: none"> <li>• Breast feeding, sensory inputs, hygienic facilities</li> <li>• Senescence (compromised microbiomic and eukaryotic cell turnover)</li> </ul>	<ul style="list-style-type: none"> <li>• Limited educational opportunity for women as a contributor to ecological degradation and loss and, therefore, health (e.g. gardens, subsistence agriculture, household economy and child health)</li> <li>• Erroneous interrelation of health relevance of body fatness in women</li> <li>• Inadequate input by women into household budgets and food choice</li> </ul>	<ul style="list-style-type: none"> <li>• Unsatisfactory personal security</li> <li>• Incompatibility with biorhythms</li> <li>• Inefficient use of environmental resources</li> </ul>

**Table 1.** Urban ecosystem health circumstances and their disorders (cont.)

<p><b>Recreational and Socialisation options which are conservationist and healthful</b></p> <ul style="list-style-type: none"> <li>• Misunderstanding of what constitutes the ‘good life’, its contributors and attention to non-monetary ends in themselves.<sup>35</sup></li> <li>• Insufficient participatory physical or social activities (educational, clubs, religious).</li> <li>• Lack of connectedness to the natural world and to others</li> <li>• Living in a virtual world</li> </ul>	<p><b>Ecosystem resilience which allows for natural challenge, unexceptional human behaviour challenge and provides for population vulnerability</b></p> <ul style="list-style-type: none"> <li>• Personal insecurity</li> <li>• Conflict proneness</li> </ul>	<p><b>Accommodates practical and sustainable personal and collective transport</b></p> <ul style="list-style-type: none"> <li>• Problems with mobility &amp; socialisation</li> <li>• Limited locomotion (walking, cycling, boating, public transport)</li> <li>• Ecological awareness, sensory input and other signalling processes, sunlight</li> </ul>
<p><b>Assimilates interpersonal communication and discourse without undue ecosystem loss and which is conservationist</b></p> <ul style="list-style-type: none"> <li>• Anthropocentric rather than ecologically-inclusive</li> <li>• Inadequate social networks</li> <li>• Limited information, misinformation, information overload</li> <li>• Discourse deficient in problem-solving orientation</li> </ul>	<p><b>Involves governance directed towards ecological awareness and insight, participatory conduct and a sustainability culture</b></p> <ul style="list-style-type: none"> <li>• Adequacy and integration of overall management of the food and health systems at the international, national and local levels</li> </ul>	

**Table 2.** Situational analysis: examples of ecosystem health disorders

<p><b>Living and working where there are compatible geographical features</b></p> <ul style="list-style-type: none"> <li>• Sunlight exposure limited by latitude, season or smog;</li> <li>• Restricted proximity to arable land, fertiliser or water source; poor soil health;</li> <li>• Non-availability of renewable energy;</li> <li>• Extensive pollution of arable land and waterways</li> </ul>	<p><b>Non-extreme climate or its change; infrequent natural disasters</b></p> <p>Health consequences of:</p> <ul style="list-style-type: none"> <li>• Increasing temperatures, drought</li> <li>• Earthquakes, volcanic, rising sea levels,</li> <li>• Typhoons/cyclones/hurricanes/tornados</li> <li>• Loss of ozone layer with increased risk of skin cancer and sun avoidance</li> <li>• Risk can be ameliorated with planning.<sup>36</sup></li> </ul>
<p><b>Extensive biodiversity</b></p> <ul style="list-style-type: none"> <li>• The appreciation of our dependency on and the limits to the sustainability and renewability of 'ecosystem services' has been recent</li> <li>• These service deliverables include the air we breathe, food and water, materials for shelter and fibre for textiles and clothes</li> <li>• Biodiversity allows for the operation of health protective mechanisms to operate inter alia by way of micro- and macro-climate, natural hygiene, biological buffers for control of pathogens.</li> <li>• Biodiversity is also more conducive to constructive social discourse than is monotony and harsh conditions.</li> </ul>	<p><b>People can function as ecological creatures</b></p> <ul style="list-style-type: none"> <li>• We are incomplete beings without intimate connection with our environment; urbanisation challenges this connectedness since the animate and inanimate features with which we have evolved are drastically reduced and it is uncertain how replaceable they are, or how much ecosystem loss we can tolerate, remain in health and survive</li> <li>• Acquired at birth and maintained through our lifetime, the microbiome forms an intimate and essential part of our being, the gut, skin, respiratory system, breast and reproductive tract. It is involved in many vital biological processes such as nutrition and metabolism, the immune system, cell differentiation and even mental health. Its malfunction may contribute to both transmissible and non-communicable chronic disease.</li> <li>• Our ability to inhabit and migrate to a vast array of ecosystems, is testimony to our resilience, but this quality is difficult to measure and, therefore, to protect.</li> </ul>
<p><b>Food, water and air systems which are adequate and safe; hygiene</b></p> <ul style="list-style-type: none"> <li>• Proximity to food production and knowledge of where and how it is grown as well as processing, packaging, storage and transport methods is a food security advantage.</li> <li>• Sanitation and hygiene are perennial requisites for water safety in food production, processing and consumption. The availability of potable water in industrialised communities can also be problematic.</li> <li>• Greater food system efficiency can improve food security. On account of generally high levels of food wastage, tackling it can produce substantial gains in food security. This can apply at all points in the food chain. For consumers this includes purchase, preparation, cooking and left-overs and disposal into a recycling program for animal feed or fertiliser.</li> <li>• Our defence against transmissible disease can be enhanced by the food we eat and modest exercise.</li> <li>• Healthy commensal micro-organisms at our apparent interface with the environment provide a defensive microbiome.</li> <li>• Clean air for sunlight exposure, respiratory health and avoidance of toxic microparticulate assimilation.</li> </ul>	<p><b>Renewable and relevant energy systems</b></p> <ul style="list-style-type: none"> <li>• Energy homeostasis is observed in environments which encourage physical activity in the course of daily routines, which are minimally sedentary and which enable eating patterns where appetite accuracy is not disrupted.</li> <li>• Levels and type of physical activity which are moderate, reach 30-40 minutes daily and involve the use of strength (against resistance) decrease most health risks in men and women.<sup>37</sup></li> <li>• Sources of fuel (as food and for infrastructural needs).</li> </ul>
<p><b>Intergenerational and life-course (conception to later life) compatibility</b></p> <ul style="list-style-type: none"> <li>• Our microbiome is first acquired during vaginal delivery from our mother- this does not obtain with Caesarean section (often more common with urbanisation).</li> <li>• Avoidance of environmental contaminants and substance abuse by both parents have long-term intergenerational health significance.</li> <li>• The behaviours, including food habits, social and physical activities (especially walking, dance and tai chi) and substance abuse (smoking, alcohol consumption) of parents and grandparents influence those of children and grandchildren.<sup>38</sup></li> </ul>	<p><b>Gender socio-biology operative and equitable, non-discriminatory ecosystem access and service provision</b></p> <ul style="list-style-type: none"> <li>• Women's life-shortening vulnerability was principally attributed to obstetric mortality, with inadequate access to health services- much of this remains a problem in rural and socio-economically disadvantaged communities. Urbanisation may partially obviate this problem.</li> <li>• Without the obstetric problem, women generally live longer than men, which may point to peculiar risks in male biology or behaviour e.g. risk-taking, substance abuse with tobacco and alcohol which may depend on socio-environmental factors.</li> </ul>

**Table 2.** Situational analysis: examples of ecosystem health disorders (cont.)

<p><b>Available and sustainable livelihoods as the primary economic platform</b></p> <ul style="list-style-type: none"> <li>• The basic needs of people in various ecosystems must be serviced.</li> <li>• It would be possible to shift the employment/unemployment paradigm to a livelihood paradigm so avoiding the stigma of unemployment and the tension that is created in the 'master-servant' arrangement which employment often constitutes. This approach is still compatible with entrepreneurship where incentives are diverse, environmentally and societally-sensitive and sustainable. This approach would be consistent with United Nations Development Programme (UNDP) measures of development in both rural and urban settings<sup>39</sup> and the UN System.<sup>40,41</sup></li> <li>• Frequent recreational activities and work opportunities should be available within the surrounding environment to encourage social networking and opportunities for livelihoods.</li> <li>• Safe environments are required for journeys to work and for recreational or social activities</li> <li>• Livelihood need to be compatible with rest and sleep.</li> </ul>	<p><b>Gender socio-biology operative and equitable, non-discriminatory ecosystem access and service provision</b></p> <ul style="list-style-type: none"> <li>• Education of women consistently and favourably affects community development – and may even be essential for it. Evidence points to women, given the opportunity, to make better use of education and resources for sustainable environments, preventive health and health care.</li> <li>• Body composition differences between men and women reflect reproductive function (e.g. relatively more body fat in breast tissue for lactation and around the hips as energy storage for pregnancy and lactation. Bone is also a critical nutrient store for elements like calcium and zinc during pregnancy).</li> </ul>
<p><b>Ecosystem resilience which allows for natural challenge, unexceptional human behaviour challenge and provides for population vulnerability</b></p> <ul style="list-style-type: none"> <li>• People solving problems together and the need for participatory approaches.<sup>42</sup></li> <li>• Feeling safe and secure with our surroundings through the use of street lighting and transportation.</li> <li>• Access to a safe environment to allow for daily exercise.</li> <li>• Well-developed communication skills with a narrative that is ecologically-inclusive.</li> </ul>	<p><b>Recreational and Socialisation options which are conservationist and healthful</b></p> <ul style="list-style-type: none"> <li>• Movement in and engagement with the natural world allows a wide range of sensory inputs and perturbations which generate biological responses basic to robust and vigorous health. Olfaction for one can accommodate thousands of molecular-receptor signals, in combinations which have been estimated to approach a trillion. The memory of these inputs and associated inputs is associated with cognitive function. Auditory, visual tactile and taste and other inputs provide a rich environmental connectedness. When lost, we lose much of what we are.<sup>34</sup></li> <li>• Social activity is documented as a positive survival indicator.<sup>37</sup></li> <li>• Combined environmental and social inputs and responses amount to a level of ecological sophistication difficult to maintain in an urbanising concrete, petrochemical and plastic world. Moreover, the production and disposal of concrete and plastic are biological stressors to which we have only recently been subject. Their miniscule by-products and remnants are now distributed globally and are likely to explain much of the changing patterns of human and environmental health.</li> </ul>
<p><b>Assimilates interpersonal communication and discourse without undue ecosystem loss and which is conservationist</b></p> <ul style="list-style-type: none"> <li>• Communication can promote an environmental and health consciousness, literacy and critique conducive to ecosystem maintenance and less related health disorder.</li> </ul>	<p><b>Accommodates practical and sustainable personal and collective transport</b></p> <ul style="list-style-type: none"> <li>• Mobility encourages the development of social networks which are associated with more favourable health outcomes.</li> <li>• The forms of transport available to us can be conducive to our levels of daily physical activity, such as walking to public transport, climbing the stairs, carrying our purchases, cycling. Reliance on cars can play a major role in the pathogenesis of obesity in several ways.<sup>6</sup></li> <li>• Transmission and geographic distribution of pathogens and invasive vectors is increasing through global air and shipping transport.</li> </ul> <p><b>Involves governance directed towards ecological awareness and insight, participatory conduct and a sustainability culture</b></p> <ul style="list-style-type: none"> <li>• Good governance is recognised as a major factor in food security.<sup>43</sup> At its best, it is both comprehensive and attentive to the needs of vulnerable groups, evidence-based and highly consultative.</li> <li>• To reduce the loss and ensure the maintenance and rehabilitation of as many ecosystems as possible through collaborative programs is a major organisational responsibility.</li> <li>• Climate change is accelerating as we mount efforts to alleviate poverty and provide livelihoods for all, in part by environmentally sound urbanisation.</li> <li>• Time is running out to control environmental degradation and abort the health deterioration which will otherwise follow.</li> <li>• Ecological governance must now be characterised by a sense of urgency and an understanding that we are ecological creatures whose health is irrevocably linked to our environment.</li> </ul>



**Table 3.** Food system dependency

<p><b>Living and working where there are compatible geographical features</b></p> <ul style="list-style-type: none"> <li>a) Inadequate sunlight predisposes to vitamin D deficiency which is difficult to overcome by food alone and supplements may not be effective;</li> <li>b) The demographic shift to ageing populations means a greater prevalence of impaired thirst and susceptibility to extreme weather like heat waves;</li> <li>c) Regional problems with soil nutrients like phosphorus, iodine and selenium, which may not be manageable by nutrient recycling or with fertiliser (especially as the global phosphate reserves become scarce, less safe and more costly);</li> <li>d) Atmospheric pollution with contaminated crops from vehicular exhaust, fossil fuel usage and industrial effluents.</li> <li>e) Sleep disturbance can affect energy balance through food choice and activity patterns.</li> </ul>	<p><b>Non-extreme climate or its change; infrequent natural disasters</b></p> <ul style="list-style-type: none"> <li>a) Dietary and fluid intake patterns which are diverse and reduce the potential impact of climate change on human biology.</li> <li>b) Food shortage consequent on Tibetan-plateau – sourced river losses<sup>17</sup> (Yellow river, Yangtze, Red River, Mekong).</li> <li>c) Food &amp; water readiness.<sup>44</sup></li> <li>d) Fish stocks down in Taiwan straits with warming of ‘shallow’ water.</li> </ul>
<p><b>Extensive biodiversity</b></p> <ul style="list-style-type: none"> <li>a) Our biology relies on a diverse and nutritious diet in order for us to have optimal health.<sup>45</sup> In this way, we are less susceptible to extraneous insults of diverse kinds through cognitive, homeostatic and immune function inter-alia.</li> <li>b) In turn, our diet depends on biodiversity, which is characteristic of a resilient ecosystem. Dwindling diversity causes less resilience.</li> <li>c) Econutrition is the way in which this understanding has been conceptualised.<sup>45</sup></li> </ul>	<p><b>People can function as ecological creatures</b></p> <ul style="list-style-type: none"> <li>a) Even though our food systems appear external to us, their operation at every stage has a bearing on our biology and health, from production to consumption.</li> </ul>
<p><b>Food, water and air systems which are adequate and safe; hygiene</b></p> <ul style="list-style-type: none"> <li>a) A risk management plan for a food and water secure urban environment will take into account the soil, water, livestock, equipment, processes, transport and people with whom they have been in contact. HACCP (Hazard and Critical Control Point) plans now assist these evaluations, but may not be sufficiently food system sensitive.</li> </ul>	<p><b>Renewable and relevant energy systems</b></p> <ul style="list-style-type: none"> <li>a) Physical exertion in the course of food acquisition (shopping), preparation (cooking) adds to health maintenance.<sup>46,47</sup></li> <li>b) Food science &amp; technology has succeeded in the design of foods which do not elicit an appropriate appetite response and sense of satiety so contributing to the epidemic energy dysequilibrium disorders.<sup>48</sup></li> <li>c) The quest for convenience has given rise to more and more foods being eaten which are devoid of physical structure and increasingly liquid (e.g. breakfast, sugary drinks fruit juice instead of fruit—important contributors to energy dysequilibrium).</li> </ul>
<p><b>Intergenerational and life-course (conception to later life) compatibility</b></p> <ul style="list-style-type: none"> <li>a) A safe and varied diet before, during pregnancy and lactation is essential for fetal and infant development, child health and health in later life.</li> <li>b) Some traditional food beliefs may have advantage for successful pregnancy – lactogogic foods like torbungan in North Sumatra which improve lactation are an example.<sup>49</sup> For these benefits agricultural production and the knowledge and practice of recipes and food preparation are required and play a central role in health and well-being.</li> </ul>	<p><b>Gender socio-biology operative and equitable, non-discriminatory ecosystem access and service provision</b></p> <ul style="list-style-type: none"> <li>a) Women are generally more food and health literate than men when given the chance.</li> <li>b) Women often favour the family over themselves with food care.</li> <li>c) Subpopulations (men without families and kitchen-less households) depend on street vendors, principally women, as an important source of adequate nutrition.</li> </ul>
<p><b>Available and sustainable livelihoods as the primary economic platform</b></p> <ul style="list-style-type: none"> <li>a) Food systems are usually the most resource and time-dependent functions of a community. With urbanisation the immediate personal commitment to the foods system may diminish, but the overall engagement or cost to the community may increase, because of the needs for transport, processing, storage, advertising and retailing.</li> </ul>	<p><b>Recreational and Socialisation options which are conservationist and healthful</b></p> <ul style="list-style-type: none"> <li>a) The ways food enables us to recreate and socialise</li> <li>b) Being involved with the entire food system as best we can – growing it, obtaining it, distributing it, sharing it, preparing it, knowing about it, understanding its health relationships.</li> <li>c) Managing it, its energy requirements, its packaging and more with environmental and social respect.</li> <li>d) Experience of growing food positively correlates with dietary and consumption habits.</li> <li>e) Food production teaches job skills and offers entrepreneurial opportunities.</li> </ul>

**Table 3.** Food system dependency (cont.)

<p><b>Available and sustainable livelihoods as the primary economic platform</b></p> <p>b) These resource demands on the food system will be amplified if food scientists and technologists and other entrepreneurs seek to 'add value' by fractionating, re-formatting and presenting so-called novel and functional foods. The affordability of basic nutritional needs can thereby be compromised, at the same time as there seems to be more work to do (and which may be automated anyhow). So the relationship between the food system and livelihoods is critical for the economic status and well-being of the population.</p> <p>c) Training programs and definition of competencies to engage with the food system as it evolves with urbanisation are required.</p> <p>d) Sleeping patterns which depend on family, work and community obligations can also alter dietary habits and health outcomes.</p> <p>e) The proximity and connectedness of peri-urban and rural inputs into the urban food environment will have a bearing on livelihoods and personal behaviours.</p>	<p><b>Recreational and Socialisation options which are conservationist and healthful</b></p> <p>f) While offering a place of retreat, recreational areas used as community gardens can contribute to food security as households can grow part of their own food supply.</p>
<p><b>Ecosystem resilience which allows for natural challenge, unexceptional human behaviour challenge and provides for population vulnerability</b></p> <p>a) Food systems which are integral with ecosystems in general; for example, the combination of decorative and ornamental with food gardens; a sense of beauty, environmental pride, responsibility and care.</p> <p>b) A well-developed social role of food, eating together with constructive conversation.</p>	<p><b>Accommodates practical and sustainable personal and collective transport</b></p> <p>a) The form of food transport is a factor in determining its safety and nutritional value.</p> <p>b) Food transport requires energy (fossil fuel or renewable), containers and packaging, each with their environmental burden.</p> <p>c) Synchronicity between cars and food outlets.</p>
<p><b>Assimilates interpersonal communication and discourse without undue ecosystem loss and which is conservationist</b></p> <p>a) Informational transparency throughout the food system is required to reassure urbanised consumers who have lost their sense of control over their food supply.</p> <p>b) Personalised tools to assess food system risk are under development.</p> <p>c) Aggressive marketing in cities and transition from a rural to urban diet can confuse consumers and be associated with ontological insecurity. Use of media outlets can educate consumers about dietary habits and ecological awareness.</p>	<p><b>Involves governance directed towards ecological awareness and insight, participatory conduct and a sustainability culture</b></p> <p>a) Even with unfavourable local conditions, food scarcity can be managed to minimise ecological damage and protect health, albeit with difficulty, if the governance is sound.</p> <p>b) A marginal food system can be made more health-favourable where there is social cohesion, attention to other basic needs and a non-materialistic emphasis on livelihoods. Abundant food systems can be environmentally and nutritionally mismanaged with adverse health consequences.</p>

### **Relevance to China**

In Table 4 we have enumerated the current situation in China in a way that might enable the optimisation of humanised ecosystems.

### **AN ECOLOGICAL APPROACH TO URBANISATION**

Our situational analysis makes a case for an ecological approach to the identification and management of the many ecological factors which influence food and health systems during urbanisation, especially when the urbanisation is large-scale and rapid.

### **Urban food systems to meet basic and changing health needs**

Current observations indicate that prior and present urbanisation in China has been associated generally with improved food security as judged by poverty and hunger reduction (MDGs report) and energy intake, but shifts

away from a more plant-based to an animal-derived diet indicate that the dietary patterns deviate from China's dietary guidelines and that increased energy intake is not being matched by appropriate levels of physical activity.<sup>57</sup> The contextual requirements of effective dietary guidelines were recognised in the UN System Food Based Dietary Guidelines Cyprus recommendations of 1995,<sup>59</sup> with China as a co-author, later customised for the Western Pacific by WHO and strategised at the community level.<sup>38</sup> Some of the discordance between guidelines and practice will be attributable to urbanisation, although there are other factors. However, urbanisation is usually associated with better health outcomes than are seen in the rural sector,<sup>60</sup> perhaps because of more readily available health services rather than on account of an underlying improvement in health, as seen with obesity where survival incurs greater costs.<sup>61,62</sup>

The over-arching features of food systems conducive to favourable health status and against which we have

**Table 4.** Relevance to China**Living and working where there are compatible geographical features**

- Single time zone across China with large differences in diurnal rhythms, weather patterns, agriculture, economic development, degree of industrialisation, education, health, food supply chain and occupational conditions.
- Residential permits (hùkǒu 户口) which relate to rural or urban as well as locality can facilitate compatibility.<sup>50</sup>
- Generational shifts in preference for residential and occupational locality, including a renewed interest in rural locations and non-industrial cities.<sup>51</sup>
- Industrialisation mixed with urbanisation.
- The interest in turning unique and rare traditional foods with possible health benefits into cash crops will require careful EHD risk management (compare the Ethiopian example of ‘teff’) which has been nominated as a ‘super grain’ and made it increasingly un-affordable for its traditional users).<sup>52</sup>

**Extensive biodiversity**

- China has a number of biodiversity ‘hotspots’ such as those in Guizhou where there are mountainous villages with disproportionate numbers of centenarians and relative longevity.<sup>53,54</sup>
- Traditionally, Chinese people have endeavoured to create food gardens, especially for fruits and vegetables, and chickens, sometimes pigs, wherever they have lived including built-up environs. There is evidence that this is happening with current urbanisation.<sup>55</sup>

**Food, water and air systems which are adequate and safe; hygiene**

- Traditionally, Chinese food systems in rural communities have been highly efficient as far as waste management is concerned, but with some risk attributable to inappropriate handling of excreta. That said, Chinese have always insisted on boiling water which has reduced the risk of food borne illness. The introduction of tea as a beverage, which required boiling water, added to the overall safety profile of the Chinese diet. Food fraud and adulteration were also readily sanctioned in closely knit villages and communities. With urbanisation has come less control and knowledge of the origins and handling of food stuffs – and mistrust and anxiety on the part of citizens. This is a manageable challenge with urbanisation if protocols and enforcement are in place.

**Intergenerational and life course (conception to later life) compatibility**

- In China there is often lack of awareness of the risks of substance abuse to the child at conception and during pregnancy.
- The presence of grandparents, increasingly part of the household arrangement with both parents working, may be of benefit in the transmission of traditional food and health knowledge and practice with urbanisation.

**Available and sustainable livelihoods as the primary economic platform**

- Many Chinese families living between the rural and urban areas remain well-connected with each other if there are three generations and ongoing grand-parental involvement, even if distance, travel costs and leisure time are prohibitive. Festivals and the digital age partially overcome the obstacles.

**Non-extreme climate or its change; infrequent natural disasters**

- China is experiencing a more rapid warming than other parts of the world, especially in the Tibetan plateau.<sup>14</sup>
- Water resources are precarious and non-potable in many districts.
- Natural disasters with earthquake proneness are experienced in regions like Sichuan province; flooding and heavy snow falls in Guizhou and Guanxi provinces. Rapid response has demonstrably reduced adverse health outcomes.

**People can function as ecological creatures**

- Chinese civilisation has pointedly regarded food as medicine and medicine as food, as has Greco-Roman based civilisation. This encourages an integrated and environmentally aware sense of who we are. The difficulties with this notion, however, are that it may be exploitative of the environment to peril.

**Renewable and relevant energy systems**

- The Chinese way of eating together, sharing food at the table, the rice bowl of small and standard size, and eating with chopsticks encourages restraint in eating and smaller serving sizes.
- The extensive use of tea (*Camellia Sinensis*), boiled and without energy, allows satiety without energy dysequilibrium.
- Barley and ginger based beverages also reduce energy throughput errors.
- Some foods may actually increase energy expenditure, like chilli.<sup>56</sup>

**Gender socio-biology operative and equitable, non-discriminatory ecosystem access and service provision**

- China’s education system treats women equally with men, and in public service, although private sector appointments may still reflect gender discrimination.
- On the whole, China is well-positioned to take advantage of the contribution of women with the emphasis on urbanisation.

**Recreational and socialisation options which are conservationist and healthful**

- The traditional Chinese food concepts, like ‘hot and cold foods’ [热和冷] take into account ‘harmony with nature’ notably seasons and weather as well as how we feel. These may now be more important concepts than ever, at a time when they are threatened.
- Traditional ideas need to be merged with the newer food and nutrition science and technologies, reflected in the ‘pagoda’.<sup>57</sup>

**Table 4.** Relevance to China (cont.)**Available and sustainable livelihoods as the primary economic platform**

- In seeking 'employment' in cities, rural people miss the immediacy of family, the economies of households and the broader social roles of food in keeping people and their affairs together – students away from home complain that they miss 'home cooking' for example which represents not only nutrition value, but care and engagement in the entire food system. This is difficult to replicate with urbanisation.

**Ecosystem resilience which allows for natural challenge, unexceptional human behaviour challenge and provides for population vulnerability**

- Chinese civilisation is characterised by a highly-developed social role for food, where few decisions are made without food.
- Cultural norms require enquiry about the food sufficiency of others – the first question of the day is 'have you eaten'?
- There is discouragement from over-eating - 'stop when you do not feel quite full'. On the other hand, feasts and celebrations when food and beverage are lavished on others can offset the underlying cultural advantages when economic and situational circumstances allow.

**Assimilates interpersonal communication and discourse without undue ecosystem loss and which is conservationist**

- China has introduced new food safety laws and increased enforcement in 2015 at a time of rapid urbanisation. This should reduce risks in the food and health systems.
- China has a high level of internet connectedness of its citizenry, an opportunity for improved communication about the optimisation of environmentally determined food-related health.

**Accommodates practical and sustainable personal and collective transport**

- China is a vast country which requires an extensive transport system at home and in connection with its trade routes – by road, rail, air, river and sea, now with a renewal of the ancient land and sea 'silk roads' to the west, Russia and Europe, along with the rest of Asia, Oceania, and the Americas. The threats and opportunities with these connections to an increasingly urbanised country are enormous.
- Food is and will be a large part of the growing transport system. Food habits could be modified to make these transport prospects more efficient and sustainable. For example, China imports 80% of its soybean needs from the Americas, mainly to feed pigs. Pig meat consumption has risen dramatically, much of it unnecessary from a nutrition and health perspective. The use of antibiotics as growth promotants in pig meat production is posing additional risks through the development of antibiotic resistant genes (ARGs) in the pig microbiome.<sup>58</sup> Travellers are acquiring and spreading these ARGs placing large populations, as well as livestock, at health risk.

**Involves governance directed towards ecological awareness and insight, participatory conduct and a sustainability culture**

- China has reduced poverty, hunger and malnutrition in accordance with the Millennium Development Goals (MDGs) for 2015 to a large extent, with promise of even more gains to come. Yet there are still some 85 million people in China, of a population of about 1.4 billion, who remain persistently in poverty without sufficient food supply despite major food waste, enough to feed 200 million people.<sup>20</sup>
- China now supports the UN System in its next phase of human development through the Sustainability Development Goals (SDGs) being introduced in 2015.
- The decision to move up to 300 million people from rural China into cities present formidable challenges and opportunities to further alleviate poverty and hunger, and to do so in a way that is favourable to environmentally-related health.

sought to evaluate them in urban settings are ultimately ecologically dependent and constitute an estimate of food security and of health risk. This is not to say that the pathways which link food habits and health are thereby novel or unfamiliar. Contemporary WHO reports of avoidable risk for mortality rank hypertension as the foremost and, for disability adjusted life expectancy, low childhood weight, along with tobacco, alcohol, unsafe sex and several other food-related risk factors including low fruit and vegetable intake and elevated blood glucose.<sup>63</sup> From a life-course perspective, a combination of maternal literacy, competent obstetric care and breast-

feeding must rank most beneficial.<sup>64</sup> But whatever the nutritional and mechanistic pathway, the ecosystem of which we are part and how we relate to it is paramount.

The conventional health risk factor analysis strengthens the argument for ecosystems to provide the facilities for maternal and child nutrition and health, as well as the food quantity and quality to prevent under-nutrition and chronic disease. These are especially cardiovascular disorders, cerebrovascular disorders, body compositional disorders (being under- and over-weight, sarcopenia and osteopenia), high blood pressure and diabetes, chronic kidney disease, neurodegenerative disease, arthritis, os-

teoporosis, various cancers and mental health problems.

Food security is reflected in food quantity, food quality (judged by diversity and ingredients), food diversity score, food variety measures,<sup>4</sup> food safety (microbiological, chemical, nutritional), other (e.g. altered system from cultivation or breeding to point of purchase or consumption), sustainability (soil nutrient depletion and contaminants; energy requirements; water availability; weather patterns; people and their health; resilience in the face of urbanisation, with natural disaster, loss of biodiversity, ecosystems) and acceptability (beliefs, culture, preferences). With rapid urbanisation, any of these features may be unavoidably perturbed and the risk profile changed.

Of particular significance is the contribution that food systems, and therefore diet, can make to climate change through loss of ecosystems and replacement with arable monocultures, inefficiency due to food waste, and the generation of greenhouse gases (GHGs).<sup>65-70</sup> Urbanisation potentially exacerbates these effects, so future food based dietary guidelines must take these considerations into account.

#### **Urban food system inputs**

The optimisation of urban food systems requires evaluation of the extent to which relevant inputs might be modifiable or made more tolerable. A harsh climate or recurrent natural disasters may not themselves be alterable, but living with them and reducing the adverse health impacts has characterised many sustainable communities. Buildings are made more earthquake-proof or typhoon resilient, fishermen do not venture out if weather forecasts reliably predict storms, coastal developments are prohibited if sea levels are rising and tides are high, and protection against mosquito bites is enhanced as dengue fever advances into less tropical cities. These examples suggest that some progress is being made towards better governance of settlements, their food supply and health risk.<sup>71</sup>

#### **Water**

Whereas rural communities are generally located adjacent to natural water sources like rivers, lakes or access to ground water through wells or bores, urban water must be fetched or reticulated at a distance. Since agriculture has been intensified and industrialisation has paralleled urbanisation, the chemical safety of urban water is often compromised through fertiliser run-off and industrial by-products. In both rural and urban settings, sewage treatment is critical for the potability and safety of food production from farm or fishery to processing and other forms of handling. Problematically, river systems in many parts of the world are markedly compromised, with the extent reflected in the different assessment methods. For example, in China, 60% of river water is said to be non-potable,<sup>72</sup> while in Bangladesh most artesian wells are contaminated with arsenic because of their geographical location or the use of arsenic in the computer chip industry.<sup>73</sup> In Australia the major Darling-Murray river system is non-potable due to over-use of fertiliser with toxic algal blooms, while in Britain, according to the European Union (EU) scoring system, 83% of rivers are 'not in good health' because of 'over-abstraction and pollution from farms, run-off from roads and effluent from sewage

works - as well as invasive species'.<sup>74</sup>

#### **Nutrients**

The major global shifts in food production which occurred with European colonisation had to do with major staple crops like corn, potatoes, wheat, rice and beans (notably soy) moving between continents, while sugar cane also became a major crop. The seas and rivers were increasingly exploited for whales, fish, crustaceans and molluscs, with cod becoming almost a currency. Poor soils were made productive with fertilisers, especially following the 'green revolution' in the second half of the 20th century which turned to plant breeding for better yields. With massive food trade, nutrients like phosphate are being moved from one continent to another (e.g. soy beans from the Americas to China). Phosphate is excreted in urine, passes into sewers, then waterways and into the sea, where its recovery would be prohibitively expensive. The magnitude of this problem in China's megacities has been well documented,<sup>58</sup> and is indicative of the imperatives to manage effectively nutrient flows with rapid urbanisation.

#### **Pollutants**

Pollution of air, water, soil and living spaces is a product of the concomitant development of industry and of urbanisation in juxtaposition and without regulatory enforcement. Its severity for ecosystems and their inhabitants depends in part on the degradability of pollutants and on the particular molecular and composite toxicologies. Among those of greatest concern are heavy metals (e.g. lead), arsenic, petrochemicals, phthalates, biphenyls and plastics (which only came into widespread use in the second half of the 20<sup>th</sup> century) pesticides, weedicides and fire retardants.<sup>27-29,75-77</sup> Many of these substances are part and parcel of the process of urbanisation, but there is increasing evidence that those with hormonal properties (endocrine disruptors) account for much of the change in environmental and human health.<sup>78</sup> The production, use and presence of these ecosystem-compromising pollutants in urban settings is a major health challenge.

#### **Natural disasters**

With climate change, the frequency and severity of natural disasters is likely to increase as is their conjunction typified by earthquakes and typhoons,<sup>71</sup> both increasing with oceanic warming.<sup>79</sup> Susceptibility will be largely determined by locality, although the risks to previously benign coastal and island communities may change for the worse with rising sea levels. New cities and buildings within existing cities are generally expected to take into account worse case scenarios for many years to come (e.g. 100 years for buildings adjacent to water in Melbourne, Australia). Where urbanisation pressure is great, these risk management protocols will need vigilance and to be under-pinned by good environmental science. In Asian cities prone to earthquakes, emergency nutrition planning is now more in evidence.<sup>44</sup>

#### **FOOD SYSTEM STRATEGY**

It should be evident from our appraisal of the current and

future prospects of urbanisation that megacities (populations above 10 million, closer to 20 million in Guangzhou and Shanghai) are to be discouraged from many points of view, but especially from the ecological perspective that identifies human health as intimately dependent on its ecosystem and food complexity that cannot be simply expressed in nutrient terms.<sup>80-82</sup> Lesser size cities have been manageable and this is what is intended for China's planned rapid urbanisation.<sup>83</sup> Thus far, China has dramatically improved its food security in recent times and most health indices have improved across the nation.<sup>84</sup> But there are emerging threats which may be ameliorated or exacerbated through rapid urbanisation even at the level of 2-3 million inhabitants or less, principally to do with oppressive temperatures, lack of water, loss of biodiversity and compromised livestock health, along with recurrent natural disasters.

In order to manage these risks, the siting of urban developments will need to be ecologically favourable in the long-term, and biologically plentiful and diverse as possible, with peri-urban and rural corridors and connections. Since some urban developments are taking place in contaminated locations, their bioremediation may be necessary for food and water safety and to deal with other health hazards.

The establishment of altogether new ecosystems ('neoecosystems') has many precedents. Some of the most successful have been the traditional cottage mixed farms of Europe, Indochina, China, Southeast and South Asia, Africa and the Americas where for generations people have grown diverse crops, kept livestock and engaged in aquaculture with unique intercrop, bird, insect and microbial populations. In recent times, Dr Tu Giay in Vietnam did much for the survival of his people during conflict by propagating food systems based on aquaculture for sustainable food production.<sup>85</sup>

#### ***How can we define and minimise adverse eco-health outcomes?***

Improving eco-health outcomes first requires that the linkages between us and our environment are understood. For example, body fatness can be increased, muscle mass lost and child growth velocity increased in some urban environments when people are cut off from ecosystem checks and balances, are less physically active and have greater access to fast food outlets.<sup>86</sup> Each of these factors can be addressed by town planning, incentivisation and collective community action as demonstrated in the EP-ODE child obesity prevention programs in Europe.<sup>87,88</sup>

Food and human health is not just about eating food but also producing food. Loss of arable rural land, cash-cropping, and decline in rural farming can affect the livelihoods of rural communities. If we are disconnected from our household and traditional food systems, we are more vulnerable to disordered food choice and its health consequences. Many Chinese consumers categorize food, not by nutritional value, but by intrinsic qualities of yīn (cold/cool) (e.g. pork), and yáng (warm/hot) (e.g. lamb). Energy (caloric) intake alone is not sufficient, and the ability to cook and choose between hot and cold meals arouses a sense of "harmony with nature", contributing to our well-being. Increasingly, the way we produce food

through monoculture is accelerating changing ecosystem loss and climate change-and, in turn, affecting our sense of well-being and contributing to ill health.

The so-called 'double burden of disease' represents the co-existence of over (energy)-nutrition with associated micronutrient (vitamin and mineral) deficiencies. Both have their respective disease outcomes, which can be synergistically adverse. For example, in different ways, each can adversely affect immune function and, therefore, the ability to cope with environmental hazards, such as those that accrue through soil and water pollution.

Changes in food demand, for example, a higher demand for pork in China raises questions about the competition between growing food for humans or to feed to animals.<sup>89</sup>

If problems in food systems are related to food distribution then composting food waste within cities and using it for urban farming would be beneficial, and this may also be one possible way of reducing health issues related to use of chemical fertilizers and pesticides. However, it will be necessary to determine whether there are health threats associated with using food waste as a compost, as there may be contaminants/substances within the waste which stay in the system, with no way out of the loop.

#### **URBAN ECOSYSTEM HEALTH DISORDER REDUCTION IN CHINA**

A key thesis of this paper is that we need to redefine health ecologically and with urban relevance. Drawing on wide experience, this might be illustrated for China as shown in Table 4.

The most troubling future scenarios for China are climate change with atmospheric warming across the mainland and on the Tibetan plateau, leading to marginal water supplies and extreme food insecurity, along with dependence on imported soy and corn for livestock rather than direct human foodstuff.

More particularly, a number of examples can inform and underscore what might need to be addressed:

##### ***Habitat- abode and work-place***

The physical and social conditions associated with food and beverage consumption play a role in health outcomes.<sup>79</sup> Most communal or solitary eating takes place at home or on-the-job, so attention to these locations is required in new and renovated urban environments. Demolition and construction may present health hazards to both workers (occupational health) and citizens (public health). A contemporary example of environmentally-connected disease might include so-called 'auto-immune' diseases such as lupus and rheumatoid arthritis, which have been linked to exposures of the emergency personnel and reconstruction workers at the Twin Towers disaster site in New York in September 2001.<sup>90</sup> While this might have been an exceptional circumstance, it may be generalisable to the thousands of labourers now involved in the urbanisation surge in China, and provide an opportunity for risk reduction.

##### ***Dwelling and built environment***

Each dwelling can be evaluated for its connectedness to nature, how much it requires ecosystem services and how

much it might contribute to them. Energy efficiency is already a priority in most new developments and so too is the material science involved in furnishings. Information science can enhance these features, and the same principles can be applied to work and recreational facilities.

### ***Environs***

Parks and gardens, thoroughfares, utilities (energy, communications, water, heating, air conditioning) and so on have to do with the ecological capacity to support food and health systems. Several studies in New Zealand attest to the well-being and health of housing improvements, as well as longer term economic advantages.<sup>91</sup>

### **LIMITATIONS TO THE ECOSYSTEM HEALTH CONCEPT**

The next step in the research process will be to gather data about the various ecological risks in a number of different settings, and then assess how well they account for an EHD. In each setting the food systems would be described and graded.

### ***The 'ecosystem health' concept***

Health has been defined by Skidelsky as one of the seven basic goods, along with security, respect, personality, harmony with nature, friendship and leisure, which are described as universal, final, sui generis and indispensable.<sup>35</sup> In reality, all of these basic goods are at risk if we do not pursue an ecological approach to health. Urbanisation is a compromise in the way we live, and worthy of efforts to make it a 'good life'.

In the Global Food Security Index (GFSI) produced by the Economist magazine's Economist's Intelligence Unit (EIU) in conjunction with DuPont, in 2013 China ranked 42<sup>nd</sup> out of 107 countries which were studied.<sup>92</sup> The GFSI takes account of natural disaster proneness and creates normalised scores from 0 to 100 based on food availability, affordability and 'quality and safety', where quality takes account of dietary diversity and various protein and micronutrient variables. Its outcome measures are to do primarily with governance (e.g. standard setting) food and nutritional status (e.g. percentage of energy obtained from staples, where higher is less desirable; stunting in children; micronutrient deficiency prevalence), but do include more integrative and social measures like the Human Development Index (HDI) and the EIU Women's Opportunity Index. While the HDI, which embraces 'a long and healthy life, being knowledgeable and have a decent standard of living',<sup>39</sup> brings the GFSI closer to the objectives of our U-FSI, it under-emphasises the ecological nature of human health and well-being. An area of ecological commonality in the two approaches is the attention given to dietary diversity, since that is dependent on biodiversity.<sup>45</sup> The GFSI is flexible and may therefore provide an opportunity for adaptation to urbanisation programs in discrete locations, although its data base requirements are more of a national than local type. The same is the case for the HDI.

The ecological food and health problem is extensive and it remains unclear whether it can be evaluated effectively. The task is much greater than can be represented in

a single paper, but we hope that this research is the beginning of a *modus operandi* which will better define the health dimension of urbanisation using systems approaches and in recognition that we are ecological creatures. The concern is that, unless we take account of our ecology-in-transition, we may pay a high health price.

### **CONCLUSIONS**

Presently, the connectedness between food and health is at best piecemeal, with energy balance (intake and expenditure) and particular foods or nutrients seen as its basis. The collective performance of the entire system is, however, able to influence health in ways which are not recognised and, therefore, not addressed. The most under-appreciated connection is that of ecosystem perturbation by the food system, which in turn allows extensive and multiple biological system changes in people with limited resilience. Rapid and major ecosystem loss may account for the shifting patterns of disease towards those reflected in food quantity and quality supply and need mismatches.

Food systems depend on both rural and urban environments. While switch and continuum from rural to urban farming provides for greater food security and may be a positive development for urban health, it carries associated risks for pollution by agricultural chemicals and livestock zoonoses.

### **ACKNOWLEDGEMENTS**

This study was financially supported by the International Science and Technology Cooperation Program of China (2011DFB91710). The authors wish to thank Dr Jonathan Vause for his constructive suggestions.

### **AUTHOR DISCLOSURES**

The authors declare no conflict of interest.

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## Review Article

## Preferred ecosystem characteristics: their food and health relevance to China's rapid urbanisation

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### 优选生态系统特征：其在中国快速城市化进程中同食品和健康的相关研究

纵观中国历史，食品系统同人类及其生境相互包容，是支撑人口增长的重要基础。维持这种关系需要充分的生态系统维护、人为改造以及高度可回收的营养流。日趋老龄化社会的人口规模和结构、基础设施的现代化改造、以及不断提高的对于更加优质生活的期望，使得生态环境可持续性迎来拐点。中国要加速城市化建设以期在未来 15-20 年承纳 3 亿新增人口，而与此同时还要兼顾环境的承载力。城市化进程将从根本上改变农村城市，以及联系二者的众多系统，其中，林林总总的生态系统以及同生态系统紧密联系的食品和健康系统是最重要的。同时，对该过程的刻画与监管对于降低生态破坏并改善人类社会福祉至关重要。本研究对于健康进行情景分析，研究有益或有损健康的生态环境；另一方面对环境与健康依赖的食品系统进行情景模拟。本文通过列表详尽描述中国的现状，以帮助寻求最优化的人造生态系统方案。

**关键字：**生态系统健康疾病、城市化、农村、自然环境、食品系统